THE STRUCTURE OF A FUNDAMENTAL INTELLECTUAL PROCESS FOR THE SCHOLARSHIP OF SUSTAINABILITY

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

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“When I compare the importance of the various driving forces that have controlled my inner development, a passionate dislike of any lack of clarity in my thinking overshadows all the others. The satisfaction I have derived from a clear, orderly perception of relationships has always been so great that I valued material success only as a means of preserving my independence and my freedom to act in accordance with my own inner needs. The erratic and frequent changes which have characterized my life are rooted in this attitude. Before I recognized my mission an oppressive sense of dissatisfaction drove me from one extreme to another, and I never hesitated to abandon a field of activity if another environment promised broader stimulation and greater opportunities for growth.”* — **Karl Terzaghi (1883 – 1963)**

*****Quoted in p.9 of:
Casagrande, A. 1964. *Karl Terzaghi, 1883-1963*. Geotechnique 14:1-12.

Declaration

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; any editorial work, paid or unpaid, carried out by a third party is acknowledged; and, ethics procedures and guidelines have been followed.

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A few words about the thesis, and acknowledgments

If someone is living in this era in time, s/he could understand that the doctoral thesis titled '*The structure of a fundamental intellectual process for the scholarship of sustainability*' is not a traditional PhD thesis. I wanted to rise up to the challenge of the age that demanded a pure intellectual understanding of sustainability and its potential scholarship, and even deeper, it fundamentally asks about holistic and pluralistic understanding of reality through integrated knowledge acquisition. It is an enquiry that goes in contrary to the reductionist modes of knowledge acquisition, and yet it needs to be pure intellectual. This presents as much a methodological as an epistemological challenge, which did not fall or does neither follow any disciplinary or interdisciplinary tradition. Responding to this challenge not only requires ignoring the risk embedded therein, but also undertaking an unusual (and often long) path that is to create its own knowledge tradition. Nevertheless, regardless of all these challenges, it is a task worth undertaking, especially given the passion for research and innovation that has a deep root in my earlier intellectual development.

The passion in me for research and innovation had actually begun to formalize when I was a 2nd Year undergraduate student, and convened voluntary applied environmental research, discovering an environmental public health issue in Bangladesh. That was the first step I undertook, withstanding myriads of obstacles and challenges, and overcoming them. These genuine research undertakings led me to realize that I have to make deeper inquiries, and not just applied ones. And so, my passion traveled deeper into 'basic research' in MSc, where I researched the basic physico-chemical properties of biomass burning emitted ultra-fine particles and assessed their global atmospheric and public health implications. As I was conducting my MSc research, I felt my thirst for research and innovation was only getting stronger, which meant, in my subsequent step I was to travel even deeper, into fundamental research. And thus, I undertook my doctoral quest on fundamental sustainability thinking.

My quest explored a *fundamental intellectual process,* inquiring on a *pluralistic knowledge avenue* for *the scholarship of sustainability* through empirically analyzing the epistemological and methodological bases of sustainability science based on its first decade's body of work. It produces a structure of sustainability scholarship based on fundamental intellectual justification amid its prevailing normative assumption-based treatments.

Looking back since when I started to develop my intellectual quests, my gradual journey through the realms of applied, basic, and fundamental research had brought me to recognize the center of my intellectual inquiry, which is in terms of finding fundamental processes of knowledge integration across domains. Inventing the integrated knowledge acquisition processes holds the potential of unfolding the central organization of human knowledge system. It is also an ardent necessity at the reality in our intellectual history where our intellectual achievements have come under the condition of integration if they are to retain the meanings that they have been associated with, and progressing thereafter. My unique doctoral dissertation journey also provides me an approach for addressing this inquiry. It is through 'fundamental knowledge management research', which has been founded in this thesis. Thus, at the completion of my PhD I actually stand at the starting point for a serious intellectual discourse, with this thesis creating the foundation of it.

Having said these, this enormous challenge could not have been disposed without a sheer motivation for it and the sheer faith that I had witnessed in both of my supervisors, Prof. Ralph Horne and Prof. John Fien. It is needless to mention how much their enormous encouragement and support had contributed in the formation and completion of this thesis. This spans from ideas refinement to analytical development to language editing.

Finally, after my wholehearted gratitude to the Almighty, all credit goes to my parents for who I am to whatever I could ever be since the first day I was in this world. It is 'You'—my parents—to have shaped me with your hands, never thinking of your own comfort before mine, and have always been the best supports and well-wishers than anyone else could ever be for me. My special gratitude also goes to the rest of my family, especially my loving wife Nusaiba, whose emotional and practical support and endurance has made this thesis possible.

To

my affectionate mother *Hosne Ara Begum,*

my wise father *Muhammad Taher*,

my loving wife *Nusaiba Reza, and*

my lovely daughter *Inaya Nawar,* coming into this world one day after I completed this.

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Abstract

This thesis addresses fundamental issues in sustainability thinking, especially in relation to its epistemological and methodological bases. The sustainability crisis has invoked multiple schools of thought cross-cutting wide range of human activities/ scholarships. The resultant diversity of perspectives has imparted a high degree of ambiguity, and an intellectual 'looseness', potentially obfuscating many sustainability issues, which in consequence deepened social confusion and political inaction. Despite this, sustainability has taken on a certain moral tone as a normative goal of society, which is based upon implicit assumptions about the constituent forms of knowledge and the methods by which this knowledge is legitimated. It is out of these normative bases of sustainability that 'sustainability science' has emerged as an overt attempt aiming to champion pluralistic and integrated forms of knowledge and research in addressing the sustainability crisis.

Chapter 1 analyzes the intellectual standing of sustainability. This reveals the necessity for an intellectual perspective to replace the normative essence associated with the notion, and a necessary pluralistic orientation and avenue of knowledge. This intellectual perspective—formed in Chapter 2—stipulates that *sustainability scholarship* needs to operate both across and within disciplines, albeit cognizant of a more integrated reality. The reductionist mode of enquiry is unable to do this. Thus, the sustainability crisis requires a *new mode of enquiry*, which can enable the production of 'bricks of knowledge while looking at the whole building', in contrary to the production of 'specialized bricks of knowledge at the expense of not seeing the whole building' as characteristic of the reductionist mode. This *new mode of enquiry* necessitates a *fundamental intellectual process*, capable of enabling the pluralistic orientation and avenue of knowledge. Accordingly, based on fundamental research the thesis aims to analyze the sustainability science discourse and, through both deductive and inductive methods, develop a *fundamental intellectual process* to inform on the dimensions and structure of a *pluralistic knowledge avenue*, leading to the laying of an intellectual foundation for the *scholarship of sustainability*. This is corresponded to three key research questions (KRQs):

KRQ-1: How can an intellectual process fundamentally be framed in order to study the pluralistic knowledge and research structures regarding sustainability?

KRQ-2: What are the basic structures of the discourse of sustainability science and how are they structured?

KRQ-3: How might a *pluralistic knowledge avenue* and the layout of an intellectual foundation for the *scholarship of sustainability* be elicited based on the rationale, framing and application of the *fundamental intellectual process*?

The thesis takes the first decade's 'body of work' of sustainability science as a dataset for analysis in answering these questions through *heuristic fundamental research*. Chapters 1-3 reflect *fundamental research*, while Chapters 4-6 and Chapter 7 present the results of *heuristic deductive analysis* and *inductive analysis*, respectively. The rationale for the KRQs is formed in Chapters 1-2, besides forming the intellectual perspective of sustainability. KRQ-1 is addressed in Chapter 3 in empirically framing a *fundamental intellectual process*. The analysis of the first decade's 'body of work' of sustainability science is presented in Chapters 4-6, elucidating the discursive, integrative and contextual structures of its discourse, thus, addressing KRQ-2. These together form a continuous thread of inquiry on the intellectual treatment of sustainability, leading to addressing KRQ-3 in Chapter 7.

In framing the *fundamental intellectual process* the Chapter 3 produces a *fundamental literature organization process* resulting in a *structure of five cross-connected layers of organizations* within the literature archive, while a *discourse analysis mechanism* produces an analytical process based on a *system of five stages of discourse analysis*. These together construct a fundamental scheme for analyzing the basic structures of pluralistic knowledge/ research.

There are four key findings (KF) arising from Chapters 4-6. KF-1 reveals an overall lack of precision in characterizing the concept of 'human-environment system' in sustainability science along with an extremely open-ended representation. KF-2, revealing the overall contribution of sustainability science as consistent across its three different basic structures demonstrates mere structural contributions while lacking in intellectual capacities to provide the functional aspects to the intellectual treatment of sustainability. Based on conceptualization and extensive exemplification of a theoretical framework on the language of conversation in sustainability research KF-3 produces a new intellectual lens for approaching effective trans-disciplinary sustainability research through facilitating knowledge co-production. KF-4 reveals a strong correlation between the dominant 'original nature' and the characters of 'literature survey' and 'literature archive analysis' (being the 'mode of conduction' and the 'utilized research method', respectively) of sustainability science research, together with a dominance of these characters across the other empirical classes. This reveals the significance of fundamental literature organization and analysis process in brokering common language and understanding for the enabling of *sustainability scholarship,* besides breaking the impasse of the conventional incompatibility between original research and literature analysis processes.

In Chapter 7, the KF 1-4 are analyzed in terms of different dimensions of the *pluralistic knowledge avenue*. The chapter also produces the structure of this avenue through inductively projecting on the characteristics of an *integration expertise* in light of the *new mode of enquiry*. Besides, Chapter 7 also extracts nine latent elements/ characters of an intellectual foundation of the *scholarship of sustainability* from the rationale, framing and application of the *fundamental intellectual process* as well as the inductive framing of the *pluralistic knowledge avenue*. These together produce the basis for an integrated theory on the intellectual foundation of sustainability.

In summary, new knowledge components are pertinent to KF 1-4 and the inductive framing of the *pluralistic knowledge avenue*. Through fundamentally analyzing the prevailing scholastic reality of sustainability that is based on normative assumption-based works, the thesis produces a structure of sustainability scholarship based on fundamental intellectual justification. Its implications for sustainability science include: (i) the possibility of overcoming reductionist methods—constraining the contribution of the practice—through active intellectual orientation of the *new mode of enquiry*, (ii) prospects for innovation in the practice stem from the integrative structure of its discourse and in developing functional-intellectual capabilities, and (iii) a *fundamental intellectual process* is a means to overcome its normative impulse.

THE STRUCTURE OF A FUNDAMENTAL INTELLECTUAL PROCESS FOR THE SCHOLARSHIP OF SUSTAINABILITY

PART I

FUNDAMENTAL RESEARCH:

THE RATIONALE & THE PLAN

Chapter 1

Introduction

1.1 The sustainability 'crisis' and the notion of Sustainable Development

> "Because traditional science focuses on the accrual of knowledge in specific disciplines, it is ill-equipped to deal with the inconsistencies and incoherence on a larger scale that result from this narrow vision. This has led to the present crisis of seemingly uncontrollable global system degradation that only now is beginning to be recognized and questioned." (Yoshikawa 2011, p.263)

This research takes as its starting point that the fundamental cause of the sustainability crisis is industrialization and the rapid economic growth that accompanied it (Komiyama and Takeuchi 2011). This implies that the concept of sustainability emerged as a response to the afflictions, or negative by-products that resulted from the scientific and technological advances brought by industrialization. In a literal sense, the term 'sustainability' implies that we do not want the afflictions as they produce uncertainty about the costs and benefits of progress. As such, sustainability means that seeking progress from development requires a consideration of the long-term prospects — or 'sustainability' — of the development. As such, sustainability is considered to be a key issue for human and planetary well-being in the 21st century (Komiyama and Takeuchi 2011).

Discussions on the issue of sustainability and the usage of the term 'sustainable' have different origins. One strand arose in Malthus's work, *An Essay on the Principle of Population*, that dealt with the tensions between the geometric increase in population and arithmetic increase in food production (Malthus 1798). The concept was echoed in the works of Mill (1848) on the impossibility of world's population and wealth continuing to increase indefinitely. Similarly, Hardin (1968) pointed to the absence of technological solutions to the issue of population growth, leading Odum (1971) to coin the term 'environmental capacity' to describe the dilemma. In *The Limits to Growth*, Meadows et al. (1972) foretold an impending crisis of sustainability if humanity continued on its present course of natural resource depletion and environmental degradation. The term 'sustainable' was, therefore, first used in the context of ecology, forestry and fisheries (Onuki and Mino 2011). Another strand of sustainability discussion focuses on the sustainability of humanity and society, hence, the book titled *The Sustainable Society* containing Daly's essay (Daly 1977) on steady-state economy, responses to the predictions of the sustainability crisis.

The World Commission on Environment and Development (WCED) report, *Our Common Future* (WCED 1987), related sustainability to development processes, thereby creating the notion of ‘Sustainable Development’, which integrates the two strands – (a) the sustainability of the ecosystem functions that provide (b) the natural resources upon which all human social and economic development depend (Kajikawa 2011). This view speaks to the nature and causes of problems such as global warming, environmental degradation, the appearance of new diseases, burgeoning world population coupled with growing inequalities between rich and poor, the North-South divide, regional conflict, insecurity, urban isolation, racial tensions, cyber-crime, and many others (Takemura 2011, Yoshikawa 2011). The WCED report gave the sustainability agenda immediate global recognition (Onuki and Mino 2011). Its definition of ‘sustainable development’ attracted global support founded on the idea that development processes must ensure the coexistence of economy, society and environment (Komiyama and Takeuchi 2011). The report defined sustainable development as ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’ (WCED 1987, p.43). The WCED report, the sequence of three United Nations conferences on sustainability (Rio de Janeiro 1992, Johannesburg 2002 and Rio de Janeiro again in 2012) and the publication of *The Future We Want* (UNCSD 2012) together with the development of the MDGs and SDGs (Millennium Development Goals, and Sustainable Development Goals) have established wide agreement that the roots of the sustainability crises are located in both the unsustainable levels of production and consumption in the Global North and the (often related) enormous poverty in the Global South. Thus, many policy makers and scholars argue that the entire range of human values are linked to any progress towards sustainable development (Ascher 2007, Kajikawa 2011).

However, this wider, integrated view of sustainability and sustainable development is subject to critique. For example, it has been criticized for ‘adopting the position that economic growth is essential to mitigating the North-South divide’ and for ‘not advocating curtailment of the environmental burden being imposed by the North’ (Onuki and Mino 2011, p.94). ‘Sustainable development’ has also increasingly been linked to political agendas. The rise of North-South issues in debates over sustainable development brought political bias into the agenda (Komiyama and Takeuchi 2011) as important differences between the North and the South exist in defining the most pressing problems of sustainable development (Clark and Dickson 2003). The trans-boundary nature of problems also imparts a complexity that hampers both the identification of and solutions to sustainability problems (Komiyama and Takeuchi 2011). Another problem is the lack of clarity of its scientific and technological underpinnings (Cohen et al. 1998).

1.2 Sustainable Development: from the 'Brundtland Report' to 'Rio Plus 20'

The WCED report *Our Common Future* (WCED 1987) popularized the term 'sustainable development'. The aim of the Commission was to find practical ways of addressing the environmental and developmental problems of the world. In particular, it had the following three general objectives.

- To re-examine the critical environmental and development issues and to formulate realistic proposals for dealing with them,
- To propose new forms of international co-operation on these issues that will influence policies and events in the direction of needed changes, and
- To raise the levels of understanding and commitment to action of individuals, voluntary organizations, businesses, institutes, and governments.

Our Common Future (WCED 1987) was written after three years of public hearings and over five hundred written submissions. Commissioners from 21 countries analyzed these materials, with the final report being submitted to the United Nations General Assembly in 1987. The report elaborated on many of the challenges facing humanity and Planet Earth, and recommended urgent action on eight key issues to ensure that development was sustainable (i.e. that it would satisfy 'the needs of the present without compromising the ability of future generations to meet their own needs'). These eight issues were: population and human resources, food security, rapid urbanization, industrial development, energy, species and ecosystem conservation, managing the commons, and conflict and environmental degradation.

These issues and many others like them were discussed at a major international conference at Rio de Janeiro in Brazil in June 1992. Known as the United Nations Conference on Environment and Development — or more simply 'the Earth Summit' —, this meeting brought together nearly 150 Heads of State where they negotiated and agreed to a global action plan for sustainable development. This action plan has subsequently been called ‘Agenda 21’. Besides Agenda 21, four other international treaties on climate change, biological diversity, desertification, and high-seas fishing were signed in the official sessions. In addition, a United Nations Commission on Sustainable Development was established to monitor the implementation of these agreements and to act as a forum for the ongoing negotiation of international policies on environment and development.

Agenda 21 has been the basis for action by many national and local governments. For example, over 150 countries set up national advisory councils to promote dialogue between government, environmentalists, the private sector and the general community. Many had also established programs for monitoring national progress on sustainable development indicators. At the local government level, nearly 2000 towns and cities around the world had charted their own ‘Local Agenda 21’ plans.

However, progress was slow and uneven. At the ‘Rio Plus Ten’ conference in Johannesburg (in 2002) and ‘Rio Plus 20’ conference in Rio de Janeiro again (in 2012), considerable progress were made in terms of the following:

1. Providing clarity and direction to the changes needed to achieve sustainable development
2. The need for the United Nations to provide stronger leadership towards achieving international development goals (i.e. Millennium Development Goals 2000-2015, followed in with the new Sustainable Development Goals) and
3. Establishing multi-sectoral partnerships for achieving them through cooperation across government, industry and civil society.

1.3 *Sustainability Science* in the discourse of the scientific perspective of sustainability

> “A transdisciplinary approach is called for, in which the quantitative and the qualitative, the natural and the social and also theory and practice (or science and policy) are reconciled and creatively combined. Such an integrating and synthesizing approach deserves the name *sustainability science*.” (de Vries 2013, p.4)
>
> “Sustainability science will need to be fundamental research, but it will also have to be concerned with how to implement this basic science for the benefit of local people.” (Moran 2010, p.145)

Sustainability science had its origins in the concept of ‘sustainable development’ proposed by WCED in 1987 (Komiyama and Takeuchi 2011). Since the advent of the ideas of sustainable development in the 1980s and early 1990s, societal and political processes, negotiations, and agreements were shaping the sustainable development agenda (Kates et al. 2001, Clark et al. 2004b). The emergence of sustainability science came from the established reality that merely political will and agreements are insufficient to successfully advance knowledge that will support the sustainable development agenda. Rather, the natural and social scientific community felt the necessity that sciences should independently help shape political and societal processes for achieving a successful transition towards sustainability (Raven 2002, Cash et al. 2003, Holdren 2007, 2008). The implication here is that the multi-disciplinarity required for sustainable development ought to come from an academic perspective as conjoint action of the natural and human sciences. Kaneshiro (Kaneshiro et al. 2005) described it in a much broader way in terms of a profound level of multidisciplinary, multi-scale, multinational, and multi-temporal integrative science. However, 'multi-disciplinarity' may not suffice if it merely reflects an eclectic add-on that potentially is an unworkable combination in terms of continuity, given the loose or even contrasting nature of the participating elements (Yoshikawa 2011). Rather, a refined form such as 'multi-, inter and trans-disciplinarity' may reflect the necessary plurality and sophistication required for it to be workable. At this point it would be desirable to articulate the assumptions for 'multi-, inter and trans-disciplinarity' as employed in this thesis. Multi-disciplinarity is referred in here as the potential eclectic adding of diverse knowledge avenues that are compatible to be grouped together, whereas interdisciplinarity refers to the scopes of studies at the juncture of disciplines that reveal coherent nature of research methods; however, trans-disciplinarity is the merger and transcendence of disciplinary researches in terms of philosophy (epistemological), theory, and research methods. Therefore, the three key terms to symbolize these three pluralistic modes are: 'compatibility' for multi-disciplinarity, 'coherency' for interdisciplinarity, and 'transcendence' for trans-disciplinarity; where coherency (for interdisciplinarity) is inclusive of compatibility, and transcendence (for trans-disciplinarity) incorporates both coherency and compatibility.

While societal and political processes have shaped the sustainable development agenda since the 1980s, science and technology took a more subordinate role (Kates et al. 2001, Clark et al. 2004b). In the 1990s science and technology came forward aspiring to contribute in advancing sustainable development objectives (Kates et al. 2001, Clark et al. 2004b). The International Council for Science (ICSU) initiated studies on science and technology for sustainable development, which was followed by increasing recognition and calls for a science of sustainability (Komiyama and Takeuchi 2011). However, significant work had also occurred prior to the inception of sustainability science in the guise of human-environment interactions research (Moran 2010).

The agenda of human-environment interactions research led to the laying of the foundation-stone for sustainability science. In October 2000, two dozen scientists drawn from the natural and social sciences and purportedly representing all parts of the world, were convened under the auspices of an *ad hoc* organizing committee at Sweden's Friibergh Manor to discuss contributions of the scientific community to the challenges of sustainable development (Jäger 2006). The meeting concluded with an emphasis that promoting sustainability should impart importance to new scientific questions, different research approaches, and institutional innovations. Subsequently, a paper titled "*Sustainability Science*" was published in *Science* in 2001 (Kates et al. 2001).

The term 'Sustainability Science' was first coined in 1999 by National Research Council, United States (NRC 1999). Starting from the publication of *Our Common Journey* (NRC 1999), scientific deliberations had continued through a number of others in shaping the practice of sustainability science. Kates et al. (2001) describes —

> "A new field of sustainability science is emerging that seeks to understand the fundamental character of interactions between nature and society. … Sustainability science needs to move forward along three pathways. First, there should be wide discussion within the scientific community—North and South—regarding key questions, appropriate methodologies, and institutional needs. Second, science must be connected to the political agenda for sustainable development … Third (and most important), research itself must be focused on the character of nature-society interactions, on our ability to guide those interactions along sustainable trajectories, and on ways of promoting the social learning that will be necessary to navigate the transition to sustainability." (pp. 641 - 642)

This sets out the perspective behind the emergence of sustainability science. It preemptively articulates a presumptuous approach in the treatment of sustainability crisis, which is in terms of seeking to understand the fundamental character of nature-society interactions. Besides, the following assumptions are also adopted for the practice to function: (i) trying to discover the key research questions and appropriate methodologies through discussions, (ii) the assumption on the necessity for science to be connected to the political agenda of sustainable development, and (iii) adopting the methodological approach for sustainability science in terms of trying to understand and guide the character of nature-society interactions along sustainable trajectories. These portray a speculative character of sustainability science, not resulting from a fundamental intellectual inquiry in terms of the direct intellectual needs of the sustainability crisis. Rather, this nature of sustainability science arises from the agenda of human-environment interactions research, thereby essentially focusing on the character of nature-society interactions. From the perspective of human-environment interactions research it is even clearer: "*Priorities for sustainability science dovetail with the priorities in other proximate areas of research such as human-environment interactions research, coupled systems, and the human dimensions of global change* (Moran 2010, p.145)". However, since the inception of the practice of sustainability science, it slowly emerged into a broader perspective of sustainability.

Europe and North America led efforts in academia to advance the practice of sustainability science following its inception (Komiyama and Takeuchi 2011). The *Forum on Science and Innovation for Sustainable Development* under the auspices of AAAS (American Association for the Advancement of Science) spearheaded the effort (Komiyama and Takeuchi 2011). Works in Tyndall Center for Climate Change Research, Potsdam Institute for Climate Impact Research, Stockholm Resilience Center, etc. in Europe had fueled the progress (Komiyama and Takeuchi 2011). However, a significant leap in the exercise has to be attributed to the establishment of IR3S (Integrated Research Systems for Sustainability Science) in Japan, although it was regionally biased with Asia as the primary focus. Emerging as the most organized effort so far in the practice of sustainability science, the IR3S approaches the problem of sustainability at the three levels of global, social and human systems (Komiyama and Takeuchi 2011). The inception of IR3S and the launch of the journal *Sustainability Science* were rooted in the same, hence *Sustainability Science* serving as the official journal of IR3S.

In the short history of the discourse of sustainability from scientific perspective, the initial focus on agricultural and/ or environmental sustainability had moved along into the context of human-environment interactions research, resulting in the inception of sustainability science, and then the practice of sustainability science yielding an even broader perspective of sustainability. The initial focus on agricultural and/ or environmental sustainability still stays in its old position as most of the sustainability-related research in the relevant fields having been conducted in field-specific and monodisciplinary fashion (Takeuchi 2011). Human-environment interactions research seeks to address the issue of sustainability within what could now be regarded as a 'narrow sense of human-environment interactions' perspective, where — (i) researchers non-native to the core disciplines of human-environment interactions research are potentially unable to participate in research, given the broad perspective of sustainability awareness inviting scholastic participation from a wider range, and that, (ii) research takes place in in-depth collaborations of specializations. However, sustainability science in its broader sense could be characterized by — (i) a much more integrated approach to sustainability than human-environment interactions research and (ii) the depths of collaboration and exchange between and among the broad range of participating scholarships expected to propagate from shallow towards deeper levels through relevant innovations in the required 'multi-, inter and trans-disciplinarity'. This broader awareness of sustainability science could be attributed to the establishment of IR3S as it sought to transform the practice from the characteristics of the human-environment interactions research to its broader form, thereby fundamentally changing the nature of the field.

1.4 Problems with the nature, definition and foundation of Sustainability Science

The IR3S generally describes the concept of sustainability science as 'a discipline that points the way towards a sustainable society' (Komiyama and Takeuchi 2011). Sustainability science has been called a discipline from other corners as well. De Vries writes, "S*ustainability science has emerged recently as a new academic discipline and is a growing area of both research and teaching.*" (de Vries 2013, p.I) However, the justification of such proclamation could be put to question. The proclamations asserting sustainability science as new academic discipline also contain ambiguity:

> "As an integrated academic discipline, sustainability science is able to propose the correct direction and path for existing academic disciplines to solve complex problems and eventually lead society to a state of peace and prosperity. All academic fields may have the same ultimate goal as sustainability science, and that is why sustainability science, with its intrinsic nature as a discipline, requires collaboration among many academic fields." (Fukushi and Takeuchi 2011b, p.116)

This proclamation can be viewed through two possible notions. In the first notion, sustainability science is positioned as an overly simplistic practice having the intrinsic quality of proposing the correct direction and path for the existing academic disciplines, provided that it requires the existing disciplines to collaborate among one another in order to advance its discourse. In this sense, the position of sustainability science would not be independent, given it requires collaboration among the existing disciplines (through accepting the direction and path proposed by it) in order to advance its discourse. Therefore, this notion of sustainability science represents a dependent form of practice, where the proclaimed intrinsic nature of it as a discipline is an independent form.

The other possible notion is in terms of a potential independent discipline, where a self-contradictory assertion becomes evident. As per this notion if the existing disciplines do not and/ or cannot collaborate, then sustainability science cannot independently advance its discourse in order to solve the complex sustainability problems, and therefore, the intrinsic nature of a discipline would come into question. If the notion of sustainability science is to be regarded with the two qualities of 'independent rather than dependent practice', and 'in-depth rather than overly simplistic discourse' (overly simplistic in terms of merely proposing the correct direction and path for the existing academic disciplines), then sustainability lacks the merit of an academic discipline as yet.

> "Reflecting its social importance sustainability science is becoming a distinct scientific field." (Kajikawa 2011, p.23)

Kajikawa summarizes the status of sustainability science with the following statement ― "*To achieve a sustainable society, sustainability science must be a distinct discipline that is at the same time engaged in a transdisciplinary effort arching over existing disciplines* …" (Kajikawa 2011, p.32). This articulates the aspiration for sustainability science, the question is, is this discipline yet a reality? Sustainability science in the 'broad sense of human-environment interactions' does not have a well-developed and credible intellectual foundation yet; and arguably it must be laying such a foundation if it is to become an independent academic discipline. The social importance of sustainability crisis and the need for urgency in solving its problems have led some to put sustainability science into the status of a new discipline without it having the required merit and characteristics. It has been put into the status of a discipline by hoping that along the way of its deliberations it would gain the required merit and characteristics of a discipline. Thus, it is given legitimacy through social importance, which, however, carries risk. The question here is not to embark on justifying whether a disciplinary form of sustainability science is important or not. Rather, the question is whether the necessary laying of a credible intellectual foundation is yet occurring. This lack of a credible intellectual foundation may lead to societal uncertainty with regard to the contribution of sustainability science. Meanwhile:

> "Still in its infancy and limited in its impact on the world, sustainability science lacks the wherewithal to construct a global sustainability strategy if the effort emanates solely from universities and research institutes in one or two regions or the research networks they have formed." (Komiyama and Takeuchi 2011, p.17)

And:

> "Sustainability science must be developed as a new discipline by integrating and reorganizing existing fields through knowledge-structuring. It is an ambitious undertaking, but one worthy of the effort." (Mizoguchi et al. 2011, p.47)

The problem in defining sustainability science is even more profound. At the launch of the journal *Sustainability Science*, sustainability science has been defined as 'an academic field that points the way to understanding the diverse issues associated with sustainability in a holistic manner and to offering visions of the development of a sustainable society and methods for achieving it' (Onuki and Mino 2011). Such frame of definition communicates an eclectic identity of the notion of sustainability science, instead of one emanating from firm intellectual foundation. The following expresses a similar hope:

> "Sustainability science requires the construction of a transdisciplinary academic framework that brings the natural sciences, social sciences and humanities together, structures academic knowledge and the issues it must address, and defines standards and indicators for sustainability." (Komiyama and Takeuchi 2011, p.13)

In order to achieve sustainability, Hay and Mimura (2006) propose full reconciliation between: (1) economic development, (2) meeting, on an equitable basis, growing and changing human needs and aspirations, and (3) conserving limited natural resources and the capacity of the environment to absorb the multiple stresses that are a consequence of human activities. Besides the practicalities of such communication scoping contentious aspects, it portrays mental conceptualization of a normative essence of sustainability science rather than fundamental and intellectually rigorous characteristics.

Another attempt for defining sustainability science follows as: "*Sustainability science is an academic field that aims to secure the sustainability of natural, social and personal systems and the peace and prosperity that human beings tend to seek.*" (Fukushi and Takeuchi 2011b, p.116). The existence of such multitude of optimistic, normative and eclectic definitions of sustainability science may rather serve to shadow it under a mist of uncertainty and obscurity.

Sustainability science has also speculatively been described with a basic character of interrelationship-based transformative science. Takeuchi writes, "*One of the key characteristics of sustainability science is that it does not end with the unilateral process of dispensing research results to the general public. Rather, it depends on a bilateral process through which changes in social values and sustainability-oriented actions taken by the public in turn transform the character of sustainability science. In other words, sustainability science itself is an interrelationship-based discipline …*" (Takeuchi 2011, p.89). Such speculation-based projection on the basic character of sustainability science communicates a desire to overcome the limitation of the reductionist way of inquiry by trying to alter the traditional unilateral process into a bilateral process without considering the fundamental innovations that would be required to overcome reductionist inquiry. This reflects a thought process that operates from within the box of reductionist mode of enquiry, which is fundamentally inconsistent with the intellectual treatment of sustainability. Moreover, as per this speculation, 'changes in social values and sustainability-oriented actions taken by the public in turn transforming the character of sustainability science' leaves the notion to be populated with disparate considerations from diverse, potentially inconsistent sources. Such speculative character may create fundamental contradictions in terms of the social/ non-academic aims within the notion of a discipline, as well as with assertions on their interrelationships.

Kajikawa et al. (2011) studied a citation network of 29,391 papers containing the words 'sustainability' or 'sustainable' in their bibliographical records, and displayed it with an algorithm. It revealed 15 research domains pursuing their individual targets for sustainability, e.g. some seeking environmental issues while the others concerned with social or human development issues. However, the reported commonly discussed topics in different citation clusters included climate change, welfare, and livelihood; characteristically representing environmental, social, and economic concerns, respectively. Kajikawa et al. (2011) had termed the citation network to be the academic landscape of sustainability science. Although the empirical approach undertaken in the work contributes into a superficial mapping of terrain, however, the potential academic landscape of sustainability science should ideally be described by its yet-to-find sound intellectual foundation.

In the concluding chapter on the concepts of sustainability and sustainability science, the IR3S communication states:

> "By integrating the knowledge produced by existing academic disciplines, sustainability science can develop innovative solutions and propose pathways to them … however, existing academic disciplines are not well prepared to link with each other, and researchers who do interdisciplinary work of this sort often suffer from a lack of recognition … Sustainability science proposes that conventional disciplines open channels to link with each other. Such linkages are the only way to reach solutions to complex problems. The specific methods of linkage and integration have to be developed for individual cases, and professionals capable of doing such work need to be educated." (Fukushi and Takeuchi 2011a, p.117)

Since the existing academic disciplines have not linked to one another yet, the methodical question of 'knowledge integration' by sustainability science remains unanswered, therefore, rendering imaginary nature to the notion of integration. Knowledge integration should occupy such a central position in any intellectual treatment on sustainability that unless such process is sufficiently described based on a credible intellectual foundation, the notion of knowledge integration cannot be taken as realistic. In terms of the potential integration of conventional disciplines the reality appears to be even more unrealistic, as without a sound intellectual foundation of a sustainability scholarship describing the path for such integration, it would be over-optimistic to expect the conventional disciplines inventing the paths and opening channels to link with one another. Moreover, it is unlikely to effectively educate or train potential sustainability scientists in the sense that no one can be trained in and around the intellectual foundation of a discourse when such a foundation has not been discovered yet.

Amid the lack of a credible intellectual foundation for sustainability science in its 'broad sense of human-environment interactions' perspective, setting out priorities for the practice or trying to drag it towards a given direction is to be considered premature. Such priorities for sustainability science exist in the objective of IR3S as: "*building a sustainable society in the 21st century that combines the characteristics of a low-carbon society, a resource-circulating society and a society in harmony with nature*" (Komiyama and Takeuchi 2011, p.13). Besides becoming another attempt of normative and eclectic speculation on sustainability science, the setting out of such priorities does not communicate logic amid the intellectual uncertainties associated with the nature of sustainability science. A gap becomes apparent in the approaches undertaken in the practice insofar. Metaphorically, the cart is being put before the horse.

Challenges are manifest in conceptualizing the nature of sustainability science when: (i) it is regarded in normative essence instead of as a fundamental intellectual process, and (ii) it is not based on a credible intellectual foundation. This is a natural consequence of a normative essence-based discourse as echoed in the following:

> "The science is in its infancy. Criteria, approaches, and even definitions of the science vary. Although there is general agreement on three key concepts that underscore sustainability science (transdiciplinarity, integrative analysis, and the creation of knowledge for action), there is no established methodology, and the means employed to measure outcomes are inconsistent." (Yoshikawa 2011, p.257)

The overall status of the discourse of sustainability science could be expressed as simplistic and normative, in effect trying to produce multi-disciplinarity through eclectic adding of disparate fields, and emphasizing the importance of the practice from sustainability's societal relevance. This could be summarized as 'over-simplified', with scholars effectively residing inside their boxes of reductionist specializations: "*There is a need to recognize the process of transcending our specific reductionist tendencies as scientists. Clearly, we all have these to hold onto, but also maturely to stand aside and critically reflect on them where necessary.*" (Marsden 2011, p.310) In rectifying this reality, first and foremost there is a necessity to form an intellectual perspective on sustainability instead of a mere normative essence, to be followed in the construction of a fundamental intellectual process for a scholarship of sustainability.

1.5 Sustainability: to perceive from an 'intellectual perspective' or with a 'normative essence'?

A key development during the 25 years since the 1992 Earth Summit has been in the recognition that sustainable development is multidimensional (social, environmental, economic, political, cultural, etc.), which has also been perceived as underpinned by a set of core or common values. As noted of the seven Millennium Goals (later changed to eight goals):

> "The goals for international development address that most compelling of human desires - a world free of poverty and free of the misery that poverty breeds ... Each of the seven goals addresses an aspect of poverty. They should be viewed together because they are mutually reinforcing ... Many poor people earn their living from the environment. So progress is needed on each of the seven goals." (United Nations et al. 2000)

This recognition of the moral or normative base of sustainable development was among the reasons for the popularity of 'sustainability' as a contemporary notion. Indeed Kajikawa (2011) and Marsden (2011), among numerous others, argue that sustainability is best seen as a normative goal of society. Instead of arising from a fundamental intellectual perspective, this notion has been characterized by the moral consciousness that surface it. This in turn populates the notion with disparate considerations, thus opening the door to chaos. As such, it becomes imperative to distinguish between the ‘intellectual perspective of’ and the ‘intellectual discourse on’ the notion of sustainability. Although the mass recognition of the notion has undoubtedly not been from an intellectual perspective and rather has been emerging from a normative essence, the notion, however, does not cease from being intellectually treated due to the paramount importance implicated to it. Therefore, attempting to *intellectually* treat the *normative essence* of the notion represents a troubled area, resulting in a chaotic intellectual discourse. This could be ameliorated with *intellectually* treating ‘a notion based on a *fundamental intellectual perspective*’.

A normative approach is not necessarily a fundamental or disciplined approach, nor is free from the scope of intellectual contamination, although it might be the most contributing factor for a notion’s rise in popularity. However, a fundamental intellectual perspective can provide a definitively disciplined approach and carefully avoid yielding intellectual chaos. The gap between a *normative essence* and a *fundamental intellectual perspective* on sustainability to be reflected in the subsequent intellectual discourse could explain ‘the chaos of sustainability’. Therefore, in the intellectual treatment of sustainability what is required above all is to go beyond this essence of normative impulse and forming an intellectually justified fundamental approach. This requires fundamental research and the formation of a new perspective on the intellectual treatment of sustainability. Emphatically, there is a prior necessity for discovering the scholarship of sustainability before imaginatively describing the normative-speculation-based treatment of sustainability.

1.6 Questioning the fundamental intellectual standing of sustainability

As a multi-faceted area in public awareness and academic discussions as well as with a global recognition as a conscious way of living, the contemporary notion of sustainability has come to host an unforeseen wave of social interest. However, the normative notion poses intellectual challenge in terms of deciphering its essence due to it referring to a values-driven nature. This renders the task of developing a structured scholarship on sustainability to be fundamentally challenging. It is also challenging due to the unprecedented necessity for a pluralistic recognition/ orientation of knowledge and the need for inventing knowledge integration processes for accommodating this orientation. As sustainability is not a firm intellectual concept, rather a notion that is values-laden and underpinned by normative assumptions and moral consciousness, as well as dependent upon cultural, historical and geographical settings; the following four questions can be asked on its fundamental intellectual standing.

- In contrary to researching sustainability based on its normative essence that has been taken for granted, to what extent can sustainability be understood and researched through a '*fundamental intellectual process*'?
- What are the implications of such fundamental intellectual process to yield a '*pluralistic knowledge approach, and avenue*' in human knowledge system?
- How such pluralistic approach to knowledge can foster the development of '*integrated knowledge acquisition processes*' that would be required for a unified knowledge base of sustainability?
- To what extent can we conceive of, and indeed engage in creating *a scholarship of sustainability* through such '*fundamental intellectual process*' and the '*pluralistic knowledge avenue*'?

As the knowledge and knowledge acquisition processes in their most effective forms exist in singular reductionist perspectives, inventing integrated knowledge acquisition processes to meet the pluralistic knowledge orientation requires the formation of an unforeseen intellectual project in our intellectual discourse. In response to this intellectual challenge, multiple speculative approaches have come to practice, which, although having differences in their perspectives of enquiry, essentially conform to the normative essence of sustainability. The point of departure of this thesis journey from the prevailing reality is in here that the notion of sustainability is treated here in a fundamental intellectual approach in contrary to the preemptively normative exercises; as in responding to the insufficiency of singular reductionist knowledge structures, the need for pluralistic knowledge orientation and integrative ways of knowledge acquisition cannot be resolved preemptively through normative exercises. Rather, addressing the grand challenge of sustainability requires a fundamental intellectual approach that could be capable of revealing the ways in which the required integrated knowledge acquisition processes can develop. Based on fundamental research this thesis aims to extract a *fundamental* *intellectual process* that can enquire on a pluralistic orientation and avenue of knowledge, and lead to the laying of an intellectual foundation for *the scholarship of sustainability*. These are researched through analyzing sustainability science from its first decade of practice (2001-2011). A *fundamental intellectual process* for *the sustainability scholarship* can also meaningfully reorient the chaotic debate around sustainability, as well as reinvigorate its intellectual basis through yielding a fundamentally justifiable and definitively disciplined approach for researching sustainability.

1.7 Chapter summary and thesis outline

The WCED Report *Our Common Future* (WCED 1987) and other contemporary milestones together invoked a historic wake-up call for humanity, the necessity of *a scholarship of sustainability* in which light is unquestionable. The growth of consciousness since the 1990s has nourished a great deal of energy for addressing the numerous and diversified issues associated with the sustainability crisis. However, epistemological, theoretical and methodological incoherencies have limited progress: "*Because such research runs counter to traditional disciplinary-based approaches that currently shape the education and training of citizens as well as scholars, we need to develop the capacity to speak across the disciplinary divides, understand the assumptions of others across the table, and learn to formulate questions, and approaches, that are truly integrative* (Moran 2010, p.143)". Before seeking to solve these myriad sustainability-related problems, a truly integrating *fundamental intellectual process* for *a scholarship of sustainability* is envisaged. This is explored in this thesis based on fundamental research.

Chapter 1 introduces this research and elaborates its rationale through reviewing and critically analyzing the relevant literature. It introduced the sustainability crisis and the concept of sustainable development in **Section 1.1**, followed by a historical snapshot of the sustainable development initiatives in **Section 1.2**. This led on to analyzing the emergence of sustainability science within the historical discourse of the scientific perspective of sustainability (**Section 1.3**). An analysis of the limitations of sustainability science in **Section 1.4** revealed fundamental problems with the nature, definition and foundation of its discourse. This is rooted in the perception that sustainability is characterized with a normative essence, which rather necessitates the formation of an intellectual perspective on it. **Section 1.5** clarified this distinction between an intellectual perspective on sustainability and the normative essence that it has become popular with. This led to a set of questions on the fundamental intellectual standing of sustainability in **Section 1.6**, which reveals the importance of developing a *fundamental intellectual process* for a pluralistic orientation and avenue of knowledge required for constructing *a scholarship of sustainability*.

The intellectual perspective on sustainability is presented in **Chapter 2**. It begins with articulating the challenge of intellectually treating sustainability in terms of a paradoxical tension prevailing at the heart of sustainability studies. With this recognition in mind, the chapter reorients the perception of the reductionist/ traditional scientific method/ practice to be seen as part of the sustainability-problem-making instead of as a tool for solving it. This is due to the limitations inherent to the reductionist/ traditional scientific method/ practice. It points to a cognitive necessity for the invention of *a new mode of enquiry* that can characterize a pluralistic orientation and avenue of knowledge. This cognitive necessity invokes the potential roles of the social sciences and humanities besides the archetypical reductionist roles of the traditional scientific disciplines in the making of a potential *pluralistic knowledge avenue* for *sustainability scholarship*. Based on these and other relevant discussions, the intellectual perspective of sustainability is presented at the end of the chapter.

The intellectual perspective on sustainability stipulates the necessity for a pluralistic orientation and avenue of knowledge, which brings in the question of developing a *fundamental intellectual process* for enquiring on these. Through a fundamental and systematic bottom-up analysis of the first decade's 'body of work' of sustainability science, **Chapter 3** frames this *fundamental intellectual process*, where the 'body of work' of sustainability science from its first decade of practice participates as an example 'pluralistic knowledge and research body'. This *fundamental intellectual process* is intended to enable the study of pluralistic knowledge and research structures as well as drawing on a potential *pluralistic knowledge avenue* for *sustainability scholarship*. This inquiry is progressed through the application of the frame of the *fundamental intellectual process* on the example 'pluralistic knowledge and research body' in terms of empirically analyzing its discursive, integrative and contextual qualities. **Chapter 3** also articulates the approaches and the epistemological as well as methodological composition of the research, besides describing the various means employed to analyze the discursive, integrative and contextual qualities of the example 'pluralistic knowledge and research body'.

Subsequent progression in research inquiry empirically analyzes the example 'pluralistic knowledge and research body' for its discursive, integrative and contextual qualities in **Chapters 4-6**, respectively. In **Chapter 4**, an empirical literature analysis is conducted on four empirical domains. This reveals the discursive practices that characterize research in sustainability science. **Chapter 5** conducts four focus analyses for revealing the qualities embedded in the ways sustainability science tries to tackle integrative concepts. In **Chapter 6**, a spatio-temporal analysis is conducted for revealing the contextual qualities i.e. the temporal, spatial and dynamic variations apparent in the practice of sustainability science. Thus, **Chapters 4-6** reveal three different kinds of insights spanning from the diversity to the integrity as well as the context of the practice of sustainability science as a pluralistic knowledge and research body, to be taken together to enquire on the pluralistic orientation and avenue of knowledge for *the scholarship of sustainability*.

The rationale, framing and application of the *fundamental intellectual process* (presented in **Chapters 1-2**, **3** and **4-6**, respectively) together reveal the dimensions and the structure of a *pluralistic knowledge avenue* in human knowledge system, as well as the latent elements of an intellectual foundation for the *scholarship of sustainability*. These are elicited in **Chapter 7** drawing from the intellectual perspective on sustainability, the framing of the *fundamental intellectual process*, as well as its application on the example pluralistic knowledge and research body. Thus, by analyzing the findings from the **Chapters 1-6**, **Chapter 7** lays out the dimensions and structure of a *pluralistic knowledge avenue* and an intellectual foundation for the *scholarship of sustainability*. **Chapter 8** concludes the thesis, drawing from the analyses, discussions and findings from **Chapters 1-7**.

In the structural mosaic of the thesis, **Chapter 2** presents the research approach by forming an intellectual perspective on sustainability. This is followed in framing a *fundamental intellectual process* for the *sustainability scholarship* in **Chapter 3**. Taken together, through introducing the research, analyzing its rationale, forming the research approach, as well as setting out the detail research plan that includes the research methods and methodology, the **Chapters 1-3** construct the first component of the thesis (i.e. Part I) based on fundamental research. The subsequent **Chapters 4-7** construct 'Part II'—

Results and Discussion—of the thesis, followed with the conclusions in **Chapter 8**. This structural mosaic of the thesis is schematically presented in **Figure 1.1**.

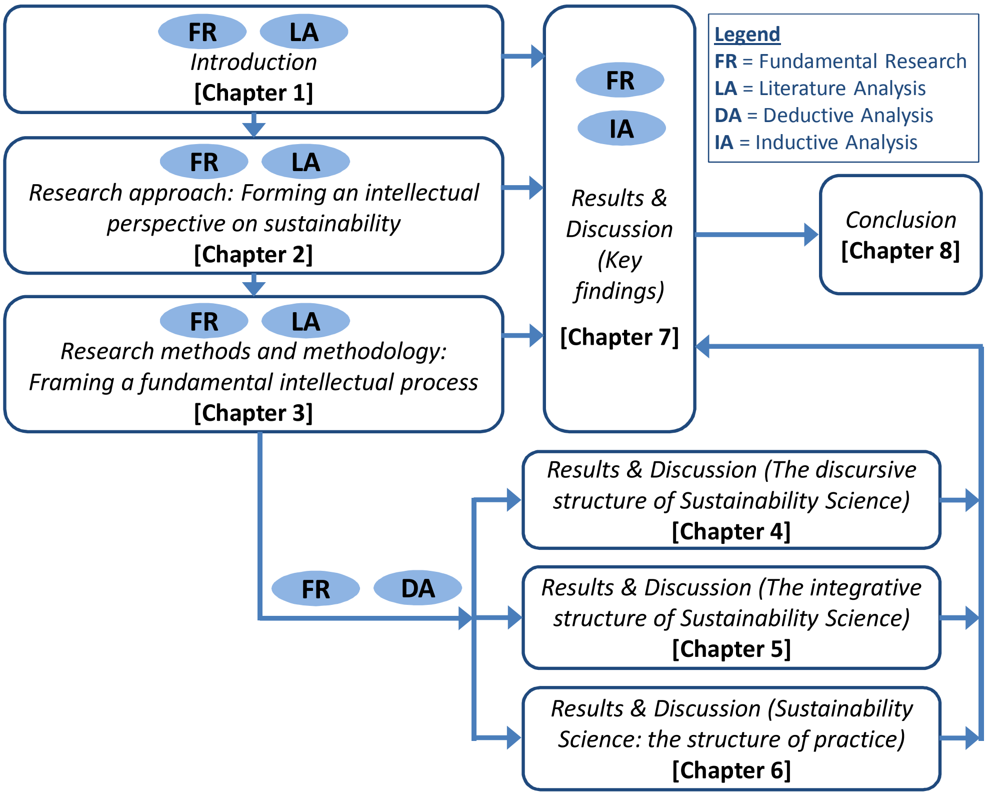


Figure 1.1 Structural mosaic of the thesis

Chapter 2

Research approach:

Forming an intellectual perspective on sustainability

Chapter 1 elucidated two problems that render the task of developing a structured scholarship on sustainability to be fundamentally challenging. The first of these is an intellectual challenge in terms of deciphering the essence of the notion of sustainability. This is due to the values-driven nature of the taken-for-granted normative essence of the notion, acting to result in an intellectual chaos. The other is the unprecedented necessity for a pluralistic recognition/ orientation of knowledge and the need for knowledge integration processes for a *pluralistic knowledge avenue*. Addressing these two problems require fundamental research on the intellectual treatment of sustainability, beginning with a critical necessity for the formulation of an intellectual perspective to replace the traditional normative character of the notion. Through forming this intellectual perspective based on fundamental analysis this chapter constructs the research approach of the thesis.

The chapter begins by elucidating the paradoxical tensions prevailing at the heart of sustainability studies (**Section 2.1**). A review of the position of the reductionist/ traditional scientific method/ practice in light of sustainability is then presented in **Section 2.2**, which reorients the perception of the method/ practice to be viewed as part of sustainability-problem-making instead of being a tool to solve it. Following this recognition on the reductionist scientific method/ practice, **Section 2.3** describes the potential roles of social sciences and humanities, beside the archetypical reductionist roles of the traditional scientific disciplines, in the making of a potential *pluralistic knowledge avenue* for *sustainability scholarship*. The orientation of *sustainability scholarship* amid the context of the diversified evolution of the disciplines is discussed in **Section 2.4**. Drawing from the findings of the **Sections 2.1-2.4**, **Section 2.5** articulates the intellectual perspective of sustainability.

2.1 The paradox of sustainability study

In the era of *Anthropocene* (Crutzen and Stoermer 2000) where human beings exert significant influence on the Earth system as an active variable, i.e. acting both as the subject and an object at the same time, imparts characteristics into modern problems that do not lie within the natural science domains, and thus, cannot be handled by the dominant natural science framework. It requires new methods and approaches to investigation and understanding, which have not been established yet (Sumi 2011). Ed Ayres (Ayres 2000) termed four *megaphenomena* (human population, materials/ energy consumption, CO_2 concentration in the atmosphere, and extinctions of species), and described how proliferation of afflictions arising from human appropriation of the planet's resources is threatening to sweep our existence away. He writes:

> "The unintended impacts of human appropriation of the planet's resources have become so numerous, voluminous, and entangled in feedback loops that they often overwhelm the capacities of decision-makers to cope with current crises, much less prepare for a sustainable future. The difficulty may be alleviated by viewing global change from a broader perspective than is normally offered either by specialists (whose views are necessarily narrow) or by mainstream media (whose interests are usually fragmentary and parochial)." (Ayres 2000, p.539)

This recognition of the scale of human influence on Earth's systems also reveals a sharp split between the nature of these afflictions and the traditional specialized scientific knowledge system (natural, social and human). The entangled nature of afflictions in feedback loops reveals the insufficiency of linear/ reductionist/ disciplinary approaches. This favors the formation of a pluralistic/ complex approach, although the trade-off between a linear/ disciplinary approach and a pluralistic/ complex approach in terms of researching sustainability is not as straightforward as it may seem at the outset.

> "For some, the term 'sustainability' is now so broad as to be meaningless. Essentially, anything, anywhere or anyone can be taken as the focus for a sustainability research project." (Franklin and Blyton 2011, p.5)

> "The time has come … to liberate the study of real-world processes from the confines of artificial, 19^{th} century boundaries between the scientific disciplines." (de Vries 2013, p.5)

The two preceding quotations together illustrate a tension prevailing at the heart of sustainability studies: the opposing risks of too much breadth (referring to the first quotation) and too much depth (referring to the second). Attempting to trade-off/ solve this tension between the two opposing realities poses a paradox for sustainability study. It becomes even more challenging given the urgent imperative to solve the growing sustainability crises. In resolving this pressing paradox a mere moral/ normative essence of sustainability would be of little help. An important inquiry towards an intellectual perspective on sustainability is founded upon reassessing the position of the traditional scientific method in light of the sustainability problem.

2.2 Traditional scientific method: A part of the problem let alone the solution

The appearance of sustainability in human intellectual discourse brings an unprecedented problematic dimension of the traditional scientific method into our perception. From a sustainability perspective, the structure of the traditional scientific disciplines could be described as containing 19^{th} century artificial boundaries among the disciplines (de Vries 2013, p.5) that enable them to function in their reductionist way. In human intellectual discourse the dominance of these artificial boundaries—that have been driving production in reductionist mode of knowledge—has been so great that others have described the same as the 'traditionalist view of sanctity, and indeed, hegemony of single disciplinary approaches' (Marsden 2011, p.297). Shaping our intellectual approach to addressing the sustainability problem implies liberating our intellectual discourse from the dominance of these artificial 19^{th} century boundaries through countering such sanctity and hegemony of traditional scientific method.

> "The inability of key scientific disciplines to engage interactively is an obstacle to the actual attainment of sustainability." (McMichael et al. 2003, p.1919)

Science in its current discipline-based reductionist mode has delivered significant technological progress. These at the same time serve to conceal the limitation of science in terms of addressing problems that span multiple disciplines (Perrings 2007). The traditional scientific method operates through obfuscating the subjective view with the objective view, as in its practice the objective view can disguise and internalize the subjective view within it (Yoshikawa 2011). While it claims to contribute to the understanding of everything in the universe, it attempts to do so only by making individual components of the universe as its focus of enquiry (Yoshikawa 2011). The argument continues as — despite its other benefits, knowledge gained from the practice of the traditional scientific method in terms of advancing the understanding of the components of the system is not sufficient to ensure the sustainability of the system.

This fundamental limitation of the traditional scientific method can metaphorically be articulated in terms of enabling research scientists to produce specialized bricks of knowledge at the expense of not seeing the whole building (Ziman 2001). This is due to the complexity of problems that necessitate knowledge subdivision in the realm of practicing the traditional scientific method (Yamaguchi and Komiyama 2001). Due to this immiscibility of the reductionist disciplines in their characteristic fragmented and narrow specialization, a researcher coming from a given discipline cannot possibly have an adequate understanding of the whole of an issue as s/he only understands as well as able to observe only a small component of it occurring to be native to his/ her discipline (Yamaguchi and Komiyama 2001, Börner et al. 2003). This—from the perspective of the practice of the traditional scientific method—results in approaching the sustainability issues from subsets of existing reductionist disciplines (Takeuchi 2011) that do neither overcome the inherent inability of the traditional scientific method to address the sustainability crisis.

Attempting to conduct sustainability research from subsets of existing reductionist disciplines through the practice of the traditional scientific method results in the following two realities (Komiyama and Takeuchi 2011) — (i) in the reductionist mode the complexity of problems does not render taking comprehensive and overarching views possible, and (ii) the disciplines examining these complex issues can only conduct research on both identification of phenomena and searching for potential solutions in a highly restricted perspective that does not correspond to the sustainability crisis in its actual reality. In overcoming these inherent inabilities of the reductionist scientific method in addressing the sustainability crisis, the formation of an alternative perspective that could lead to the invention of a *pluralistic knowledge avenue* along with integrated knowledge acquisition processes has become imperative. However, in the absence of such alternative perspective, it is the compartmentalized specialization of reductionist scholarships that renders the real complexity to the sustainability problems as we are limited in perceiving and addressing the problems in a fragmented reality that does not correspond to the way the sustainability problems exist. Thus, it emerges as a paradox that as we started to perceive the wide-scale problems of sustainability, the much-cherished tool of reductionist enquiry at our hands now appears to be useless, rendering us effectively empty-handed.

In delivering the dominant role in human intellectual discourse <u>how could the traditional scientific method not prevent the emergence of these complex and wide-scale problems</u>; and indeed, <u>has it actually led to the creation of these problems</u> that <u>it is inherently unable to solve</u>? The exercise of the traditional scientific method has led to the creation of the sustainability crises through fragmented scientific and technological advances that yield inconsistent/ contradictory artifacts leading to excessive, localized and uncoordinated human actions that were meant to improve the quality of life. By shining light along the vertical shafts of narrow and specialized reductionist progress (in terms of knowledge and the associated scientific and technological advances), the traditional scientific method has also cast a shadow across the horizontal nature of knowledge and so over the integrated reality, thus, preventing the development of an alternative perspective: "*Ironically, the growth of diversified disciplines and specialization of knowledge that has helped humankind to overcome earlier threats and has contributed so much to human progress has also hindered the ability to recognize the emergence of new threats to the sustainability of the planet* (Yoshikawa 2011, p.262)".

This reality could metaphorically be expressed in terms of losing in mental perception the entirety of an integrated object when too much focus is applied on the minute fragments of the object. In the practice of the traditional scientific method this is how the research scientists become enabled to produce specialized bricks of knowledge at the expense of not seeing the whole building (Ziman 2001). In reality this implies that the specialized disciplinary progress in reductionist mode of enquiry had taken place without the reality match of advancing our understanding on the entirety of the reality, whereas the fragmented scientific and technological advances arising from the reductionist disciplinary progress did not cease from yielding inconsistent/ contradictory artifacts that led to excessive, localized and uncoordinated human actions meant to improve the quality of life. Apparently, the vertical advancement of knowledge in segregated disciplines has yielded an unintended vertical seepage along the interstitial spaces of the artificial borders of reductionist disciplines through the actions and artifacts that were meant to improve the quality of life. This accumulated seepage represents the unintended consequences of these actions and artifacts on the integrated human reality, yielding the grand sustainability crisis. These artificial borders among the reductionist disciplines also acted to prevent modern science from seeing this effect until reaching at today's reality.

The preceding discussion on assessing the position of the traditional scientific method in light of the sustainability crisis demonstrates that the reductionist scientific method and its mode of enquiry: (i) cannot address the entirety of the reality, (ii) can observe and explain its matters of enquiry merely in an objective manner by excluding the subjective as well as holistic aspects of the reality, and (iii) cannot yield artifacts but within highly restrictive scopes and manners. This poses a question as to the true level of accomplishment in human intellectual discourse from the exercise of the reductionist scientific method while at one end there is an explosion of reductionist results and artifacts inconsistent to the integrity of the reality, and at the other end there is a dire poverty of knowledge of the system and its sustainability. Instead of continuing with the exercise of the reductionist mode of enquiry in addressing the problems of sustainability, it thus becomes necessary to reorient the perception on the traditional scientific method to be viewed as a part of sustainability-problem-making instead of assuming it to be a tool to solve it.

With respect to — (i) the constraints of the paradox of sustainability study between the breadth and depth of comprehending the reality (see **Section 2.1**), and (ii) the role of the reductionist mode of enquiry in sustainability-problem-making instead of potentially being a tool to solve it; the human intellectual discourse must embrace *a new mode of enquiry* and the necessity for the invention of a *pluralistic knowledge avenue* in order to resolve its poverty in knowledge of the integrity of the reality and its sustainability. The fundamental intellectual orientation of such a mode of enquiry could metaphorically be articulated in terms of its capacity to produce bricks of knowledge while looking at the whole building, as opposed to the production of specialized bricks of knowledge at the expense of not seeing the whole building (with reference to Ziman's (2001) words). Others have tried to speculate on this through proposing notions that operate from inside the box of reductionist mode of enquiry, such as the notions of 'knowledge-broker' or 'boundary-spanner' to be necessary for sustainability studies (Kajikawa and Komiyama 2011, p.43), or else the idea that a sustainability researcher needs to be a philosophical thinker (Yoshikawa 2011). However, there is a critical necessity to recognize that the problem of sustainability does not reside within the intellectual grasp of the reductionist mode of enquiry, and therefore, it cannot be resolved through devising concepts that operate from within the realm of the reductionist enquiry. Rather, a *new mode of enquiry*—to be characterized with a unique intellectual orientation—becomes absolutely necessary. This is to be coupled with the development of *fundamental intellectual process(es)* that can lead towards the invention of a *pluralistic knowledge avenue* for *a sustainability scholarship*.

The *new mode of enquiry* would also require a new epistemological interpretation of knowledge and knowledge production to characterize its unique intellectual orientation. Although in philosophical interpretation knowledge is considered as 'justified true belief' (Dretske 1981) and most of our knowledge is not strictly justified in that sense (Kajikawa 2011), there is a controversy as to the nature of knowledge among the disciplines. Each discipline tries to define knowledge as per relevant to it, instead of flowing from a common/ shared philosophical viewpoint. The lack of a uniform philosophical stand as to the nature of knowledge with the disciplines has thus resulted in a number of schools of thought in the discourse of philosophy of science with little agreement among the different schools (Riggs 1992). Due to multitude of disciplines functioning with multitude of epistemological perspectives, the intellectual orientation of the *new mode of enquiry* needs to epistemologically arbitrate with the already complex philosophical reality of knowledge and its production.

2.3 Cognitive necessity: On roles of Social Sciences and Humanities in *sustainability scholarship*

> "Sustainability in its radical form must question the trends [*i.e. the doctrines of efficiency and technological necessity, successfully directing and sustaining modernization and economic development*] that placed the sustainability issue on the table. If anyone is to challenge the basic assumptions of development, it must be academics in the social sciences and the humanities." (Sato 2011, p.333-334)

Section 2.2 demonstrated the inability of the reductionist mode of enquiry in addressing the sustainability crisis, as well as reoriented the perception of the traditional scientific method to be viewed as part of the sustainability-problem-making. As '*losing the grasp of the whole building while trying to produce a specialized brick of knowledge*' (with reference to Ziman's (2001) words) has no utility in offering an effective approach for studying sustainability, the traditional reductionist mode of enquiry is fundamentally unable to provide a framework for the cognitive necessities for *sustainability scholarship*. However, this does neither mean that there is no utility of the various reductionist disciplines for sustainability studies. As the *new mode of enquiry* (**Section 2.2**) represents the intellectual orientation of 'producing bricks of knowledge while looking at the whole building', the existing reductionist disciplines have definite roles to play in terms of assisting with the production of these bricks of knowledge for the making of the *pluralistic knowledge avenue* for *sustainability scholarship*. Besides the archetypical reductionist roles of the traditional scientific disciplines, there are other important roles of the social sciences and the humanities in the making of this *pluralistic knowledge avenue*.

In the social sciences there has been a steady environmentalization in terms of the implementation of sustainability-related concepts such as carrying capacity, ecological footprints, sustainable environmental assessment techniques, intergenerational equity, deliberative and participatory processes, etc. (Marsden 2011). The social scientific tools that have so far been applied to sustainability-related problems include environmental cost-benefit analysis, emissions trading, conflict resolution techniques, institutional analysis of common property management, re-appreciation of indigenous knowledge, etc. (Sato 2011). However, there are specific reasons to emphasize on the role of the social sciences including it having an advantage over the natural sciences in terms of addressing the questions of values and power, i.e. what is variable and contextual and what aims towards informed judgment (Sato 2011). However, the social science studies that operate within the realm of judgment and practical wisdom have come to sustain an underprivileged status compared to those that emulate the physical science doctrines such as efficiency and technological necessity. Sato (2011, p.333-334) writes: "*The doctrines of efficiency and technological necessity are so dominant that they in effect shut the door on the exploration of alternative possibilities* [i.e. appreciation of local/ tacit/ experiential knowledge] … *An important function of social science is to recover the realm of judgment and practical wisdom as a distinct field of academic contribution. This is not only because this area of knowledge has been neglected and downplayed in the social sciences, but because the problem of sustainability demands a new way of thinking.*"

It is due to this dominance of the doctrines of efficiency and technological necessity that the reductionist knowledge practices like the natural sciences and 'the social sciences oriented to emulate the natural sciences' take 'analytical' as preferred over the 'integrative', and the 'universal' over 'the particular'. This causes a hierarchy in our knowledge system that takes the universal and the quantifiable as privileged over the local and the qualitative regardless of how total the 'local and qualitative knowledge' could potentially be in contrast to the partial nature of the 'universal and quantifiable knowledge' (Sato 2011). For sustainability studies such is ideally not the case. Rather 'the integrative' and 'the particular' have special relevance in sustainability studies as sustainability requires 'integration' among different components of reality within the context of different scales (i.e. referring to 'the particular'). In the 'realm of judgment and practical wisdom oriented social science' these traits (i.e. 'integrative', and 'the particular') are characteristic to experiential and practical knowledge, which are: (i) integrative rather than analytical, (ii) something that must be learnt by doing instead of by reading, and (iii) which place attention to 'the particular' instead of directly heading towards the universal (Sato 2011). This relevance between the 'realm of judgment and practical wisdom oriented social science' and sustainability studies in terms of the contextual and integrative necessities is a further avenue of contribution from the social sciences into the making of the *pluralistic knowledge avenue* for *sustainability scholarship*. This aspect of the social sciences is even more relevant for sustainability studies as in addressing the questions of ethical judgment, '*science does not tell us who and how much should be sacrificed for the sake of the general good; such decisions require deliberation and ethical judgment*.' (Sato 2011, p.331)

Compared to the roles of the natural sciences and the social sciences, the potential role of humanities in the making of the *pluralistic knowledge avenue* for *sustainability scholarship* is far deep-rooted and profoundly significant:

> "[*In addressing the sustainability issues*], the cutting-edge achievements of both the natural and the social sciences should naturally be mobilized. But the humanities also have a role to play in examining the thought, cultures and ways of seeing and thinking that underlie these problems, as well as in identifying problems still on the horizon, conceptualizing a desirable state of human existence and global society, and offering a direction towards solutions." (Takemura 2011, p.336)

Takemura translates the work of Hisatake Kato (1991), criticising three of the most important institutions regarded as ideal in modern society:

> "The market economy is inadequate because resource depletion and waste accumulation are external to economic relationships.
>
> Democracy is inadequate because it has no binding authority to protect the interests of future generations or people in other countries.
>
> Fundamental human rights are inadequate because they are too narrow, failing to address the human responsibility to protect non-human life." (Takemura 2011, p.337)

Takemura argues that since the beginning of the modern age an atomistic perception of human reality together with respect for 'independent individual' pervaded social principles, resulting in the practice of excessive individualism and the principle of unrelenting competition (Takemura 2011). He explains the role of scientific methodology acting behind this, as in seeking to break existence into its most basic elements, modern rationalism has been based on a dualism of 'the subject' and 'the object'; where it asks no questions about the subject and rather directs its focus exclusively towards the object. This, in the paradigm of modern rationalism, results in 'the subject' becoming manipulated and dominated. It has, as Takemura argues, made mass production and mass consumption possible through encouraging the competitive pursuit of economic profit to be a good thing, with the resultant mass waste, pollution and damage to the global environment:

> "The problem of the environment and that of disparities – in other words, the crisis of nature and the social chaos of contemporary society – are both rooted in modern rationalism. Therefore, if one aspires to solve the problems of the global environment and of contemporary society, it is essential to change the paradigm of modern rationalism." (Takemura 2011, p.338)

Rectifying this fundamental flaw in modern rationalism would demand an unprecedented intellectual capacity, capable of simultaneously focusing on the object and the subject. Such an intellectual orientation would also impart fundamental change to the conventional paradigm of objective and logical scholarship (Takemura 2011). Takemura emphasizes that such integrated study (i.e. focusing on the subject and the object at the same time) can neither effectively take place by studying a system where the 'self' is placed outside, or the self is expanded through an objective understanding achieved by objectively connecting the self and the world, or by involving one merely objectively, as in any of these cases the perspectives on and the awareness of 'the self', the subject, and the life becomes lost. Unless such intellectual capability could be established, people could remain in a state where one cannot distinguish between what should be regarded as the most important and what should not; which in turn would not solve the fundamental flaws in the world view of the modern era (Takemura 2011):

> "[*Fragmentation of the holistic workings of organic life*] manifests itself in symptoms of fragmentation or disconnectedness caused by the division of labour and narrowed specialization in human activities, which result from the never-ending pursuit of higher productivity and efficiency in the process of modernization. ... The feelings of alienation and isolation, various kinds of psychological mal-adaptation and the loss of a sense of satisfaction or purpose in life observed in advanced countries can be attributed to people's disconnection from the lives that surround them and to the fragmentation of holistic human activities in societies with a high level of division of labour. ... As long as the current industrial society pursues segmentation and meticulous management with the objective of higher efficiency, the emergence of specialized fields in the educational system that prepares students for life in this society cannot be avoided. … A crucial step in correcting fallacies of composition or the fragmentation problem is to recognize that all things are basically connected with people's existence. A paradigm shift from traditional atomism and reductionism to relationalism and a holistic view of the world seems to be necessary." (Nakagawa et al. 2011, p.359-360)

The pursuit of efficiency has reflected its character in scientific practices through ‘reductionism’, which was followed in encouraging the perception of human reality through ‘atomism’. These have resulted in undermining the relational view of human life and the holistic view of the world system. The root cause of this reality has been in acknowledging reductionism to be the overwhelming characteristic of scientific methodology in pursuits of efficiency and objective benefits. This philosophical position of scientific methodology has been adopted in human society in terms of acknowledging an atomistic view of human reality with the hope of achieving similar success in efficiency and objective benefits as how reductionist scientific methodology has served. However, the improved efficiency and objective benefits derived from this narrow scientific reductionist vision has also yielded inconsistent, incoherent and contradictory artifacts, leading to uncontrollable global system degradation. The reflection of reductionist philosophy in human society has also served promoting the competitive pursuit of profit to be a good thing, leading to excessive, localized and uncoordinated human actions. These also led to social disparity such as the North-South divide, as well as added into the sustainability crisis through unsustainable consumption from both of over-wealth and over-poverty in the North and the South, respectively.

The reductionist vision in scientific practices has imparted obvious benefits to human progress. However, the inappropriateness has been in acknowledging this narrow vision to be the overwhelming characteristic of the scientific paradigm, and in parallel, adopting atomism as the overwhelming view of human reality. The resultant traits, i.e. the inconsiderate pursuits of efficiency, higher productivity and objective benefits, as well as the competitive pursuit of economic profit have grasped human reality and dragged it to the edge of oblivion. The root of sustainability crisis is no lesser deep than the reductionist characteristic of the scientific paradigm and the atomistic characteristic of human social paradigm. Unless these roots can be corrected/ rectified, any effort directed towards resolving the crisis of sustainability could seem to only be scratching on the surface:

> “With the collapse of a social system that is based on individualism and the competition principle and that has operated according to the supremacy of the market economy, the formation of a social order based on new values is a matter of urgency. … The social role of the humanities today can be found in fundamental criticism of the inhumane state of contemporary society, as exemplified by excessive individualism and the competition principle, institutions that positively evaluate only efficiency and achievements, the unrelenting pursuit of self-interest

> and the physical and mental domination of many losers by a few winners." (Takemura 2011, p.348, 350-51)

2.4 The orientation of *sustainability scholarship* amid the diversified evolution of disciplines

> "In a broad sense, the origins of academic disciplines can be traced back to the need to understand and gain control over untamed and chaotic forces. The problems addressed were seen not as of humanity's own making but, rather, as stemming from natural causes over which human beings had no dominion … From the sustainability perspective, the diversified evolution of disciplines and concomitant growth in specialization and contradictory artefacts have already had a detrimental effect on the planet, endangering the environment through excessive, localized and uncoordinated human actions." (Yoshikawa 2011, p.260-262)

Scientific disciplines have either emerged through a concept-oriented, or problem/ use-oriented evolution (Yarime 2011), or through interdisciplinary evolution (Kajikawa 2011). Examples of concept-oriented evolution includes the disciplines of chemical engineering and soil mechanics, while agricultural sciences and health sciences characterize problem/use-oriented evolution, and nanotechnology and bioinformatics reflecting interdisciplinary evolution (Kajikawa 2011, Yarime 2011). The establishment of the discipline of chemical engineering is articulated by Yarime:

> "In the case of establishing chemical engineering as an academic discipline, it was of critical importance that diverse chemical processes were conceptualized in 1915 into "unit operations" such as drying, distillation, separation, extraction, evaporation, absorption and adsorption (Rosenberg 1998). Based on this intellectual foundation, the School of Chemical Engineering Practice was established at MIT, followed by the establishment of an independent academic department in 1920. Then a standard textbook, Principles of Chemical Engineering, was published in 1923. The conceptualization of unit operations in effect functioned as a "focusing devise" in elaborating the purposes of research in chemical engineering. Concepts, tools and methodologies were applied to actual problems in industry, and the knowledge and experiences obtained were fed back to education and research at universities, leading to the development and institutionalization of chemical engineering." (Yarime 2011, p.101)

In contrast to the institutional character for the establishment of the discipline of chemical engineering, the creation of the discipline of soil mechanics had rather happened by the genius of one individual, Karl Terzaghi, who as a student was about to be expelled from university due to 'excessive indulgence in academic freedom' except for the intercession of a professor reminding the faculty that the three previously expelled students had become eminently successful including Nicolas Tesla (Casagrande 1964). Casagrande describes how Terzaghi singlehandedly invented the discipline of soil mechanics:

> "… he began a systematic digest of all German, French, and English literature on earthwork and foundation engineering for the period 1860-1917, resorting chiefly to libraries in Vienna during visits to that city. As a result of this effort and of his experience in the United States, he concluded that there was no hope of condensing empirical knowledge into a useful system without methods describing clearly and measuring quantitatively the engineering properties of the vast spectrum of soils. Because such methods did not exist, he concluded that it was a hopeless task to find any relationships between the records of the subsoil conditions and the performance of the structures. Once this conclusion was clearly established in his mind, he wasted no more time on trying to find the key by studying available empirical knowledge. Instead he began a systematic experimentation with soils, starting with sands. … Night after night he worked with his primitive equipment and thus discovered the mechanism of consolidation of clay and other important principles which form the basis of modern soil mechanics. In 1923 he published the fundamental differential equation for the consolidation processes … ." (Casagrande 1964, p.3)

Two years later in 1925 Terzaghi published the monumental book *Erdbaumeckanik auf bodenphysikalischer Grundlage*, the publication of which is considered to be the birth of soil mechanics. On the other hand, in interdisciplinary evolution a scientific discipline emerges from an intermediary interdisciplinary state by analyzing new phenomena with new approaches that require integration of a variety of disciplinary knowledge, as evidenced from the birth of bioinformatics and nanotechnology (Kajikawa 2011).

Besides the concept-oriented, or problem/ use-oriented or interdisciplinary evolution, the disciplines could also be classified in terms of their necessity types as they arise out of necessity regardless of their varying evolution. These could either be in terms of the lure of achieving basic understanding (such as in case of the basic sciences) or the usefulness of the produced knowledge (such as in the applied sciences), or the combination of both, which is characterized by use-inspired basic research (Clark 2007). Among these types, the *sustainability scholarship* combines both of these necessities of basic and applied research. On one hand it requires fundamental research for creating a pluralistic orientation and avenue of knowledge, while on the other hand it needs to engage with applied research in addressing the sustainability problems/ issues. Therefore, the research orientation of *sustainability scholarship* could be identified with use-inspired basic research, also known as Pasteur's Quadrant in the scheme of classification of scientific research (Clark 2007).

As discussed in **Section 1.3**, the *sustainability scholarship* also seeks to draw on the three pluralistic modes of ‘multi-, inter and trans-disciplinarity’. For the interdisciplinary and trans-disciplinary modes, the scholarship needs to draw on the character of interdisciplinary evolution. Examples of interdisciplinary functions of *sustainability scholarship* include ‘enabling integration of separately evolved disciplines’, ‘the capacity to ameliorate conflicts among disciplines arising from their ongoing fragmentation’, as well as ‘serving to offset the negative effects of relentless specialization becoming the fate of the modern science’ (Takeuchi 2011b, p.355). However, as for the multi-disciplinary mode, the scholarship could combine the properties of both ‘concept- and problem/ use-oriented’ evolution, reflecting from the research orientation of use-inspired basic research. Therefore, with a research orientation of use-inspired basic research and the three pluralistic modes of ‘multi-, inter and trans-disciplinarity’, the establishment of the potential *scholarship of sustainability* could combine the elements of all three concept-oriented, problem/ use-oriented and interdisciplinary evolution.

However, the difficulties towards the establishment of *sustainability scholarship* with such orientation also need to be recognized. As essential differences exist among the natural sciences, the social sciences and the humanities, merely amassing knowledge from different disciplines would not be sufficient given that no method has yet been found to integrate them (Sumi 2011). Yoshikawa (2011) has referred to the task of sophisticated integration of research in multiple domains as being ‘nightmare phase’ in contrast to ‘dream research’ where knowledge is generated for its own sake without any necessity of reality check:

> “Because different disciplines are involved in addressing many issues related to sustainability, the concept of interdisciplinarity or transdisciplinarity has been emphasized … It then needs to be investigated how that could be possible theoretically and to elaborate how transdisciplinarity can actually be implemented in research and education. A given issue can be tackled through different approaches, which, however, are not necessarily connected or integrated, let alone transcended.” (Yarime 2011, p.102)

2.5 The intellectual perspective of sustainability

This chapter frames the research approach of the thesis through deducing an intellectual perspective on sustainability based on fundamental analysis. This section articulates this intellectual perspective drawing from the findings in the preceding sections. The starting point on the intellectual perspective of sustainability is with the fundamental question of the constraints of the paradox of sustainability study between the breadth and depth of comprehending the reality. As the reductionist mode of enquiry produces narrow and fragmented vertical advancement in knowledge, this linear/ reductionist disciplinary approach does not suffice the necessity for addressing the sustainability crisis while on one hand the sustainability problems are characterized with a proliferation of afflictions with entangled nature in feedback loops, and on the other hand this vertical knowledge advancement produces disintegrated comprehension on the integrity of the reality along with a resultant pool of fragmented, inconsistent or even contradictory artifacts. While attempting to intellectually address the sustainability issue through the reductionist disciplinary practice forms a part of the problem in terms of disintegrated vertical comprehension on the reality, the other part of the problem lies at the other end of the spectrum, i.e. in terms of the breadth of comprehending the reality. The expanse and complexity of sustainability problems could potentially be as vast as incorporating anything and everything in reality, which, in human intellectual capacity, could potentially mean reducing the sustainability issue into an empty/ meaningless notion. These two extremes, thus, together construct an intellectual tension and a paradox, where the *sustainability scholarship* should operate through the imaginary center line between them, together with simultaneously covering sufficient breadth and depth of comprehending the reality. The breadth here denotes horizontal comprehension <u>of the integrity of the reality</u>, whereas the depth is in vertical comprehension <u>of the specificity of the integrated reality</u>. The sufficiency in the extents of the concomitant horizontal and vertical comprehension—i.e. the breadth and depth of comprehending the reality—is to remain a dependent function on our progress in *sustainability scholarship* under the constraint of the paradoxical intellectual tension, which brings in the necessity of reassessing the position of the traditional scientific method in light of the sustainability crisis.

The traditional scientific method and its characteristic reductionist practice exhibit the following limitations:

(i) It operates based on an objective view that obfuscates, disguises and internalizes the subjective views of the fragments of the reality that the reductionist scientific practice is capable of studying,

(ii) The reductionist scientific disciplines are composed of artificial boundaries among one another that enable them to function in their reductionist way through compartmentalized disintegration of the domains, but since these boundaries define the method they are unable to engage interactively across domains, and

(iii) The training in traditional scientific method constrains practitioners to producing specialized bricks of knowledge that disregard the entirety of the building.

These limitations have simultaneously prevented the reductionist scientific practice from recognizing its deleterious effects in terms of brewing the sustainability crisis at a scale beyond its compartmentalized narrow domains. While the specialized disciplinary progress in the reductionist mode of enquiry had taken place without the reality match of also advancing our understanding on the entirety of the reality, the fragmented scientific and technological advances arising from the reductionist practice did not cease from yielding the inconsistent/ contradictory artifacts that led to excessive, localized and uncoordinated human actions intended to improve the quality of human life. The unintended consequences of these actions and artifacts on the integrated human reality together yielded the grand sustainability crisis.

On the other hand, the dominance of the reductionist mode of enquiry in human intellectual discourse has been so great that this reality has also served to prevent the development of alternative intellectual perspectives. As evident from our present intellectual reality, it took until after the emergence of the grand sustainability crisis for our intellectual discourse to be able to effectively recognize the existence of the crisis, due to such overwhelming influence of the reductionist mode of enquiry. A crucial recognition on the intellectual perspective of sustainability would, therefore, be in reorienting the perception of the traditional scientific method to be viewed as part of sustainability-problem-making instead of assuming it to be a tool to solve it.

Apart from the inherent limitations of the reductionist mode of enquiry outlined above, attempting to conduct sustainability research from subsets of existing reductionist disciplines does not render taking comprehensive and overarching views of sustainability problems possible, while the disciplines can only conduct research on both phenomenon identification and searching for potential solutions in a highly restricted perspective that does not correspond to the sustainability crises in their actual realities. In a situation where the inherent limitations of the traditional scientific method had prevented its reductionist practice from recognizing its deleterious effects in leading to the emergence of the sustainability crisis, while at the same time preventing the development of alternative intellectual perspectives through its overwhelming influence on human intellectual discourse as well as its inherent incapacity to solve the problem of sustainability; the formation of an alternative perspective i.e. *a new mode of enquiry* for our intellectual discourse has become imperative. This *new mode of enquiry* needs to be capable of addressing the sustainability problems in their actual realities, besides overcoming the fundamental limitations of the reductionist mode of enquiry in addressing the sustainability crisis.

The *new mode of enquiry* needs to simultaneously progress the horizontal comprehension of the integrity of the reality (i.e. the breadth of comprehending the reality) as well as the vertical comprehension of the specificity of the integrated reality (i.e. the depth of comprehending the integrated reality). The importance of this simultaneous production of the horizontal and vertical understandings lies in the nature of the produced knowledge that would reveal the nature of the integrated reality in both of its characteristic dimensions instead of either a fragmented and disintegrated vertical comprehension, or a shallow and superficial horizontal comprehension that does not tell much on the specificity of the reality. It is through the center line between these standalone horizontal and vertical extremes that the *new mode of enquiry*, and thus, the *scholarship of sustainability* should operate.

The intellectual orientation of this *new mode of enquiry* can be articulated in terms of its capacity to produce bricks of knowledge while looking at the whole building, as opposed to the production of specialized bricks of knowledge at the expense of not seeing the whole building, being the characteristic of the reductionist mode of enquiry. Such intellectual orientation requires the formation of a *fundamental intellectual process* to enable and characterize its pluralistic knowledge definition. This can lead to the development of integrated knowledge acquisition processes for the establishment of *a pluralistic knowledge avenue* for *a scholarship of sustainability.* In addition, this *new mode of enquiry* also needs to epistemologically arbitrate with the already complex philosophical reality of knowledge for a new epistemological interpretation on knowledge and its production, in order to characterize its unique intellectual orientation.

The subsequent aspect in the intellectual perspective of sustainability would be in the cognitive necessities towards the development of such *pluralistic knowledge avenue* for *sustainability scholarship*. As the traditional reductionist mode of enquiry—with its characteristic 'loss of grasp of the whole building while trying to produce a specialized brick of knowledge'—is fundamentally unable to provide a framework for this cognitive necessity, the *new mode of enquiry* with its intellectual orientation of 'producing bricks of knowledge while looking at the whole building' needs to churn out these necessities for the *sustainability scholarship*. Following this framework on the cognitive necessities, the *fundamental intellectual process* for the *new mode of enquiry* can enable and characterize the pluralistic knowledge orientation and lead to the development of integrated knowledge acquisition processes for the establishment of the *pluralistic knowledge avenue*. However, there are potential roles of the reductionist disciplines in the making of this *pluralistic knowledge avenue* in terms of assisting with the production of the bricks of knowledge for the *new mode of enquiry*. Besides the archetypical reductionist roles of the traditional scientific disciplines, there are other important roles of the social sciences and humanities to this end.

Apart from a steady environmentalization evident in terms of the implementation of sustainability-related concepts in the social sciences, there are multiple perspectives in practice including the realm that emulate the physical science doctrines of efficiency and technological necessity, as well as the studies operating within the realm of judgment and practical wisdom. Although the social science studies that operate within the realm of judgment and practical wisdom have come to sustain an underprivileged status compared to those oriented to emulate the natural sciences, the realm of judgment and practical wisdom have specific relevance for sustainability studies beyond the archetypical reductionist roles of the 'efficiency and technological necessity'-oriented studies.

Due to the natural sciences and the 'efficiency and technological necessity'-oriented social sciences preferring 'analytical aspects' over 'integrative understanding', as well as 'universal deduction' over 'particular characteristics'; there is a hierarchy in our knowledge system that takes 'the universal and the quantifiable' as privileged over 'the local and the qualitative' regardless of the partial nature of the universal and the quantifiable knowledge. As sustainability requires integration among different components of reality within various scales, 'the integrative' and 'the particular' have direct relevance for sustainability studies in terms of the contextual and integrative necessities. Furthermore, the realm of judgment can also address questions of ethical judgment for sustainability studies such as whom and how much should be sacrificed for the sake of the general good.

The roles of the humanities studies in the making of the *pluralistic knowledge avenue* for *sustainability scholarship* is far deep-rooted compared to the relevance of the natural and the social sciences for sustainability studies. One of the most important of these roles is in the criticism of the paradigm of modern rationalism that has been built based on a reductionist, objective perception of the world, along with an atomistic perception of human reality. The pursuits of efficiency and objective benefits have reflected their characters into scientific practices through the acknowledgment of reductionism to be the overwhelming characteristic of it. This reductionist scientific philosophy encouraged the adoption of an atomistic perception of human reality with the hope of achieving similar success in terms of efficiency and objective benefits, as how reductionist scientific methodology has materialistically served in improving the quality of life. In consequence, the improved efficiency and objective benefits derived from the narrow, reductionist scientific vision have yielded inconsistent, incoherent and contradictory artifacts that led to uncontrollable global system degradation. On the other hand, the reflection of this reductionist philosophy in human society has also served promoting the competitive pursuit of profit to be a good thing, leading to excessive, localized and uncoordinated human actions. The resultant traits from both of these trends — i.e. the unrelenting pursuits of efficiency, higher productivity and objective benefits, as well as inconsiderate competitive pursuit of economic profit — have together yielded the sustainability crisis.

Therefore, the root of the sustainability crisis is no lesser deep than the reductionist characteristic of the scientific paradigm and the atomistic characteristic of human social paradigm, together shaping the paradigm of modern rationalism. Through examining the thought, cultures, and ways of seeing and thinking the humanities studies can contribute in rectifying these fundamental flaws of modern rationalism through replacing its objective, reductionist character with a holistic view of the world, and the atomistic human perception with relationalism. These also project another important characteristic for the *new mode of enquiry* in terms of the intellectual capacity of simultaneously focusing on both the subject and the object, revealing a sharp contrast from the conventional objective and logical scholarship.

The last but not the least component of the intellectual perspective of sustainability would be in determining the position of the potential sustainability scholarship amid the diversified evolution of the disciplines. There have been various modes of emergence for the disciplines such as their concept-oriented evolution, or problem/ use-oriented evolution, or even interdisciplinary evolution. Besides these various disciplinary evolution, the disciplines also arise out of their types of necessity, such as the lure of achieving basic understanding (as in case of basic sciences), or the usefulness of the produced knowledge (such as in the applied sciences), or a combination of both, which is characterized as use-inspired basic research.

Among the various necessity types, the *sustainability scholarship* combines both of the basic and applied necessities, as on one hand it requires fundamental research for creating a pluralistic orientation and avenue of knowledge; while on the other hand, it needs to address the sustainability problems/ issues i.e. engaging with applied research. Therefore, the research orientation of *sustainability scholarship* could be identified as ‘use-inspired basic research’.

In terms of the various modes of emergence of the disciplines, the three pluralistic modes of ‘multi-, inter and trans-disciplinarity’ of the *sustainability scholarship* could combine all three elements of concept-oriented, problem/ use-oriented as well as interdisciplinary evolution. The interdisciplinary evolution becomes relevant to the interdisciplinary and trans-disciplinary modes of the scholarship, while the multi-disciplinary mode could combine the properties of both ‘concept- and problem/ use-oriented’ evolution, reflecting from its research orientation of use-inspired basic research. In summary, with a research orientation of use-inspired basic research and three pluralistic modes of ‘multi-, inter and trans-disciplinarity’, the potential *scholarship of sustainability* could combine the elements of all three concept-oriented, problem/ use-oriented and interdisciplinary evolution.

Chapter 3

Research methods and methodology:

Framing a fundamental intellectual process

Chapter 2 began with recognizing two problems that render the task of developing a structured scholarship on sustainability to be fundamentally challenging. One of these is the intellectual challenge of deciphering the essence of the notion of sustainability, which is due to the values-driven nature of the taken-for-granted normative essence of the notion. The other is a necessity of a pluralistic recognition/ orientation of knowledge and the need for knowledge integration processes for a *pluralistic knowledge avenue*. In responding to these two problems **Chapter 2** formed an intellectual perspective on sustainability that is to replace the traditional normative character of the notion as well as produces the research approach of the thesis. A summary of contents of the intellectual perspective on sustainability follows:

(i) *Sustainability scholarship* seeks to operate between a horizontal comprehension of the integrity of the reality and a vertical comprehension of the specificity of the integrated reality.

(ii) There is an implicit need to replace the traditional reductionist mode of enquiry with *a new mode of enquiry* that would be capable of addressing the sustainability problems in their actual realities as well as would overcome the fundamental limitations of the reductionist mode of enquiry in addressing the sustainability crisis.

(iii) The *new mode of enquiry* would be required to churn out the cognitive necessities for the development of a *pluralistic knowledge avenue* for *sustainability scholarship*, where the reductionist natural and social sciences and the humanities scholarships have definitive roles for sustainability studies.

(iv) A *fundamental intellectual process* is required for the *new mode of enquiry* in order to enable and characterize the pluralistic knowledge orientation and development of integrated knowledge acquisition processes for the establishment of the *pluralistic knowledge avenue*.

(v) The *new mode of enquiry* and the potential *sustainability scholarship* reflects a research orientation of ‘use-inspired basic research’ with their three pluralistic modes of ‘multi-, inter and trans-disciplinarity’ requiring a combination of concept-oriented, problem/ use-oriented as well as interdisciplinary modes of evolution.

In order to enable and characterize this pluralistic orientation and avenue of knowledge, the *new mode of enquiry* requires the development of a *fundamental intellectual process*, which is framed below in **Chapter 3,** in five sections. **Section 3.1** elucidates the central problem addressed in the thesis, leading to the articulation of a set of three Key Research Questions (KRQs). This is followed by discussion of the epistemological and methodological composition of the research in **Section 3.2,** while the approaches to addressing the three KRQs are elucidated in **Section 3.3**. The methods of data collection and analysis are detailed in **Section 3.4**, while **Section 3.5** outlines the limitations and a summary of the research design.

3.1 Problem definition and Key Research Questions (KRQs)

Based on the discussions in **Chapters 1** and **2**, there is a need for a *fundamental intellectual process* that would be capable of effectively studying pluralistic knowledge and research structures as well as providing structured pluralistic *scholarship of sustainability*. In developing a novel philosophy for the *fundamental intellectual process* for *sustainability scholarship*, an ontological starting point is that some level of reconciliation of the different disciplines are required, while accepting that this reconciliation task is potentially contrary to the nature, expertise and practice of the disciplines.

Yarime (2011) summarizes the challenge for sustainability science. In addressing dynamic interactions among natural, human and social systems, a broad range of academic disciplines are typically called upon along with their multitude of concepts, methodologies and theories, which present many, complex and possibly conflicting knowledge. It is in this context that Yoshikawa writes:

> "Rather than leading to more coherent results, the diversity and division of the disciplines may simply exacerbate confusion in the interpretation of results by society, resulting in a fragmented response to problems that is ultimately detrimental to systems that support the sustainability of the planet … Professionals are trained to delve deeply into their subject or field with little cross-fertilization of ideas and methods across the professions. As a result, the solutions and artefacts of social development that accrue to address needs or problems in one area may be inconsistent with, and even harmful to, those in another area." (Yoshikawa 2011, p.261-262)

Besides this discursive challenge of reconciliation, there are other important questions with regard to the potential *sustainability scholarship* —

- Is the vibrancy of a scholarship best supported by a *fundamental intellectual process* leading to a pluralistic orientation and avenue of knowledge; or through a more open set of collective efforts?
- What benefits does a 'grand' or 'integrated theory' have with regard to sustainability?
- What are the places of the 'post-structuralist' notions of knowledge and diversity in knowledge and its production?

These questions reflect the broader considerations with regard to *sustainability scholarship*, which require extensive deliberation; and therefore, are generally outside of the scope of this thesis except for where they encroach into the key research questions. Nevertheless, what is in scope provides a considerable methodological challenge, necessitating both deductive and inductive inquiry.

Be it in terms of the *new mode of enquiry* or the *fundamental intellectual process* or the *pluralistic knowledge avenue* for the *sustainability scholarship*, the analysis here is concerned with the acquisition of integrated knowledge or more simply knowledge integration—both laterally (across the breadth of the integrity of the reality) and vertically (along the depth of the integrated reality)—based on a pluralistic orientation of knowledge. This need is addressed in the thesis in terms of ordering and mapping of knowledge, with 'structuring' and 'integration' employed as the central ideas.

In terms of 'structuring', the sustainability science literature discusses 'knowledge-structuring' (Kajikawa 2011), 'problem-structuring' (Komiyama and Takeuchi 2011), and 'action-structuring' (Kajikawa and Komiyama 2011). As knowledge-structuring is not as straight-forward concept as the problem- and action-structuring, the potential role of knowledge-structuring in knowledge integration for sustainability scholarship requires deliberation.

> "An essential component of knowledge-structuring is to elucidate a structure of knowledge so as to obtain a total view of knowledge that will facilitate communication among disciplines." (Kajikawa 2011, p.27)

The concept of knowledge-modeling—adapted from the approach of the basic use of modeling in the natural sciences (Rosenblueth and Wiener 1945)—has been utilized in the knowledge-structuring models proposed by Ostrom (2007) and Turner et al. (2007b). Ostrom (2007) had proposed an analytical framework where resource systems, resource units, users of the systems, and the governance system undergo interactions that are bound by other related ecosystems as well as constrained by social, economic and political settings. On the other hand, Turner et al. (2007b) mentioned about observing, monitoring, understanding and spatial modeling of system dynamics in the coupled human-environment system, and then assessing the system outcomes in terms of vulnerability, resilience or sustainability. These approaches provide insights into formulating useful frameworks for knowledge-structuring; however, reflecting the 'narrow sense of human-environment interactions' research these are rather empirical than fundamental approaches. On the other hand, the framework proposed by Kajikawa (2008) reveals a generalized structure in contrast to these empirical approaches. Kajikawa's (2008) framework too is proposed through knowledge-modeling, involving the following key components: goal-setting, indicator-setting, indicator measurement, causal chain analysis, forecasting, backcasting, and problem-solution chain analysis. His framework is extended to include an additional concept identified as 'research on research', as the author finds it necessary for the purposes of collecting and structuring the problem-solution chains that are reported in fragmentary fashion in the different research papers coming from different disciplines (Kajikawa 2011).

Through proposing the framework on knowledge-structuring Kajikawa tried to reveal what he believes to be the basic characteristics of sustainability science, as incorporating — (1) broad time spans with normative characteristics, (2) the normative nature of sustainability science, (3) the problem-solving perspective of sustainability science, (4) the diffuse scope and interdisciplinarity of the field, and (5) a proactive aspect of the scholarship. Some of these characteristics appear problematic for an effective scholarship on sustainability. The problem with the normative nature of sustainability science as discussed in **Chapter 1** is that a normative assumption, not having any fundamental distinction over any other theory, leads to intellectual uncertainty instead of contributing to coherence of sustainability scholarship. Although the author emphasizes on the technological, social and political aspects of solutions necessitating a creative combination of engineering, psychology, economics, institutional design, legal studies, political science and other social sciences; however, the methods of combining these into a uniform reality remains undiscovered, as the author remarks: "*proposing solutions from a different perspective from those of existing disciplines is a necessary role of sustainability science …*" (Kajikawa 2011, p.31). With regard to the diffuse scope, arguably, the scope for sustainability scholarship has to be solid rather than diffuse in order for its approach to be disciplined; while in terms of the interdisciplinarity of the field, a truly pluralistic sustainability scholarship also needs to incorporate the two other pluralistic modes i.e. the multi-disciplinarity and the trans-disciplinarity.

The characteristics of the conventional reductionist knowledge practices (discussed in **Section 2.2**) reveal ‘the constraint of research scientists being trained at producing specialized bricks of knowledge at the expense of not looking at the whole building’ (Ziman 2001), where the ‘researchers examining a domain from a particular discipline not possibly being able to have an adequate understanding of the whole’ (Börner et al. 2003). The ‘fundamental difficulty due to the gap between the complexity of problems and subdivision of the knowledge base studying them’ (Yamaguchi and Komiyama 2001) creates a reality for ‘a researcher finding it difficult grasping the whole of an issue due to only a small part of it being native to his/ her specific field’ (Yamaguchi and Komiyama 2001). As this forms a reality where at one end we have an explosion of reductionist results and artifacts and at the other end there is a dire knowledge crisis in terms of the scholarship on sustainability; knowledge-structuring becomes an important deliberative task of sustainability scholarship (Kajikawa 2011) despite the limitations of its proposed frameworks discussed insofar. Nonetheless, the knowledge-structuring needs to be conducted in a fundamental way so that it can resolve the knowledge crisis produced from the part of the conventional scholarships as well as effectively facilitate knowledge integration.

The IR3S discourse of sustainability science (Integrated Research Systems for Sustainability Science, discussed in **Sections 1.3-1.4**) proposes that the task of ‘knowledge-structuring’ should be followed by ‘problem-structuring’ in order to address the complex and interconnected nature of sustainability problems, which should subsequently be followed by ‘assembling a platform of knowledge’ for revealing the entire web of problems; and then, a ‘systematic organization of disparate fields of enquiry’ should enable replacement of the current piecemeal approach with an integrative solution (Komiyama and Takeuchi 2011, p.9-10). This prescribes on the fundamental tasks of sustainability scholarship in terms of the four consecutive steps of knowledge-structuring, problem-structuring, assemblage of platforms of knowledge, and systematic organization of disparate fields of enquiry. Given the lack of a credible intellectual foundation for sustainability science, this approach, however, exhibits limitations.

Effective knowledge-structuring requires careful definition and arguably must extend beyond superficial ordering. The position of the thesis in this regard is in participating in creating a credible intellectual foundation for *sustainability scholarship*. Meanwhile, the absence of an intellectual foundation impedes problem-structuring due to a myriad of perspectives presented from the myriad of segregated disciplines towards a given problem. The intellectual foundation can also provide know-how for both the assemblage of platforms of knowledge (the third step) and the systematic organization of disparate fields of enquiry (the fourth step). Both of these third and fourth steps require definitive forms of epistemological as well as methodological reconciliation among the different knowledge structures and their corresponding disciplines, which is contrary to the nature, expertise and practice of the disciplines. Deciphering an intellectual foundation for the *scholarship of sustainability* could, thus, enable these structuring processes aimed at producing knowledge integration.

Enabling the integration of the exponentially growing knowledge-base through information technology related mechanistic processes can assist in part in the larger intellectual process required. Such attempts to map sustainability science include: (i) trying to analyze the academic landscape of sustainability science from a bibliographic collection of 29,391 papers that included the words 'sustainability' or 'sustainable' in their bibliographical records (Kajikawa et al. 2007), and (ii) the consideration of assessing more than 3000 papers published about sustainability and sustainable development to try to grasp the overall structure of sustainability science (Kajikawa 2011). This brings in a question as to the extent to which all or any given paper published about sustainability or sustainable development, or having 'sustainability' or 'sustainable' in their bibliographical records, should be deemed sustainability science *per se*. Such mechanistic attempts may reveal the extent of what '*is*' being done; however, the question on what this means and what '*should*' be done summarizes the problem definition of the research.

The range of questions and concerns revealed insofar with regard to knowledge integration for *sustainability scholarship* include the question of reconciling different knowledge avenues and their knowledge structures, the fundamental task of knowledge-structuring as well as other accompanying structuring processes for the purpose of enabling knowledge integration, as well as the need for deciphering an intellectual foundation for the *scholarship of sustainability*. These culminate in an outstanding need for a process that could enable the study of pluralistic knowledge and research structures as well as can epistemologically provide a measure for developing a structured scholarship on sustainability based on a pluralistic orientation of knowledge and effective knowledge integration. This is reflected in the identification of the following three Key Research Questions (KRQs), the first of which enquires on fundamentally framing such a process.

KRQ 1: How can an intellectual process fundamentally be framed in order to study the pluralistic knowledge and research structures regarding sustainability?

KRQ 1 is addressed in the following sections of this chapter. The progression of the research enquiry continues from the position of the **KRQ 1** through the application of the product of this KRQ (i.e. the frame of the *fundamental intellectual process*) into an example ‘pluralistic knowledge and research body’, which has been taken as the first decade’s ‘body of work’ of sustainability science. It reveals the basic structures of the discourse of sustainability science, besides providing a mechanism for the development of the *fundamental intellectual process*.

As the knowledge and knowledge acquisition processes in their most effective forms exist in singular reductionist perspectives, attempting to yield a pluralistic orientation and avenue of knowledge requires the formation of a new, fundamental intellectual project. The challenges, questions, and concerns with respect to this intellectual need have been elucidated in **Chapters 1** and **2**, which can functionally be summarized in terms of three challenges:

(i) the discursive challenges for the pluralistic orientation of knowledge/ research,

(ii) the epistemological, theoretical and methodological challenges of knowledge integration, and

(iii) the practical challenge of carrying out the intellectual practice where the scholars are instead trained as well as function within their extremely narrow, disciplinary-based reductionist paradigms.

Solving these three challenges requires epistemological, theoretical and methodological breakthroughs. These could be regarded as the long-range goals of the potential *scholarship of sustainability*. However, what is at hand is to initiate the discourse towards this intellectual necessity through the framing, application and development of the *fundamental intellectual process*. In applying this process on a given pluralistic knowledge and research entity with regard to sustainability, the lines of enquiry need to be along these three challenges so that it can be tested if and to what extent the given pluralistic knowledge and research entity can provide useful insights for *sustainability scholarship*. Addressed in **KRQ 2**, these correspond to the queries on three basic structures of the discourse of sustainability science, these being: the discursive structure, the integrative structure, and the structure of practice. The elucidation of these structures is facilitated with framing three corresponding research questions under the **KRQ 2** (the **KRQ 2.1**, **KRQ 2.2** and **KRQ 2.3** corresponding to the discursive structure, integrative structure, and the structure of practice, respectively). The research design, thus, enables the study of pluralistic knowledge and research structures through a *fundamental intellectual process*.

KRQ 2: What are the basic structures of the discourse of sustainability science and how are they structured?

KRQ 2 is addressed in **Chapters 4-6**.

i. Discursive structure: Fundamental empirical aspects

KRQ 2.1: What discursive practices characterize research in sustainability science? *[Addressed in **Chapter 4**]*

ii. Integrative structure: Qualitative aspects

KRQ 2.2: What qualities are apparent in the ways sustainability science tries to tackle integrative concepts? *[Addressed in **Chapter 5**]*

iii. The structure of practice: Spatio-temporal dimensions

KRQ 2.3: What temporal, spatial and dynamic variations are apparent in the practice of sustainability science? *[Addressed in **Chapter 6**]*

Once these three basic structures of the example pluralistic knowledge and research body (i.e. the discourse of sustainability science) are elucidated, the insights produced from these analyses together with the rationale and framing of the *fundamental intellectual process*—that includes the methods of studying the example pluralistic knowledge and research body—together provides the necessary tools for embarking into an integrated inquiry on eliciting the dimensions and structure of a *pluralistic knowledge avenue* and the layout of an intellectual foundation for the *scholarship of sustainability*. The **KRQ 3**, addressed in **Chapter 7**, reveals this opportunity.

KRQ 3: How might a *pluralistic knowledge avenue* and the layout of an intellectual foundation for the *scholarship of sustainability* be elicited based on the rationale, framing and application of the *fundamental intellectual process*?

3.2 Epistemological and methodological composition of the research

> "In the case of studies that require the coming together of researchers from different sciences and disciplines, developing a coherent methodology can be further complicated by the fact that neither a shared understanding nor shared enthusiasm will necessarily exist from the outset as to the range of methods that could be applied." (Franklin and Blyton 2011, p.7)

Beyond the obvious benefits of a 'shared understanding' and 'common enthusiasm', there are numerous other reasons to pursue the idea of a coherent methodology for sustainability studies. One of the most important of them is the pursuit of integrated knowledge acquisition, which also defines the research problem of the thesis (see **Section 3.1**). In terms of integrated knowledge acquisition, the long-running division between the natural sciences and the human sciences (i.e. the social sciences and the humanities) in ways that stand as bars to engaging in collaborative, coherent, and transcending research presents a particularly important consideration. Termed as the 'hard' and the 'soft' sciences, the effects of the tensions between these two remain considerable, despite the concerted efforts from many academic and research institutions espousing cross-disciplinary work. Franklin and Blyton (2011) quote Denzin and Lincoln (1998, p.7): "*The academic and disciplinary resistances to qualitative research illustrate the politics embedded in this field of discourse. The challenges to qualitative research are many. Qualitative researchers are called journalists, or soft scientists. Their work is termed unscientific, or only exploratory, or entirely personal and full of bias. It is called criticism and not theory, or it is interpreted politically as a disguised version of Marxism, or humanism.*" Given this prevailing tension between the hard and the soft sciences it could be commented based on the intellectual perspective of sustainability (formed in **Chapter 2** and articulated in **Section 2.5**) that both of these discourses have their distinctive strengths and limitations.

The strength of the discourse of the hard sciences is in terms of its quantitative, discipline-based, reductionist mode of enquiry that is built on the traditional scientific method and has yielded significant technological progress. Ironically, the other side of the coin reveals the limitations of this discourse, i.e. the quality defining its strength also becoming the reason to render its limitations. As analyzed in **Sections 2.2** and **2.5**, the inherent limitations of the reductionist mode of enquiry include its narrow and fragmented specialization and objective view of fragmented reality, its artificial boundaries among the disciplines creating compartmentalized disintegration of the domains, and its weakness in terms of engaging interactively. These limitations have led to the creation of the sustainability crises borne out of contradictory artifacts leading to excessive, localized and uncoordinated human actions that were purportedly meant to improve quality of life.

On the other hand, the strengths of the soft sciences or qualitative research are many. **Section 2.3** discusses some of these strengths with regard to the cognitive necessities for *sustainability scholarship*, which include their relevance in contextual and integrative necessities, in conducting ethical judgment, as well as in criticizing the paradigm of modern rationalism that has been built based on a reductionist and objective perception of the world—that has been driving unrelenting pursuits of efficiency, higher productivity and objective benefits—and an atomistic perception of human reality that has resulted in an inconsiderate competitive pursuit of economic profit. Ironically, a number of the strengths of the soft sciences are in areas that reveal inherent limitations of the hard sciences. However, the soft sciences also exhibit limitations with regard to sustainability studies as the expanse and complexity of the sustainability problems could potentially be as vast as incorporating anything and everything in reality, which can result in a potential intellectual emptiness.

Thus, the strengths and limitations of the hard and the soft sciences substantiate what has been articulated in the intellectual perspective of sustainability (**Section 2.5**) that the *sustainability scholarship* needs to operate between a horizontal comprehension of the integrity of the reality (resembling the soft sciences) and a vertical comprehension of the specificity of the integrated reality (resembling the hard sciences, although the hard sciences function based on disintegrated/ fragmented reality). Given this unique intellectual perspective of *sustainability scholarship*, the formation of a fundamental epistemological approach that excludes any preconceived notion of privilege from the compartmentalized specializations of scholarships is seen to be imperative for this research. In doing so, the concepts of knowledge-structuring, problem-structuring, action-structuring, and ‘research on research’ (see **Section 3.1)** are taken together in their most fundamental forms to provide an epistemological platform.

While the concepts of knowledge-structuring and problem-structuring have been discussed in **Section 3.1**, with regard to action-structuring, Kajikawa and Komiyama (2011, p.36) had proposed an action-structuring model for sustainability science describing three consecutive phases: (i) the decomposition of actions into unit actions, (ii) the integration of unit actions into new actions, and (iii) the promotion of collective actions. In this model, the process of ‘decomposition of actions into unit actions’ is expected to assemble all necessary components of knowledge—that are currently available and implemented—through interpreting them at the level of actions i.e. in a manner that promotes action. This is to be followed by the integration of these unit actions into some new actions. However, the model does not address the theoretical, epistemological and methodological hurdles for such disintegration and reintegration processes, given the existing lack of a credible intellectual foundation for sustainability science. Besides, the sum of such disintegration and reintegration processes yields a ‘knowledge-modeling’ process, which puts the fundamental character of such action-structuring model into question.

In the epistemological mosaic of the concepts of knowledge-structuring, problem-structuring, action-structuring, and research on research; the methods of knowledge-structuring and action-structuring in the IR3S discourse appear simple in form as being derived from speculative conceptualization. In order to construct an intellectual process for fundamentally developing the *scholarship of sustainability*, the epistemological ground for such research needs to be derived from fundamental intellectual analysis instead of presumptive speculation. Such a fundamental epistemological ground based on a ‘knowledge, problem and action-structuring’ discourse for sustainability is constructed in this chapter through a bottom-up analysis of the example ‘pluralistic knowledge and research body’ (i.e. the first decade’s ‘body of work’ of sustainability science). As employed in this thesis, the fundamental use of the concept of knowledge-structuring also stands in a broader sense to arch over the three other structuring concepts employed in the epistemological composition, as these various forms of structuring also correspond to different forms of knowledge in their fundamental interpretation. Thus, in a broader sense, knowledge-structuring also stands as an umbrella concept to refer to the entirety of the ‘knowledge, problem and action-structuring’ discourse.

Methodologically the research combines both deductive and inductive approaches. A deductive approach is undertaken to heuristically elucidate the three basic structures (i.e. the discursive structure, the integrative structure, and the structure of practice) of the example pluralistic knowledge and research body (i.e. the first decade's 'body of work' of sustainability science) in **Chapters 4-6** through the application of the *fundamental intellectual process* framed in this chapter. The heuristic elucidation of the basic structures of the discourse of sustainability science through the deductive approach is utilized as a tool to inductively enquire—together with the rationale and framing of the *fundamental intellectual process*—on the pluralistic orientation and avenue of knowledge required for *the scholarship of sustainability*. Due to being inductive in nature, this analysis does not have a methodological clash, being projected in part from the 'heuristically deduced' basic structures of the discourse of sustainability science. In the overall methodological mosaic, the indirect form of analytical rigor present in the inductive analysis stands in contrast to the direct reductionist rigor of the deductive analysis.

The overall methodological position of the research can be summarized as *heuristic fundamental research* that incorporates — (i) the fundamental analysis in **Chapters 1-2** based on robust literature analysis, (ii) the fundamental bottom-up modeling with an example pluralistic knowledge and research body in **Chapter 3**, (iii) the heuristic deductive analysis in **Chapters 4-6**, and (iv) the integrated inductive analysis on eliciting the dimensions and structure of a *pluralistic knowledge avenue* as well as the layout of an intellectual foundation for the *scholarship of sustainability* in **Chapter 7**. The heuristic approach in this composition necessitates discussion of its precedents and justification for trans-disciplinary sustainability research:

> "Recently, scholars have started to develop and describe methods and heuristics that address specific challenges of transdisciplinary research (Hadorn et al. 2002, Bammer 2006, Eigenbrode et al. 2007, Pohl and Hadorn 2007, McDonald et al. 2009, Bergmann et al. 2012, Wuelser et al. 2012, Bammer 2013, Gaziulusoy and Boyle 2013). … Some of these methods and heuristics are old and rediscovered in the context of transdisciplinary research, like the Delphi method (1975, McDonald et al. 2009) or systems practice (Ison 2008). Others are explicitly designed for transdisciplinary research processes, like integrative hypothesis formulation (Burkhardt-Holm 2008, Bergmann et al. 2012)." (Pohl 2014)

Pohl (Pohl 2014, p.103) comments regarding trans-disciplinary research: "*Outside observers of transdisciplinary research, who are expecting rigorous methods at work* *proceeding in well-defined steps, might get confused by the chaotic process they perceive. … What looks chaotic from the outside is therefore a sign of the highly adaptive way of doing transdicsiplinary research. Furthermore, it is a sign of a form of research without standardized theories, methods and a widely accepted state of the art.*" He writes in comparison to precise methodical procedure (Pohl 2014, pp.103-104), "*'Heuristics', in comparison, are more rough and general suggestions for how to go about a problem; for example, a suggestion to focus research on factors that hinder or help a specific sustainable development in society (Hadorn et al. 2002). Heuristics are not ready-made methods, but need to be substantiated and adapted to the particular context of application by the researchers who apply them.*"

The edited book *Transdisciplinary Sustainability Studies: A Heuristic Approach* (2014) brings together the application of heuristics in a range of environmental studies and as a necessary approach for sustainability studies. It argues that while scientific reasoning is being guided by the disciplinary traditions, the trans-disciplinary research rests, on the contrary, on other cognitive strategies. Taking heuristics as a strong contender of these other cognitive strategies, the volume sets out the use of heuristics as the guiding cognitive approach for the intellectual processes needed to tackle the complex sustainability problems, and compares these as much about heuristic problem solving as about methodical work. With the theory of post-normal science (Funtowicz and Ravetz 1993) breaking free of reductionist and mechanistic assumptions about the ways things are related as well as operate, it is through the heuristic approach as a new mode of argumentation that the trans-disciplinary sustainability studies are engaged in creating solutions that do not derive from applying the traditional methods (Klein 2014).

If sustainability in its current paradigm can be considered as a *wicked problem* (Rittel and Webber 1973), the adoption of a heuristic approach takes this wickedness as an epistemological challenge instead of merely as its management, governance or decision challenges (Huutoniemi 2014). Huutoniemi writes, "*In the face of wicked sustainability challenges, the foundations of modern science are increasingly called into question. The simplistic, reductive and linear logic behind disciplinary knowledge production is portrayed as helpless in addressing wicked problems that are beyond its scope and methods …*" (Huutoniemi 2014, p.3). She emphasizes that in situations of complexity and uncertainty (such as in the problem of sustainability) where an overwhelming crisis of disciplinary knowledge is prevailing, responding to the quest for finding out the potential strategies that could be capable of leading a constructive discussion on this comes out to be none other than 'an experimental approach to problem solving' rather than an analytically exact one. Thus, a heuristic approach—properly substantiated and adapted to the particular context of application by the researcher—can provide a fresh and reasonable basis for building a constructive discourse on the intellectual treatment of sustainability:

> "Transdisciplinary research requires skills to engage with complexity and conceptualize indeterminate situations in purposeful ways. Contrary to the doctrine of technical rationality, on which much scientific and professional ethos is built (Schon 2001), there are no ready-made rules for making sense out of a mess. At the same time, we are usually able to distinguish between a more and less workable strategy after it has been established. It thus seems that success depends on the match between the situation at hand and the strategy of approaching it. … Instead of a heuristic approach being a fallback position or second-best option in the face of methodological crisis, it appears as a well-grounded alternative for making sense of wicked situations." (Huutoniemi 2014, pp.9-11).

3.3 Approaches to addressing the Key Research Questions (KRQs)

Figure 1.1 illustrates the methodological connections between the KRQs, where the **Chapters 3**, **4-6** and **7** address **KRQs 1**, **2** and **3**, respectively. This section elaborates on the approaches undertaken in addressing each of these KRQs.

KRQ 1: How can an intellectual process fundamentally be framed in order to study the pluralistic knowledge and research structures regarding sustainability?

Approach to KRQ 1

In addressing the **KRQ 1** an empirical approach has been undertaken, analyzing a time-bound cross-section of a body of research. The use of an empirical approach imparts a practical character into the process to be framed.

The first decade's 'body of work' of sustainability science is utilized for framing the intellectual process. As discussed in **Section 3.2**, this framing process constructs an epistemological ground for the research based on a 'knowledge, problem and action-structuring' discourse for sustainability. The methodical details of the framing process as well as the 'knowledge, problem and action-structuring' discourse are elaborated in **Section 3.4**.

KRQ 2: What are the basic structures of the discourse of sustainability science and how are they structured?

Approach to KRQ 2

In **Section 3.1** the basic structures for a given pluralistic knowledge and research entity are functionally summarized. These correspond to **KRQs 2.1-2.3**. While the methodological approach for addressing these KRQs has been elucidated as *deductive heuristic analysis* in **Section 3.2**, the deductive approaches for each of these KRQs are described as follows.

i. Discursive structure: Fundamental empirical aspects

KRQ 2.1: What discursive practices characterize research in sustainability science?

KRQ 2.1 is addressed through empirical domain-based literature analysis, where the domains are sampled from critically reflecting on the literature base (i.e. the first decade's body of work of sustainability science) as part of framing the *fundamental intellectual process* in this chapter. These empirical domains are sampled based on what the first decade's body of work in the field reveals in terms of the domains represented in the body of work. The importance of this approach is in terms of projecting how sustainability science is discursively structured, as well as how insights on its fundamental empirical aspects produced from such empirical domain-based analysis can inductively inform on the intellectual foundation of a *sustainability scholarship*. The fundamental 'knowledge, problem and action-structuring' discourse—based on which the *fundamental intellectual process* is epistemologically grounded—analyses the discursive diversity of the research practices in sustainability science, which produces detail literature maps on the sampled domains. These literature maps provide the grounds for the deductive application of the *fundamental intellectual process* into the corresponding empirical domains in order to heuristically elucidate the discursive structure of the discourse of sustainability science.

ii. Integrative structure: Qualitative aspects

KRQ 2.2: What qualities are apparent in the ways sustainability science tries to tackle integrative concepts?

KRQ 2.2 is addressed in a similar approach as with **KRQ 2.1**, however, instead of empirical domain-based analyses in **KRQ 2.1**, the nature of analysis in **KRQ 2.2** is deductive qualitative analysis based on four foci. These four foci represent four different integrative/ qualitative aspects of sustainability science, together which elucidate the integrative structure of the discourse in terms of the ways it tries to tackle integrative concepts.

iii. The structure of practice: Spatio-temporal dimensions

KRQ 2.3: What temporal, spatial and dynamic variations are apparent in the practice of sustainability science?

KRQ 2.3 is approached with a straightforward 'place/ scale-based deductive analysis' of the literature that enquires into the temporal, spatial and dynamic variations apparent in the practices characterized with the empirical domains analyzed in **KRQ 2.1**, as well as cross-compares these to the trend projected from the entire literature base (i.e. the first decade's 'body of work').

KRQ 3: How might a *pluralistic knowledge avenue* and the layout of an intellectual foundation for the *scholarship of sustainability* be elicited based on the rationale, framing and application of the *fundamental intellectual process*?

Approach to KRQ 3

The intellectual perspective on sustainability, the framing and application of the *fundamental intellectual process*, and the insights produced from elucidating the basic structures of the discourse of sustainability science together culminate in the potential for an integrated inductive analysis on eliciting the dimensions and structure of a *pluralistic knowledge avenue* as well as the layout of an intellectual foundation for the *scholarship of sustainability*. Through inductively sketching the theoretical and functional aspects of a *pluralistic knowledge avenue* both in terms of its dimensions and structure based on these elements, **KRQ 3** provides a realistic measure for designing the fundamental tasks of the *scholarship of sustainability* as well as constructing an integrated theory on its intellectual foundation. The intellectual perspective on sustainability (formed in **Chapter 2**), the *fundamental intellectual process* for *sustainability scholarship* (framed in **Chapter 3**), the application of the *fundamental intellectual process* on the example pluralistic knowledge and research body (conducted in **Chapters 4-6)**, as well as the intellectual foundation of *sustainability scholarship* (inductively elicited in **Chapter 7**) — together form a continuous thread of inquiry on the intellectual treatment of sustainability. In this continuous thread, it is the framing of the *fundamental intellectual process* in **Chapter 3** and its application throughout the **Chapters 4-6** that connect the intellectual perspective on sustainability to the intellectual foundation of its scholarship through inductively eliciting a *pluralistic knowledge avenue*.

3.4 Methods of data collection and analysis

The following seven methods are utilized in the research reported in this thesis: (1) Fundamental research, (2) Secondary data collection, (3) Structural organization in a bottom-up approach, (4) Discourse analysis, (5) Empirical literature analysis, (6) Focus analysis, and (7) Place/ scale-based analysis. The methods 1-4 are elaborated in **Sections 3.4.1-3.4.4**, respectively; while **Section 3.4.5** elaborates the rest of the three methods (5-7).

3.4.1 Fundamental research

Chapters 1 and **2** together fundamentally question the intellectual basis of sustainability. This reveals the necessity of developing a *fundamental intellectual process* for the *scholarship of sustainability*. The gap in understanding and researching its potential scholarship is not superficial. Rather it requires a sound intellectual basis. Building an intellectual project through a bottom-up process from the ground echoes the overarching design of the research.

3.4.2 Secondary data collection

An archive of sustainability science literature is compiled in order to serve as the platform for investigating the basic structures of its discourse. Research articles that are published within the genre of sustainability science including additional materials within its neighboring clusters, plus the articles, books and reports that are considered to be important for the genre are grouped together and labeled as ‘Group-A’ archive, having a count of 464 items. In order to impart universality into the analysis on the basic structures of the discourse of sustainability science, the ‘Group-A’ archive includes representative sustainability science practices from around the world as well as the published materials considered as important for the practice. The items comprised in ‘Group-A’ archive were mostly published on or before the year 2011, marking a decade since the birth of sustainability science (in 2001), and therefore, this study analyzing 10 years of sustainability science scholarship to reveal its basic structures. The archive also includes items that had been published before the year 2001, which is due to considering them as important for the genre of sustainability science by the representative sustainability science practices from around the world. This data collection, however, raises questions.

The first of them would be with regard to the method of choosing the titles, including the pre-2001 ones. The method for choosing the titles since 2001 is through scanning English research literatures arising from around the world that directly address sustainability science. These together form the genre of sustainability science, which is mostly comprised of journal research articles. These practices are found to be the most commonly occurring in North America, Europe and Asia (mainly Japan). Articles from the journal *Sustainability Science* are also incorporated unless any given title exhibits clear distance from directly addressing sustainability science. The pioneering sustainability science practices have also led to publications on sustainability science curricula, which include necessary suggested readings for the discourse. It is from these sources as well as from the general communications on sustainability science from these pioneering efforts that the pre-2001 titles are compiled. The articles, books and reports that are considered to be important for the genre of sustainability science are compiled in this way for both pre-2001 and post-2000 titles.

The subsequent question requires comparison with other studies attempting to do similar to what is embarked on in this thesis, and based on this, articulating why and how the method developed in this thesis becomes necessary. As discussed in **Sections 1.4** and **3.1**, the prevailing studies mapping sustainability utilizes mechanistic algorithm, or else recognizing the improbability of manually reviewing its vast literature base. The limitations of the use of mechanistic processes are described in **Section 3.1**, which necessitates the development of new approaches that can enable heuristic fundamental research on the intellectual treatment of sustainability. The research designed in this chapter is developed in this necessity through constructing a bottom-up process from the ground that utilizes the sustainability science literature base. As in the secondary data collection, the genre of sustainability science has been delineated from the vast publication base on sustainability; this enabled heuristic fundamental research with sustainability science literature base.

A third dimension is with regard to the challenge of revisiting the literature towards the end of the research. As the first decade's body of work of sustainability science—as archived in the secondary data collection—serves as an 'example pluralistic knowledge and research body' on which the analyses are to be fundamentally drawn out based on heuristic fundamental research, the consideration of more recent publications forms a different group in terms of the nature and extent of their participation in the research.

The first decade's body of work of sustainability science—acting as the example pluralistic knowledge and research body—participates in the research in a fundamental and extensive manner instead of merely appearing as references. Besides, this body of work is inclusive of all materials published within the genre of sustainability science; while in case of revisiting the literature, the publications appearing thereafter are to be selected based on a defined criterion. Given these considerations, the methodological challenge of revisiting the literature towards the end of the research is addressed through searching for publications that are relevant to the key findings of the research, followed by incorporating them within the discussions on these key findings in **Chapter 7**. Each of the **Sections 7.2 – 7.6** specifically mentions about revisiting the literature with regard to their findings and discusses the available researches in light of these findings.

The 'Group-A' archive produces literature maps for conducting sets of 'empirical literature analyses' and 'focus analyses into the quality of sustainability science', while the same archive also acts as the primary source of data in conducting the analyses on the basic structures of the discourse of sustainability science.

3.4.3 Structural organization in a bottom-up approach

Structuring the 'Group-A' literature archive in carrying out the fundamental bottom-up process reveals five layers of organizations and a structure that positions them consequentially.

The first layer of organization

Providing unique IDs for every item in the archive becomes the first layer. This is done in 'Group-A' archive by the first alphabet of the last name of the first author, followed by a numbering based on the alphabetic order of the subsequent letters. In the case of institutional authorship, this is done by the first letter of the abbreviation of the institute name, or by the document title followed by the numbering in the same manner.

The second layer of organization

This layer organizes the 'Group-A' archive based on a comprehensive classification of the entire subject matter of sustainability. Franklin and Blyton (2011, p.5) writes, "*Although it [the term 'sustainability'] remains a contested concept, since the 1980s there has been a noticeable shift in thinking from a primarily environmental conception of sustainability to a more tripartite prioritization of environmental, social and economic pillars of sustainability. This broad approach is embraced in the concept of sustainable development.*" The tripartite representation is also evident from a citation network analysis on sustainability literature, where the commonly discussed topics in all citation clusters based on different research domains included climate change, welfare and livelihood (Kajikawa 2011), characteristically representing environmental, social, and economic concerns, respectively. The classification into the subject matter of sustainability as introduced in this research takes it further, which provides a mean for comprehensive understanding.

Based upon the mutually overlapping broad clusters of environmental, social and economic concerns of sustainability, a maximum of 10 areas are distinctively identified in their overlapping mosaic as per the different manners and degrees of overlap. This produces the classification scheme in this research, where the 10 distinct areas are referred to as 'spheres'. In **Figure 3.1(A)**, the delineation of the 10 spheres provides the maximum possible classification across the mutually overlapping three broad spheres of economy, society, and environment (symbolized as A, B, and C, respectively). This facilitates the degree of subtlety required for elucidating the basic structures of sustainability science based on a 'knowledge, problem and action-structuring' discourse. Academically, the 'sphere-D'—having common share from all three A, B, and C (**Figure 3.1(A)**)—is identified as the 'central organization of sustainability' with the aim of providing the central intellectual organization of the intellectual treatment of sustainability.

In the second layer of organization, all items from 'Group-A' archive are uniquely distributed among the 10 spheres without any apparent inconvenience arising due to any item appearing to be placed in more than one spheres out of the 10. This also reveals the maturity and potential of the archive in providing an effective example pluralistic knowledge and research body for the analysis here. Although in the second layer all 10 spheres are distinct and considered to be independent from one another, the spheres are referred here in two different conventions due to these being demarcated from the overlapping of the three broad spheres of economy, society, and environment (A, B, and C, respectively). The first of these conventions is in terms of the use of the spheres in the second layer where the 10 spheres are mentioned separately. The other convention mentions A, B and C as the 'broad sphere(s)'. In this latter convention the total count of the spheres becomes four instead of 10, where the broad sphere 'A' stands as the sum of [A, AB, and AC], 'B' being the sum of [B, BA, and BC], 'C' being the sum of [C, CA, and CB], and the fourth sphere being 'sphere-D'. Although the broad spheres 'A', 'B', and 'C' extend beyond these sums such as 'A' extending to BA, CA, and D, and so forth; these repetitions are disregarded here for the convenience of analysis as they appear as major components in alternate broad spheres. In the second convention, these broad spheres of 'A', 'B', and 'C' could be referred to as the economic, social, and environmental perspectives of sustainability, respectively.

The percentage distribution as per total count of archive items under each of the 10 spheres (**Figure 3.1(B)**) reveals the 'sphere-D' (i.e., central organization of sustainability) representing the largest share, followed by socio-environment (sphere-CB) and environo-society (sphere-BC). From among the three broad spheres, the economic perspectives of sustainability (the spheres A, AB and AC taken together) exhibit apparent low percentages, whereas both of the social (B, BA, and BC) and the environmental (C, CA, and CB) perspectives exhibit similar shares. This could be indicative of a general antagonism present between the perceptions on economy and sustainability, whereas the apparent antagonism should in effect facilitate even more contributions from the economic perspectives than the others, as the area where the apparent antagonism exists holds more potential for solutions. Notably, there are disciplinary discourses such as *ecological economics*, attempting to provide some extent of plurality. However, these do not deem to be sufficient to represent the diversity and complex plurality required for an effective discourse on the intellectual treatment of sustainability. The research literatures arising from such perspectives as well as from individualistic reductionist disciplinary practices that potentially participate in the complex mosaic of a *scholarship of sustainability*, are not generally considered in the 'Group-A' archive as the archive mainly considers research literatures coming from within the genre of sustainability science. Hence, the comparative lack of literature from economic perspectives is particularly communicative to the genre of sustainability science.

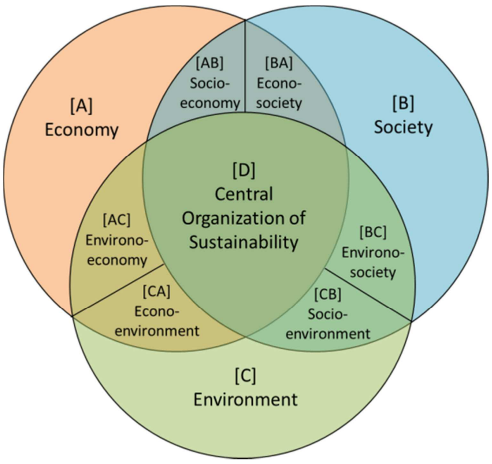


Figure 3.1(A) Spheres of literature organization

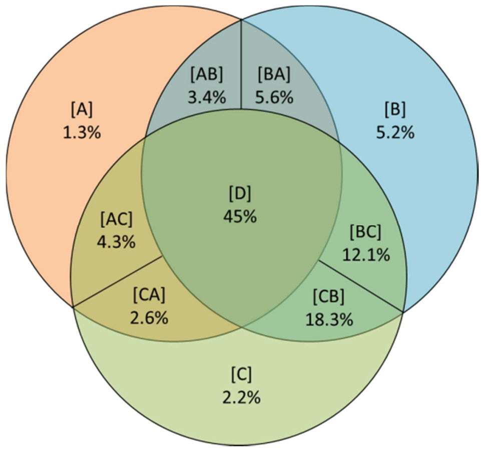


Figure 3.1(B) Percentage distribution of items as per total count across spheres

The third layer of organization

The third layer is produced by extracting a set of topics revealing two different kinds of analyses, followed by the preparation of literature maps for each of these topics by extracting relevant items from the literature archive. The first kind of analysis is empirical domain-based literature analysis, while the other analyzes the quality of the discourse of sustainability science. There are eight topics in this layer, four among which are issues on which the empirical domain-based literature analyses are conducted for analyzing the discursive structure of the discourse of sustainability science. The rest of the four topics represent four foci identified for analyzing the integrative structure of the discourse. As the focus of the intellectual treatment of sustainability is the acquisition of integrated knowledge, or more simply knowledge integration (see problem definition in **Section 3.1**), the analyses on the integrative structure of sustainability science could also be referred to as analyses on the quality of its discourse. The topics are articulated from observing their representative presence in or indication from the prepared literature archive. **Figure 3.2** lists the topics of these empirical literature analyses and focus analyses along with their rationale, preceded by the rationale of the discourse analysis on sustainability science that serves as the ground for these to occur under the third layer. The four issues of empirical literature analyses also exhibit a pattern of representatively situating on the three broad spheres of economy—'A' (issue #1), society—'B' (issue #2), and environment—'C' (issues #3-4), whereas they also cross-overlap across the spheres. The third layer is, thus, produced on these sets of empirical literature analyses and focus analyses, on top of unique placement of all archive items among the 10 spheres in the second layer.

Figure 3.2 The topics and their rationale in the third layer of organization

Foundation

Discourse analysis on sustainability science: 'Analysis on diversification of sustainability science research practices'

[Rationale: An analytical coverage of the diverse sustainability science research practices is required in order to function as a ground for further analysis.]

Empirical Literature Analyses

The ways studies in sustainability science are conducted are empirically examined through the following empirical literature analyses.

Issue - 1: Ecologically-benign development pathways in 'Global South'

[Rationale: As currently the major growth activities are taking place in the 'Global South', innovations in ecologically-benign development pathways for the countries in 'Global South' has become a high priority.]

Issue - 2: Hunger and food insecurity in human societies and the agricultural production issues

[Rationale: Hunger on the face of growing food insecurity is shaping one of the major challenges for human societies, while the greatly challenged agricultural production is the only path to address it.]

Issue - 3: Sustainability science issues in urban planning

Issue - 4: Sustainability science issues in water security syndrome

[Rationale for issues 3 and 4: 'Urban' is the dominating feature of humanity's residence today, and water security is one of the most dominant issues faced by societies in the urban up to remote rural areas.]

The quality of sustainability science – Focus Analyses

Focus analysis - I: Existing 'philosophical, theoretical and methodological' avenues in sustainability science

Focus analysis - II: Characterization of 'human-environment system' in sustainability science

Focus analysis - III: Nature of complexity in sustainability science

Focus analysis - IV: Analysis of practices on 'global sustainability'

[Rationale for the focus analyses: The focus analyses I – IV represent four foci on the integrative structure of the discourse of sustainability science, these being the 'philosophical, theoretical and methodological' background of the discourse, precision in the characterization of coupled human-environment system, the nature of complexity in the discourse, and the dimension of its practice on global sustainability, respectively. These analyses elucidate the integrative qualities of the discourse.

In producing the literature maps the archive items except for under the sphere-D do not appear as potential contents for the focus analyses – I, III and IV. Therefore, appropriate items only from the sphere-D (i.e. central organization of sustainability) are utilized in preparing literature maps for these three focus analyses. However, the 'focus analysis – II' (i.e. characterization of 'human-environment system' in sustainability science) reflects not only on the sphere-D but also on the intersections between environment-economy (spheres CA and AC) and environment-society (spheres CB and BC), as 'human' in the term 'human-environment system' is considered to be reflecting on both of economic and social perspectives. Therefore, appropriate items from the spheres D, AC, CA, BC, and CB are utilized in producing the literature map for the 'focus analysis – II', as the remaining five spheres out of the 10 do not conjugally address both 'human' and 'environment' counterparts conceptualized in the coupled 'human-environment system' (see **Figure 3.1(A)**). The archive items from under all 10 spheres are potentially utilized in producing literature maps for the empirical literature analyses. One of the merits of the structuring scheme is observed here in terms of its comprehensive analytical density that the majority of items in 'Group-A' archive are found to individually reflect on more than one of these empirical analyses and/ or focus analyses, hence, appearing in the respective literature maps.

As the layers of organizations are produced consequentially, the third layer becomes super-imposed on the second layer (i.e. based on the 10 spheres — see **Figure 3.1(A)**) in such a way that the archive items bearing the topic IDs of empirical literature analyses and/ or focus analyses are grouped by the 10 spheres. These cross-connections among the different layers of organizations become vital tools in furthering the fundamental mechanism.

The fourth and fifth layers of organizations

The fourth layer of organization is based on four categories that describe a 'knowledge, problem and action-structuring' discourse —

Category i – 'Problem/ issue/ challenge/ syndrome-sphere'

Category ii – 'Action/ approach-sphere'

Category iii – Academic-sphere, and

Category iv – 'Place/ scale-sphere'

As knowledge-structuring fundamentally refers to the entirety of the ‘knowledge, problem and action-structuring’ discourse based on which the entirety of structuring in this research epistemologically stands (see epistemological composition in **Section 3.2**), the fourth layer of organization does not include knowledge-structuring as one of the categories under this layer, and instead the individual categories in the fourth layer correspond to the other three structuring concepts present in the epistemological composition of the research (i.e. problem-structuring, action-structuring, and research on research). The problem-structuring relates to the ‘Category - i’ being the ‘problem/ issue/ challenge/ syndrome-sphere’. The action-structuring has two components, the first referring to the ‘Category ii – Action/ approach-sphere’, while the other refers to the ‘Category iv – Place/ scale-sphere’ where the actions are to be applied or carried out. The remaining ‘Category - iii’, i.e. the academic-sphere incorporates ‘research on research’.

While placing the archive items into the four categories, all items are found to be uniquely distributed into the first three categories, while the items placed in the first three categories equally appear to be placed in the fourth category i.e. the ‘place/ scale-sphere’. This necessitates the ‘place/ scale-sphere’ to be treated separately into a ‘place/ scale-based’ analysis, appearing in **Chapter 6**. Hence, only the first three categories are functionalized in the fourth layer of organization, and therefore, categories under the fourth layer in the remainder of the thesis only refer to the categories – i to iii.

Under each of these three categories in the fourth layer, an archive item is only placed with a ‘standard heading’ (referred to as ‘theme’) so that more archive items conforming to the same theme under the same category could be grouped together. This constitutes the fifth layer of organization based on ‘themes’, occurring under each of the three categories in the fourth layer. This creates a list of themes under each of the three categories, where each archive item is placed under a ‘theme’ (in the fifth layer) plus under one of the three categories (in the fourth layer).

The fourth and fifth layers of organizations are carried out with all archive items being grouped by the 10 spheres (in the second layer of organization). On the other hand, the third layer (based on issues of empirical literature analysis and focuses for investigating the quality of sustainability science) is cross-connected to the second layer as archive items with the topic IDs of ‘empirical literature analyses’ and/ or focus analyses are grouped by the 10 spheres. Thus, the fourth (based on categories) and fifth (based on themes under each category) layers of organizations become cross-connected to the second and the third layers. These cross-connections from the second throughout the fifth layer of organizations in all possible manners provide some of the most important keys in the research mechanism, besides providing robustness into the analysis.

In the mosaic of the five layers of organizations, the second through the fifth layers are established in the 'Group - A' archive as per the alphabet-number IDs in the first layer. Exemplifying this in a reverse sequence (from fifth to the first layer) would appear as: the archive items under each theme (the fifth layer) and under each category (the fourth layer), with the particular affiliation for empirical literature analysis and/ or focus analysis topics (the third layer), and under each of the 10 spheres (the second layer) are organized by the unique alphabet-number IDs in the first layer. The first layer, thus, also enables efficient tracing of any given archive item for its features corresponding to the subsequent four layers of organizations. This consequential and thoroughly cross-connected unit structure produced through these five layers of organizations completes the application of the fundamental bottom-up approach. This structural organization, also referred to as knowledge-structuring in a broad sense, provides a web for revealing the basic structures of the discourse of sustainability science (in **Chapters 4-6**).

3.4.4 Discourse analysis

After the completion of the structural organization resulting in a super-imposing structure of five layers of organizations in 'Group-A' literature archive (i.e. the first decade's body of work of sustainability science), the diversity of sustainability science research practices is analyzed through a discourse analysis based on this structural organization. This discourse analysis—on the first decade of practice of sustainability science—is conducted in a straight-forward methodical way through employing the different modes of connections among the five layers of organizations. The analysis is presented in five stages, with the corresponding data appearing in **Appendices 1-5**, respectively. These five stages are discussed here, together with their relevance and importance.

Presentation of analysis: The first stage

A thematic map appearing in **Appendix-1** lists all themes in the fifth layer of organization (denoted with Arabic numbers) under each of the three 'categories' in the fourth layer (denoted with Roman numbers) with a color variation of entries. Blue, black, green and yellow colors indicate the first emergence of the themes in the sequence of the broad spheres of A, B, C, and D, respectively. This means that the pool of themes for a preceding broad sphere for any given category do not contain the themes that occurred in the subsequent broad spheres, appearing in different colors. On the contrary, once the themes occur, they potentially share archive items from the subsequent broad spheres as well (in the sequence of A, B, C, and D). This provides a measure of comparison in terms of 'accumulative pool of themes' under each of the four broad spheres for any given category. It could be exemplified as: the themes that occur corresponding to the broad sphere B are to be considered as absent for the broad sphere A, whereas they can also contain archive items from the subsequent broad spheres of C and D.

The themes under the three categories in **Appendix-1** present the thematic map of the diversity of sustainability science research practices. In the map, all three categories and all themes under each of the categories reveal scopes for undertaking studies on them, whereas the 'Category - iii' being the academic-sphere refers to scopes of studies on subject matters that can fundamentally advance understandings pertaining to the *scholarship of sustainability*. The 'Category - i' in the map contains 19 'problem/ issue/ challenge/ syndrome' topics, whereas the 'Category - ii' locates 25 action/ approach areas, and the 'Category - iii' listing 49 aspects for fundamentally advancing understandings pertaining to the *scholarship of sustainability*. **Figure 3.3** reveals this collection of 93 themes under the three categories.

Figure 3.3 Thematic map of the diversity of sustainability science research practices

<u>Category (i): 'Problem/ issue/ challenge/ syndrome-sphere'</u>

[Food security—Agricultural challenges/issues], [Water availability/quality], [Industrialization—Energy—Environment], [Urbanization—Consumption—Environment], [Air pollution—GHG Emission—Emission transfers], [Biodiversity—Habitat destruction—Trade], [Public health], [Human insecurity—Conflict], [Population—Consumption—Environment], [African poverty], [Climate change problem/impacts], [Drought], [Delta — problems], [Ecological crisis], [Coastal vulnerability issues & sea level rise], [Global warming—Natural disaster], [Estuaries & coastal seas — problems], [Open water bodies — problems] and [River — problems]

<u>Category (ii): Action/ approach-sphere</u>

[Energy policy/innovation], [Alternative livelihood], [Interventions and development, and conservation], [Community involvement], [Low-carbon transitions], [Biodiversity—Agriculture—Poverty], [Social learning], [Population policy], [Forest management policy/innovation], [Agricultural policy/innovation], [Regional cooperation], [Modeling], [Adaptation—Natural Disaster—Migration—Benefits], [Urban policy/innovation], [Reuse—Recycling—Pollution control], [Technology and nanotechnology], [Water policy/innovation], [Treaties—Agreements], [Emission estimation/control], [Land use system planning/innovation], [Biodiversity conservation policy/innovation], [Ecosystem services policy/innovation], [Air quality policy/innovation], [Environmental restoration policies/innovation] and [Sustainable Development strategies/innovation]

<u>Category (iii): Academic-sphere</u>

[Transition theory], [Dematerialization], ["Reuse" as theory], [Circular economy], [Quantitative sustainability], [Natural capital & ecosystem services management/governance], [Ecological economics], [Resilience], [Value—Attitude—Behavior], [Institutional reform], [Sustainability challenge], [Regulatory capitalism], [Rural-urban transformation], [Poverty—Development], [Sustainable architecture], [Urban sustainability and adaptive urban governance], [Adaptation], [Political ecology], [Land cover and land use change science], [Sustainability—Culture—Religion], [World System theory], [Learning—Knowledge—Ignorance—Condition], [Earth System analysis and tipping elements/points], [Environmental regulation], [Environmental assessment], [Sustainability related discourses], [Ethics], [Sustainable engineering education], [Sustainability Science education/curriculum], [Policy science], [Cosmopolitanism], [Decision making], [Ecological modernization], [Case studies for sustainability science], [Inter-/multi-/trans-/Disciplinarity of Sustainability Science research], [Anthropocene and Earth stewardship], [Ontology and/or epistemology of Sustainability Science], [Complex systems, analysis, and adaptive planning/management], [Cultural theory], [Urban agriculture], [De-growth], [Anthropocentrism vs. deep ecology], [Sustainable health], [Industrial ecology], [Reframing], [Globalization], [Scenario analysis—Visioneering], [Syndromes] and [Landscape ecology]

These 93 themes portray 10 years' discourse of sustainability science. A primitive appreciation of the collection reveals that the researches have taken place in arbitrary manner, which could be due to facing the unforeseen challenge of producing a nature of scholarship that goes in contrary to the traditional disciplinary-based education and training of citizens as well as scholars. However, these 93 themes as subject matters do not carry fundamental significance due to the researches taking place without being shaped from a cognitive consciousness arising from a sound intellectual foundation. Instead, the approach adopted here views it in the opposite manner. The growth of the arbitrary consciousness in the first decade of research in sustainability science is rather taken to project characteristics into a new avenue in human knowledge system that can host the nature of scholarship required for sustainability. The design of the fundamental research extracts what is significant from what is arbitrary for the potential new way of scholarship (i.e. the *scholarship of sustainability*). **Figure 3.3** draws that arbitrary reality, from which the subsequent four stages of presentation of analysis extract organizable depth.

As the 93 themes—as subject matters—do not carry fundamental significance for this research, engaging to try to define them is a task outside of the scope of this research. Instead, it falls on the interests of the individual arbitrary research practices and their domains, trying to reach sustainability science from their own perspectives. The focus here is not on taking the collection for granted, as in arbitrary fashion the reality could arguably have taken many other forms in terms of the participating elements in the collection. Besides, conducting the sets of 'empirical literature analyses' (**Chapter 4**) and 'focus analyses into the quality of sustainability science' (**Chapter 5**), as well as the place/scale-based analysis (**Chapter 6**) functionally address the participation of this thematic map in sustainability science, which is required for extracting what is significant from what is arbitrary through carrying out the fundamental research.

Presentation of analysis: The second stage

The second stage of presentation of analysis produces a detail literature map on the entire sustainability science research during the decade. The full literature map is presented in **Appendix-2**, in the consecutive sequence of the broad spheres of A (= A + AB + AC), B (= B + BA + BC), C (= C + CA + CB), and D; which is as per the second layer of organization within the 'Group-A' archive. In the literature map in **Appendix-2**, the association of individual items from 'Group-A' archive with the particular 'empirical literature analyses' and/ or 'focus analyses into the quality of sustainability science' are briefly coded as 'Dev3rd', 'Agri', 'Urban', 'Water', 'SusSD', 'Hum-Env', 'Cmplx', and 'Global' to represent the topics of 'empirical literature analysis – 1', 'empirical literature analysis – 2', 'empirical literature analysis – 3', 'empirical literature analysis – 4', 'focus analysis – I', 'focus analysis – II', 'focus analysis – III', and 'focus analysis – IV', respectively. The parallel noting of categories (the fourth layer, with the descriptor 'i/ii/iii') and themes (the fifth layer, with the descriptor '1/2/3/4/..') for each archive item in the literature map connect the second and the third layers to the fourth and the fifth layers of organizations. In the map the archive items also occur in the order of alphabet-number IDs (the first layer) under each theme (the fifth layer). This completes the demonstration of the interconnected mosaic of the five layers of organizations in the literature map, which provides a full-fledged platform for investigating into the basic structures of sustainability science based on a 'knowledge, problem and action-structuring' discourse.

Presentation of analysis: The third stage

The third stage of presentation produces detail individual literature maps for all of the 'empirical literature analyses' and 'focus analyses into the quality of sustainability science', by extracting relevant data from the full literature map produced in the second stage of presentation. These literature maps appear in **Appendix-3**, which are utilized in conducting the 'empirical literature analyses' and the 'focus analyses into the quality of sustainability science' in **Chapters 4** and **5**, respectively. The maps reveal the cross-connections among four out of the five layers of organizations, as the third layer represents the affiliation with the 'empirical literature analyses' and/ or 'focus analyses into the quality of sustainability science'.

Presentation of analysis: The fourth stage

The fourth stage is produced through combining the first and the third stages. In the thematic map in **Appendix-1**, highlighting the themes corresponding to the archive items present in the literature maps for the empirical literature analyses and focus analyses (**Appendix-3**) provides the scope of comparing the pool of themes associated with each empirical literature analysis and focus analysis against the entire pool of themes. These highlighted thematic maps appear in **Appendix-4**, which also reveal the scope of comparing the accumulative pool of themes (discussed in the first stage of presentation) for each empirical literature analysis and focus analysis. Although analytically this stage of discourse analysis produces the opportunity to analyze the corresponding pool of themes for each of the empirical literature analyses and focus analyses, due to the qualitative nature of the focus analyses, these maps are not utilized within the scope of the focus analyses as conducted in this research.

Presentation of analysis: The fifth stage

The fifth and final stage of presentation provides the scope of sphere-wise comparison of the corresponding themes under the three categories for each of the empirical literature analyses and focus analyses. This generates a sphere-wise thematic comparison across the three categories, presented in **Appendix-5** (**Tables A5.1–A5.4** for the four 'empirical literature analyses' and **Tables A5.5–A5.8** for the four 'focus analyses into the quality of sustainability science').

Tables A5.5, **A5.7** and **A5.8** provide data only on the sphere-D, while **Table A5.6** provides data only on the spheres of AC, CA, BC, CB and D, due to the respective focus analyses drawing data only from those particular spheres, which has been discussed in the third layer of organization (**Section 3.4.3**). The other tables (**Tables A5.1–A5.4**) provide data on all 10 spheres although some spheres for some categories do not exhibit any data, which project vacuums in sustainability science literature instead of potential theoretical scope of studies on them. Similar to the fourth stage, due to the qualitative nature of the focus analyses, the maps produced in the fifth stage are also not utilized within the scope of the focus analyses as conducted in this research.

3.4.5 Conducting the empirical literature analyses, focus analyses, and 'place/ scale-based' analysis

With the various kinds of literature maps prepared for the conduction of the empirical literature analyses and the focus analyses into the quality of sustainability science, the subsequent aspect in the research mechanism is in the conduction of these analyses. The mechanism for conducting these analyses (presented in **Figure 3.4**) utilizes the cross-connections among four out of the five layers of organizations in the 'Group-A' literature archive.

Although both of the ‘empirical literature analyses’ and ‘focus analyses into the quality of sustainability science’ are conducted as per the flow diagram presented in **Figure 3.4**, the six ideas presented in the diagram are executed only in case of the empirical literature analyses. As the focus analyses are qualitative in nature, the entirety of each archive item present in the respective literature maps are taken to directly reflect on the content of the respective focus analysis topics. A separate notebook is developed for every empirical literature analysis and focus analysis for recording these observations and/ or thoughts, which are then put into the thought process to produce the results.

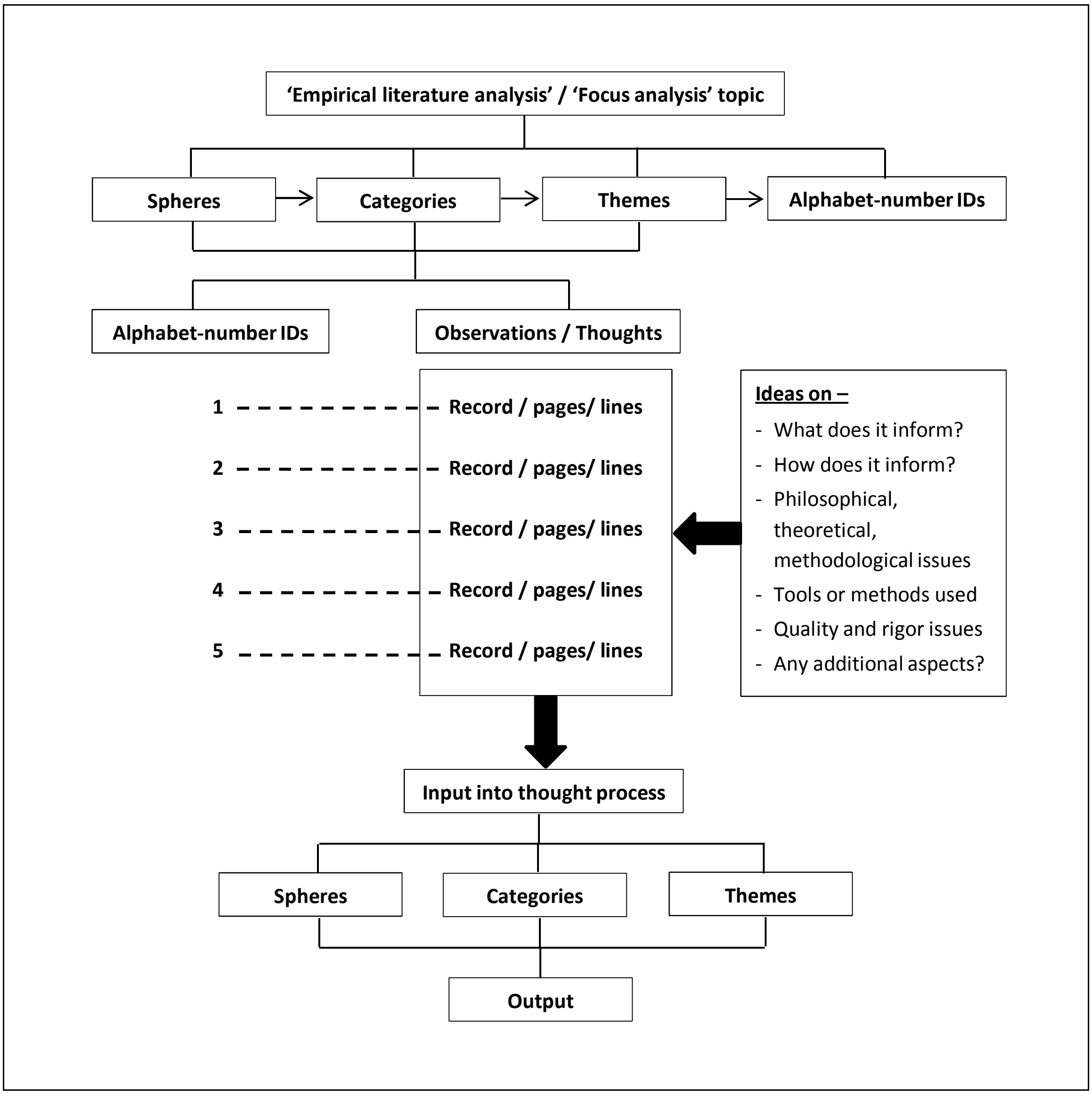


Figure 3.4 Mechanism for conducting empirical literature analyses and focus analyses

The 'place/ scale-based' analysis utilizes the relevant literature maps of the empirical literature analyses (presented in **Appendix-3**) as well as the full literature map (**Appendix-2**), and produces the results from appropriating on the different layers of organizations therein, including the respective scale, place and temporal characteristics of the archive items present in the maps. The analysis examines these scale, place and temporal characteristics as per the already present organizations in the literature maps, and cross-compares the projected trends from the empirical domains (representing the empirical literature analyses) to the entire literature base. Thus, based on an extended use of the literature maps (extended in terms of the added scale, place and temporal characteristics of the archive items present in the maps) the 'place/ scale-based' analysis provides a third kind of analysis to accompany the empirical literature analyses and the focus analyses for revealing the basic structures of the discourse of sustainability science.

3.5 The limitations and a summary of the research design

3.5.1 Limitations of the research design

The necessity and perspective behind the novel research design developed in this thesis for projecting on a new avenue in human knowledge system—to be termed as the *scholarship of sustainability*—is outlined in **Chapters 1** and **2**. Although the developed method provides a way for investigating into a *scholarship of sustainability* based on a *fundamental intellectual process*, the research contained in this thesis should be considered as a beginning point towards an effective intellectual treatment of sustainability. The approach developed here opens up novel intellectual opportunity for studying sustainability; however, it needs to keep resolving the challenges that would arise along its continued deliberations. These challenges are potentially no lesser than the challenges confronted at the beginning of this research, the development of a fundamental bottom-up approach from the ground was a response to which. Nevertheless, a limitation of the approach is that it had to analyze the contemporary researches—i.e. an example pluralistic knowledge and research body with regard to sustainability—in order to form an empirical approach in framing the *fundamental intellectual process*. As discussed in **Section 3.3**, this forms a part of the continued methodological necessity in terms of the adoption of an empirical approach, as the subsequent research component requires the application of this frame of the *fundamental intellectual process* on the same example pluralistic knowledge and research body. This—as clarified in **Section 3.3**—imparts methodological consistency in the progression of the research inquiry.

Two other weaknesses are implicated with the method, which are the 'data gaps' and the 'varying data quality' in the published research. The weakness in terms of 'data gaps' is treated here in a theoretical manner. The fundamental intellectual analysis projects all available areas requiring the presence of data, and thus, the absence of data in any given area exhibit data vacuums in the projected places. The question of the 'varying data quality' in the published researches is treated in the empirical literature analyses through incorporating the quality/ rigor issues in one of the empirical literature analyses, followed by synthesizing some generalized formulae (denoted as 'Archetype-I', and 'Prototype-I theoretical assumption') based on the analysis, which are then taken to compare the data in the other empirical literature analyses in order to provide consistency on the quality/ rigor issue. A similar treatment on the focus analyses was not required as these analyses are conducted qualitatively. The 'place/ scale-based' analysis does neither require data quality treatment as it merely reveals the spatial and temporal dynamics of the sustainability science practice.

3.5.2 A summary of the research design

The research design—constructed throughout this chapter based on fundamental analysis—is composed of the following components: (i) articulating the problem definition of the research, (ii) extracting the key research questions (KRQs) and approaches to addressing them, (iii) elucidating the epistemological and methodological composition of the research, as well as (iv) detailing the data collection and analysis methods including the structuring of a detail discourse analysis. This design begins with recognizing the two problems that are elucidated in **Chapter 1** in terms of the intellectual problem of deciphering the essence of the normative notion of sustainability, as well as the necessity of the formation of a *pluralistic knowledge avenue* for reflecting a pluralistic recognition/ orientation of knowledge. Through forming an intellectual perspective on sustainability, the **Chapter 2** responds to these problems in terms of replacing the normative character of the notion with its intellectual perspective, as well as criticizing the reductionist mode of enquiry that needs to be replaced with *a new mode of enquiry* for *sustainability scholarship*. This *new mode of enquiry* requires the development of a *fundamental intellectual process* in order to enable and characterize its pluralistic orientation and avenue of knowledge, which is responded to in C**hapter 3**.

The problem definition of the research (in **Section 3.1**) synthesizes this outstanding need of the *fundamental intellectual process* for enabling the study of pluralistic knowledge and research structures as well as epistemologically providing a measure for the development of a structured scholarship on sustainability. This requires fundamental research, the epistemological ground of which has been constructed based on a 'knowledge, problem and action-structuring' discourse for sustainability (**Section 3.2**). This 'knowledge, problem and action-structuring' discourse reflects on the fundamental use of four structuring concepts discussed in sustainability science literature i.e. knowledge-structuring, problem-structuring, action-structuring, and research on research (see **Sections 3.1-3.2**).

The methodological composition of the research—as elucidated in **Section 3.2—** combines deductive and inductive approaches, together with a fundamental character of the analyses to be carried out. The application of the deductive approach takes place in a heuristic manner that also becomes compatible in its coupling with the inductive component of the analysis. The precedents and justifications for the use of heuristic approach in terms of its genuine necessity in trans-disciplinary sustainability studies are also discussed in detail from the literature (**Section 3.2**).

In the overall methodological design of the research, the heuristic deductive application of the *fundamental intellectual process* elucidates the basic structures of the discourse of sustainability science based on its first decade's 'body of work', which, together with the intellectual perspective of sustainability and the framing of the *fundamental intellectual process*, culminate in the potential for an integrated inductive analysis on eliciting the dimensions and structure of a *pluralistic knowledge avenue* as well as the layout of an intellectual foundation for the *scholarship of sustainability*.

The first decade's 'body of work' of sustainability science, framed in a literature archive of 464 items, serves as the secondary data collected for this research. A structural organization—involving a consequential and cross-connected web of five layers—has been established within this secondary data based on a fundamental bottom-up approach. These cross-connections among the five layers provide the mechanism for elucidating the basic structures of the discourse of sustainability science.

A discourse analysis—based on the structural organization established within the literature archive—reveals the diversity of sustainability science research practices in **Section 3.4.4**. This discourse analysis is presented through five stages of presentation, yielding a thematic map on the diversity of sustainability science research, a detail literature map involving the five layers of organizations, as well as individual literature maps for each of the deductive analyses aimed at elucidating the basic structures of the discourse of sustainability science. This follows in formulating the mechanisms for the conduction of these deductive analyses, which completes the framing of the *fundamental intellectual process*.

Structurally the **Chapters 1-3** together form the 'Part I' (Fundamental research: the rationale & the plan) of the thesis that analyzes the rationale of the research (in **Chapter 1**), forms an intellectual perspective on sustainability (in **Chapter 2**), as well as frames a *fundamental intellectual process* for the *scholarship of sustainability* (in **Chapter 3**) based on fundamental research. This is followed in 'Part II' (Results & Discussion) of the thesis, involving — (i) heuristic deductive application of the *fundamental intellectual process* on the example pluralistic knowledge and research body (in **Chapters 4-6**), and (ii) conducting an integrative inductive analysis in **Chapter 7** that draws from the findings from the fundamental analyses carried out in 'Part I' (i.e. the C**hapters 1-3**) as well as the deductive analyses in **Chapters 4-6**.

PART II

RESULTS & DISCUSSION

Chapter 4

The discursive structure of Sustainability Science

Part II of the thesis is composed of four chapters (**Chapters 4-7**). These together produce the results and discussion component of the thesis. As clarified in **Chapters 1** and **3**, the intent of the thesis is the development of a *fundamental intellectual process* for advancing the intellectual treatment of sustainability based on a pluralistic orientation and avenue of knowledge. This development of the process takes place through analyzing its rationale (in **Chapters 1-2**), framing (in **Chapter 3**) and application (in **Chapters 4-6**), leading to its completion through the integrated inductive analysis in **Chapter 7**. The rationale and framing of the intellectual process are analyzed/ conducted based on fundamental research, where the framing utilizes a fundamental bottom-up modeling based on an 'example pluralistic knowledge and research body' (i.e. the first decade's body of work of sustainability science). It is on this same 'example pluralistic knowledge and research body' that the process is applied, leading to elucidating the basic structures of its discourse through heuristic deductive analysis. The significance in the elucidation of the basic structures of sustainability science is in terms of the utilization of fundamental means in extensively analyzing its body of scholarship in the process of developing a *fundamental intellectual process* for the intellectual treatment of sustainability. Thus, elucidating the basic structures of sustainability science becomes a subsequent contribution of the thesis. These basic structures are in terms of its discursive, integrative, and contextual qualities (see **Section 3.1**), analyzed in **Chapters 4**, **5** and **6**, respectively; which together produce a deductive discourse on sustainability science based on 'knowledge, problem and action-structuring' (see **Sections 3.2** and **3.4**). The discursive structure is elucidated in this chapter based on empirical domain-based literature analysis, or more simply, empirical literature analysis (ELA).

The ELAs are based on four issues (see **Section 3.4.3**), sampled from observing their representative presence in or indication from the prepared literature archive. Following is a list of these issues.

[Issue - 1]: Ecologically-benign development pathways in 'Global South'

[Issue - 2]: Hunger and food insecurity in human societies and the agricultural production issues

[Issue - 3]: Sustainability science issues in urban planning

[Issue - 4]: Sustainability science issues in water security syndrome

The ‘ELAs – 1-4’ utilize the literature maps produced for these analyses in **Section 3.4.4**, while the mechanism for conducting these analyses is elucidated in **Section 3.4.5** as well as summarized in **Figure 3.4**. **Section 4.1** presents a detail outline of this mechanism based on which the ELAs are conducted. This is followed in the conduction of the ELA-4 in **Section 4.2**, while the ‘ELAs – 1-3’ are addressed together in **Section 4.3**. A discussion on the findings follows in **Section 4.4**.

4.1 Outline of the Empirical Literature Analyses (ELAs)

The literature maps produced in **Section 3.4.4** for the four ELAs are of varying sizes in terms of their article counts. These maps contain 270, 120, 94 and 36 archive items for the ELAs – 1, 2, 3 and 4, respectively. Given that the ELAs examine the ways the studies are conducted in sustainability science, due to the varying sizes of the literature maps the four ELAs are split in two groups and conducted in two manners and extents of analysis while maintaining the overarching purpose of examining the ways the studies are conducted. The ‘ELA-4’—containing 36 archive items in its literature map—is selected for a full-length empirical analysis, whereas the other three ELAs—corresponding to bigger literature maps—are selected for semi-empirical nature of analysis.

The full-length empirical analysis (on ELA–4) is conducted as per the mechanism presented in **Section 3.4.5**, which describes on the application of a set of six questions aiming at enquiring into six respective aspects on the ways the studies are conducted in sustainability science. The **Figure 3.4** briefly articulates these six questions/ aspects, the details of which are conceptualized underneath.

The following description on the six questions/ aspects depicts a reality where a research consortium is attempting to address a research topic on sustainability, and the researchers are conversing based on a bottom-up approach that examines the reported diverse researches on the topic or fragments of it in order to apply a ‘multi-, inter and trans-disciplinary approach’ for the research in question. These six questions/ aspects are described with respect to a given research on which the consortium is conversing.

Q1. The first question asks on what a given research reports about. This aspect communicates on the nature of the reported research topic as well as its relation to its corresponding research stream (either disciplinary or ‘multi- or inter or trans-disciplinary’) with respect to the purpose of the consortium. This makes the research consortium aware of what they are going to work with.

Q2. The second question enquires about the overarching method in the conduction of the reported research. This is necessarily not a summary of all research methods that were utilized in the work, and instead it reflects on the mode of the conduction of the research in a generalized manner. This makes the consortium aware of the nature of analysis that they are working with.

Q3. The third aspect deals about the overarching ‘philosophical, theoretical and methodological issues’ on the work in a generalized manner, such as asking on what the work does and doesn’t do. In a strict sense these are not criticisms on the work, and instead these are to make the research consortium aware on the general ‘philosophical, theoretical and methodological standing’ of the work.

Q4. The fourth question enquires on the essence of the utilized research methods in the work. This does not necessarily capture the details of these methods with all of their particularities; instead it focuses on describing how these research methods could be communicated so that the research consortium could consider utilizing them in addressing the topic in question.

Q5. The fifth question is aimed to provide the research consortium an overview into the aspects of the quality and rigor of the work being examined. Instead of this being a detail and quantitative account on the quality and rigor aspects, it is rather a simplified version aimed at making the consortium generally aware of the degree of usefulness and acceptability of the work. This may or may not be connected to the third question enquiring on what the work does and doesn’t do.

Q6. The sixth question leaves room for any additional aspects to learn with regard to the research being examined, including and not limited to — appreciating the work for its unique usefulness, useful implications that the work opens into but does not accomplish, critically questioning the position of the work in terms of its pragmatic limitations versus intellectual soundness, based on the reported things projecting what other things could have been done within the doable range in order to make the work more useful and credible, as well as the shortcomings of the work that limit its strength, etc.

The full-length empirical analysis applies this conceptual frame on all archive items present in the ELA-4 literature map, which can be referred to as the exemplification of the dimensions of a potential language of conversation for sustainability research. The conceptualization of the frame followed by its exemplification on a well-organized literature map consisting of 36 archive items from sustainability science research (i.e. on ELA-4) offers the opportunity of producing a theoretical framework on the language of conversation in sustainability research. The purpose of such a language of conversation is to provide a common mean for revealing the proper and error-free extent of understanding on a given research being examined by a research consortium engaged in sustainability research. In contrast to the full-length empirical analysis, the semi-empirical analysis conducted on the ELAs – 1, 2 and 3 address the first two out of the six questions.

As the ELAs – 1, 2 and 3 are not selected for the full-length empirical analysis due to their bigger literature maps, not addressing the third till the sixth questions render the first question not to be necessitating an answer particular to the ELA topics. Instead, a brief and general answer to the first question for each archive item—irrespective of its particular form with regard to the ELA topics—is considered, which makes it possible to conduct the semi-empirical analysis in a combined form across these three ELAs. This also provides consistency as the answer to the second question for a given archive item remains the same irrespective to the differences in the ELA topics. This way, although the answers to the first and second questions appear irrespective to the three ELA topics in the semi-empirical analysis, the findings are conveniently extracted for the individual ELAs from this combined analysis.

In terms of the general nature of the analyses, although the issues dealt in the ELA topics have paramount importance for discerning the quest for sustainability, the ELAs as analyzed in this thesis do not try to review the pool of research findings embedded in the articles present in the corresponding literature maps, nor they attempt to abstract insights from these research findings for the purpose of utilizing such insights in addressing the given sustainability issue. Instead, the analyses deal with 'a structured quest' on the ways the researches in the reported literature are conducted. Thus, the focus in the analyses is not in terms of the outputs of the reported researches, and instead, it is in the manner these researches are conducted.

Despite the different extents of analysis among the ELAs (i.e. ELA-4 as full-length empirical analysis while semi-empirical analysis with the others), the nature of analysis as well as the different modes therein remain the same across all ELAs. These different modes of analysis appropriate the different analytical conveniences from the cross-connected mosaic of the five layers of organizations produced in the prepared literature archive in **Section 3.4.3**. There are four modes of analyses that emerge from this fundamental bottom-up approach.

1. The first mode is the main analysis, utilizing the respective literature maps for the ELAs in enquiring on the six aspects on the ways the studies are conducted in sustainability science. This analysis is systematically arranged as per ‘Spheres → Categories → Themes’ (i.e. the ‘second layer → fourth layer → fifth layer’ within the five layers of literature organization), while the ELAs represent the third layer.

2. The second mode compares the pool of themes corresponding to each ELA’s literature map against the entire pool of themes, as presented in **Appendix-4**. This analysis presents a comparison on the extent of coverage of the themes in terms of each of the ELAs. It is indicative of a state of balance in the practice of sustainability science for each of these ELA topics in contrast to the mosaic of all themes under the three categories that could be applied to these ELAs.

3. The third mode of analysis is based on the comparison of accumulative pool of themes as described in **Section 3.4.4** (in the first and the fourth stages of presentation of analysis) and exhibited in **Appendix-4**. This analysis compares the absence of themes in the broad spheres of A (economic perspectives of sustainability), B (social perspectives of sustainability) and C (environmental perspectives of sustainability), and the sphere D (central organization of sustainability) in the practice of sustainability science on these given ELA topics.

4. The fourth mode deals with a sphere-wise comparison of the corresponding themes under the three categories for each ELA, as presented in **Appendix-5**.

Besides these four modes of analyses, some additional observations are noted in terms of the nature of the articles present in the respective literature maps, the place-scale characteristics of these articles both in terms of the place-scale that the articles are concerned with as well as the origin of these articles by their corresponding authorship, and the temporal dimension of the articles. The place/ scale characteristics and the temporal dimensions observed for the ELAs – 1, 2 and 3 are taken to compare against the same on the entire ‘Group-A’ literature archive, which is due to the bigger literature maps of the ELAs – 1, 2 and 3 compared to the ELA-4. Therefore, these characteristics for the ELAs – 1, 2 and 3 are subsequently placed in **Chapter 6** within the broader place/scale-based analysis.

4.2 ELA-4: Sustainability science issues in water security syndrome

The literature map corresponding to this ELA includes 36 archive items, appearing in **Appendix-3**. It elucidates on the sustainability science issues for water security syndrome from the first decade’s body of work of the practice. The *German Advisory Council on Global Change* (WGBU 1996) developed the concept of ‘syndrome’ to describe the diverse, complex and interdependent issues challenging both humans and the environment. The council had identified the following nine spheres to represent such syndromes: ‘biosphere’, ‘atmosphere’, ‘hydrosphere’, ‘population’, ‘pedosphere’, ‘economy’, ‘psychosocial sphere’, ‘social organization, and ‘science/ technology’. Arising from out of these nine spheres, the most prioritized syndromes were identified as –

i. *Contaminated land syndrome* — the local contamination of the environmental assets at industrial locations,
ii. *Dust bowl syndrome* — unsustainable agro-industrial use of soils and water bodies,
iii. *Mass tourism syndrome* — the development and destruction of nature for recreational ends,
iv. *Sahel syndrome* — the over-cultivation of marginal lands,
v. *Smokestack syndrome* — the environmental degradation through large-scale diffusion of long-lived substances,
vi. *Urban sprawl syndrome* — the destruction of landscapes through planned expansion of urban infrastructures, and
vii. *Waste dumping syndrome* — the environmental degradation through controlled and uncontrolled disposal of waste.

In light of this definition on syndrome, the concept of a ‘water security syndrome’ in the context of the megacities of the ‘developing world’ is constructed in this research through systematic analysis of the relevant literature based on a bottom-up approach. On one hand it symbolizes the development of the fundamental bottom-up approach in this research; while on the other hand, it reveals the nature of the complicated reality for sustainability in terms of such water security syndrome. This ‘water security syndrome’ is developed in the perspective of the capital of Bangladesh and the megacity Dhaka, due to the megacity constructing an ideal case for such study. As this component of the research has been published as an original article in the journal *Sustainable Water Resources Management*, instead of articulating the detail research in here, the published article is presented in **Appendix-6**. **Figure 4.1** schematically presents this water security syndrome.

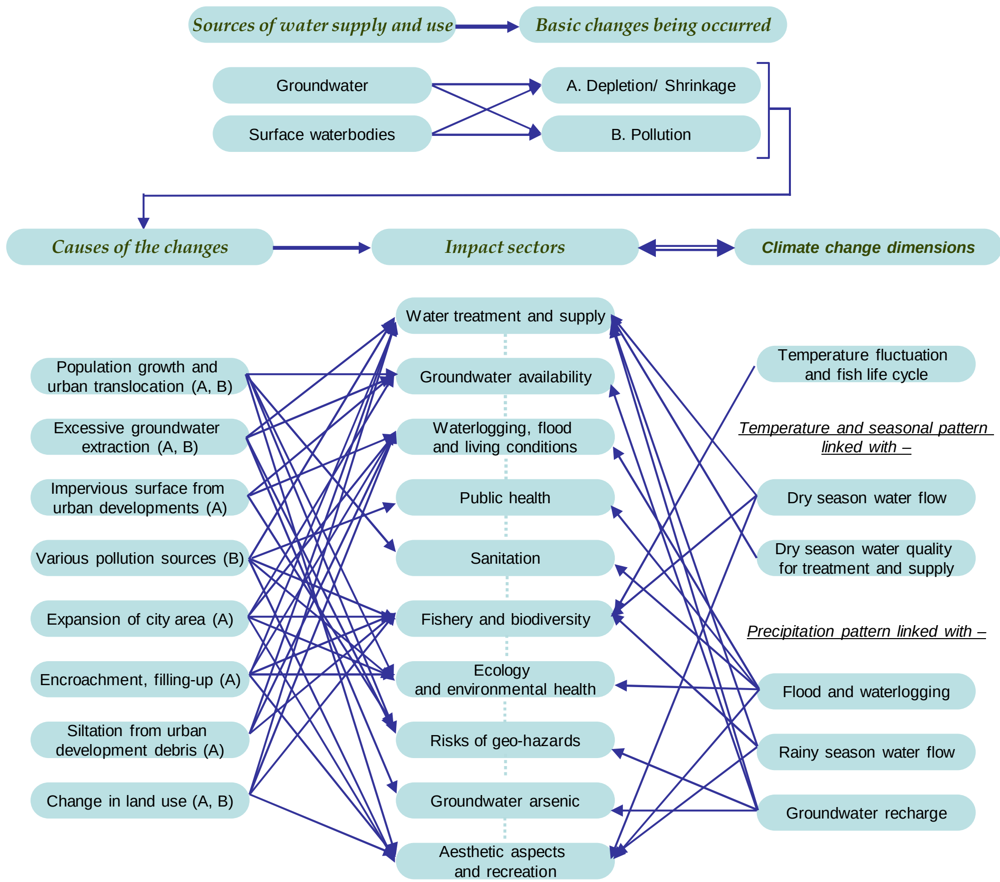


Figure 4.1 ‘Water security syndrome’ of the megacity, Dhaka

Out of the 10 spheres classified from the three overlapping 'broad spheres' of economy, society and environment, the literature map corresponding to this ELA does not contain any archive items within the spheres of economy[A], society[B], environment[C] and socio-economy[AB]. These represent vacuums in the first decade of sustainability science research with respect to this ELA. Nevertheless, the literature map containing contributions from within the spheres of environo-economy[AC], econo-environment[CA], environo-society[BC], socio-environment[CB], econo-society[BA], and 'central organization of sustainability'[D] reveals that the studies have exclusively taken place at the interface of the three broad spheres of economy, society and environment. This represents on the purpose and design of these studies as incorporating multiple considerations across the broad spheres instead of addressing singular considerations—i.e. either of the spheres of economy, society or environment—which is indicative of the integrated nature of the studies in sustainability science around the issue of water security, reflecting the intended purpose and aspiration of the practice.

4.2.1 Analysis under the Category – i: The 'problem/ issue/ challenge /syndrome-sphere'

Under the 'Category – i', the literature map contains the following themes, accompanied with the answers to the six questions (Q1-Q6) for the archive items corresponding to each theme. These six questions in brief (see **Section 4.1** for their detail meanings and purposes) precede the Q1-Q6 observations grouped under the themes.

Q1. *What does it inform?*
Q2. *How does it inform?*
Q3. *What are the philosophical, theoretical and methodological issues with the study?*
Q4. *What are the tools or methods used in conducting the study?*
Q5. *What are the quality and rigor issues of the study?*
Q6. *If, what additional aspects are to be learnt about the study in light of the purpose treated in* ***Section 4.1****?*

Q1-Q6 observations grouped under the themes

- *Water availability/quality*

Q1. Under this theme the topics have ranged from the complications of water supply, water demand, water markets and water trading in local USA context (Chong and

Sunding 2006), the multi-scaled and simultaneous water-related urban environmental burdens in South-East Asia (Marcotullio 2007), and water policy to redress inequality in South African context (Funke et al. 2007). These studies are wide-ranging from the problem of supply, to the quality of water, to the issue of policy.

The way these studies have been conducted are literature survey and policy analysis (Q2), and therefore, the philosophical, theoretical and methodological issues are to remain limited to the others' works that have been analyzed on, or to the merit of the policy dealt (Q3). The research methods remain limited to literature archive analysis and policy analysis (Q4), whereas the quality and rigor issues are to be referred to the works cited by the study (Q5).

- *Industrialization—Energy—Environment*

Only one archive item corresponds to this theme, revealing water shortage, drinking water contamination, and freshwater and marine pollution in East Asia (Kim 2006) (Q1). The study is a literature survey (Q2), while the philosophical, theoretical and methodological issues remain limited to the others' works that have been analyzed on (Q3). The research method remains limited to literature archive analysis (Q4), while the quality and rigor issues are to be referred to the works cited by the study (Q5).

- *Public health*

Q1. Only one archive item corresponds to this theme, modeling the risk of waterborne infectious diseases due to inundation in Cambodia (Kazama et al. 2012). The study conveys its findings through risk modeling (Q2). It uses field calibrated simulation rather than field experiment (Q3). The research methods are literature archive analysis, field observations, modeling, and risk assessment (Q4). The study is 'indicative' rather than actual (Q5). It makes indicative estimate doable, however such could have been compared with some field experiment derived data on the same (Q6).

- *Population—Consumption—Environment*

There is only one archive item under the theme, which presents a global study in water use (Gleick 2003b) (Q1). The study is a literature survey (Q2) with literature archive analysis being the research method (Q4), while the philosophical, theoretical and methodological issues as well as the quality and rigor issues are to be limited and referred to the published works cited by the study (Q3 and Q5, respectively).

- *Climate change problem/impacts*

There is also merely one archive item corresponding to the theme, which presents the highlights of our understanding and response to climate change (NAS 2008) (Q1). It is a literature review study (Q2 and Q4), while the philosophical, theoretical and methodological issues as well as the quality and rigor issues are to be limited and referred to the published works cited by the study (Q3 and Q5, respectively).

- *Drought*

Only one archive item belongs to this theme, providing a systemic assessment of drought impacts in Iran (Shahbazbegian and Bagheri 2010) (Q1). This study is a systemic assessment (Q2), utilizing the research methods of literature archive analysis, system dynamics, and casual loop diagram (Q4). It adopts a holistic approach, and presents an integrated understanding (Q3). The study is a qualitative assessment, which is not paired with field data (Q5).

- *Coastal vulnerability issues & sea level rise*

There are two studies corresponding to this theme, dealing with the methodologies for studying compound events of disasters in coastal areas in Japan (Yasuhara et al. 2011), and studying urban coastal infrastructural instability due to natural hazards resulting from groundwater-level variations (groundwater abstraction) and sea-level rise in Asian context (Yasuhara et al. 2007) (Q1). The first study is a literature survey (Q2) with literature archive analysis being the research method (Q4), while the philosophical, theoretical and methodological issues as well as the quality and rigor issues are to be limited and referred to the published works cited by the study (Q3 and Q5, respectively). In contrast, the second study is conducted using modeling and case histories (Q2), which uses the research methods of literature archive analysis, modeling, and case history (Q4). This study presents its findings through modeling rather than being empirical in nature (Q3), which needs to be paired with empirical observations (Q5). However, potential empirical studies could be guided from the findings of the study (Q6).

- *Estuaries & coastal seas — problems*

There is one archive item pertaining to this theme, exploring the depletion, degradation, and recovery potential of estuaries and coastal areas (Lotze et al. 2006) (Q1). It is a literature survey study (Q2); however, it uses the research methods of literature archive analysis and modeling (Q4). The philosophical, theoretical and methodological issues are limited to the published works cited by the study (Q3). The quality and rigor issues are referred to the works cited; however, the repercussions of conducting modeling study on the past needs to be addressed in terms of the question of certainty (Q5). Although historical reconstruction is the only mechanism available for advancing such understanding; however, the potential for enhancing the accuracy needs to be harvested (Q6).

- *Open water bodies — problems*

The only archive item corresponding to this theme produces results on the loss of open water areas due to agricultural practices in Myanmar (Sidle et al. 2007). The study is partly literature survey and partly field survey (Q2), thereby using the research methods of literature archive analysis and field survey (Q4). This study is qualitative in nature (Q3), and the inclusion of the other potential factors is required besides exploring into the interplay of such other factors with the agricultural factor (Q5).

Summary on the Q1-Q5 observations

In summary, the analytical data on the six questions under the ‘problem/ issue/ challenge/ syndrome-sphere’ (i.e. Category – i) reveal issues in water security on the following themes: ‘Water availability/quality’ (for issues on complications of water supply and trade, the complex water-related urban environmental burdens, and water policy for equity), ‘Industrialization—Energy—Environment’ (the issue of drinking water contamination and marine and freshwater pollution, coupled with water shortage), ‘Public health’ (the issue of waterborne infectious disease risk due to inundation), ‘Population—Consumption—Environment’ (the consumption of water at global scale), ‘Climate change problem/impacts’ (our understanding of, and responses to climate change), ‘Drought’ (systematically assessing the impacts of drought), ‘Coastal vulnerability issues & sea level rise’ (the issues of understanding the compound events of disasters in coastal areas, and urban coastal infrastructural instability due to water-related natural hazards), ‘Estuaries & coastal seas — problems’ (the depletion, degradation, and recovery potential of estuaries and coastal areas), and ‘Open water bodies — problems’ (the loss of open water areas due to agricultural practices). As it may appear that some of these themes potentially cover wider meanings compared to the extent imparted by the archive items associated with this ELA (i.e. the issues appeared in the archive items), it is due to the themes being inclusive of the entire literature archive map, where the themes group all archive items conforming to them.

Out of the 12 archive items under the ‘Category – i’ for this ELA, six studies have been conducted in the manner of ‘literature survey’ (Q2) with straightforward observations on Q3 – Q5 (i.e. ‘literature archive analysis’ being the research method (Q4), and the philosophical, theoretical and methodological issues as well as the quality and rigor issues are to be limited and referred to the published works cited by the study (Q3 and Q5, respectively)). The repeated occurrence of this type of ‘Q2 – Q5 observations’ could be considered as an archetype—and subsequently labeled as ‘**Archetype-I**’ in the remainder of the thesis—although there is also one study utilizing literature archive analysis and modeling as research methods while the type of the study being literature survey. Moreover, these six literature survey studies are not just literature reviews, and instead one of them is original article while another two being overview articles, besides the rest of the three being review articles. This refers to a beauty in the studies in sustainability science that the studies can take many forms while working at the intersections of the three broad spheres of economy, society and environment. Furthermore, out of the 12 examined studies, five are found to be original articles, three review articles, two overview articles, and the rest two being report and policy analysis each. This reveals a rich presence of widely varying nature of the reported research in sustainability science.

As studying sustainability aims to obtain the understanding of matters on larger and complex scales, one step towards this is to grow our understanding by looking at the ‘overview’ of the matters at the interface of the broad spheres of economy, society and environment. Such a grasp provides the scope and windows for undertaking original researches on complex sustainability issues. Apart from the usual article types of original articles (five counts), reports (one count), and policy analyses (one count), the presence of overview articles in two counts and review articles in three counts in the analytical data, reveal the perceived importance of these types of studies in sustainability research.

The methods of conduction of the examined studies include modeling, policy analysis, case history, systemic assessment, and field survey, apart from the more commonly appeared 'literature survey'. The research methods employed in these studies include literature archive analysis, field survey, policy analysis, case history, risk assessment, system dynamics, casual loop diagram, and modeling. The philosophical, theoretical and methodological issues occurring with respect to the studies include — deriving results through utilizing field calibrated simulation rather than field experiment, the adoption of holistic approach, a tendency of attempting to present integrated understanding, utilizing modeling rather than empirical approach, being of qualitative nature, the question of the inherent merit of a policy under analysis, as well as the philosophical, theoretical, and methodological issues of other works being analyzed in a literature survey study. It is notable that in conducting the studies the merits of utilizing — (a) field calibrated simulation rather than field experiment, (b) modeling rather than empirical approach, and (c) the qualitative rather than quantitative nature of analysis, have the philosophical and methodological merits of enabling studies at the complex interface of the broad spheres of economy, society and environment, which is matched with the presence of the tendencies of adopting a holistic approach as well as attempting to present integrated understanding, as observed in the analytical data. This could symbolically be regarded as the construction of a credible way for approaching the complex matters.

The conduction of modeling and simulation studies in cases where an empirical study on the same is possible is usually seen as a criticism in terms of the lack of certainty and contended extent of truth in contrast to the actual reality of the things. However, when it is improbable in reality to undertake empirical studies in attempting to address the complex matters or similar questions in research, it could rather be a philosophical and methodological merit to adopt such simulation or modeling study as well as its nature being qualitative, as long as — (a) the study has a complex nature of lying at the interface of academically disparate areas or at the interface of the broad spheres of economy, society and environment, (b) the adopted approach is holistic, and (c) the attempt is to present an integrated understanding. Met with these criteria, a modeling/ simulation/ qualitative study could rather be a gateway to explore our understandings at the complex interface of economy, society and environment in the pursuit of a sustainability transition. This combination (i.e. between the criteria and the modeling/ simulation/ qualitative nature of the study) could be taken to derive a theoretical assumption, provided that it continues to appear useful in practice. For the remainder of the thesis, such a combination is recognized and consequently labeled as '**Prototype-I theoretical assumption**' in order to identify similar studies conducted through utilizing such a combination.

An extension to this '**Prototype-I theoretical assumption**' could come from the considerations of analyzing the quality and rigor issues of the studies. The quality and rigor issues in the analytical data include — (a) a study being indicative rather than actual, (b) a qualitative assessment not being paired with field data, (c) the consideration of other probable factors in qualitative studies as well as the interplay of such factors with the factor(s) addressed, (d) a modeling study not being paired with empirical observations, and (e) the consideration of properly addressing the question of certainty in conducting modeling on the past in order to enhance accuracy as well as avoiding incorrect repercussions. In this list of analytical data, the issue of 'a study being indicative rather than actual' does not go in contrary to the characteristics of the '**Prototype-I theoretical assumption**'. However, the remaining quality and rigor issues could potentially go in contrary to the characteristics of the '**Prototype-I theoretical assumption**' if the issues are not addressed properly. For example, in order for a qualitative assessment or modeling study to qualify under the '**Prototype-I theoretical assumption**' it would require to be paired with some field data or empirical observations—unless improbable—that could be acquired through the application of some existing research methods, i.e. field data or empirical observation that would go in agreement and conform to the outcomes of the modeling or qualitative assessment; or the case of a qualitative study—trying to find out the role of a given factor in inducing a particular effect—needing to address the question of the other possible factors and their interplay in it, etc. These examples could come in many different ways, however, the principle in interpreting these would be in terms of satisfying the quality and rigor aspects for a given study to qualify under the '**Prototype-I theoretical assumption**'. Therefore, an extension to the '**Prototype-I theoretical assumption**' could be articulated as — *in conducting a research, the method needs to properly satisfy the quality and rigor aspects associated with the study.*

Therefore, including the extension on the quality and rigor issue, the '**Prototype-I theoretical assumption**' could be summarized as: "*Unless it is improbable in reality to undertake empirical studies in addressing the complex matters or questions of this sort in research, it could be a philosophical and methodological merit to adopt simulation or* *modeling study as well as its nature being qualitative, as long as — (a) the study has a complex nature of lying at the interface of academically disparate areas or at the interface of the broad spheres of economy, society and environment, (b) the adopted approach is holistic, (c) the attempt is to present an integrated understanding, as well as (d) the study properly satisfies the quality and rigor aspects associated with it*." Based on this criteria, none of the 12 studies examined under the 'problem/ issue/ challenge/ syndrome sphere' correspond to the '**Prototype-I theoretical assumption**'.

Summary on the Q6 observations

Answering the Q6 i.e. any additional aspects to be learnt about a given study in light of the purpose of the Q6 (as treated in **Section 4.1)**, can provide useful insights into exploring the possibilities of new researches at the interface of the broad spheres of economy, society and environment; or can be contributory to sustainability research through resulting in an awareness on such aspects as well as appreciating their merits. Besides playing an important role in the language of conversation for sustainability research, the Q6 can, thus, also contribute in terms of expanding the scopes of research on sustainability. For example, out of the 12 studies examined under the 'Category – i', the Q6 observations generate insights such as: a 'risk modeling' study—making indicative estimate doable—can lead to further research enquiries in sustainability science, or new empirical studies could possibly be guided from the findings of a study utilizing the methods of modeling and case history; or even appreciating the method of historical reconstruction to be the only available mechanism for a particular type of study, however, together with emphasizing on the potential of enhancing the accuracy in conducting such, which in turn can contribute into sustainability science.

Discussion on the remainder modes of analyses

As the topic of water security syndrome in the first decade of sustainability science research corresponds to only nine out of the 19 themes under the 'Category – i', from among the rest of the themes there are several others that could potentially be explored for the relevant understanding on the issue of water security syndrome, e.g. 'Food security—Agricultural challenges/issues', 'Urbanization—Consumption—Environment', 'Human insecurity—Conflict', 'African poverty', 'Delta — problems', 'Ecological crisis', 'Global warming—Natural disaster', and 'River — problems'. These areas could appear as essential for advancing our understanding on water security syndrome in the quest for sustainability.

It is notable that themes such as ‘Public health’, ‘Population—Consumption—Environment’, ‘Climate change problem/impacts’, and ‘Drought’ did not appear in the economic perspectives of sustainability (i.e. the broad sphere ‘A’); while the themes ‘Coastal vulnerability issues & sea level rise’, ‘Estuaries & coastal seas — problems’, and ‘Open water bodies — problems’ did not appear in either of the economic or social perspectives (i.e. the broad spheres of ‘A’ and ‘B’, respectively). Besides the literature map for ELA-4 not containing any items from the spheres of economy[A], society[B], environment[C] and socio-economy[AB] (as discussed at the beginning of **Section 4.2**), under the ‘Category – i’ the spheres of econo-environment[CA] and ‘central organization of sustainability’[D] also do not contain any archive items. This is indicative of further vacuums in terms of studies at the interfaces of the three broad spheres.

The temporal dimension of the 12 archive items under the ‘Category – i’ reveals a distributed pattern with the highest count of studies observed for the year 2006. The pattern follows as — 2003 (with one count of study), 2006 (six count of studies), 2007 (one), 2008 (one), 2009 (two), and 2011 (one). The place-scale characteristics of these studies also exhibit a distributed pattern. The 12 studies are found to be equally distributed to four of the corresponding scales—local, country-scale, regional, and global—with three studies corresponding to each scale. As employed in the analysis in this thesis, the scale characteristic is comprised of six different scales: (1) the ‘local’ scale referring to a part of a country and not concerning the entire country, (2) the ‘country’ scale concerns about the entirety of a country, (3) the ‘regional’ scale involves more than a country either within the same continent or across different continents, (4) the ‘continent’ scale concerns the entirety of a continent, (5) the ‘global’ scale, and (6) the sixth kind referring to the absence of any scale i.e. a study not having any associated scale characteristic.

In terms of the places the studies are concerned with, 10 out of the 12 examined studies concern Asia at different scales (including the three studies corresponding to the global scale), while the rest of the two are concerned with USA and South Africa, respectively. The origins of the articles by the places of the corresponding authors reveal four articles from USA and Japan each, while the rest of the four coming from Canada, Republic of

Korea, Iran and South Africa. A comparison on the linkage between the place-scale characteristics of the studies and the places of the corresponding authorship of the articles reveal USA, Japan and Canada exhibiting a characteristic of producing studies that also address issues on other regions of the world including global studies, whereas the studies arising from the other places are limited to their local or regional concerns. A cross-comparison between the presence of 'original articles' (within the examined articles) and their places of corresponding authorship is not undertaken as the 'original articles' are not placed with any particular prominence over the other article types while we are yet to unlock an effective intellectual treatment of sustainability, to which end the diverse article types could have unique contribution in their own ways.

4.2.2 Analysis under the Category – ii: The 'Action/ approach-sphere'

Under the 'Category – ii', the literature map contains the following themes, accompanied with the answers to the six questions (Q1-Q6) for the archive items corresponding to each theme.

Q1-Q6 observations grouped under the themes

- *Interventions and development, and conservation*

One archive item corresponds to this theme, analyzing decentralized and pro-poor rural 'water supply policy' implementation in Tanzania (de Palencia and Pérez-Foguet 2011) (Q1). The study is a policy analysis (Q2), utilizing literature archive analysis, interviews, group-discussions with stakeholders, and policy analysis as research methods (Q4). It is a social pragmatic research (Q3), and the quality and rigor issues rest with the interview content and sample (Q5).

- *Regional cooperation*

The archive item corresponding to this theme explores the scope of regional cooperation for competitive, secure and sustainable large-scale freshwater supply across the Europe, Middle East and North Africa (Trieb and Müller-Steinhagen 2007) (Q1). It corresponds to the 'Archetype-I' (see **Section 4.2.1**) (Q2 – Q5).

- *Modeling*

Two archive items correspond to this theme, one forecasting on municipal waste generation in Europe (Antanasijević et al. 2013) while the other evaluating the cost of flood damage through simulating extreme rainfall pattern in Japan (Kazama et al. 2010) (Q1). The first article is a modeling study (Q2), utilizing literature archive analysis and modeling (artificial neural networks) as research methods (Q4). The second article is a modeling and simulation study (Q2) that utilizes literature archive analysis, modeling, and simulation as research methods (Q4). A common 'philosophical, theoretical and methodological issue' with both of the studies is that they are modeling rather than field study (Q3), and therefore, the results are modeled rather than actual (Q5). Besides, the use of sustainability indicators in the first study is questionable (Q3), which is also a problem in terms of the quality and rigor of the study (Q5). The first study aids towards solving the problem of the absence of data (hence, modeling acts as a good alternative); however, it needs to be paired with some extent of field study, along with resolving the problem of using sustainability indicators (Q6). The second study creates a probable clue for enabling actual study; however, it also needs to be paired with empirical evidence (Q6).

- *Urban policy/innovation*

The first archive item under this theme discusses the water-related issues in a map of climate change vulnerabilities and responses in terms of integrated adaptation in an Indian developing city (Wilbanks et al. 2007) (Q1). The second item addresses the water challenge in urban planning based on integrated management, which in a global context elaborates on the ideas of understanding the dimensions of the challenge, reducing water consumption, integrating water management and spatial planning, as well as carefully considering subsidies, etc. (UN-Habitat 2012) (Q1). Both of these archive items correspond to the 'Archetype-I' (Q2 – Q5).

- *Technology and nanotechnology*

There is only one archive item corresponding to this theme, presenting the status of the available nanotechnologies in support of achieving the goal of water sustainability, especially in water treatment, desalination and reuse (Diallo and Brinker 2011) (Q1). This study also corresponds to 'Archetype-I' (Q2 – Q5).

- *Water policy/innovation*

There are six studies under this theme. Esposto (2009) studies the application of sustainability in the design of water treatment plant in Iraq (Q1). This study is a case report (Q2), utilizing literature archive analysis and case reporting as research methods (Q4). It is a pragmatic study with the problem of scale, together with the quality and rigor issue of the question and problem of the sustainability concept used in the study (Q3 and Q5). The study is indicative to potential scopes, however, the weaknesses in the study need to be addressed (Q6).

Daniell et al. (2010) presents intervention research on participatory water management processes (Q1). This study is a literature survey (Q2), utilizing literature archive analysis and intervention research as research methods (Q4). It investigates on the participatory working dynamics in human groups (Q3), although with the limitations of being a case-study as well as the absence of wide range of cross-comparison (Q5).

Hermanowicz (2008) studies the changes in the meaning and perceptions about sustainability in water resources management and tries to promote an arbitrary framework towards sustainability metrics (Q1). It is a literature survey study (Q2), and the research method being literature archive analysis (Q4). The incorporation of pre-defined 'dimensions of sustainability' as well as 'elements of sustainability metrics' in the study become questionable (Q3 and Q5). It tries to get somewhere in the abyss of a lack of our understanding on sustainability, however, this also needs to find and validate a sound intellectual basis for sustainability (Q6).

Schmandt (2006) tries to bring sustainability science into water basin management in the context of North America, whereas Gleick (2003a) analyzes the soft-path solutions for the global freshwater resources, such as lower cost community-scale systems, decentralized and open decision-making, water markets and equitable pricing, and the application of efficient technologies. (Q1). Both of the studies correspond to 'Archetype-I' (Q2 – Q5).

The final archive item under this theme attempts to synthesize the pragmatic linkages between 'water' and human well-being (Zwane et al. 2009) (Q1). It is a summary report on multi-stake executive session (Q2), with multi-stake and multi-executive discussion being the method utilized (Q4). The results comprise executive session outcomes (Q3), which have been produced through the synthesis of ideas based on common sense, however, with questionable intellectual basis (Q5). The study opens as well as guides avenues that warrant our attention, which, however, need to be justified with adequate theoretical basis and empirical framework (Q6).

- *Ecosystem services policy/innovation*

The only archive item under this theme analyses policy lessons in designing payments for ecosystem services (PES) such as in water purification, flood mitigation, etc. (Jack et al. 2008) (Q1). It is a policy analysis study (Q2), utilizing literature archive analysis and policy analysis as research methods (Q4). The philosophical, theoretical and methodological issues are limited to the merit of the policies analyzed (Q3), whereas the quality and rigor issues are to be referred to the published works cited by the study (Q5).

Summary on the Q1-Q6 observations

Summarizing the analytical data on the six questions produces the following actionable approaches — the implementation of decentralized and pro-poor water supply policy (under the theme 'Interventions and development, and conservation'), regional cooperation for sustainable large-scale water supply (the theme being 'Regional cooperation'), the use of simulation and modeling in forecasting municipal waste generation and evaluating cost of flood damage (under the theme 'Modeling'), the application of integrated adaptation and management in addressing water-related issues in 'climate change'-vulnerable areas ('Urban policy/innovation'), the utilization of available nanotechnologies in water treatment, desalination and reuse ('Technology and nanotechnology'), the designing of water-related 'payments for ecosystem services' ('Ecosystem services policy/innovation'), the application of sustainability in designing water treatment plant, understanding and intervening the dynamics of participatory water management processes, the utilization of arbitrary framework on defining sustainability metrics for water resources management, the application of sustainability science into water basin management, the adoption of soft-path solutions for freshwater resources, as well as, the utilization of pragmatic linkages between water and human well-being (under the theme of 'Water policy/innovation'). These reveal a wide range of actionable approaches in terms of addressing the water security syndrome.

Out of the 14 archive items under the 'Category – ii', six studies have corresponded to the 'Archetype-I' (see **Section 4.2.1**) i.e. conducted in the manner of 'literature survey' (Q2) with straightforward observations on Q3 – Q5 (i.e. ‘literature archive analysis’ being the research method (Q4), and the philosophical, theoretical and methodological issues as well as the quality and rigor issues are to be limited and referred to the published works cited by the study (Q3 and Q5, respectively)). However, there is also one literature survey study (Q2) observed out of the rest of the eight archive items, which utilizes literature archive analysis as the research method (Q4) although having distinctive observations on the rest of the questions (i.e. Q3, Q5 and Q6) besides being an ‘original article’. Out of the six literature survey studies corresponding to the ‘Archetype-I’, four are ‘original articles’ in nature while the rest of the two being reports. The significance of the ‘Archetype-I’ is revealed in this phenomenon that instead of the usually expected ‘review articles’, the other articles types—such as original articles, etc.—can even be more crucial in the archetype.

Out of the 14 studies examined in this category, eight are found to be ‘original articles’, with four reports, and the rest of the two articles being synthesis and policy analysis, respectively. This distribution represents a dominance of original articles in the ‘action/ approach-sphere’ (‘Category – ii’) for the issue of water security syndrome, communicating genuine and contemporary efforts in undertaking actions and approaches with regard to the issue. The ways these original researches are conducted include literature survey (in five out of the eight articles), modeling and simulation (in two articles), and the remainder being policy analysis. This distribution demonstrates the importance of literature survey in undertaking original research in sustainability science. The remaining six studies out of the 14 are conducted in the ways of literature survey (three studies), case reporting (one study), policy analysis (one study), and multi-stake executive session (one study). This pattern exhibits that the use of literature survey can play a prominent role in undertaking original as well as other types of research in sustainability science.

The employed research methods in the studies include literature archive analysis, interviews, group-discussions with stakeholders, multi-stake and multi-executive discussion, intervention research, modeling, simulation, case reporting, and policy analysis. The philosophical, theoretical and methodological issues occurring with respect to these studies include — deriving results through pragmatic social research, utilizing modeling rather than field study, the questionable use of sustainability indicators, a pragmatic study having applicability only to particular scale, the problematic use of sustainability concept, the use of intervention in participatory working dynamics in human groups, the questionable uses of dimensions of sustainability as well as sustainability metrics, and producing results through executive session outcomes; apart from the merits of the given policies under analysis as well as the philosophical, theoretical, and methodological issues of other works being cited in the literature survey studies.

The quality and rigor issues in the analytical data include — the questions of interview size and content in social pragmatic research, the results being modeled rather than being actual, the problematic use of sustainability indicators to produce results, the limitation of scale, the questionable use of sustainability concept, the limitations of case-study and the absence of a wide range of cross-comparison in intervention research, the problematic use of sustainability dimensions and sustainability metrics, and synthesizing normative ideas based on common sense without an intellectual basis. A common tendency in these issues relate to the chaotic use of notions on sustainability without attempting to find and validate a sound intellectual basis for such. This chaos can, in reality, act as an inhibitor towards progressing our understanding on sustainability as well as the ways sustainability research could be put to use in addressing the sustainability issues.

Similar to the 'problem/ issue/ challenge/ syndrome-sphere' (i.e. Category – i), in the 'action/ approach-sphere' none of the 14 studies are found to correspond to the 'Prototype-I theoretical assumption' (see **Section 4.2.1**). In answering the Q6, the insights that can be learnt from these 14 studies include – (i) a study creating a probable clue for actual study, however, the study not being paired with empirical evidence from an actual study, (ii) a study being indicative to scopes, however, containing weaknesses, (iii) a study trying to get somewhere in a vast lack of our understanding, however, without the presence of a valid intellectual basis, and (iv) a study opening and guiding avenues that warrant attention, however, not being justified with appropriate theoretical basis and empirical framework. Although these additional insights can aid in exploring the possibilities for new researches towards understanding the complex interface of the broad spheres of economy, society and environment, these also reveal fundamental weaknesses that in retrospect questions the viability of such new possibilities. This is unlike the nature of the additional aspects (Q6) learned in the 'problem/ issue/ challenge/ syndrome-sphere' (i.e. Category – i), where the studies led to the broadening of the research scopes in sustainability science without having substantial weaknesses in portraying so. The nature of the additional aspects learned in the 'action/ approach-sphere' (Category – ii) having fundamental weaknesses could be explained in terms of the nature of the studies under this sphere communicating actual approaches for tackling the sustainability issues, instead of merely trying to articulate the 'problems/ issues/ challenges/ syndromes' as in 'Category – i'. Regardless of that, answering the Q6 remains a valuable component in the language of conversation in sustainability research, enabling the research consortium to look at both sides of the coin.

Discussion on the remainder modes of analyses

The studies under the topic of water security syndrome in the first decade of sustainability science research correspond to only seven out of the 25 themes under the 'Category – ii', from among the rest of the themes there are several others that could potentially be explored for the purpose of harvesting effective approaches within the 'action/ approach-sphere' such as, 'Alternative livelihood', 'Community involvement', 'Biodiversity—Agriculture—Poverty', 'Agricultural policy/innovation', 'Adaptation—Natural Disaster—Migration—Benefits', 'Reuse—Recycling—Pollution control', 'Treaties—Agreements', 'Land use system planning/innovation', 'Environmental restoration policies/innovation', and 'Sustainable Development strategies/innovation'.

It is notable that themes such as 'Regional cooperation', 'Urban policy/innovation', and 'Technology and nanotechnology' did not appear in the economic perspectives of sustainability (i.e. the broad sphere 'A'); while the themes 'Water policy/innovation', and 'Ecosystem services policy/innovation' did not appear in either of the economic or social perspectives (i.e. the broad spheres of 'A' and 'B', respectively). Besides the literature map for ELA-4 not containing any items from the spheres of economy[A], society[B], environment[C] and socio-economy[AB] (as discussed at the beginning of **Section 4.2**), under the 'Category – ii' the sphere environo-economy[AC] does neither contain any archive item, which is indicative of further vacuum in terms of studies at the interfaces of the three broad spheres.

The temporal dimension of the 14 archive items under the 'Category – ii' reveal a distributed pattern from the year 2003 to 2012 (with the exceptions of 2004 and 2005) with one or two studies observed in each year, while the highest count of studies is observed in the year 2008 (four studies). A count of five out of the 14 studies are found devoid of any place-scale characteristics, whereas from among the rest, three studies were conducted at local scale, one at country scale, two at regional, one continental, and the rest two at global scale. Therefore, the place-scale characteristics also reveal a distributed pattern involving all different scales. This pattern also resembles with the distributed pattern observed in terms of the places concerned in the studies (e.g. Asia, North America, Europe and Africa). The five studies not exhibiting any place-scale characteristics can be explained in terms of these being on ‘action/ approach-sphere’, which focuses more on the actions or approaches in addressing the sustainability challenges instead of characteristically focusing on the places and scales. This is a distinction compared to the ‘problem/ issue/ challenge/ syndrome-sphere’ (Category – i), where the studies are more place-scale focused, including Asia being concerned in most of the studies.

The origins of the articles by the places of the corresponding authors reveal seven articles out of the 14 coming from USA alone, whereas the remainder seven coming from seven different countries (Germany, Spain, Switzerland, Serbia, Japan, Australia, and Kenya). The dominant representation of USA may indicate significant innovation practices under the ‘action/ approach-sphere’ taking place in there, together with a distributed awareness observed across the globe. The comparison between the place-scale characteristics of the studies and the places of the corresponding authorship of the articles does not reveal any significant relation.

4.2.3 Analysis under the Category – iii: The Academic-sphere

Under the ‘Category – iii’, the literature map contains the following themes, accompanied with the answers to the six questions (Q1-Q6) for the archive items corresponding to each theme.

Q1-Q6 observations grouped under the themes

- *“Reuse” as theory*

One archive item corresponds to this theme, studying wastewater re-use for peri-urban agriculture as an adaptive water management practice in India (Kurian et al. 2013) (Q1). It is a combined literature survey and empirical field study (Q2), utilizing literature archive analysis, field survey and empirical quantitative analysis as research methods (Q4). The study produces its contribution through combining three types of analyses i.e. literature survey, field survey and empirical quantitative analysis (Q3). However, it is a local study, with the question of its universal validation (Q5). The study is well-balanced, however localized (Q6).

- *Natural capital & ecosystem services management/governance*

There are four archive items corresponding to this theme. Wilderer (2007) tries to address the question of sustainable water resource management (Q1) through an editorial piece (Q2). The study utilizes literature archive analysis and personal opinion from the author (Q4). It enquires on the philosophical question of sustainable water resource management (Q3), which is devoid of any quality and rigor issues as it only asks the question and not trying to produce an answer (Q5). The study also draws a similar question for sustainability science (Q6).

Hoekstra and Mekonnen (2012) study the water footprint pattern of humanity (Q1), which is a literature survey study (Q2), utilizing literature archive analysis as research method (Q4). The study conducts the water footprint estimation at different scales (Q3), while the quality and rigor issues are to be referred to the works cited (Q5). Although it is an estimation-based analysis that makes such kind of understanding possible, however, when the input data are designed to produce particular grand outputs, any difference in the base-study that produces the design can lead to the production of different datasets, in turn imparting difference in the grand estimate. This question on validating the base points in an analytical framework need to be addressed (Q6).

Out of the rest of the two archive items under this theme, one studies the tools for incorporating community knowledge, preferences and values into the decision making in natural resources management (Lynam et al. 2007) (Q1), whereas the other does a policy-oriented review of the ecosystem services in relation to floods in urban areas (Depietri et al. 2012) (Q1). Both of these studies correspond to the ‘Archetype-I’ (see **Section 4.2.1**) (Q2 – Q5).

- *Urban sustainability and adaptive urban governance*

The first archive item under this theme studies the hazards and disasters in urban areas (Satterthwaite 2007) (Q1), whereas the other deliberates on sustainable urban water and resources management (Daigger 2011) (Q1). Both of these studies correspond to the ‘Archetype-I’ (Q2 – Q5).

- *Sustainability—Culture—Religion*

The archive item that corresponds to this theme studies 'culture' as a triggering factor for promoting sustainability in the water domain in Spain (Tàbara and Ilhan 2008) (Q1). This study also corresponds to the 'Archetype-I' (Q2 – Q5).

- *Land cover and land use change science*

The only archive item that corresponds to this theme studies the linkages of riverine nitrate concentration with agriculture, urban expansion and forest reduction in a local context in Japan (Ileva et al. 2009) (Q1). This study is an empirical analysis (Q2), utilizing the research methods of literature archive analysis, empirical analysis and statistical analysis (Q4). It extrapolates data through statistical analysis to produce its results (Q3), whereas the same (i.e. the problem of statistical analysis in producing results through the extrapolation of data) could also be questioned as a quality and rigor issue (Q5). This study requires empirical ways/ methods of result generation rather than statistical analysis (Q6).

- *Urban agriculture*

There is only one archive item corresponding to this theme, studying the dynamics and sustainability of urban agriculture in sub-Saharan African context (Drechsel and Dongus 2010) (Q1). It is a literature survey study (Q2), with literature archive analysis utilized as the research method (Q4). The study utilizes the FAO (Food and Agricultural Organization of the United Nations) – FESLM (Framework for Evaluating Sustainable Land Management) framework to derive some 'pillars of sustainability', based on which the results are synthesized (Q3). However, without providing any intellectual basis in utilizing such framework to derive the so-called pillars of sustainability followed by synthesizing the results based on these pillars produce a contentious quality and rigor issue with the study (Q5). The study tries to get to somewhere in a lack of our understanding with regard to the issue, however, the question of the intellectual basis for such also needs to be addressed (Q6).

Summary on the Q1-Q6 observations

Summarizing the analytical data on the six questions produces the following subject matters from this ELA that aim at fundamentally advancing our understanding on sustainability — sustainable water resources management, the water footprint pattern of humanity, tools for incorporating community knowledge, preferences and values into decision making, the policy orientation of ecosystem services in relation to floods in urban areas (where the theme for these being ‘Natural capital & ecosystem services management/governance’), hazards and disasters in urban areas, sustainable urban water and resources management (under the theme ‘Urban sustainability and adaptive urban governance’), culture as trigger for transition to sustainability in water domain (under the theme ‘Sustainability—Culture—Religion’), the dynamics and sustainability of urban agriculture (‘Urban agriculture’), wastewater reuse for peri-urban agriculture as an adaptive water management (“Reuse” as theory), and the linkages of riverine nitrate concentration with agriculture, urban expansion and forest reduction (under the theme ‘Land cover and land use change science’).

Out of the 10 archive items under the ‘Category – iii’, five studies have corresponded to the ‘Archetype-I’ (see **Section 4.2.1**) i.e. conducted in the manner of ‘literature survey’ (Q2) with straightforward observations on Q3 – Q5 (i.e. ‘literature archive analysis’ being the research method (Q4), and the philosophical, theoretical and methodological issues as well as the quality and rigor issues are to be limited and referred to the published works cited by the study (Q3 and Q5, respectively)). However, there are also two literature survey studies (Q2) observed out of the rest of the five archive items, which utilizes literature archive analysis as the research method (Q4) although having distinctive observations on the rest of the questions (i.e. Q3, Q5 and Q6) besides being an ‘original article’. Out of the five literature survey studies corresponding to the ‘Archetype-I’, four are original articles in nature while the remainder being a review. In conformity to the observation under the ‘Category – ii’ (**Section 4.2.2**) this phenomenon of the majority of the ‘Archetype-I’ articles being original articles (four out of five) further reveals the significance of the ‘Archetype-I’, i.e. instead of the usually expected ‘review articles’, the other articles types (such as original articles) becoming even more crucial in the archetype.

Out of the 10 studies examined in this category, eight are found to be ‘original articles’, and the rest of the two being review article and editorial, respectively. This represents a major dominance of original articles in the academic-sphere (‘Category – iii’) for the issue of water security syndrome, communicating genuine and contemporary efforts in advancing understandings on sustainability science with regard to the issue. The ways these original researches have been conducted include literature survey (in six out of the eight articles), empirical analysis (in one article), and the rest being a combination of literature survey and empirical field study. In conformity to the findings under the ‘Category – ii’ (**Section 4.2.2**), the findings in the ‘Category – iii’ further demonstrates the importance of literature survey in undertaking original research in sustainability science. The remaining two studies out of the 10 are conducted in the ways of literature survey and editorial, respectively. This observation too agrees to the earlier finding (in **Section 4.2.2**) on the prominent role of literature survey in undertaking original as well as other types of researches in sustainability science.

The employed research methods in the studies include literature archive analysis, field survey, empirical quantitative analysis, and statistical analysis. Noticeably, in the academic-sphere, apparent fewer varieties of research methods are seen to be utilized in the studies, together with a major use of literature archive analysis. These observations reveal the character of the academic sphere in terms of the researches under this sphere being characterized with original studies involving literature archive analysis.

The philosophical, theoretical and methodological issues occurring with respect to the studies include — deriving results through the combination of different types of analyses (such as literature survey, field survey and empirical quantitative analysis), enquiring on the philosophical question of sustainable water resource management, conducting the estimation of water footprint pattern across different scales, extrapolating data through statistical analysis in order to produce results, and utilizing FAO-FESLM (Framework for Evaluating Sustainable Land Management) to derive ‘pillars of sustainability’ and synthesizing results based on this; apart from the merits of the given policies under analysis as well as the philosophical, theoretical, and methodological issues of other works being cited in the literature survey studies. These issues under the academic-sphere correspond to the academic nature of research where the analyses are carried out through various pathways that mainly utilize literature archives as data source.

The quality and rigor issues in the analytical data include — a local study subject to the question of universal validation, the problem of statistical analysis in producing results through the extrapolation of data, and the utilization of external frameworks to derive pillars of sustainability and synthesizing results based on this, without providing any intellectual basis. These relate to the philosophical, theoretical and methodological issues already discussed in the 'Categories – i and ii'. The additional aspects that could be learned from these studies (through answering Q6) are also related to these, including — (i) a study analytically being well-balanced, however, localized, (ii) the conduction of estimation making a particular kind of understanding possible, however, the base-points in the analytical framework not being validated for their exclusive suitability, (iii) a study requiring empirical ways/ methods of result generation rather than extrapolation of data based on statistical analysis, and (iv) a study trying to get somewhere in a lack of our understanding, however, without the presence of valid intellectual basis.

Similar to the 'problem/ issue/ challenge/ syndrome-sphere' (i.e. Category – i) as well as in the 'action/ approach-sphere' (i.e. Category – ii), none of the 10 examined studies under the academic-sphere corresponded to the 'Prototype-I theoretical assumption' (see **Section 4.2.1**).

Discussion on the remainder modes of analyses

The studies under the topic of water security syndrome in the first decade of sustainability science research correspond to only six out of the 49 themes under the 'Category – iii'. It demonstrates a poor representation of sustainability science research within the water security syndrome in the academic-sphere, as from among the rest of the themes there could be quite a large number of others that could potentially be explored for the purpose of advancing understanding on sustainability science with regard to the water security syndrome.

The temporal dimension of the 10 archive items under the 'Category – iii' reveals an abrupt pattern unlike the distributed pattern observed in the 'Categories – i and ii'. The pattern follows as — 2007 (with four count of studies), 2008 (two count of studies), and 2011 (four count of studies). A count of five out of the 10 studies are found devoid of any place-scale characteristics, whereas from among the rest, three studies were conducted at local scale, one at country scale, and the other at global scale. The large count of studies not exhibiting any place-scale characteristics in the academic-sphere can be explained due to the basic nature of understanding aimed out of this theme, which takes precedence over the conduction of localized studies with definite place-scale characteristics.

The origins of the articles by the places of the corresponding authors reveal a distributed pattern with no particular major representation: two articles from the UK and Spain each, and one article from each of USA, Japan, Germany, the Netherlands, Sri Lanka and Zimbabwe. This observation reveals that in the academic-sphere the interest is shared with no dominant representation unlike in the 'action/ approach-sphere'. The comparison between the place-scale characteristics of the studies and the places of the corresponding authorship of the articles does neither reveal any significant relation.

4.2.4 Theoretical framework on the language of conversation in sustainability research

Chapter 4 begins with articulating the intent of the thesis in terms of the development of a *fundamental intellectual process* for advancing the intellectual treatment of sustainability based on a pluralistic orientation and avenue of knowledge. The purpose of this *fundamental intellectual process* is articulated in **Section 3.1** in terms of enabling the study of pluralistic knowledge and research structures with regard to sustainability, an ontological starting point for which becomes the recognition that some level of reconciliation of the different disciplines is required. The intellectual perspective on sustainability formed in **Chapter 2** further articulates the need for discerning the cognitive necessities required for the development of the *pluralistic knowledge avenue,* where the reductionist natural and social sciences and the humanities scholarships have definite roles to play. The challenges, questions and concerns with regard to these intellectual needs are summarized in **Section 3.1** in terms of the discursive challenge of pluralistic knowledge/ research, the epistemological, theoretical and methodological challenges of knowledge integration, and the practical challenge of carrying out the intellectual practice in a reality where the scholars are trained as well as function within extremely narrow disciplinary-based paradigms.

In response to these challenges that define the problem addressed in the research as well as reflect the long-range goals of the potential *scholarship of sustainability*, what is at hand has been identified in terms of initiating the discourse towards these intellectual necessities (**Section 3.1**). One of the implications of this recognition implies that the sustainability researchers are required to conduct their researches on sustainability within some frame of research consortia, where the research task begins from examining the reported diverse researches on the similar or fragments of the topic in question, and the researchers participating in the consortia represent the corresponding research streams.

The examination process of the existing congregational contributions from the reductionist disciplinary as well as 'multi-, inter and trans-disciplinary' researches with respect to the sustainability problem/ issue in question, and the subsequent progression in the research enquiry essentially needs to address ‘the science of working together’ (Yarime 2011), requiring the formation of an appropriate language across the diverse disciplinary research streams. Such a language must have the capacity to enable conversation across the fields of disciplinary as well as ‘multi-, inter and trans-disciplinary’ researches.

Based on the discussions in **Section 2.2**, a fundamental assumption for the language of conversation could be framed in terms of the recognition that a researcher coming from a different research stream is not able to entirely understand the depths and details of the research embedded in a given study, yet there is a necessity for the researcher to understand the research to the extent that would enable him/ her to participate and contribute in the research consortium in addressing the sustainability problem/ issue in question. Without necessarily enabling the understanding of the depths and details of a given research, the practice of the language of conversation in sustainability research should, therefore, enable the researcher to accurately understand a sufficient extent on the nature of conduction of the given research so that the conversation amidst the researchers representing disparate research streams can proceed on. Reflecting from the need to provide a common mean for effective research communication within the consortium, this language of conversation is required to provide the mean for revealing the proper and error-free extent of understanding on a given research being examined by the consortium. In **Section 4.1** the dimensions of this language of conversation is conceptualized, followed by its extensive exemplification through the empirical literature analysis (ELA) **–** 4 in **Section 4.2**. This provides the opportunity of producing a theoretical framework on the language of conversation in sustainability research, presented in **Table 4.1**.

Table 4.1 Theoretical framework on the aspects of the language of conversation	
Aspect/ Question	**Particulars and comment**
A (Q1)	***The theme of the study to be learnt***
	Comment**:** This account reveals the nature of the research topic in a reported research as well as its relation to its corresponding research stream(s) with respect to the purpose of a research consortium. It does not detail out the contributions of the work, which should ideally come after the communication on the six aspects if such deems necessary and appropriate for furthering the research on the given sustainability problem/ issue in the process of 'co-creation of knowledge' in the consortium. This aspect is expected to make the consortium aware of the study and its research field so that the researchers can relate from their general scholarly appreciation on it in advancing the sustainability problem/ issue in question.
B (Q2)	***Generalized communication on the overarching method(s) in the conduction of the study***
	Comment: This aspect does not connect to any of the particular research methods employed in the study, and instead, it deliberates on the mode of conduction of the research. It makes the research consortium understand the way the research has been conducted in terms of relating from their own experience of conducting research, irrespective of the fact that the particular research methods as employed in the study could drastically vary.
C (Q3)	***Generalized account on the overarching 'philosophical, theoretical and methodological' issues***
	Comment: In universally understandable general terms this account informs the research consortium on what the study does and doesn't do in contrast to ideally what it should be doing if it was possible to do so.
D (Q4)	***Communication on the utilized research methods in simplified and universally understandable terms***
	Comment: This aspect describes the research methods employed in the study as per their general nature—instead of necessarily capturing all of their particularities—so that the research consortium can understand these methods in terms of referring to their own experience in conducting research, as well as can use these as signposts in continuing the processes of conversation and co-creation of knowledge in advancing the sustainability problem/ issue in question.
E (Q5)	***Simplified view on the quality and rigor issues***
	Comment: It is not a detail and quantitative account on the quality and rigor issues of the study; instead it makes the research consortium aware of the degrees of usefulness and acceptability of the study.
F (Q6)	***If, any additional aspects to be learnt that are non-generalizable into a common structure***
	Comment: This leaves the scope for any additional aspects to be learnt on the study that otherwise cannot be generalized as part of a common structure, however, can provide valuable insights with regard to the study and contribute into the language of conversation within the limits of the level of understanding portrayed by the A-E aspects (i.e. Q1-Q5).

As a standard practice, the answers to the set of six questions (Q1-Q6) for the researches under examination could come as written reports to be provided by the researchers representing the corresponding research streams, for the other researchers present in the consortium who are non-native to the given research streams. Alternatively, such task could also be considered as an avenue of expertise, where the researchers with their acquaintance with a wide array of academic fields could provide such general contribution.

4.3 Empirical Literature Analyses (ELAs) – 1, 2 and 3

A semi-empirical analysis is conducted on the 'ELAs – 1, 2 and 3' through utilizing a cluster of 10 tables of the observed data for each of the ELAs. These tables, appearing in **Appendix-7**, are presented as per the second layer of organization in the 'Group–A' literature archive (**Section 3.4.3**), i.e. each of the 10 tables representing each of the 10 spheres for each ELA. These tables present the observed data in 14 columns in the following sequence —

- 'Item ID' (the first layer of organization, **Section 3.4.3**),
- 'Item' reference (the bibliographic detail of the archive item),
- 'Sphere' (the second layer of organization, **Section 3.4.3**),
- 'Category' (the fourth layer of organization, **Section 3.4.3**),
- 'Theme ID' and 'Theme' (together comprising the fifth layer of organization , **Section 3.4.3**),
- 'Article type' (the nature of the article as a research literature),
- 'Scale' (the scale that the article is concerned with),
- 'Place' (the place that the article is concerned with),
- 'Place of authorship (corresponding author)' (the origin of the article by its corresponding authorship),
- 'Temporal' (the year of conduction of the study, which usually is taken as the year the article is published unless a different 'date of acceptance' referring to an earlier year exists),
- 'Q1' (the 'Theme' of the study to be learnt, **Table 4.1**),

- ‘Q2’ (generalized communication on the overarching method(s) in the conduction of the study, **Table 4.1**), and
- ‘Archetype (1) / Prototype (2)’ (the observation informing if the article corresponds to ‘Archetype-I’ (**Section 4.2.1**), to be denoted by the symbol ‘1’ in the tables; and/ or ‘Prototype-I theoretical assumption’ (**Section 4.2.1**), to be denoted by ‘2’).

However, a difference exists in the ways the ‘Archetype-I’ is utilized in the full-length empirical analysis on the ELA-4 and the semi-empirical analysis on the ELAs – 1, 2 and 3. In the full-length analysis an archive item is only assigned with ‘Archetype-I’ if it is conducted in the manner of ‘literature survey’ (Q2) with straightforward observations on the Q3 – Q5 (i.e. ‘literature archive analysis’ being the research method (Q4), and the philosophical, theoretical and methodological issues as well as the quality and rigor issues are to be limited and referred to the published works cited by the study (Q3 and Q5, respectively)). However, as in the semi-empirical analysis the Q3 and Q5 questions are not regarded, the assigning of the ‘Archetype-I’ in the semi-empirical analysis is conducted irrespective to the ‘would be’ observations on the Q3 and Q5. As the semi-empirical analysis is conducted based on the Q1-Q2, from within the presence of Q2-Q5 in the ‘Archetype-I’, the observations on Q4 (i.e. communication on the utilized research methods in simplified and universally understandable terms) is also carefully accommodated together with recording the Q2 observations. As in the Q4 the research method has to be ‘literature archive analysis’ in order for an item to be assigned with ‘Archetype-I’, if a given study has utilized any other major research method as recorded within the Q2 observation, the study is not assigned as ‘Archetype-I’.

A cross-examination of this method of characterizing the ‘Archetype-I’ (i.e. in terms of only the Q2 and Q4) with the ELA-4 reveals that as per this method there would be 19 archive items out of the 36 in the ELA-4 literature map to be assigned with ‘Archetype-I’, whereas in the way the ‘Archetype-I’ is utilized in the ELA-4 the count was found to be 16. As the importance of the ‘Archetype-I’ is firmly established through the ELA-4 with a count of 16 items (out of the 36) corresponding to it, an addition of three more counts would not create much difference into the analysis, especially when these 16 items are distributed among the three ‘Categories’.

Tables A7.1.1 – A7.1.10 in **Appendix-7** present the observed data for the ELA-1, and similarly, **Tables A7.2.1 – A7.2.10** and **Tables A7.3.1 – A7.3.10** in **Appendix-7** present the observed data for the ELAs – 2 and 3, respectively. The analyses on these ELAs are produced through extracting and analyzing the data contained in the tables. Due to the extensive extent of these analyses—with a repetitive pattern for the three ELAs—these analyses are executed in two consecutive stages. The first is an intermediary stage, directly utilizing the set of the 10 tables of observed data from the **Appendix-7** to produce the detail results for each of the three ELAs. This stage of analysis is placed in **Appendix-8**, which also includes an overview for each of the three ELAs preceding the analyses. The second stage matures the findings through extracting insights from the results produced in **Appendix-8**. This is conducted through cross-comparing the direct findings on these ELAs, and articulating them as cross-compared insights of the semi-empirical literature analysis, presented in the remainder of this section.

4.3.1 Cross-compared insights of the semi-empirical literature analysis

The empirical literature analyses in this chapter begin with the full-length analysis on ELA-4 (**Section 4.2**), with the objective of exemplifying the empirical analysis in detail, which leads to the development of a theoretical framework on the language of conversation in sustainability research (**Section 4.2.4**) as well as reveals characteristic trends in analysis such as the 'Archetype-I' and 'Prototype-I theoretical assumption' (**Section 4.2.1**), which are utilized in the semi-empirical analysis. The exemplification of the full-length empirical analysis on ELA-4 paves the way for the conduction of the 'ELAs – 1-3'. As the manner the 'Archetype-I' is applied in the semi-empirical analysis is explained at the beginning of **Section 4.3**, the definition of the 'Prototype-I theoretical assumption' (for details see **Section 4.2.1**) is articulated before presenting the cross-compared insights for the ELAs – 1, 2 and 3.

Prototype-I theoretical assumption: "*Unless it is improbable in reality to undertake empirical studies in addressing the complex matters or questions of this sort in research, it could be a philosophical and methodological merit to adopt simulation or modeling study as well as its nature being qualitative, as long as — (a) the study has a complex nature of lying at the interface of academically disparate areas or at the interface of the broad spheres of economy, society and environment, (b) the adopted approach is holistic, (c) the attempt is to present an integrated understanding, as well as (d) the study properly satisfies the quality and rigor aspects associated with it.*"

There are six clusters of cross-compared insights for the ELAs – 1, 2 and 3, preceded with their respective headings.

The distributive characteristics across the categories and article types

All three ELAs exhibit the following four main characteristics —

(i) a significant majority of the articles (between 60.7% – 64.1% across the ELAs) being 'original articles', a majority of which (between 67.5% – 77.9% across the ELAs) are also 'Archetype – I' articles,

(ii) a pronounced presence of the 'Archetype – I' articles across all article types,

(iii) articles corresponding to the 'Prototype – I theoretical assumption' being nearly absent, and

(iv) the presence of a great variety of article types.

In category-wise comparison, the highest proportion of 'original articles' are observed under the 'Category – iii' (i.e. the academic-sphere) across all three ELAs, provided that the three literature maps for these ELAs are characterized with a significant majority of such articles irrespective of the different categories. This trend characterizes the sustainability science researches with original research practices. The dominant presence of 'Archetype – I' articles within these original articles—thus, revealing a strong connection between the 'Archetype – I' criteria and 'original research' in sustainability science—resolves the conventional incompatibility between the 'Archetype – I' criteria and 'original research'. Instead, the compatibility between these could characterize sustainability research.

The near absence of articles corresponding to the 'Prototype – I theoretical assumption' communicates a weak aspect in sustainability science research, as the intellectual treatment of sustainability requires the conduction of researches at the complex interface of nature and human society, which can develop through fundamentally utilizing the 'Prototype – I theoretical assumption'.

In terms of the diverse article types present in the ELAs, the 'original', 'report', 'review', 'perspective', and 'overview' articles count the top ranking types in the list, followed by a number of other article types. On one hand, the wide variety of article types reveal richness in the approaches in addressing the complex intellectual needs of sustainability research. On the other hand, the importance placed on 'report', 'review', 'perspective' and 'overview' type articles besides the more common 'original articles' reveal noticeable empirical characteristics of sustainability science with regard to these article types.

The 'perspective' articles justify their importance in terms of providing the perspectives necessary for navigating the complexity of sustainability research, while the importance of 'overview' type articles is in terms of looking at the overview of matters at the interface of the broad spheres of economy, society and environment in attempting to understand the larger and more complex scales. These 'perspective' and 'overview' type articles can also provide the scopes and windows for undertaking new original-type researches on sustainability issues/ problems. The overview articles exhibited an overall distributed presence except for under the 'Category – i' for the ELAs – 1 and 2, whereas the 'perspective' articles mostly occurring under the 'Categories – ii and iii' across the ELAs communicates that in articulating the problems in 'Category – i' usually a perspective is not necessary.

The 'report' type articles mainly appearing in the 'Categories – i and ii' exemplifies its importance and necessity for the 'problem/ issue/ challenge/ syndrome-sphere' and the 'action/ approach-sphere'. Such prominence not occurring under the 'Category – iii' can also be explained in terms of the 'report'-type articles being less compatible to the 'academic-sphere'. On the contrary, the 'review' articles reveal a distributed presence across the three categories, exhibiting its necessity irrespective of the natures of these different categories.

The distributive characteristics across the categories and the broad spheres

The following main characteristics are exhibited across the three ELAs —

(i) In terms of the article counts, quite a distributed pattern exist among the three categories within the broad spheres of A, B and C (i.e. the economic, social and environmental perspectives of sustainability, respectively).

(ii) In the sphere-D, the majority of the articles correspond to the 'Category – iii' i.e. the academic-sphere. This observation establishes the importance of the sphere-D (i.e. central organization of sustainability) to the category of 'academic-sphere'.

(iii) The broad spheres of B and C reveal a high visibility of archive items across the three ELAs, with very low presence observed in the broad sphere A. This variation reveals a general ignorance existing with respect to the study of the economic perspectives of sustainability, which is consistent to the observation on the percentage distribution of archive items as per total counts across the spheres, appearing in **Section 3.4.3**.

(iv) The presence of the 'Archetype-I' articles remain equally pronounced across all four broad spheres of A, B, C and D, which re-establishes the importance of the 'Archetype-I' articles for sustainability research from widely varying perspectives.

Cross-comparison between the empirical classification and the broad spheres across the categories

The empirical classifications of the archive items refer to the Q2 aspect of the language of conversation in sustainability research (see **Table 4.1**). The analysis revealing a variety of 19 empirical classes in the ELAs communicate great richness in terms of the overarching methods of the conduction of the sustainability science researches. Such a wide variety also reveals the importance as well as the necessity of approaching the complex matters of sustainability through a variety of ways. 'Literature survey'—being quite an ordinary and mundane mode of research practice—continued to exhibit pronounced presence across the three ELAs. Over 70% of the studies—invariably across the three ELAs—are solely or partly consisting of 'literature survey' as the overarching method for their conduction, coupled with a quite distributed pattern of its presence across the three categories. In the cases of combined presence of 'literature survey' with other empirical classes, these other classes do not become significant enough—compared to 'literature survey'—to render the studies to correspond to a different empirical class. This dominance of 'literature survey' as an overarching method of research conduction also indicates on its potential to produce a variety of types of analyses in combination with other empirical classes in sustainability research.

The predominant appearance of the modes of 'field survey' and 'reporting' under the 'Category – ii' exemplify their importance for studies corresponding to the 'action/ approach-sphere'. In the case of 'opinion' as an empirical class, expectedly the majority of the studies corresponded to the 'Categories – ii and iii', demonstrating its least importance for the 'problem/ issue/ challenge/ syndrome-sphere' (i.e. 'Category – i').

However, the empirical class ‘empirical field study/ analysis’ remaining absent under the ‘Category – i’ reveals a weak aspect in sustainability science research in terms of approaching to understand the problems/ issues through these manners.

Cross-comparison between the empirical classification and the article types across the categories

In the cross-comparison between the empirical classes and the article types, the dominant empirical class ‘literature survey’ remains strongly corresponded to the ‘original’ article-type across all three categories. All other empirical classes are also observed as majorly constituted with ‘original articles’ except for the classes that are not usually meant for this article-type, such as reporting, review, editorial, opinion, commentary, summary, action research, and synthesis. These observations—consistent across all three ELAs—reveal the innovative aspect of sustainability science research, which is empirically characterized with a dominant presence of ‘literature survey’ along with a wide variety of the empirical classes.

Representative themes in their respective categories based on the ELAs

The common and most frequently occurring themes for the ELAs – 1 and 2 under the ‘Category – i’ (i.e. the ‘problem/ issue/ challenge/ syndrome-sphere) are observed as ‘*climate change problem/impacts*’ and ‘*food security—agricultural challenges/issues*’, representing the two most significant problems encountered in terms of the ecologically benign development pathways for ‘Global South’ (i.e. the ELA-1) as well as for the problems of food insecurity and agricultural production (the ELA-2). Subsequent to these, the third most frequent theme for the ELA-1 is observed to be the two equally frequented themes of ‘*human insecurity—conflict*’ and ‘*coastal vulnerability issues & sea level rise*’, while for ELA-2 it is found to be ‘*biodiversity—habitat destruction—trade*’, characteristically representing the problems/ issues/ challenges for these ELAs. However, the only frequently occurring theme for the ELA-3 is observed to be ‘*coastal vulnerability issues & sea level rise*’, lying in common with the ELA-1. Reflecting the concern for the vulnerability of a number of global cities situating along the coastal lines, this theme represent the most significant issue for sustainability science in urban planning (i.e. ELA-3).

Under the ‘Category – ii’, the three most frequently occurring themes for the ELA-1 are observed to be ‘*energy policy/innovation*’, ‘*interventions and development, and conservation*’, and ‘*agricultural policy/innovation*’, which represent the most prioritized approaches in pursuing ecologically-benign development in ‘Global South’. For the ELA-2 such themes are observed to be ‘*agricultural policy/innovation*’, ‘*forest management policy/innovation*’ as well as the equally pronounced themes on ‘*land use system planning/innovation*’, ‘*biodiversity conservation policy/innovation*’, and ‘*ecosystem services policy/innovation*’, occurring as the third most frequently appearing themes. These represent the most important approaches in addressing the issue of food security. In the case of ELA-3, the themes of ‘*low-carbon transitions*’, ‘*urban policy/innovation*’, and ‘*water policy/innovation*’ reveal the three most highlighted avenues for urban planning.

Under the ‘Category – iii’, ‘*sustainability challenge*’, ‘*natural capital & ecosystem services management/governance*’, and ‘*land cover and land use change science*’ are found to be the most frequently occurring themes for the ELA-1, while the latter two being the most frequent themes for the ELA-2, and the first and the third themes appearing mostly in ELA-3 together with a subsequent frequent theme of ‘*urban sustainability and adaptive urban governance*’.

Frequency distribution of archive items under the themes across the broad spheres

Under the ‘Category – i’, hardly any representation of the themes observed in sphere-D (central organization of sustainability) communicates a lack in sustainability science research in attempting to understand the problems/ issues from a conjoint perspective of the economic, social and environmental aspects. Apart from this, a dominant representation of the themes is observed in the broad spheres of B and C i.e. the social and the environmental perspectives of sustainability.

Under the ‘Category – ii’, the archive items are found well-distributed across all four broad spheres, with a further dominant representation of the themes occurring in the broad spheres of B and C. However, under the ‘Category – iii’, the dominance is observed on the broad spheres of B, C and D together, therefore, continuing to communicate the degree of negligence existing in terms of the economic perspectives of sustainability.

4.4 Discussing the findings

This chapter analyzes the discursive qualities of sustainability science through extracting a variety of analytics based on the *fundamental intellectual process* framed in **Chapter 3**. This frame of the *fundamental intellectual process* involves the following three structural components:

(i) It develops a *fundamental literature organization process* based on a bottom-up approach, which results in a *structure of five cross-connected layers of organizations* within the literature archive.

(ii) This cross-connected structure of literature organization establishes the *fundamental literature organization process* through resulting in the development of a full-fledged *discourse analysis mechanism* that is epistemologically based on a 'knowledge, problem and action-structuring' discourse, as well as derived from employing the different modes of connections within the cross-connected structure. This mechanism produces an analytical process based on a *system of five stages of discourse analysis*, thus, functionalizing the cross-connected structure of literature organization.

(iii) The *structure of five cross-connected layers of literature organization* and the *system of five stages of discourse analysis* become connected through a fundamental scheme of analyzing the basic structures of pluralistic knowledge/ research in terms of the discursive, integrative and contextual qualities. These discursive, integrative and contextual structures reflect the three corresponding functional challenges of the pluralistic orientation and avenue of knowledge for sustainability scholarship, i.e. the discursive challenge of pluralistic knowledge/ research (corresponding to the discursive structure), the epistemological, theoretical and methodological challenges of knowledge integration (corresponding to the integrative structure), and the practical challenge of carrying out the intellectual practice (corresponding to the contextual structure). The design of this fundamental scheme of analyzing these basic structures is formulated through the empirical literature analyses, focus analyses, and the 'place/ scale-based' analysis, respectively. Therefore, the third structural component of framing the *fundamental intellectual process* becomes the designing of these three types of analyses that utilize the *structure of five cross-*

connected layers of literature organization as well as the *system of five stages of discourse analysis.*

It is through the framing of the *fundamental intellectual process* through its three structural components that the research design enables the conduction of the empirical literature analyses (in **Chapter 4**), the focus analyses (in **Chapter 5**), and the 'place/ scale-based' analysis (in **Chapter 6**). These analyses are conducted through extensive application of the three components of the *fundamental intellectual process*, taken together, which becomes the application of the *fundamental intellectual process*. These empirical literature analyses, focus analyses, and the 'place/ scale-based' analysis together produce the functional aspect of the *fundamental intellectual process*, besides the three structural components. It is through this functional aspect that the *fundamental intellectual process* enables the study of pluralistic knowledge and research structures. A literature archive, prepared in **Chapter 3** based on the first decade's 'body of work' of sustainability science, is taken as an example pluralistic knowledge and research body in deriving the structural components of the *fundamental intellectual process,* as well as in producing its functional aspect through the application of its structural components on the same example pluralistic knowledge and research body (i.e. the literature archive on sustainability science).

The application of the structural components of the *fundamental intellectual process* in conducting the empirical literature analyses (ELAs) begins with a full-length empirical analysis on the ELA-4. Although in **Figure 3.4** the mechanism for the conduction of the ELAs is briefly articulated, before commencing the ELA-4 it was necessary to produce a detail outline for the extensive analysis. As part of producing this outline (**Section 4.1**), a frame of six aspects (Q1-Q6) on the ways the studies are conducted in sustainability science is conceptualized in detail, followed by synthesizing all different modes of analyses to occur in the ELAs based on the application of the *fundamental intellectual process*. The full-length empirical analysis presented the results on ELA-4 based on these different modes of analyses as well as extensively exemplified the six aspects on the ways the studies are conducted.

As the *fundamental intellectual process* enables the study of pluralistic knowledge and research structures through its functional aspect, the first significant component of this functional aspect becomes the development of a language of conversation for sustainability research. The detail conceptualization of the frame of the six aspects as well as its extensive exemplification on ELA-4 provided the opportunity to produce a theoretical framework on such a language of conversation in sustainability research (**Table 4.1**), where the six aspects represent the dimensions of the language. This *language of conversation for sustainability research* (**Section 4.2.4**) provides the mean for revealing the proper and error-free extent of understanding to be derived from a given research in order to be utilized in the pluralistic knowledge/ research practice.

Although the different modes of analysis—synthesized for the conduction of the ELAs—are to be considered as components to the functional aspect of the *fundamental intellectual process* that elucidate the discursive structure of the example pluralistic knowledge and research body, two trends arising from the analysis, namely, the *Archetype-I* and the *Prototype-I theoretical assumption*, reveal significant empirical characteristics for sustainability research (**Section 4.2.1**). Discussed in **Section 4.2.1**, these archetypical and theoretical patterns are developed from the analysis based on the exemplification of the *language of conversation for sustainability research*. Thus, the full-length analysis on ELA-4 produces the theoretical framework on the *language of conversation for sustainability research* as well as the *Archetype-I* and the *Prototype-I theoretical assumption*, besides providing the model for an extensive empirical analysis, capable of elucidating the discursive structure of pluralistic knowledge and research body (in this case, the literature map for ELA-4 acts as a pilot ‘example pluralistic knowledge and research body’).

Although the results produced from the ELA-4 are discussed in **Sections 4.2.1-4.2.3** along with the respective interpretations for sustainability science, the summary discussion is based on the findings produced from the ‘ELAs – 1-3’ along with their insights with respect to the *Archetype-I* and the *Prototype-I theoretical assumption*. This is due to the bigger literature maps of the ‘ELAs – 1-3’ compared to the ELA-4 literature map that is utilized mainly as a pilot ‘example pluralistic knowledge and research body’ in order to derive the three significant components of the functional aspect of the *fundamental intellectual process* (i.e. the *language of conversation for sustainability research*, the *Archetype-I*, and the *Prototype-I theoretical assumption*) as well as exemplifying the full-length empirical analysis involving all different modes therein. It is also the full-length empirical analysis on the ELA-4 that enabled the semi-empirical analysis on the ‘ELAs – 1-3’ (due to having bigger literature maps) through providing the necessary analytics derived from the full-length analysis.

The definition of *Archetype-I*, as it is utilized in the full-length empirical analysis, articulates that an archive item is assigned with *Archetype-I* if it is conducted in the manner of ‘literature survey’ (Q2), ‘literature archive analysis’ being the research method (Q4), and the philosophical, theoretical and methodological issues as well as the quality and rigor issues are to be limited and referred to the published works cited by the study (Q3 and Q5, respectively). However, due to the semi-empirical nature of the ‘ELAs – 1-3’, instead of utilizing the Q2-Q5 aspects in defining the *Archetype-I*, the Q2 and Q4 observations (i.e. conducted in the manner of ‘literature survey’, and ‘literature archive analysis’ being the research method) are taken to classify an archive item as corresponding to the archetype.

The summary findings on the empirical literature analyses (i.e. ‘ELAs – 1-3’) reveal that empirically sustainability science is characterized with original research practices as the nature of the significant majority of the articles present in the literature maps are original articles. This observation becomes coupled with a subsequent observation that establishes a strong correlation between the characteristic original nature and the *Archetype-I* characters of the articles as the majority of the original articles correspond to the *Archetype-I*. This resolves the conventional incompatibility between the *Archetype-I* criteria and ‘original research’, as based on the findings of the ELAs the dominant empirical nature of sustainability research should be characterized with ‘original’, ‘*Archetype-I*’ research.

Although the ‘original’, ‘*Archetype-I*’ characters represent the empirical nature of sustainability science in terms of the intensity of its research, in terms of the diversity in its research it rather reveals the presence of a great variety of article types, revealing the required richness in the approaches in addressing the complex intellectual needs of sustainability research. Within this characteristic presence of a great variety of article types in sustainability science research, a pronounced presence of *Archetype-I* articles is also observed across all these types, hence, in terms of diversity, sustainability research needs to be characterized with ‘a wide range of approaches’ as well as the ‘*Archetype-I*’ characters.

The characteristic dominance of ‘*Archetype-I*’ criteria both in terms of the intensity and the diversity of sustainability research proves three fundamental postulates appearing in the **Chapters 2-4**. First, the intellectual perspective on sustainability formed in **Chapter 2** articulates the need for discerning the cognitive necessities required for the development of a *pluralistic knowledge avenue*. This implies that these cognitive necessities need to come from a variety of knowledge avenues, and thus, the necessity for the coming together of an array of knowledge practices. The ‘*Archetype-I*’ characteristics of ‘literature survey’ (Q2) and ‘literature archive analysis’ (Q4) becoming the empirical characteristics of sustainability research both in terms of the intensity and the diversity of its research establish the reality of the coming together of an array of knowledge practices with their characteristics contributions for sustainability research. The second postulate (in **Section 3.1**) describes the ontological starting point for developing a novel philosophy for the *fundamental intellectual process* to be the recognition that some level of reconciliation of the different disciplines is required. This is also established through the characteristic dominance of ‘*Archetype-I*’ criteria both in terms of the intensity and the diversity of sustainability research.

A by-product of the second postulate is with the utilization of a fundamental bottom-up approach in developing the *fundamental literature organization process* for sustainability research based on a prepared literature archive (in **Chapter 3**). Thus, the utilization of the fundamental bottom-up approach in structuring archives of literature in sustainability research also gets supported from the dominant empirical characteristic of sustainability research in terms of ‘*Archetype-I*’ criteria.

The third postulate is with regard to the necessity for the language of conversation in sustainability research (**Section 4.1** and **4.2.4**), which states that the sustainability researchers need to conduct their researches on sustainability within some frame of research consortia, where the research task should begin from examining the reported diverse researches on the similar or fragments of the topic in question, and the researchers participating in the consortia represent the corresponding research streams. This postulate is also supported with the evidence on the characteristic dominance of ‘*Archetype-I*’ criteria. Therefore, all three postulates—plus the by-product of the second postulate—proposed so forth through the exercise of fundamental research in this thesis becomes established with the ‘*Archetype-I*’ characteristics of ‘literature survey’ (Q2) and ‘literature archive analysis' (Q4) becoming the empirical characteristics of sustainability research both in terms of the intensity and the diversity of its research.

The *Prototype-I theoretical assumption* is defined in **Section 4.2.1** as: "Unless it is improbable in reality to undertake empirical studies in addressing the complex matters or questions of this sort in research, it could be a philosophical and methodological merit to adopt simulation or modeling study as well as its nature being qualitative, as long as — (a) the study has a complex nature of lying at the interface of academically disparate areas or at the interface of the broad spheres of economy, society and environment, (b) the adopted approach is holistic, (c) the attempt is to present an integrated understanding, as well as (d) the study properly satisfies the quality and rigor aspects associated with it." The findings of the 'ELAs – 1-3' demonstrating a near absence of articles corresponding to the *Prototype-I theoretical assumption* construct a poor dimension of sustainability science research as the intellectual treatment of sustainability requires the conduction of researches at the complex interface of nature and human society, which can develop through fundamentally utilizing the *Prototype-I theoretical assumption*.

In terms of the distributive characteristics of the archive items across the categories and the broad spheres, the majority of the studies under the sphere on 'central organization of sustainability' corresponding to the 'Category – iii' (i.e. the academic-sphere) across the three ELAs, establishes the importance of the sphere on 'central organization of sustainability' to the 'academic-sphere'. This provides justification for both of the demarcation of the sphere on 'central organization of sustainability' under the second layer of organization as well as the epistemological basis of 'knowledge, problem and action-structuring' discourse, based on which the categories under the fourth layer of organization (including the academic-sphere) are produced. Although a general ignorance with respect to the study of the economic perspectives of sustainability is evident in the practice of sustainability science (consistent with similar observation in **Section 3.4.3**), a distributed presence of the studies in terms of the three categories across the ELAs justifies the importance of the fourth layer of literature organization in terms of the individual categories of the 'problem/ issue/ challenge/ syndrome-sphere', the 'action/ approach-sphere' and the academic-sphere. Therefore, these findings across the second and the fourth layers of literature organization establish the significance of these structuring in framing the *fundamental literature organization process* in **Chapter 3**. Notably, the equally pronounced presence of the *Archetype-I* studies across the widely varying perspectives of the four broad spheres re-establishes the significance of *Archetype-I* in sustainability research.

The presence of a great variety of 19 empirical classes (i.e. the Q2 aspect of the language of conversation) in the ELAs reveals the necessary richness in terms of the practice of the overarching methods in sustainability research, as these enable approaching the complex matters of sustainability through a variety of ways. The pronounced presence of 'literature survey' in over 70% of the studies invariably across the three ELAs—while it being regarded as quite an ordinary and mundane research practice—justifies its potential in producing a variety of types of analyses solely or in combination with other empirical classes in sustainability research. As Q2 in terms of 'literature survey' forms a part of the *Archetype-I* criteria, this finding, is therefore, in continuity with the findings on *Archetype-I*. Although the prominence of the varying empirical classes appear justified in terms of the necessary categories for their presence, the empirical class 'empirical field study/ analysis' remaining absent under the 'Category – i' reveals a weak aspect in sustainability science research in terms of approaching to understand the problems/ issues through these manners.

The cross-comparison between the empirical classes and the article types revealing all relevant empirical classes—including the dominant empirical class 'literature survey'—being predominantly constituted with 'original articles' re-affirms the innovative aspect of sustainability science research. Therefore, based on the findings on the empirical classes, the innovative aspect of sustainability research could empirically be characterized with a dominant presence of 'literature survey' along with a wide variety of other empirical classes.

The frequency distribution of archive items under the themes (i.e. fifth layer of literature organization) across the broad spheres revealing nearly no representation under the 'Category – i' for the sphere-D (i.e. central organization of sustainability) communicate a lack in sustainability science research in attempting to understand the problems/ issues from a conjoint perspective of the economic, social and environmental aspects. Besides, regardless of the different categories, a poor representation of the themes under the economic perspectives of sustainability continues to communicate the degree of negligence existing in terms of the economic perspectives of sustainability science research.

4.4.1 Intermediary summary discussion

The detail discussion on the findings could be summarized into a brief, intermediary summary discussion in order to facilitate the logical progression on arriving at the 'summary strong and weak aspects' of the discursive structure of sustainability science, in **Section 4.4.2**.

The discursive analysis of the discourse of sustainability science reveals that the practice is empirically characterized with original research, which is further characterized with the *Archetype-I* criteria i.e. the studies being conducted in the manner of 'literature survey' (Q2) and the research method being 'literature archive analysis' (Q4). Besides revealing the innovative aspect of sustainability science, these findings also resolve the conventional incompatibility between the *Archetype-I* criteria and 'original research'. As these characteristics of 'original', '*Archetype-I*' research reveal the dominant empirical characteristics of sustainability science research, these are to be regarded in terms of the intensity of its research. Structurally, it leaves the room for the latitudinal dimension of the empirical characteristics of sustainability science i.e. in terms of the diversity in its research.

In terms of the diversity, the presence of a great variety of article types exhibit richness in the approaches that sustainability science utilizes in addressing the complex intellectual needs of sustainability research. This dimension of sustainability science research is also coupled with a continued pronounced presence of *Archetype-I* articles across all these article types. Together, these findings render sustainability science to be empirically characterized with 'a wide range of approaches' as well as '*Archetype-I*' characters in terms of the diversity in its research.

Therefore, the discursive qualities of the discourse of sustainability science could be articulated in terms of its two empirical dimensions of 'the intensity' and 'the diversity' of its research, together which could be characterized with a 'predominant original research practice along with the practice of a wide range of approaches' as well as the 'dominant *Archetype-I* criteria'. This dominance of the *Archetype-I* criteria is also evident across the widely varying perspectives of the environmental, social and economic perspectives of sustainability. While these qualities communicate the strong aspects of the discursive qualities of sustainability science, a near absence of articles corresponding to the *Prototype-I theoretical assumption* construct a weak dimension of its research.

The *Prototype-I theoretical assumption* (**Section 4.2.1**) is defined as: "Unless it is improbable in reality to undertake empirical studies in addressing the complex matters or questions of this sort in research, it could be a philosophical and methodological merit to adopt simulation or modeling study as well as its nature being qualitative, as long as — (a) the study has a complex nature of lying at the interface of academically disparate areas or at the interface of the broad spheres of economy, society and environment, (b) the adopted approach is holistic, (c) the attempt is to present an integrated understanding, as well as (d) the study properly satisfies the quality and rigor aspects associated with it." As the intellectual treatment of sustainability would require the conduction of research at the complex interface of the nature and human society, these can develop through a fundamental utilization of the *Prototype-I theoretical assumption*, appearing as nearly absent in sustainability science research.

A subsequent strong aspect in the discursive qualities of sustainability science becomes its balance in equally emphasizing on the 'problem/ issue/ challenge/ syndrome-sphere', 'action/ approach-sphere' as well as the academic-sphere in the conduction of its research. Besides, the presence of a great variety of empirical classes in terms of the overarching methods in sustainability research communicates richness in its research in approaching the complex matters of sustainability through a variety of ways. Out of these variety of empirical classes (Q2), the pronounced presence of 'literature survey' in over 70% of the studies across a variety of domain-based literature clusters reveals the potential of 'literature survey' in producing various types of analyses solely or in combination with other empirical classes, while conventionally it is considered as quite an ordinary and mundane research practice instead.

Cross-compared with the types of studies, these empirical classes, including the class of 'literature survey', are found to be mostly comprising of 'original research'. This correlation further establishes the innovative aspect of sustainability science research, which could empirically be characterized with a dominant presence of 'literature survey' along with a wide variety of other empirical classes.

Although the practice of the various empirical classes appear justified with the necessities of their categorical presence, the empirical class 'empirical field study/ analysis' remaining absent in the 'problem/ issue/ challenge/ syndrome-sphere' reveals a weak aspect of sustainability science research in terms of approaching to understand the problems/ issues through these manners. Besides, the absence of studies corresponding to the categorical ‘problem/ issue/ challenge/ syndrome-sphere’ under the common broad sphere of the ‘central organization of sustainability’ communicate a subsequent lack in sustainability science research in attempting to understand the problems/ issues from a conjoint perspective of the economic, social and environmental aspects. The discursive analyses also reveal negligence with respect to the study of the economic perspectives of sustainability in the practice of sustainability science.

4.4.2 Summary on the strong and weak aspects of the discursive structure

Following are the strong aspects of the discourse of sustainability science in terms of its discursive structure:

1. The sustainability science research is innovative in nature as being characterized with ‘predominant original research along with the practice of a wide range of approaches’, where this innovative nature both in terms of the intensity and the diversity in research predominantly utilizes *literature survey* as the mode of conduction of research along with the utilization of *literature archive analysis* as research method.
2. The practice is well-balanced in terms of emphasizing on the different categorical aspects of addressing sustainability.
3. The practices of the various empirical classes in the conduction of research appear well-justified in terms of their necessities across the different categorical aspects of addressing sustainability.

In contrast to these strong aspects, the weak aspects of the discursive structure of sustainability science include:

1. a characteristic lack in attempting to develop research at the complex interface of the nature and human society,
2. a characteristic lack in attempting to understand the problems/ issues from a conjoint perspective of the economic, social and environmental aspects,
3. a lack of empirical field approaches in attempting to understand the problems/ issues pertaining to sustainability, and

4. a characteristic negligence with respect to the study of the economic perspectives of sustainability.

4.4.3 Major findings

In elucidating the discursive structure of sustainability science, three major findings have occurred in addition to the findings on the strong and weak aspects of its discursive qualities summarized in the preceding section.

[1] The first major finding is identified as *Archetype-I*. While the majority of the articles present in the literature maps are of original nature, the majority of these original articles correspond to the *Archetype-I*. A pronounced presence of *Archetype-I* articles has also been observed across the great variety of article types present in these maps.

The strong correlation between the characteristic original nature and the *Archetype-I* characteristics of the articles resolves the conventional incompatibility between the *Archetype-I* criteria and 'original research'. Besides, the characteristic dominance of *Archetype-I* criteria both in terms of the intensity and the diversity of sustainability science research proves three fundamental postulates appearing in the **Chapters 2-4**. The first of these articulates the need for discerning the cognitive necessities required for the development of the *pluralistic knowledge avenue*, which occurred in formulating the intellectual perspective on sustainability in **Chapter 2**. This postulate implies that these cognitive necessities need to come from a variety of knowledge avenues, and thus, the necessity for the coming together of an array of knowledge practices. The '*Archetype-I*' characteristics of 'literature survey' and 'literature archive analysis' becoming the empirical characteristics of sustainability science research establish the reality on the necessity of the coming together of an array of knowledge practices in terms of their potential contributions for sustainability research. The second postulate (occurring in **Section 3.1**) describes the ontological starting point for developing a novel philosophy for the *fundamental intellectual process* to be the recognition that some level of reconciliation of the different disciplines are required. This is also established through the characteristic dominance of '*Archetype-I*' criteria both in terms of the intensity and the diversity of sustainability science research.

A by-product of the second postulate is with the utilization of a fundamental bottom-up approach in developing the *fundamental literature organization process* for sustainability research based on the prepared literature archive (in **Chapter 3**). Thus, the utilization of the fundamental bottom-up approach in structuring archives of literature in sustainability research also gets supported from the dominant empirical characteristic of sustainability science research in terms of the '*Archetype-I*' criteria. The third postulate is with regard to the necessity for the language of conversation in sustainability research (**Section 4.1** and **4.2.4**), which states that the sustainability researchers need to conduct their research on sustainability within some frame of research consortia, where the research task should begin from examining the reported diverse research on the similar or fragments of the topic in question, and the researchers participating in the consortia represent the corresponding research streams. This postulate is also supported with the evidence of the characteristic dominance of '*Archetype-I*' criteria. Therefore, all three postulates—plus the by-product of the second postulate—proposed through the exercise of fundamental research in this thesis become established with the '*Archetype-I*' characteristics of 'literature survey' and 'literature archive analysis' becoming the empirical characteristics of sustainability science research both in terms of the intensity and diversity in research.

[2] The second major finding is in terms of the development of a theoretical framework on the language of conversation in sustainability research (produced in **Table 4.1**) based on the conceptualization of its frame of aspects in **Section 4.1** and its extensive exemplification throughout the **Sections 4.2.1-4.2.3**. The language of conversation is based on a frame of six questions, and therefore, six corresponding aspects, enquiring on the ways the studies are conducted in sustainability research. These six aspects describe — (Q1) – the theme of a given study to be learnt, (Q2) – a generalized communication on the overarching method(s) in the conduction of the study, (Q3) – a generalized account on the overarching 'philosophical, theoretical and methodological' issues, (Q4) – communication on the utilized research methods in simplified and universally understandable terms, (Q5) – a simplified view on the quality and rigor issues, and (Q6) – if, any additional aspects to be learnt that are non-generalizable into a common structure. The utility of this language of conversation in sustainability research would be in terms of providing the proper and error-free extent of understanding on a given research being examined by a research consortium (that is working on a given sustainability problem/ issue), where a researcher coming from a different research stream is not able to entirely understand the depths and details embedded in that study despite the necessity for him/ her to understand the research to the extent that would enable him/ her to participate and

contribute in the research consortium in addressing the sustainability problem/ issue in question. It has already been mentioned under the preceding major finding that the postulate with regard to the necessity for this language of conversation — which states that the sustainability researchers need to conduct their research on sustainability within some frame of research consortia, where the research task should begin from examining the reported diverse research on the similar or fragments of the topic in question, and the researchers participating in the consortia represent the corresponding research streams — has been supported with the evidence of the characteristic dominance of '*Archetype-I*' criteria.

[3] The third major finding under the discursive structure of sustainability science is with regard to the *Prototype-I theoretical assumption*, framed in **Section 4.2.1** and defined as: "Unless it is improbable in reality to undertake empirical studies in addressing the complex matters or questions of this sort in research, it could be a philosophical and methodological merit to adopt simulation or modeling study as well as its nature being qualitative, as long as — (a) the study has a complex nature of lying at the interface of academically disparate areas or at the interface of the broad spheres of economy, society and environment, (b) the adopted approach is holistic, (c) the attempt is to present an integrated understanding, as well as (d) the study properly satisfies the quality and rigor aspects associated with it." Although the discursive findings on sustainability science research reveal a near absence of articles corresponding to the *Prototype-I theoretical assumption*, thus, becoming a poor dimension of sustainability science research; the intellectual treatment of sustainability requires the conduction of studies at the complex interface of the nature and human society, which can develop through fundamentally utilizing the *Prototype-I theoretical assumption*.

Chapter 5

The integrative structure of Sustainability Science

In elucidating the basic structures of the discourse of sustainability science based on its first decade's 'body of work', the integrative structure of the discourse is analyzed based on four foci representing four different integrative/ qualitative aspects of the discourse. These reveal the qualities embedded in the ways sustainability science tries to tackle integrative concepts. As the problem definition (**Section 3.1**) clarifies the focus of the intellectual treatment of sustainability to be the acquisition of integrated knowledge, or more simply knowledge integration, these focus analyses on the integrative structure of sustainability science can also be considered as analyses on the quality of its discourse. Due to the foci-based qualitative nature of the analyses, these are also referred to as 'focus analyses into the quality of sustainability science' or simply focus analyses. The following list presents these four foci.

[Focus analysis - I]: Existing 'philosophical, theoretical and methodological' avenues in sustainability science

[Focus analysis - II]: Characterization of 'human-environment system' in sustainability science

[Focus analysis - III]: Nature of complexity in sustainability science

[Focus analysis - IV]: Analysis of practices on 'global sustainability'

The focus analyses I-IV utilize the literature maps produced for these analyses in **Section 3.4.4**, while the general mechanism for conducting these analyses is elucidated in **Section 3.4.5**. The analyses are not conducted in a uniform manner due to their varying qualitative nature, and therefore, these are produced separately in **Sections 5.1 – 5.4**, with **Section 5.5** discussing the findings.

5.1 Focus analysis – I [Existing 'philosophical, theoretical and methodological' avenues in sustainability science]

The 'focus analysis – I' (FA-I) synthesizes ideas on the existing 'philosophical, theoretical and methodological' avenues embedded in sustainability science research in order to project an intellectual story on its theoretical structure. First, the embedded 'philosophical, theoretical and methodological' avenues in the researches corresponding to the literature map for FA-I are articulated for sustainability science. These mount to a count of 91 seemingly disparate observations, which are then structured through subjecting them to relate to one another based on the most closely possible relational pattern in terms of creating definitive senses. Grouped under 10 'general themes' (in contrast to the use of 'themes' in the fifth layer of literature organization in **Section 3.4.3**), these 91 observations are arranged in a pattern in **Table 5.1** to project an intellectual story on the theoretical structure of sustainability science. This pattern does not record the counts of appearance for each observation throughout the literature map. Instead an observation appearing for once is considered as sufficient for taking part in forming the theoretical structure due to the qualitative nature of the analysis. Although each component (i.e. general theme) in the structure is deduced from the corresponding literature map—with the detail set of observations presented in **Appendix-9**—the comparison of these components against the 'themes' in the fifth layer of organization (**Section 3.4.3**) is not conducted due to such not aligning with the purpose of this focus analysis. Such comparison is instead undertaken for the FA-III and FA-IV (**Sections 5.3** and **5.4**, respectively). The following discussion articulates the projected intellectual story on the theoretical structure of sustainability science based on the sequence of the facets under the general themes in **Table 5.1**. From among the 10 themes, the themes 1-7 form direct components of the theoretical structure, whereas the remainder themes are reflective to the structure.

General theme 1: Sustainability challenge

The structure begins with the place for apprehending the sustainability challenge. A proper understanding and appreciation of the dimensions of the sustainability challenge is the most important requisite, if not only, in beginning the theoretical discourse. 'The question' first needs to be asked clearly before searching out for its answers, and therefore, properly detailing out and understanding the complexities and sophistications inherent to the sustainability challenge becomes the first component of the theoretical structure of sustainability science. This follows in the need for understanding the nature of sustainability science, beginning with the understanding of the human-environment interactions system with clarity.

General theme 2: Nature of sustainability science

Given the widely varying use of the concept of 'human-environment system' occurring in the current literature of sustainability science as exhibited in FA-II (**Section 5.2**), it is important to characterize the concept with precision. Otherwise the widely varying use of the term might render the studies not dovetailing with one another. This necessity of understanding the human-environment interactions system is to be followed by the facet on globalization and North-South divide in sustainability science. In the global society and economy, the North-South divide provides a difference of perspectives for sustainability science, which must conceptually be properly dealt for the theoretical structure of sustainability science. This is followed in the tension imparted into the nature of sustainability science by the call for 'urgency', adding a new kind of dimension requiring a satisfactory treatment. Then the structure proceeds with the necessity of discovering the nature of innovation required in sustainability science, being an extremely necessary dimension for the intellectual treatment of sustainability. In order for developing solutions to this quest of sustainability, it is also necessary for the quest to operate under a paradigm of sustainability that acts as the driver of innovation. Finally, interpreting the philosophical/ epistemological nature of sustainability science in line with its scientific proceedings needs to provide a paradigm of rationality for advancing its discourse.

General theme 3: The dimensions of sustainability science

The necessity of understanding the nature of sustainability science follows into the exploration of its wide-scale dimensions. Quite an extensive list of these dimensions are synthesized from the literature map, including the conceptual understanding of economic-ecological-and-social systems, the society-nature divide, the theoretical positions of place and scale, the operational tie between institutions and ecosystems, the institutional dimensions of environmental and land change, the conceptual treatments of human needs and poverty with respect to sustainability science, the governance system and the management and governance strategies, the conceptual position of the interdisciplinary concept of vulnerability in sustainability science, the adaptation and management of ecological thresholds, the decision processes in relation to sustainability science, the role of strategic thinking for sustainability science, the ethical make-up and dilemmas in sustainability science, the mode and nature of engagement for the scientific practices with multi-stakeholders, as well as dealing with sustainability indicators, and the system and discourse of sustainability assessment.

General theme 4: Research system in sustainability science

After the necessity for clarifying the nature of sustainability science as well as exploring its wide-scale dimensions, the subsequent step in the intellectual story directly engages with its research systems. It begins with the need for a satisfactory treatment of the pluralistic modes of research in sustainability science as well as the coupling between institutions and research, as the institutions are the primary venue for the conduction of these researches. This follows in the exploration of knowledge structuring in sustainability science, which represents the epistemological basis for the fundamental bottom-up modeling of a body of research literature conducted in **Chapter 3**. This epistemological basis is articulated in **Chapter 3** as a ‘knowledge, problem and action-structuring’ discourse, where all different structuring concepts are represented under the umbrella concept of knowledge-structuring. This includes problem-structuring, appearing as the next facet. The problem-structuring is also connected to the facet next to it, i.e. the syndromes, referring to a form of interconnected characteristic representation of the sustainability problems. The concept of syndrome is utilized in **Section 4.2** in developing a ‘water security syndrome’ in the perspective of a developing world megacity (the details in **Appendix-6**). These facets on knowledge-and-problem-structuring are followed into the subsequent facet of knowledge integration, which is the focus of the problem definition in the thesis (see **Section 3.1**). The theme on research systems in sustainability science ends with emphasizing on the complex interplay of agency, institutions and innovation in sustainability science, as well as the special place of university-industry collaborations in its research.

General theme 5: Disciplinarity of sustainability science

Chapter 1 reveals a questioned disciplinary status of sustainability science. The theme on the disciplinarity of sustainability science needs to begin by treating the pluralistic modes of its potential disciplinarity that incorporates the two subsequent facets: knowledge systems for sustainability science, and the inter-linked knowledge base of sustainability science. In a deeper level it then unfolds the challenge of the epistemological treatment of such disciplinarity, being crucial for its intellectual existence. The contentious position of social science perspectives in sustainability research—as articulated in **Section 2.3**—comes next. The theme of disciplinarity then encompasses the questions of non-science in sustainability science as well as the necessity of demarcating the scientific from the non-scientific cognitive practices in sustainability science.

General theme 6: The knowledge-action link

After the treatments on the research system and the question of disciplinarity of sustainability science, the link between knowledge and action becomes the next avenue to pursue. This begins with imparting importance on understanding the aspects of both 'knowledge' and 'action' with respect to each other. Two other strategic facets connected to the knowledge-action links conclude this theme, aiming to understand the role of carrying out intervention in complex systems as well as the implications of institutional failure for sustainability science.

General theme 7: Education in sustainability science

The projected intellectual story on the theoretical structure of sustainability science completes with 'education' in sustainability science. It begins with the necessity of understanding the challenge of learning in sustainability, which paves the way for the rest of the facets under this theme. After the need for articulating the overall paradigm of education in sustainability science, the first detail facet deals with the doctoral program due to its enormous importance as well as potential both as a part of education in sustainability science and as a carrier of its research and innovation. It is followed with the scope of sustainability engineering education for its potential in preparing the technological framework of innovation required for sustainability science. The story then proceeds on dealing with universities for being the most important medium for dispensing sustainability science education. This connects with the remaining components of the institutional basis involved in sustainability science education, i.e. the involvement of stakeholders together with institutions, as well as the position of multi-stakeholder networks in sustainability science education.

General themes 8-10: Reflective themes

The three reflective themes to the theoretical structure of sustainability science are 'transition and resilience' (theme #8), 'conceptual references' (theme #9), and 'sustainable development' (theme #10). The theme on 'transition and resilience' deals with the scientific characteristics of sustainability transition, the place of socio-technical transition paths and resilience in sustainability science as well as their interplay. The 'conceptual references' enlist 25 conceptual entities, the relation of which to sustainability science becomes important in terms of rendering the intellectual making of the practice an integrative and accommodative one. The final theme on 'sustainable development' references sustainability science to the agenda of sustainable development. First, it articulates the need for understanding the scientific underpinnings of sustainable development, followed with focusing on the scientific making of case studies for the same.

Table 5.1 A projected intellectual story on the theoretical structure of sustainability science

General themes		Sequence	Facets of theoretical structure
1	**Sustainability challenge**	1	Dimensions of sustainability challenge
2	**Nature**	1	Nature of sustainability science
		2	Human-Environment interactions system in sustainability science
		3	Globalization and North-South divide in sustainability science
		4	Urgency and nature of sustainability science
		5	Nature of innovation in sustainability science
		6	Sustainability as driver of innovation
		7	Philosophical nature of sustainability science
3	**Dimensions**	1	Dimensions of sustainability science
		2	Economic, ecological and social systems in sustainability science
		3	Society-Nature divide with respect to sustainability science
		4	Theoretical position of place in sustainability science
		5	Theoretical position of scale in sustainability science
		6	Ecosystems and institutions in sustainability science
		7	Institutional dimensions of environmental and land change in sustainability science
		8	Poverty and human needs in sustainability science
		9	Governance system in sustainability science
		10	Place of governance strategies in sustainability science
		11	Natural resource governance in sustainability science
		12	Interdisciplinary concept of vulnerability in sustainability science
		13	Vulnerability of social-environmental systems and sustainability science
		14	Ecological thresholds management in sustainability science
		15	Adaptation in sustainability science
		16	Natural resource management in sustainability science
		17	Complex adaptive social systems in sustainability science
		18	Decision processes and sustainability science
		19	Place of strategic thinking in sustainability science
		20	Ethics in the making of sustainability science
		21	Ethical dilemmas of future in sustainability science
		22	Place of multi-stake discussion in scientific activities
		23	Place of sustainability indicator in sustainability science
		24	Sustainability assessment system
		25	Discourse of sustainability assessment
4	**Research system**	1	Pluralistic modes of research in sustainability science
		2	Research systems for sustainability science

General themes		Sequence	Facets of theoretical structure
		3	Institutions and research in sustainability science
		4	Knowledge structuring in sustainability science
		5	Problem structuring in sustainability science
		6	Syndromes in sustainability science
		7	Knowledge integration in sustainability science
		8	Agency, institutions and innovation in sustainability science
		9	University-Industry collaborations for sustainability science
5	**Disciplinarity**	1	Pluralistic modes of disciplinarity in sustainability science
		2	Knowledge systems for sustainability science
		3	Interlinked knowledge-base for sustainability science
		4	Epistemology of sustainability science
		5	Social science perspectives in sustainability science
		6	Question of non-science in sustainability science
		7	Demarcating science from non-science
6	**Knowledge-Action link**	1	Knowledge and action in sustainability science
		2	Intervention in complex systems in sustainability science
		3	Institutional failure and sustainability science
7	**Education**	1	Challenge of learning in sustainability
		2	Education in sustainability science
		3	Doctoral program and sustainability science
		4	Engineering education in sustainability science
		5	Education and university in sustainability science
		6	Institutions, stakeholders, and education in sustainability science
		7	Education and multi-stakeholder networks in sustainability science
8	**Transition and Resilience**	1	Scientific characteristics of sustainability transition
		2	Place of sustainability transition in sustainability science
		3	Place of socio-technical transition paths in sustainability science
		4	Place of resilience in sustainability science
		5	Resilience versus socio-technical transitions in sustainability science
9	**Conceptual references**	1	Complex land systems in sustainability science
		2	Science of land change in sustainability science
		3	Political ecology in sustainability science
		4	Land change science and political ecology with respect to sustainability science
		5	World system theory in sustainability science
		6	Ecological economics in sustainability science

General themes		Sequence	Facets of theoretical structure
		7	Panarchy versus world system approaches with respect to sustainability science
		8	Adaptive management and sustainability science
		9	Landscape ecology and sustainability science
		10	Earth stewardship and sustainability science
		11	Tipping elements analysis in sustainability science
		12	Scientific underpinnings of integrated analysis and management
		13	Cultural theory and sustainability science
		14	Cultural theory and integrated assessment in sustainability science
		15	Critical realism and political ecology with respect to sustainability science
		16	Industrial ecology and sustainability science
		17	Anthropocentrism and deep ecology with respect to sustainability science
		18	Ecological modernization and sustainability science
		19	Global environmental discourses in sustainability science
		20	Degrowth and sustainability science
		21	Cosmopolitanism and sustainability science
		22	Policy science in sustainability science
		23	Scenario analysis and sustainability science
		24	Place of planetary boundary studies in sustainability science
		25	Visioneering and sustainability science
10	**Sustainable Development**	1	Scientific underpinnings of sustainable development
		2	Place of balance in the scientific making of sustainable development case study

5.2 Focus analysis – II [Characterization of ‘human-environment system’ in sustainability science]

The ‘focus analysis – II’ (FA-II) examines the ways ‘human-environment system’ is used in sustainability science literature. Although this focus analysis aims to identify the patterns in the characterization of human-environment relation, surprisingly the observations reveal a great variety of use of ‘human-environment system’ in the FA-II literature map. **Table 5.2** summarizes the observations on the use of ‘human-environment system’ in sustainability science literature, while the detail set of observations appear in **Appendix-9**. The 141 archive items present in the FA-II literature map exhibits 86 kinds of uses of ‘human-environment system’, where noticeably only two kinds of uses have had occurred in sufficient multiplicity (taken to mean an occurrence with a minimum of three counts or more).

The descriptor ‘human-environment interactions system’ is utilized in **Table 5.2** to refer to the general representation of ‘human-environment system’ that does not have any specificity. Such has occurred for 38 times within the literature map of 141 archive items, comprising 27% of the map. The remainder 73% of the literature map uses ‘human-environment system’ in specific ways, among which the mostly occurred type is observed as ‘human manipulation – natural setting’ (appearing for nine times), followed by ‘adaptation – climate change’ (appearing for thrice). Apart from these three types of uses (including the type on general representation) all the rest of the 83 types have either occurred twice (eight types) or merely once (75 types, corresponding to 87% of the types of uses). These findings reveal a great diversity in the use of ‘human-environment system’ in sustainability science literature, which, however, means an extremely open-ended representation in terms of the characterization of the concept. Besides, such disperse reality also limits the scope for potential generalization for deducing patterns from the data.

In sphere-wise comparison, it is noticeable that 36 out of the 38 appearances of ‘human-environment interactions system’ as well as eight out of the nine appearances of ‘human manipulation – natural setting’ have occurred in the sphere D (i.e. central organization of sustainability). These 36 out of the 38 appearances of ‘human-environment interactions system’ under the sphere D refer to the general nature of research corresponding to this sphere, which does not require any specificity in the use of ‘human-environment system’.

In terms of the various use of the ‘human-environment system’, the broad spheres of B and C (i.e. the social and environmental perspectives of sustainability) exhibited 30 and 32 types of uses, respectively; whereas the least count has appeared under the broad sphere A (i.e. economic perspectives of sustainability) with only nine types of uses. The broad sphere D accounts for its 20 types of uses. This apparent low representation from the economic perspectives of sustainability in terms of the types of uses of the concept of ‘human-environment system’ could be explained by the lowest percentage distribution of archive items (as per total count) under the economic spheres (see **Figure 3.1** in **Section 3.4.3**).

In comparing the counts of type of use of ‘human-environment system’ with the total counts of their occurrence for individual broad spheres, the broad spheres of A, B and C exhibit similar pattern (with 9 types occurring for a total count of 10 times in the broad sphere A, 30 types occurring for the total count of 34 times in the broad sphere B, and 32 types occurring for only the sum of 34 times in the broad sphere C). This is dissimilar to some extent with the way the types have occurred in the sphere D. Overall, the 20 types of use of ‘human-environment system’ in the sphere D has occurred for a total count of 63 times. However, two of them—i.e. ‘human-environment interactions system’ with 36 counts and ‘human manipulation – natural setting’ with 8 counts—together correspond to 44 counts of occurrence out of the total 63 counts, thereby rendering the rest of the 18 types to have occurred for the total count of only 19 times. Therefore, except for these two types of uses, the sphere D also exhibits similar pattern as with the other three broad spheres. Furthermore, from among these two types, as ‘human – environment interactions system’ occurs for the general representation of ‘human-environment system’ without having any specificity, this further normalizes the resemblance of the sphere D with the other broad spheres.

The overall similar pattern across all four broad spheres together reveal the great complexity that the ‘human-environment system’ is placed with in terms of researching at the intersection of nature and human society. This warrants serious attention with regard to the need for characterizing the ‘human-environment system’ with precision.

Table 5.2 Use of 'human-environment system' in sustainability science literature

Broad sphere	Consecutive serial	FA-II observation (type of human-environment relation)	Total number of occurrence	*Breakdown*			
				A	***B***	***C***	***D***
A	**1**	Agricultural product market - Global warming	1				
	2	Market - Water	1				
	3	Human manipulation - Natural setting	9	*1*			*8*
	4	Market - Biodiversity	1				
	5	Biofuels - Agricultural land	2	*2*			
	6	Renewable energy - Fluvial water	1				
	7	Economy - Environment	1				
	8	Economy - Natural capital	1				
	9	Ecological economy of oceans and coasts	1				
B	**10**	Human consumption - Water resources	2		*2*		
	11	Infectious disease - Tropical monsoon inundation	1				
	12	Human security - Natural resources	2		*2*		
	13	Human consumption - Natural resource	2		*1*		*1*
	14	Human water consumption - Drought vulnerability	1				
	15	Human manipulation - Vulnerable deltas	1				
	16	Conservation intervention - Environmental benefits	1				
	17	Low carbon society	1				
	18	Poverty reduction - Biodiversity conservation	1				
	19	Rural community institutions - Exclosure management	1				
	20	Agriculture - Environment	2		*1*	*1*	
	21	Adaptive migration - Natural disaster	2		*2*		
	22	Disaster-resilient eco-community	1				
	23	City response - Climate change vulnerability	1				
	24	Agricultural re-use of wastewater - Peri-urban areas	1				

Broad sphere	Consecutive serial	FA-II observation (type of human-environment relation)	Total number of occurrence	*Breakdown*			
				A	***B***	***C***	***D***
	25	Co-management community decision making - Natural resources	1				
	26	Human activities - Ecosystem services	1				
	27	Historical root - Ecological crisis	1				
	28	Poor community - Place	1				
	29	More human well-being - Less ecosystem services	1				
	30	Infrastructural projects - Environmental impacts	1				
	31	Adaptive urban governance	1				
	32	Concentrated consumption - Urban areas	1				
	33	Urbanization - Metropolitan environment	1				
	34	Adaptation - Climate change	3		*2*	*1*	
	35	Politics - Environment	1				
	36	Population and institution - Land-use and land-cover	1				
	37	Agriculture - Land	1				
	38	Agriculture - Land use	1				
	39	Culture - Water domain sustainability	1				
C	**40**	Urban productivity - Global warming-induced typhoon intensity	1				
	41	Food damage - Extreme rainfall	1				
	42	Economic value - Ecosystem services and natural capital	2			*2*	
	43	Farming practices - Land impacts	1				
	44	Megacity atmospheric pollution	1				
	45	Human manipulation - Tropical deforestation	1				
	46	Human manipulation - Marine biodiversity	1				
	47	Floating garden agriculture - Open water surface	1				
	48	Alternative livelihood - Dryland development	1				
	49	Forest land use and biodiversity	1				

Broad sphere	Consecutive serial	FA-II observation (type of human-environment relation)	Total number of occurrence	*Breakdown*			
				A	***B***	***C***	***D***
	50	Sustainable agriculture - Natural resources and environmental quality	1				
	51	Conservation - Marine resources	1				
	52	Agriculture - Natural areas	1				
	53	Logging - Forested watershed	1				
	54	Urban horticulture - Environmental conservation	1				
	55	Rural resource recycling - Environmental pollution management	1				
	56	Greenhouse gas emissions - Land systems	1				
	57	Mixed land-use planning - City periphery	1				
	58	Land use combinations - Low environmental impact	1				
	59	Sustainable land use systems	1				
	60	Species conservation - Local place	1				
	61	Land use change - Environmental services	1				
	62	Agricultural nitrogen application - Ecology	1				
	63	Human - Environment interactions system	38			*2*	*36*
	64	Urbanization - Environmental hazards	1				
	65	Human manipulation - Natural areas	1				
	66	Human manipulation - Environmental impacts	1				
	67	Urban consumption - Land use and cover change	1				
	68	Land use - River ecosystem health	1				
	69	Land-use and land-cover change in tropical regions	1				
D	**70**	Global 'environmental-social' system	1				
	71	Development intervention - Conservation intervention	1				
	72	Industrialized urban system	1				
	73	Human settlement - Local natural geography	1				
	74	Human health and well-being - Water	1				

Broad sphere	Consecutive serial	FA-II observation (type of human-environment relation)	Total number of occurrence	*Breakdown*			
				A	***B***	***C***	***D***
	75	Land tenure system - Forests	1				
	76	Human - Ecological resilience	2				*2*
	77	Society - Nature intellectual divide	1				
	78	Social-biophysical systems	1				
	79	Human activity - Ecosystem health	1				
	80	Human activity - Global system	1				
	81	Community - Place	1				
	82	Complex land system	1				
	83	Institutions - Ecosystems	1				
	84	Institutions - Land change	1				
	85	Agriculture - Urban area	1				
	86	Community - Landscape	1				
Total			***141***				

5.3 Focus analysis – III [Nature of complexity in sustainability science]

In contrast to the modes of analyses in FA-I and FA-II—FA-I projecting an intellectual story on the theoretical structure of sustainability science, while FA-II empirically observing the patterns of occurrence in the literature on the varying use of 'human-environment system'—the 'focus analysis – III' (FA-III) compares its observations on the complexity embedded in the sustainability science researches against the 'themes' in the fifth layer of literature organization (see **Section 3.4.3**). The FA-III interprets the sophistication implicated to a given research and articulates it in terms of the complexity embedded therein. These observations are then analyzed against the 'themes' in the fifth layer of literature organization to reveal the nature of complexity that the discourse of sustainability science needs to embrace. **Table 5.3** summarizes the detail results, with the full set of observations appearing in **Appendix-9.** A discussion on the core of the nature of complexity that sustainability science needs to embrace follows here.

Table 5.3 enlists a total count of 41 themes (from the fifth layer of literature organization) that correspond to the FA-III observations, out of which 34 themes are found to contain two or lesser FA-III observations (eight themes containing two observations in each, while the rest of the 26 themes corresponding to only one observation each). The remainder seven themes—corresponding to a minimum of three or more FA-III observations in each, thereby, rendering them to be considered as 'prominent themes'—contain various cluster sizes of FA-III observations, the biggest of which is comprised of 17 observations, followed by 11 and eight observations in the two subsequent cluster sizes. As to the rest of the four themes, two themes contain five observations in each, while the rest of the two containing three and four observations, respectively.

In **Table 5.3**, the theme with the biggest cluster size (i.e. 17 observations) is seen to be 'inter-/multi-/trans-disciplinarity of sustainability science research', followed by the themes of 'ontology and/or epistemology of sustainability science' and 'complex systems, analysis, and adaptive planning/management' to represent the two subsequent cluster sizes (i.e. with 11 and eight observations each). The four other themes containing a minimum of three FA-III observations in each are 'sustainability challenge' and 'quantitative sustainability' (having five observations in each), 'sustainable development strategies/innovation' (with four observations), and 'natural capital & ecosystem services management/governance' (with three observations). The prominence of these seven themes—with their varying degrees of prominence as per the cluster sizes—in the mosaic of the 41 themes appearing with FA-III observations in **Table 5.3** reveal the challenges of sustainability science with the highest degrees of complexity.

Compared to the intellectual story on the theoretical structure of sustainability science projected in FA-I, these seven themes out of the entire mosaic of themes with observations in FA-III are found to represent the core of the theoretical structure in FA-I. This could be ascertained through comparing the record of FA-III observations in these seven themes against the facets of the theoretical structure in FA-I. Based on this comparison, the only facet under the general theme of ‘sustainability challenge’ (the general theme 1), five facets out of the seven under the general theme of ‘nature of sustainability science’ (the general theme 2), eight facets out of the nine under ‘research system in sustainability science’ (the general theme 4), six facets out of the seven under the ‘disciplinarity of sustainability science’ (general theme 5), and two facets out of the three under the ‘knowledge-action link in sustainability science’ (general theme 6), are corresponded to the FA-III observations present in these seven themes (‘themes’ in the fifth layer of literature organization in contrast to the ‘general themes’ in FA-I). The general themes of 3 and 7 under the theoretical structure of sustainability science projected in FA-I represent the ‘dimensions of sustainability science’ and ‘education in sustainability science’, which comprise the peripheral considerations in the theoretical structure as these do not directly address the theoretical core of sustainability science. Therefore, the observations under the seven prominent themes in FA-III corresponding to 22 out of the 27 facets present within the general themes of 1, 2, 4, 5 and 6 in FA-I represent the core of the theoretical structure projected on sustainability science, and thus, reveal the core of the nature of complexity that sustainability science needs to embrace. Nonetheless, the FA-III observations under the seven prominent themes also correspond to 12 out of the 25 facets under the ‘dimensions of sustainability science’ (the general theme 3) and one out of the seven facets under ‘education on sustainability science’ (the general theme 7).

Table 5.3 The observed nature of complexity that sustainability science needs to embrace

Category	Theme ID	Theme	FA-III (observation)	*Reoccurrence code*
i	10	African poverty	Theoretical position of place	
	11	Climate change problem/impacts	Methodology in simpler form of communication	
	19	River — problems	Trading-off human interest from/with natural setting	
ii	3	Interventions and development, and conservation	Trading-off between development intervention and conservation intervention	
	9	Forest management policy/innovation	Management of uncertainty in managing natural resources	
	12	Modeling	Empirical- and agent-based modeling in social sciences	
	13	Adaptation—Natural Disaster—Migration—Benefits	Framework for diagnosis of barriers to climate change adaptation	
	14	Urban policy/innovation	Innovation system for industrialized urban sustainability	
	17	Water policy/innovation	Methodology of multi-stake discussion for scientific activity	***1***
			Scientific soundness in balance of integrated analysis	
	21	Biodiversity conservation policy/innovation	Methodology of multi-stake discussion for scientific activity	***1***
	25	Sustainable Development strategies/innovation	Governance in sustainability	***2***
			Innovation system in sustainability	
			Methodology of strategic thinking in sustainability science	***3***
			Scientific soundness in balance of sustainable development case study	
iii	1	Transition theory	Framework for socio-technical transition paths in sustainability science	
	4	Circular economy	Multi-perspective performance analysis	
	5	Quantitative sustainability	Developing sustainability indicators	***4***
			Methodology of strategic thinking in sustainability science	***3***
			Scientific complexity of sustainable development	***5***
			Sustainability assessment system	
			Sustainability transition	***6***
	6	Natural capital & ecosystem services management/governance	Methodology of governance strategies	
			Natural resource governance	

Category	Theme ID	Theme	FA-III (observation)	*Reoccurrence code*
			Natural resource management	
	8	Resilience	Politics of resilience and socio-technical transitions	
			Resilience in sustainability science	
	11	Sustainability challenge	Dimensions of sustainability challenge	
			Dimensions of sustainability science	
			Nature of sustainability science	***7***
			Scientific complexity of sustainable development	***5***
			Theoretical position of scale	
	14	Poverty—Development	"Human needs" in sustainability science	
	16	Urban sustainability and adaptive urban governance	Urban sustainability assessment system	
	17	Adaptation	"Adaptation" in sustainability science	
	18	Political ecology	Political ecological complexity of sustainability science	
	19	Land cover and land use change science	Land system modeling	
			Science of land change	
	21	World System theory	World system in sustainability science	
	22	Learning—Knowledge—Ignorance—Condition	Learning for sustainability	
	23	Earth System analysis and tipping elements/points	Analysis of tipping elements in sustainability science	
	25	Environmental assessment	Developing environmental assessment frameworks and sustainability indicators	***4***
			Environmental assessment system	
	26	Sustainability related discourses	Sustainability assessment discourse	
	28	Sustainable engineering education	Engineering curricula in sustainability science	
	29	Sustainability Science education/curriculum	Curriculum for sustainability science	***8***
			Institutional complexity of education in sustainability science	
	30	Policy science	Innovation policies for sustainability	
			Policy science analysis for sustainability	

Category	Theme ID	Theme	FA-III (observation)	*Reoccurrence code*
	32	Decision making	Decision process in complex Human - Environment interactions system	
	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Agency, institutions and innovation	
			Complexity imparted by urgency in sustainability science	
			Governance in sustainability	***2***
			Institutional complexity of research in sustainability science	
			Integration of social science in sustainability science	
			Knowledge system for sustainability science	
			Linkages in knowledge base, and sustainability science	
			Mixing of science and non-science	
			Nature of innovation in sustainability science	
			Nature of sustainability science	***7***
			Pluralistic disciplinarity in sustainability science	
			Pluralistic research in sustainability science	***9***
			Question of non-science in sustainability science	
			Research system for sustainability science	
			Sustainability science with regard to conceptual structures	***10***
			University-industry collaboration in sustainability science	
			Use of "vulnerability" in sustainability science	
	36	Anthropocene and Earth stewardship	"Anthropocene" and Earth stewardship with respect to sustainability science	
	37	Ontology and/or epistemology of Sustainability Science	Curriculum for sustainability science	***8***
			Knowledge integration	
			Linkages of knowledge and action	
			Nature of sustainability science	***7***
			Philosophical nature of sustainability science	
			Pluralistic research in sustainability science	***9***

Category	Theme ID	Theme	FA-III (observation)	*Reoccurrence code*
			Structuring of knowledge in sustainability science	
			Structuring of problems in sustainability science	
			Sustainability science with regard to conceptual structures	***10***
			Sustainability transition	***6***
			Theoretical position of place	
	38	Complex systems, analysis, and adaptive planning/management	Adaptive management	
			Complexity of land systems	
			Economic, ecological and social systems	
			Human - Environment interactions system	
			Institutional dimensions of environmental and land change	
			Intervening into a complex system	
			Planning in uncertainty in complex adaptive systems	
			Vulnerability analysis	
	39	Cultural theory	Institutional failure	
			Treating bias in integrated assessment	
	40	Urban agriculture	Dynamics of urban agriculture	
	43	Sustainable health	Health program planning	
	47	Scenario analysis—Visioneering	Analysis of future scenario	
			Visioneering and system's thinking	
	48	Syndromes	Syndromes	
	49	Landscape ecology	Theoretical position of landscape	

5.4 Focus analysis – IV [Analysis of practices on 'global sustainability']

The 'focus analysis – IV' (FA-IV) analyzes the sustainability science practices on global sustainability, which is conducted in a manner similar to the FA-III i.e. through comparing the FA-IV observations against the corresponding themes in the fifth layer of literature organization (see **Section 3.4.3**), plus an additional analysis on the type of relation between the themes and the observations. **Table 5.4** presents the results of the analysis, with the unprocessed data appearing in **Appendix-9**.

In terms of the 'theme to observation relation' the **Table 5.4** reveals three relation types: 'direct', 'thematic', and 'application'. A direct relation from a theme to an observation refers to the direct reflection of the content of the theme into the observation with specific details i.e. the reiteration of the content of the theme with specifics, whereas a thematic relation refers to an indirect type of relation where the observation reflects somewhat different content within the scope of the theme. An application-type relation from a theme to an observation refers to some application of the content of the theme reflected in the observation. In terms of considering a theme as prominent, a similar approach is undertaken as in FA-III, i.e. corresponding to a minimum of three or more observations. Following is a discussion on the results of the analysis on sustainability science practices on global sustainability.

There are 14 themes corresponding to the FA-IV observations on global sustainability in **Table 5.4**, out of which six themes correspond to only one observation in each, four containing two observations in each, three with three observations, and the remaining theme (i.e. 'sustainability challenge') having the biggest cluster size of eight observations. This theme with the biggest cluster size of observations reveal five observations with direct relation to the theme and the remaining three observations referring to a thematic relation. Such pronounced presence of the theme 'sustainability challenge' in the analysis of the sustainability science practices on global sustainability inform that the practices on global sustainability are still largely at the outset of appreciating the 'sustainability challenge' for the globe. Undoubtedly there are complications inherent to it, such as the trans-boundary nature of problems and the North-South divided perspectives on sustainability (as discussed in **Chapter 1**), imparting an intellectual obscurity into our understanding on global sustainability as well as acting to catalyze splits in political motivations. Furthermore, the capacity for conducting studies at the intersection of nature and society at a global scale requires a unified pluralistic research approach and tremendous innovations occurring in terms of the compatibility, coherency, and transcendence of research methods. It is the combined effects of these realities that contribute into the appreciation of the practice of global sustainability staying largely at the outset of understanding the challenge for the globe.

The three subsequent prominent themes after ‘sustainability challenge’ are ‘anthropocene and Earth stewardship’, ‘ontology and/or epistemology of sustainability science’, and ‘natural capital & ecosystem services management/governance’, containing three observations in each. The theme ‘anthropocene and Earth stewardship’ corresponds to the ‘conceptual references’ for the theoretical structure of sustainability science in FA-I. ‘Ontology and/or epistemology of sustainability science’ appears with thematic relations on all three of its observations, where none of these observations appearing in direct relation indicates on the scopes of ontological/ epistemological studies in sustainability science to hold potential for global sustainability. On the other hand, the direct type of relation on all three observations for the theme ‘natural capital & ecosystem services management/governance’ reveals a high priority for the governance/ management of the global natural capital and ecosystem services.

Table 5.4 enlists a total count of 31 observations on global sustainability, 21 of which are in direct-type ‘theme to observation’ relation, while eight observations having thematic-type and the rest of the two with application-type relations. The occurrence of direct-type relation for nearly two-thirds of the observations (approximately 68%) reveal some degree of clarity on the sustainability science practices on global sustainability, whereas the occurrence of thematic-type relation in one-quarter of the observations (approximately 26%) also communicate scopes of thematic projections required for the practice.

Table 5.4 Analyzing the mode of practice on global sustainability

Item ID	Item	Sphere	Category	Theme ID	Theme	FA-IV (observation)	'Theme' to 'Observation' relation
JA6	(Alcamo et al. 2005)	**D**	**ii**	**12**	Modeling	Future estimates on global ecosystem services	Direct
JG18	(Goodchild 2003)	**D**	**ii**	**12**	Modeling	Applying GIS in environmental management systems	Application
JN1-1	(Fink 2011)	**D**	**ii**	**14**	Urban policy/innovation	Urban genome mapping for global sustainability	Direct
JH2	(Haberl et al. 2007)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance	Global depiction of human ecosystem primary production appropriation	Direct
JH18	(Hoekstra and Mekonnen 2012)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance	Global depiction of water use by humans	Direct
JT3	(Tallis and Kareiva 2006)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance	Global ecosystem assessment models	Direct
JA19	(Ayres 2000)	**D**	**iii**	**11**	Sustainability challenge	Understanding global trends in sustainability challenge	Direct
JC13	(Clark et al. 2004a)	**D**	**iii**	**11**	Sustainability challenge	Sustainability science for global sustainability	Thematic
JK8	(Kates and Torrie 1998)	**D**	**iii**	**11**	Sustainability challenge	Local places to carry out global actions	Thematic
JK17	(Kates and Parris 2003)	**D**	**iii**	**11**	Sustainability challenge	Long-term global trends and sustainability transition	Direct
JR5	(Raskin et al. 2010)	**D**	**iii**	**11**	Sustainability challenge	Global future studies for sustainability science	Direct
JR7	(Raven 2002)	**D**	**iii**	**11**	Sustainability challenge	Global dimensions of sustainability challenge	Direct
JS39	(Doran et al. 2012)	**D**	**iii**	**11**	Sustainability challenge	Global sustainable development deliberation	Direct
JW8	(Wilbanks and Kates 1999)	**D**	**iii**	**11**	Sustainability challenge	Local places to carry out global actions	Thematic
JS11	(Schaldach and Priess 2008)	**D**	**iii**	**19**	Land cover and land use change science	Land system modeling at global scale	Direct
JT18	(Turner et al. 2007a)	**D**	**iii**	**19**	Land cover and land use change science	Global utility of land change science	Direct

Item ID	Item	Sphere	Category	Theme ID	Theme	FA-IV (observation)	'Theme' to 'Observation' relation
JS12	(Schellnhuber 2009)	D	iii	23	Earth System analysis and tipping elements/points	Tipping elements in Earth system	Direct
JG19	(Gotts 2007)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	World-systems analysis versus panarchy	Thematic
JW1	(Wallerstein 2010)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	World-system perspective on social sciences	Thematic
JS26	(Steffen et al. 2011)	D	iii	36	Anthropocene and Earth stewardship	Global change and planetary stewardship	Direct
JS29	(2011)	D	iii	36	Anthropocene and Earth stewardship	Global change and planetary stewardship	Direct
JT16	(Turner et al. 1994)	D	iii	36	Anthropocene and Earth stewardship	Global change and planetary stewardship	Direct
JJ8	(Jerneck et al. 2011)	D	iii	37	Ontology and/or epistemology of Sustainability Science	Global sustainability issues in structuring sustainability science	Thematic
JK21	(Kates 2011)	D	iii	37	Ontology and/or epistemology of Sustainability Science	Unity of nature and sustainability science	Thematic
JK38	(Kristjanson et al. 2009)	D	iii	37	Ontology and/or epistemology of Sustainability Science	Linking knowledge and action in agricultural research	Thematic
JY9	(Young et al. 2006)	D	iii	38	Complex systems, analysis, and adaptive planning/management	Institutional dimensions of global environmental change	Direct
JJ7	(Jerneck and Olsson 2011)	D	iii	45	Reframing	Pluralistic mode of research for global health challenges	Application
JJ11	(Jorgenson and Kick 2003)	D	iii	46	Globalization	Environment in globalization	Direct
JK15	(Kates 2003a)	D	iii	46	Globalization	North-South divide and global sustainability transition	Direct
JS37	(Kosamu 2011)	D	iii	47	Scenario analysis—Visioneering	Future scenarios of combined social and environmental systems	Direct
JL21	(Lüdeke et al. 2004)	D	iii	48	Syndromes	Syndromes of global change	Direct

5.5 Discussing the findings

This chapter analyzes the integrative qualities of sustainability science through employing a variety of qualitative deductive means. As the integrative structure of sustainability science does not exist in terms of some quantitative analytics and rather stays in an abstract form, this can be revealed through employing qualitative measures capable of reflecting on these abstract qualities. This is accomplished in the **Sections 5.1-5.4** through the four focus analyses (FA I-IV).

The FA-I extracts any philosophical, theoretical or methodological avenues that underlie the sustainability science researches, and articulates them as observations on the 'philosophical, theoretical and methodological' avenues embedded therein. This produces a collection of 91 seemingly disparate observations that does not tell a story about their entirety. The integrative structure of sustainability science—based on the focus of its 'philosophical, theoretical and methodological' avenues—should reveal a pattern in these avenues that can communicate a meaningful intellectual story. The FA-I approaches this task by attempting to see if subjecting these observations on the embedded 'philosophical, theoretical and methodological' avenues to relate to one another based on the most closely possible relational pattern could create any meaningful intellectual story. This intellectual story is projected in **Table 5.1**, revealing a theoretical structure of the discourse. Based on the consecutive seven general themes of 'sustainability challenge', 'nature of sustainability science', 'the dimensions of sustainability science', 'research system in sustainability science', 'disciplinarity of sustainability science', 'the knowledge-action link', and 'education in sustainability science'; the array of facets under these general themes extracted from the archive items indeed produces an intellectually complete and continuous theoretical structure projected for the discourse. As the intellectual story deliberates, the tasks under this theoretical structure are in terms of the necessities that sustainability science would be required to respond to, in order to contribute into the intellectual treatment of sustainability.

The second focus for analyzing the integrative structure of sustainability science is in terms of the characterization of 'human-environment system' as it is utilized in sustainability science research. The results from the FA-II reveal a great diversity in the use of 'human-environment system' in sustainability science literature. The concept of 'human-environment system' is found to have been used in 86 different types within a literature map of 141 archive items (see **Table 5.2**). 87% of these various types of use occur only once in the literature map, revealing an extremely open-ended characterization of the concept. The pattern remains the same across the economic, social and environmental perspectives of sustainability with 9 types of use of the concept occurring for a total count of 10 times in the economic perspectives, 30 types for the total count of 34 times in the social perspectives, and 32 types for a sum of 34 times in the environmental perspectives. Although this reality, on one hand, reveals the great complexity that the 'human-environment system' presents; on the other hand, it also reveals an unsatisfactory integrative structure.

The third focus for elucidating the integrative structure of the discourse is in analyzing the complexity that is embedded in sustainability science research. The FA-III interprets this complexity through a list of observations based on the archive items present in its literature map, where each observation is corresponded to a theme on sustainability science research extracted in the literature organization task. This results in a total count of 41 themes in **Table 5.3**, 34 out of which are identified with two or lesser observations (26 themes with merely one observation). This means the remaining seven themes correspond to three or more observations each. The nature of complexity is interpreted in the analysis in terms of the mode of this connection between the observations and the themes, which should indicate a greater complexity with a bigger cluster size of the observations corresponding to a given theme. It is based on this measure that the core of the nature of complexity that sustainability science needs to embrace is revealed, being another dimension of the integrative structure of its discourse.

Out of the seven prominent themes in **Table 5.3**, the biggest cluster size of observations is found with 'inter-/multi-/trans-disciplinarity of sustainability science research', followed by the themes of 'ontology and/or epistemology of sustainability science' and 'complex systems, analysis, and adaptive planning/management' to represent the two subsequent cluster sizes (with 11 and eight observations, respectively). The four other themes containing a minimum of three observations in each are 'sustainability challenge' and 'quantitative sustainability' (with five observations in each), 'sustainable development strategies/innovation' (with four observations), and 'natural capital & ecosystem services management/governance' (with three observations). The observations corresponding to these seven prominent themes are found to correspond to the majority (22 out of 27) of the facets present within the general themes of 1, 2, 4, 5 and 6 in FA-I.

These general themes in FA-I are: ‘sustainability challenge’, ‘nature of sustainability science’, ‘research system in sustainability science’, ‘disciplinarity of sustainability science’, and the ‘knowledge-action link in sustainability science’. The remaining two general themes (3 and 7) in constructing the theoretical structure of sustainability science in FA-I represent the ‘dimensions of sustainability science’ and ‘education in sustainability science’, which comprise the peripheral considerations in the theoretical structure as these do not directly address the theoretical core of sustainability science. These two general themes correspond to some extent with the observations under the seven prominent themes in FA-III. Therefore, the observations under the seven prominent themes in FA-III correspond to the general themes of 1, 2, 4, 5 and 6 in FA-I and represent the core of the theoretical structure projected on sustainability science, as well as revealing the challenges of the discourse with the highest degrees of complexity.

Analyzing the sustainability science practices in global sustainability is the fourth and final focus revealing the integrative structure of the discourse. FA-IV is conducted in a similar manner as FA-III, i.e. through comparing the observations (on global sustainability) against the corresponding themes on sustainability science research, plus an additional analysis on the type of the relations between the themes and the observations. The ‘theme to observation relation’ reveals three relation types: ‘direct’, ‘thematic’, and ‘application’, where a direct relation from a theme to an observation refers to the direct reflection of the content of the theme into the observation with specific details i.e. the reiteration of the content of the theme with specifics; while a thematic relation refers to an indirect relation between the theme and the observation, with the observation reflecting somewhat different content within the scope of the theme. An application-type relation refers to some application of the content of the theme reflected in the observation. Similar to FA-III, FA-IV also utilizes the definition of corresponding to a minimum of three or more observations for a theme to be considered as prominent.

Table 5.4 presents a list of 14 themes corresponding to the FA-IV observations on global sustainability, where only four themes appear as prominent (the biggest cluster size with eight observations and the remaining three with three observations in each). ‘Sustainability challenge’ is the theme with the biggest cluster size of eight observations, where five of the observations display direct-type relation to the theme and the remaining three producing a thematic relation. Such pronounced presence of the theme ‘sustainability challenge’ in the analysis inform that the practices on global sustainability are still largely at the outset of appreciating the ‘sustainability challenge’ for the globe, where the concept of global sustainability is already implicated with the trans-boundary nature of problems and the North-South divided perspectives on sustainability, imparting intellectual obscurity as well as serving to catalyze splits in political motivations.

The three subsequent prominent themes in **Table 5.4** are ‘Anthropocene and Earth stewardship’, ‘ontology and/or epistemology of sustainability science’, and ‘natural capital & ecosystem services management/governance’. In terms of the ‘theme to observation relation’ the theme ‘ontology and/or epistemology of sustainability science’ appearing without any direct-type relation with its three corresponding observations—instead appearing in thematic-type ‘theme to observation relations’—indicates on the scopes of ontological/ epistemological studies holding potential for global sustainability. On the other hand, the direct-type ‘theme to observation relation’ on all three observations for the theme ‘natural capital & ecosystem services management/governance’ reveals a high priority for the governance/ management of global natural capital and ecosystem services. In **Table 5.4** the occurrence of direct-type ‘theme to observation relation’ for approximately 68% of the observations reveal some degree of clarity on sustainability science practices regarding global sustainability, whereas the occurrence of a thematic-type relation in approximately 26% of the observations also communicates the scope of thematic projections required for the practice.

5.5.1 Intermediary summary discussion

The discussion on the findings could be summarized into an intermediary summary discussion of four paragraphs—each discussing one of the four focus analyses—in order to facilitate the logical progression on arriving at the ‘summary strong and weak aspects’ of the integrative structure of sustainability science, in **Section 5.5.2**.

[1] The integrative structure of the discourse of sustainability science refers to the abstract qualities of the discourse in terms of the ways sustainability science tries to tackle integrative concepts. The first focus (FA-I) to project on these abstract qualities of the discourse embarks onto revealing if the ‘philosophical, theoretical and methodological’ avenues that underlie the sustainability science research could be taken to produce an intellectually complete and continuous theoretical structure. A collection of 91 seemingly disparate observations on the underlying ‘philosophical, theoretical and methodological’

avenues extracted from the literature map does have the potential to construct an intellectually complete and continuous theoretical structure based on seven consecutive general themes of ‘sustainability challenge’, ‘nature of sustainability science’, ‘the dimensions of sustainability science’, ‘research system in sustainability science’, ‘disciplinarity of sustainability science’, ‘the knowledge-action link’, and ‘education in sustainability science’. This communicates a potential strong aspect in the integrative structure of sustainability science although the practice needs to respond to these theoretical necessities in order to truly contribute into the intellectual treatment of sustainability.

[2] The subsequent aspect for analyzing the integrative structure (FA-II) is in terms of the manners the practice characterizes the ‘human-environment system’. The concept of ‘human-environment system’ being used in 86 different types where the use of 87% of these various types occurring for only once in the literature map reveals an extremely open-ended representation of the concept in sustainability science research. The pattern becomes strengthened with a similar reality prevailing across the environmental, social and economic perspectives of sustainability. Although such a reality reveals the great complexity that the ‘human-environment’ system presents, the lack of precision in the characterization of the concept along with the extremely open-ended representation does not reveal a satisfactory integrative structure.

[3] An analysis in terms of the complexity that sustainability science needs to embrace (FA-III) reveals seven themes implicated with the greatest complexity, which are ‘inter-/multi-/trans-disciplinarity of sustainability science research’, ‘ontology and/or epistemology of sustainability science’, ‘complex systems, analysis, and adaptive planning/management’, ‘sustainability challenge’, ‘quantitative sustainability’, ‘sustainable development strategies/innovation’, and ‘natural capital & ecosystem services management/governance’ in their decreasing order of complexity. The observations under these seven themes corresponding to the general themes of – ‘sustainability challenge’, ‘nature of sustainability science’, ‘research system in sustainability science’, ‘disciplinarity of sustainability science’, and ‘the knowledge-action link’ as displayed under the FA-I represent the core of the theoretical structure projected on sustainability science, as the remaining two general themes under the FA-I—i.e. ‘the dimensions of sustainability science’ and ‘education in sustainability science’—comprise the peripheral considerations in the theoretical structure. The strong correlation

between the core of the projected theoretical structure for sustainability science and the challenges of the discourse with the highest degrees of complexity communicate another strong aspect of the integrative structure of the discourse.

[4] The fourth and final focus on analyzing the integrative structure is in terms of the sustainability science practices on global sustainability. The theme 'sustainability challenge' appearing as the most prominent theme with the biggest cluster size of observations with mostly direct-type 'theme to observation' relations inform that the practices on global sustainability are still largely at the outset of appreciating the 'sustainability challenge' for the globe. The subsequent observations under this analysis indicate on the scopes of ontological/ epistemological studies in sustainability science to hold potential for global sustainability, while on the whole the 68% direct-type 'theme to observation' relations reveal some degree of clarity on the sustainability science practices on global sustainability.

5.5.2 Summary on the strong and weak aspects of the integrative structure

Following are the strong aspects of the discourse under the integrative structure:

1. The underlying 'philosophical, theoretical and methodological' avenues of the sustainability science research do contain the maturity of projecting an intellectually complete and continuous theoretical structure, although the practice needs to respond to these theoretical necessities in order to truly contribute into the intellectual treatment of sustainability.
2. The researches reveal a strong correlation between the core of the projected theoretical structure and the challenges of the discourse with the highest degrees of complexity, revealing an alignment of the challenges of the discourse with its potential theoretical structure. This aspect is in terms of truly appreciating the challenges that the discourse would be required to address satisfactorily.

In contrast to these strong aspects, the weak aspects of the integrative structure of sustainability science include:

1. A lack of precision in characterizing the concept of 'human-environment system' along with an extremely open-ended representation of the concept, and

2. A lack in clarity in addressing the aspect of global sustainability, while the practices of the discourse on global sustainability still largely being at the outset of appreciating the sustainability challenge for the globe.

Chapter 6

Sustainability Science: the structure of practice

In elucidating the basic structures of the discourse of sustainability science based on its first decade's 'body of work', a 'place/ scale-based' analysis in this chapter reveals the spatio-temporal dimensions of the discourse in terms of the temporal, spatial and dynamic variations apparent in the practice. Although the term 'place/ scale-based analysis' denotes the two aspects of 'place' and 'scale', an additional temporal dimension is intrinsically embedded into this. Together, these variables elucidate contextual qualities of the discourse, revealing the structure of its practice.

The chapter is composed of four sections. **Sections 6.1-6.3** analyze the scale, place and temporal dimensions of the discourse of sustainability science, respectively. Each of these analyses begins with exploring the respective dimension in the 'empirical literature analyses (ELAs) – 1, 2 and 3', and then sets out a broader analysis based on the entirety of the 'Group-A' literature archive. A discussion on the findings follows in **Section 6.4**.

As exemplified in **Section 4.2**, the scale analysis is conducted based on six different scales:

(1) the 'local' scale refers to a part of a country rather than the entire country;
(2) the 'country' scale concerns the nation state;
(3) the 'regional' scale involves more than a country either within the same continent or across different continents;
(4) the 'continent' scale concerns the entirety of a continent;
(5) the 'global' scale is self-explanatory, and
(6) the absence of any scale i.e. a study not having any associated scale characteristic.

In the place analysis the 'place' characteristic is regarded in the same manner as 'place' is used in **Section 4.2**, i.e. both in terms of 'the place the research is concerned with' as well as 'the place of authorship (of the corresponding author)'. The detail scale, place and temporal observations appear in **Appendix-10**, based on which the results are synthesized in **Sections 6.1-6.3**.

6.1 Scale analysis

The scale characteristics of 'ELAs – 1, 2 and 3' across the four broad spheres (i.e. the broad spheres of A, B, C and D) and the three different categories (i.e. categories – i, ii and iii) are summarized in **Tables 6.1**, **6.2** and **6.3**, respectively.

Table 6.1 Scale characteristics of ELA–1

Broad spheres	Scale	Count of items in ELA-1 literature map			
		Category-i	*Category-ii*	*Category-iii*	Total
A	-	2	6	7	15
	Local	2	4	-	6
	Country	1	4	1	6
	Regional	-	1	-	1
	Continent	1	-	-	1
	Global	3	3	-	6
	Total	***9***	***18***	***8***	***35***
B	-	5	5	11	21
	Local	4	12	4	20
	Country	2	5	5	12
	Regional	3	2	2	7
	Continent	1	2	-	3
	Global	14	12	3	29
	Total	***29***	***38***	***25***	***92***
C	-	5	19	9	33
	Local	3	11	4	18
	Country	2	2	2	6
	Regional	3	5	-	8
	Continent	-	-	-	0
	Global	11	6	1	18
	Total	***24***	***43***	***16***	***83***
D	-	-	7	27	34
	Local	-	2	3	5
	Country	-	-	-	0
	Regional	1	1	2	4
	Continent	1	-	1	2
	Global	1	2	12	15
	Total	***3***	***12***	***45***	***60***
Overall	-	12	37	54	103
	Local	9	29	11	49
	Country	5	11	8	24
	Regional	7	9	4	20
	Continent	3	2	1	6
	Global	29	23	16	68
	Total	***65***	***111***	***94***	***270***

Table 6.2 Scale characteristics of ELA–2

Broad spheres	Scale	Count of items in ELA-2 literature map			
		Category-i	*Category-ii*	*Category-iii*	Total
A	-	2	1	-	3
	Local	-	2	-	2
	Country	-	1	-	1
	Regional	-	-	-	0
	Continent	1	-	-	1
	Global	2	-	-	2
	Total	***5***	***4***	***0***	***9***
B	-	2	3	2	7
	Local	2	1	3	6
	Country	1	1	1	3
	Regional	-	1	1	2
	Continent	-	1	-	1
	Global	7	1	2	10
	Total	***12***	***8***	***9***	***29***
C	-	2	14	4	20
	Local	2	9	7	18
	Country	-	2	-	2
	Regional	1	5	-	6
	Continent	-	-	-	0
	Global	10	5	2	17
	Total	***15***	***35***	***13***	***63***
D	-	-	3	6	9
	Local	-	1	1	2
	Country	-	-	-	0
	Regional	1	-	1	2
	Continent	-	-	-	0
	Global	1	1	4	6
	Total	***2***	***5***	***12***	***19***
Overall	-	6	21	12	39
	Local	4	13	11	28
	Country	1	4	1	6
	Regional	2	6	2	10
	Continent	1	1	-	2
	Global	20	7	8	35
	Total	***34***	***52***	***34***	***120***

Table 6.3 Scale characteristics of ELA–3

Broad spheres	Scale	Count of items in ELA-3 literature map			
		Category-i	*Category-ii*	*Category-iii*	Total
A	-	1	3	-	4
	Local	1	-	1	2
	Country	1	2	-	3
	Regional	1	-	-	1
	Continent	-	-	-	0
	Global	-	-	-	0
	Total	***4***	***5***	***1***	***10***
B	-	1	1	4	6
	Local	1	4	3	8
	Country	1	1	5	7
	Regional	1	1	1	3
	Continent	-	1	-	1
	Global	3	2	1	6
	Total	***7***	***10***	***14***	***31***
C	-	4	7	3	14
	Local	1	3	1	5
	Country	3	1	1	5
	Regional	2	2	-	4
	Continent	-	-	-	0
	Global	4	2	-	6
	Total	***14***	***15***	***5***	***34***
D	-	-	2	8	10
	Local	-	-	3	3
	Country	-	-	-	0
	Regional	-	-	1	1
	Continent	-	-	1	1
	Global	-	1	3	4
	Total	***0***	***3***	***16***	***19***
Overall	-	6	13	15	34
	Local	3	7	8	18
	Country	5	4	6	15
	Regional	4	3	2	9
	Continent	-	1	1	2
	Global	7	5	4	16
	Total	***25***	***33***	***36***	***94***

A comparison of the article counts corresponding to each of the five different scales (local, country, regional, continent, and global) against the total count of articles that are devoid of any scale-place characteristic produce a mix of findings. Comparing the count of articles for any given scale, in the broad spheres of A, C and D the highest counts of articles in the three ELAs do not have any scale-place characteristic. Only in the broad sphere B, the count of articles corresponding to the global scale in the ELAs – 1 and 2, and the article count corresponding to the local scale for ELA-3 outnumber the count of articles devoid of any scale-place characteristic. This renders a significant count of sustainability science articles being produced without any scale-place characteristic, which is contrary to the desired characteristic of the practice in terms of ‘connecting to the different scales of given places’ in conducting research.

Taking the article counts corresponding to the five different scales altogether (i.e. the local, country, regional, continent, and global scales combined) against the count of articles devoid of any scale-place characteristic, as association with any of the five different scales for a given article would serve the purpose of ‘connecting to the different scales of given places’. **Table 6.4** summarizes this comparison, which reveals a steady pattern across all three ELAs. In **Table 6.4** the broad spheres of A and C exhibit similar pattern, whereas the other two broad spheres (B and D) reveal two dissimilar patterns. However, all these respective patterns are steadily maintained across the ELAs. The highest percentage of articles with scale characteristic is observed in the social perspectives of sustainability (i.e. the broad sphere B) across all three ELAs (77.8% averaged), whereas the lowest percentage is exhibited from the broad sphere D (i.e. the central organization of sustainability) across the three ELAs (47.7% averaged). The economic and environmental perspectives of sustainability reveal closely similar trends (with averaged 61.2% and 62.4% counts for broad spheres of A and C, respectively). Overall, an averaged 64.4% of the articles do contain scale-place characteristics. However, this also renders the count of articles devoid of any scale-place characteristic remaining significant.

Table 6.4 Summary of scale characteristic of articles in ELAs – 1, 2 and 3

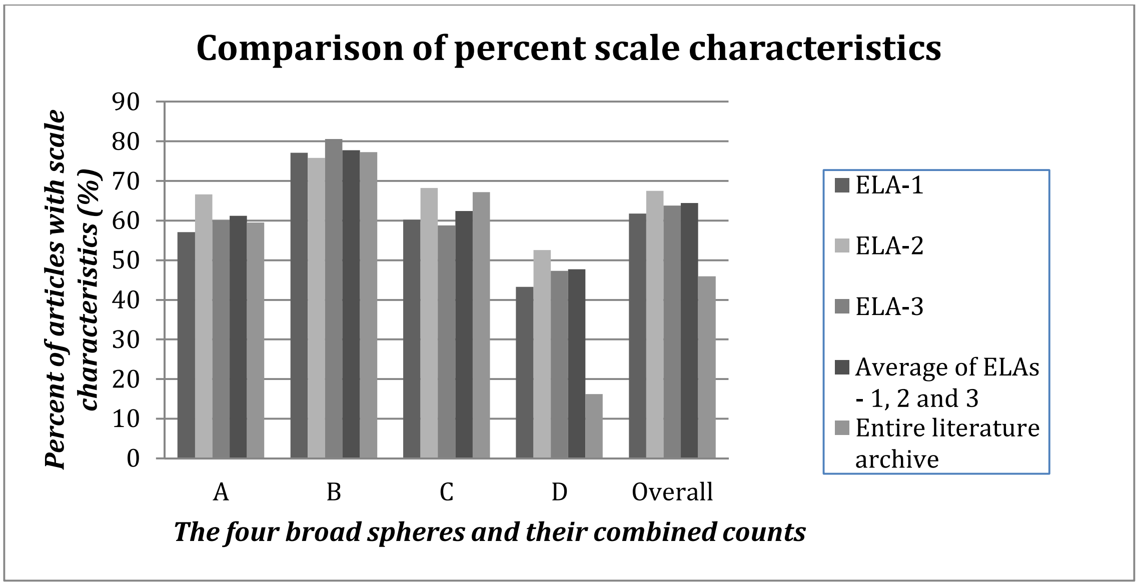
Broad spheres	**ELA-1 with scale (%)**	**ELA-2 with scale (%)**	**ELA-3 with scale (%)**	**Average (%)**	***SD***
A	57.1	66.6	60	61.2	*4.9*
B	77.1	75.8	80.6	77.8	*2.5*
C	60.2	68.2	58.8	62.4	*5.1*
D	43.3	52.6	47.3	47.7	*4.7*
Overall	61.8	67.5	63.8	64.4	*2.9*

Coming to the scale characteristic of the entire literature archive (presented in **Table 6.5**), the projected trends become somewhat different from the combined results of the 'ELAs – 1, 2 and 3' (summarized in **Table 6.4**). The data on the broad spheres of A, B and C based on the entire literature archive—which are 59.5%, 77.3% and 67.2%, respectively—are similar to the combined results of the 'ELAs – 1, 2 and 3' (see **Table 6.4**) for the respective broad spheres. However, in the sphere D the data based on the entire literature archive becomes significantly low—a mere 16.2%—compared to the combined results of ELAs – 1, 2 and 3 on sphere D (which is 47.7%, **Table 6.4**). This can be explained by the presence of a great number of articles produced to articulate what sustainability science is or should/ could be, which do not necessarily contain scale-place characteristic. Should the sphere D be disregarded, the data based on the entire literature archive on the rest of the three broad spheres are in agreement with the results from the three ELAs. Furthermore, it is the participation of the sphere D into the overall picture in **Table 6.5** that serves to skew the overall percentage to reduce to merely 45.9%, whereas it is as high as 64.4% for the three ELAs averaged (see **Table 6.4**). This influence of the sphere D on the overall scenario is graphically presented in **Figure 6.1**.

Table 6.5: Scale characteristics of the entire literature archive

Broad spheres	Scale	Number of items in 'Group-A' literature archive			
		Category-i	***Category-ii***	***Category-iii***	**Total**
A	-	3	7	7	17
	Local	2	6	-	8
	Country	1	6	1	8
	Regional	1	1	-	2
	Continent	1	-	-	1
	Global	3	3	-	6
	Total	***11***	***23***	***8***	***42***
B	-	6	6	12	24
	Local	4	13	5	22
	Country	3	6	6	15
	Regional	3	2	3	8
	Continent	1	2	-	3
	Global	14	12	8	34
	Total	***31***	***41***	***34***	***106***
C	-	5	20	10	35
	Local	5	13	7	25
	Country	3	3	3	9
	Regional	3	8	-	11
	Continent	-	-	-	0
	Global	14	7	6	27
	Total	***30***	***51***	***26***	***107***
D	-	-	10	165	175
	Local	-	2	3	5
	Country	-	-	3	3
	Regional	1	1	3	5
	Continent	1	-	3	4
	Global	1	3	13	17
	Total	***3***	***16***	***190***	***209***
Overall	-	14	43	194	251
	Local	11	34	15	60
	Country	7	15	13	35
	Regional	8	12	6	26
	Continent	3	2	3	8
	Global	32	25	27	84
	Total	***75***	***131***	***258***	***464***

Figure 6.1 Comparison of percent scale characteristics



6.2 Place analysis

The place characteristics for the 'ELAs – 1, 2 and 3' as well as for the entire literature archive across the three different categories are summarized in **Tables 6.6**, **6.7**, **6.8**, and **6.9**, respectively. The descriptor 'PoA(CA)' in these tables stands for 'place of authorship (corresponding author)', which refers to the place characteristic of the articles in terms of the place of authorship of the corresponding author, in contrast to the other convention for place characteristic that refers to the place that a given research is concerned with, and therefore, described in the tables with the mere descriptor 'Place'. A cross-comparison between these 'place' and 'place of authorship' characteristics is also embarked on in **Table 6.10**. The **Tables 6.6-6.10** reveal the following group characteristics, where a cluster of articles is meant to refer to the article collection of a given ELA or the entire literature archive.

1. All three ELAs as well as the entire literature archive reveal a great variety of places both in terms of the places the articles are concerned with as well as the places of authorship by the corresponding authors. Considering three or more articles referring to a given place to be a pronounced presence in the mosaic of the variety of places, there are only 8 countries out of a total 32 counties and 13 countries out of a total 39 countries appearing as pronounced in ELA-1 for the 'place' and 'the place of authorship' characteristics, respectively. A similar pattern is reflected throughout the three other clusters—i.e. for the ELA-2, ELA-3, and the entire literature archive—with 4 (out of 21), 5 (out of 17) and 9 (out of 35) countries appearing as pronounced in the place characteristic, while in the place of authorship characteristic it is 8 (out of 26), 5 (out of 23) and 18 (out of 42) countries, respectively.

2. In terms of the count of articles corresponding to a given place (e.g. an individual continent or country), the count of articles with global characteristics are found to be the highest in all article clusters. This reveals an importance on the global aspect of sustainability, although the count of articles corresponding to all countries altogether outnumbers the count with global characteristic for any of the clusters. It is also worth noticing that the count of articles with global characteristic also outnumbers the article counts corresponding to all continents taken together, in all four article clusters.

3. The common ‘place characteristics’—i.e. the characteristics that are common throughout all four clusters of articles—both in terms of ‘the place a given research is concerned with’ as well as ‘the place of authorship of the article’, produce interesting findings.

   i. The common ‘place characteristic’ in terms of the continents (corresponded to in the articles) reveals Asia as the most pronounced. Africa has appeared as the second most pronounced after Asia in the ELAs – 1 and 2, whereas it becomes Europe for the ELA-3. For the entire literature archive this appears in the sequence of Asia, Africa and Europe.

   ii. The common ‘place characteristic’ in terms of the countries (corresponded to in the articles) reveals China, Japan and USA as pronounced (i.e. corresponding to at least three or more article counts). For the entire literature archive these three countries appear as equally pronounced (i.e. with same article counts), while with varying counts for the three ELAs.

   iii. The common ‘place characteristic’ in terms of the places of authorship reveals in the order of USA, Japan, UK and Germany as pronounced, although the appearance of USA greatly outnumbers the other three countries.

4. In terms of the ‘pronounced place characteristics’ that are not common ‘place characteristics’ (i.e. the pronounced places that are not uniform across all four article clusters), the analysis reveals the following countries (in place characteristic) for the entire literature archive: India, Australia, Malaysia, Nigeria, Tanzania and Brazil. In terms of the ‘place of authorship characteristic’ this includes the countries of Canada, Australia, Netherlands, Sweden, Austria, France, Italy, China, Belgium, Switzerland, Spain, Kenya, Norway and India.

5. All other countries appearing in the ‘place’ or ‘place of authorship’ characteristics in any of the four article clusters correspond to merely one or two articles each, with 24 and 26 countries for the ELA-1 (out of a total of 32 and 39 countries), 17 and 18 countries for the ELA-2 (out of a total of 21 and 26 countries), 12 and 18 countries for the ELA-3 (out of a total of 17 and 23 countries), and 26 and 24 countries for the entire literature archive (out of a total of 35 and 42 countries), respectively. This reveals a dominantly distributive nature for both of the ‘place’ and the ‘place of authorship’ characteristics.

6. As observed in **Table 6.10**, with an increase in the article cluster size, a steady increase takes place in the counts of articles per place, both in terms of the ‘place’ and the ‘place of authorship’ characteristics. For example, from the ELA-3 to the ELA-2 to the ELA-1 to ‘the entire literature archive’, the cluster size increases from 94 to 120 to 270 and to 464 archive items, with the corresponding counts of articles per place steadily increasing from 5.53 to 5.71 to 8.44 and to 13.26, respectively. In a similar manner the counts of articles per ‘place of authorship’ also steadily increases from 4.09 to 4.61 to 6.92 and to 11.05, respectively. This reveals a steady trend of saturation of the ‘place characteristic’ with an increase in the counts of studies conducted. This steady trend of saturation is also reflected in the factor for ‘place’ to ‘place of authorship’ characteristics with a steady decrease from 1.35 for the ELA-3 to 1.24 for the ELA-2 to 1.22 for the ELA-1 (averaged 1.27 across the ELAs), and to 1.20 for the entire literature archive.

Table 6.6 Place characteristics of ELA–1

Place	Count of items in ELA-1 literature map			
	Category-i	Category-ii	Category-iii	*Total*
N/A	12	37	54	***103***
Global	29	23	16	***68***
Asia	6	5	5	***16***
Africa	4	3	1	***8***
Europe	-	2	-	***2***
North America	-	2	-	***2***
South America	-	1	-	***1***
Total	***10***	***13***	***6***	***29***
China	2	5	5	***12***
India	1	7	1	***9***
USA	4	2	2	***8***
Japan	1	2	-	***3***
Malaysia	-	1	2	***3***
Nigeria	-	3	-	***3***
Tanzania	-	2	1	***3***
Brazil	-	2	1	***3***
Australia	-	2	-	***2***
Iran	1	1	-	***2***
Bangladesh	-	2	-	***2***
Senegal	-	2	-	***2***
Malawi	-	1	1	***2***

PoA (CA)	Count of items in ELA-1 literature map			
	Category-i	Category-ii	Category-iii	*Total*
USA	28	53	39	***120***
Japan	11	15	5	***31***
UK	6	5	12	***23***
Canada	5	3	4	***12***
Germany	2	4	5	***11***
Netherlands	1	4	2	***7***
Australia	1	3	3	***7***
China	1	3	2	***6***
Belgium	1	1	2	***4***
Kenya	-	3	1	***4***
Austria	-	2	1	***3***
Switzerland	1	1	1	***3***
Spain	-	1	2	***3***
France	1	1	-	***2***
Italy	1	1	-	***2***
Sweden	-	-	2	***2***
New Zealand	-	-	2	***2***
Thailand	1	1	-	***2***
India	-	2	-	***2***
Malaysia	-	-	2	***2***
Sri Lanka	-	-	2	***2***
Mexico	1	1	-	***2***
Cameroon	-	1	1	***2***
Denmark	-	-	1	***1***

Place	Count of items in ELA-1 literature map			
	Category-i	Category-ii	Category-iii	*Total*
Indonesia	1	-	-	***1***
Cambodia	1	-	-	***1***
Myanmar	1	-	-	***1***
Taiwan	1	-	-	***1***
Iraq	-	1	-	***1***
Thailand	-	1	-	***1***
Philippine	-	1	-	***1***
Uganda	-	-	1	***1***
Kenya	1	-	-	***1***
Ethiopia	-	1	-	***1***
Mozambique	-	-	1	***1***
Honduras	-	1	-	***1***
UK	-	1	-	***1***
Sweden	-	1	-	***1***
France	-	1	-	***1***
Scotland	-	1	-	***1***
Spain	-	-	1	***1***
Mexico	-	-	2	***2***
Cameroon	-	-	1	***1***
Total	***14***	***41***	***19***	***74***

PoA (CA)	Count of items in ELA-1 literature map			
	Category-i	Category-ii	Category-iii	*Total*
Norway	1	-	-	***1***
Finland	-	-	1	***1***
Serbia	-	1	-	***1***
Philippines	1	-	-	***1***
Iran	1	-	-	***1***
Singapore	-	-	1	***1***
South Africa	-	-	1	***1***
Tanzania	-	1	-	***1***
Nigeria	-	1	-	***1***
Senegal	-	1	-	***1***
Ethiopia	-	1	-	***1***
Malawi	-	-	1	***1***
Brazil	-	1	-	***1***
Zimbabwe	-	-	1	***1***
Global	1	-	-	***1***
Total	***65***	***111***	***94***	***270***

Table 6.7 Place characteristics of ELA–2

Place	Count of items in ELA-2 literature map			
	Category-i	Category-ii	Category-iii	*Total*
N/A	6	21	12	***39***
Global	20	7	8	***35***
Asia	1	3	2	***6***
Africa	2	2	1	***5***
Europe				
North America	-	1	-	***1***
South America	-	1	-	***1***
Total	***3***	***7***	***3***	***13***
China	-	4	2	***6***
Japan	-	2	2	***4***
USA	2	-	1	***3***
Brazil	-	2	1	***3***
India	-	1	1	***2***
Iran	1	1	-	***2***
Senegal	-	2	-	***2***
Canada	1	-	-	***1***
Italy	-	-	1	***1***
Australia	-	1	-	***1***
Thailand	-	1	-	***1***
Philippine	-	1	-	***1***
Malaysia	-	-	1	***1***

PoA (CA)	Count of items in ELA-2 literature map			
	Category-i	Category-ii	Category-iii	*Total*
USA	17	21	16	***54***
Japan	3	8	2	***13***
UK	4	1	4	***9***
Canada	2	2	1	***5***
Germany	1	2	1	***4***
China	-	3	1	***4***
Belgium	1	1	1	***3***
Kenya	-	2	1	***3***
Mexico	1	1	-	***2***
Netherlands	1	1	-	***2***
Italy	-	1	1	***2***
Australia	-	2	-	***2***
India	-	2	-	***2***
Brazil	-	1	1	***2***
Cameroon	-	1	1	***2***
Austria	-	-	1	***1***
France	1	-	-	***1***
Norway	1	-	-	***1***
Thailand	-	1	-	***1***
Malaysia	-	-	1	***1***
Sri Lanka	-	-	1	***1***
Iran	1	-	-	***1***
Senegal	-	1	-	***1***
Ethiopia	-	1	-	***1***

Place	Count of items in ELA-2 literature map			
	Category-i	Category-ii	Category-iii	*Total*
Nigeria	-	1	-	***1***
Tanzania	-	-	1	***1***
Malawi	-	1	-	***1***
Kenya	1	-	-	***1***
Ethiopia	-	1	-	***1***
Honduras	-	1	-	***1***
Mexico	-	-	1	***1***
Cameroon	-	-	1	***1***
Total	***5***	***19***	***12***	***36***

PoA (CA)	Count of items in ELA-2 literature map			
	Category-i	Category-ii	Category-iii	*Total*
Zimbabwe	-	-	1	***1***
Global	1	-	-	***1***
Total	***34***	***52***	***34***	***120***

Table 6.8 Place characteristics of ELA–3

Place	Count of items in ELA-3 literature map			
	Category-i	Category-ii	Category-iii	*Total*
N/A	6	13	16	***35***
Global	7	5	4	***16***
Asia	4	2	3	***9***
Africa	-	1	-	***1***
Europe	-	3	-	***3***
North America				
South America				
Total	***4***	***6***	***3***	***13***
USA	1	1	3	***5***
Japan	1	4	-	***5***
China	1	-	3	***4***
Australia	1	1	1	***3***
India	-	2	1	***3***
Scotland	-	1	-	***1***
Spain	-	-	1	***1***
Malaysia	-	-	1	***1***
Thailand	-	1	-	***1***
Iran	1	-	-	***1***
Iraq	-	1	-	***1***
Cambodia	1	-	-	***1***
Taiwan	1	-	-	***1***

PoA (CA)	Count of items in ELA-3 literature map			
	Category-i	Category-ii	Category-iii	*Total*
USA	10	11	13	***34***
Japan	5	8	2	***15***
UK	1	2	6	***9***
Germany	1	3	3	***7***
Australia	2	2	2	***6***
Canada	-	1	1	***2***
Spain	-	-	2	***2***
France	2	-	-	***2***
China	1	-	1	***2***
Kenya	-	2	-	***2***
Netherlands	-	1	-	***1***
Austria	-	1	-	***1***
Switzerland	-	1	-	***1***
Italy	1	-	-	***1***
Serbia	-	1	-	***1***
New Zealand	-	-	1	***1***
Malaysia	-	-	1	***1***
Rep. Korea	1	-	-	***1***
Sri Lanka	-	-	1	***1***
Iran	1	-	-	***1***
Singapore	-	-	1	***1***
South Africa	-	-	1	***1***
Malawi	-	-	1	***1***
Total	***25***	***33***	***36***	***94***

Place	Count of items in ELA-3 literature map			
	Category-i	Category-ii	Category-iii	*Total*
Tanzania	-	-	1	***1***
Malawi	-	-	1	***1***
Uganda	-	-	1	***1***
Fiji	1	-	-	***1***
Total	***8***	***11***	***13***	***32***

PoA (CA)	Count of items in ELA-3 literature map			
	Category-i	Category-ii	Category-iii	*Total*

Table 6.9 Place characteristics of the entire literature archive

Place	Count of items in 'Group-A' literature archive			
	Category-i	**Category-ii**	**Category-iii**	***Total***
N/A	14	43	194	***251***
Global	32	25	27	***84***
Asia	7	7	5	***19***
Africa	4	3	1	***8***
Europe	-	3	3	***6***
North America	-	2	1	***3***
South America	-	1	1	***2***
Total	***11***	***16***	***11***	***38***
China	2	5	6	***13***
USA	4	4	5	***13***
Japan	1	9	3	***13***
India	1	7	1	***9***
Australia	1	2	1	***4***
Malaysia	-	1	2	***3***
Nigeria	-	3	-	***3***
Tanzania	-	2	1	***3***
Brazil	-	2	1	***3***
Iran	1	1	-	***2***
Bangladesh	-	2	-	***2***

PoA (CA)	Count of items in 'Group-A' literature archive			
	Category-i	**Category-ii**	**Category-iii**	***Total***
USA	31	59	115	***205***
Japan	12	24	21	***57***
UK	6	6	25	***37***
Germany	2	6	16	***24***
Canada	6	3	9	***18***
Australia	3	4	9	***16***
Netherlands	1	4	7	***12***
Sweden	-	-	12	***12***
Austria	-	2	4	***6***
France	2	1	3	***6***
Italy	1	1	4	***6***
China	1	3	2	***6***
Belgium	1	1	3	***5***
Switzerland	1	1	3	***5***
Spain	-	1	4	***5***
Kenya	-	3	1	***4***
Norway	1	-	2	***3***
India	-	3	-	***3***
Finland	-	-	2	***2***
New Zealand	-	-	2	***2***
Thailand	1	1	-	***2***
Rep. Korea	1	-	1	***2***

Place	Count of items in 'Group-A' literature archive			
	Category-i	Category-ii	Category-iii	*Total*
Senegal	-	2	-	***2***
Malawi	-	1	1	***2***
Mexico	-	-	2	***2***
Indonesia	1	-	-	***1***
Cambodia	1	-	-	***1***
Myanmar	1	-	-	***1***
Taiwan	1	-	-	***1***
Iraq	-	1	-	***1***
Thailand	-	1	-	***1***
Philippine	-	1	-	***1***
South Africa	1	-	-	***1***
Uganda	-	-	1	***1***
Kenya	1	-	-	***1***
Ethiopia	-	1	-	***1***
Mozambique	-	-	1	***1***
Honduras	-	1	-	***1***
UK	-	1	-	***1***
Sweden	-	1	-	***1***
France	-	1	-	***1***
Scotland	-	1	-	***1***
Spain	-	-	1	***1***
Canada	1	-	-	***1***
Cameroon	-	-	1	***1***
Fiji	1	-	-	***1***
Total	***18***	***50***	***27***	***95***

PoA (CA)	Count of items in 'Group-A' literature archive			
	Category-i	Category-ii	Category-iii	*Total*
Malaysia	-	-	2	***2***
Sri Lanka	-	-	2	***2***
South Africa	1	-	1	***2***
Mexico	1	1	-	***2***
Cameroon	-	1	1	***2***
Brazil	-	1	1	***2***
Denmark	-	-	1	***1***
Serbia	-	1	-	***1***
Philippines	1	-	-	***1***
Iran	1	-	-	***1***
Singapore	-	-	1	***1***
Tanzania	-	1	-	***1***
Nigeria	-	1	-	***1***
Senegal	-	1	-	***1***
Ethiopia	-	1	-	***1***
Malawi	-	-	1	***1***
Zimbabwe	-	-	1	***1***
Chile	-	-	1	***1***
Colombia	-	-	1	***1***
Global	1	-	-	***1***
Total	***75***	***131***	***258***	***464***

Table 6.10 ‘Place’ versus ‘place of authorship’ characteristics

Cluster of articles	Cluster size	Count of PoA (country)	Count of articles per PoA	Count of places (country)	Count of articles per place	Factor of Place/PoA
ELA-1	270	39	6.92	32	8.44	1.22
ELA-2	120	26	4.61	21	5.71	1.24
ELA-3	94	23	4.09	17	5.53	1.35
Entire literature archive	464	42	11.05	35	13.26	1.2

6.3 Temporal analysis

The temporal characteristics of the 'ELAs – 1, 2 and 3' and of the entire literature archive across the three different categories are summarized in **Tables 6.11**, **6.12**, **6.13** and **6.14**, respectively. The **Figures 6.2**, **6.3** and **6.4** are drawn with the findings extracted from these tables in order to reveal the general temporal characteristics.

In processing the findings from the temporal analysis it is convenient to divide the temporal dimension into two distinct periods, one preceding the birth of sustainability science and the other after it. The year 2002 has been found to be the point in time separating these two periods. Although officially the birth of sustainability science is to be attributed to the year 2001 (Kates et al. 2001), the year 2002 appearing to be the dividing line could be explained by a lag period of one year for the new awareness to traverse through, besides being the period required for the completion of the studies conducted in response to the new awareness. Therefore, in this analysis the period after the birth of sustainability science is referred to as 2003–2012, whereas all the preceding years till 2002 together reflecting the period before the birth of sustainability science.

The analysis on the temporal characteristics for the period after the birth of sustainability science exhibits all years between 2003–2012 represented in all four article clusters (see **Figure 6.4**), whereas for the period before the birth of sustainability science they appear in fragmented forms, besides not all of the appeared years appearing in all three ELAs (see **Tables 6.11-6.14**). Therefore, in producing the **Figure 6.3** only those years that have appeared in at least two of the three ELAs are considered.

The temporal analysis reveals the following group characteristics, where a 'cluster of articles' is meant to refer to the article collection of a given ELA or the entire literature archive.

1. With regard to the periods preceding and after the birth of sustainability science, some 88.58% studies in the entire literature archive correspond to the period after the birth of sustainability science, whereas only the remainder 11.42% studies corresponding to the period before its birth. A similar trend occurring for all three ELAs (see **Figure 6.2**) confirms the majority of the studies to correspond to the period after the birth of sustainability science.

2. In **Figure 6.2**, with a decrease in cluster size, the difference between the percent counts of the articles corresponding to the periods before and after the birth of sustainability science becomes increased. For example, instead of the entire literature archive—consisting of 464 items—when a smaller cluster of 270 items (for the ELA-1) is considered, the statistic of 88.58% studies increases to 91.48% studies corresponding to the period after the birth of sustainability science. This trend continues with the ELA-2 (consisting of 120 archive items) with 92.5% studies and for the ELA-3 (consisting of 94 archive items) with 97.87% studies. It indicates that before the birth of sustainability science the researches with smaller scopes regarding sustainability science were conducted in a lesser extent compared to the ones with bigger scopes, and vice versa for the period after its birth.

3. The analysis of the period preceding the birth of sustainability science communicate a steady increase in terms of the awareness for sustainability science, peaking in the years 2000 and 2001 (see **Figure 6.3**). Following the birth of sustainability science this leads to a small peak observed in the year 2003 based on the levels in 2002, with two other larger peaks appearing around the years 2006–2007 and 2010–2011 (**Figure 6.4**). This is characteristically different from the singular nature of the peak, characterizing the period preceding the birth of sustainability science. In the period after the birth of sustainability science (2003–2012), the first peak in the year 2003 could be attributed to the aftermath of the official birth of sustainability science occurring in 2001 (Kates et al. 2001), whereas the second peak during the years 2006–2007 could be attributed to the establishment of the IR3S (Integrated Research Systems for Sustainability Science) in 2006 in Japan. The third peak during the years 2010–2011 could be attributed to a combined effort towards sustainability science globally.

Table 6.11 Temporal characteristics of ELA–1

Year	**Count of items in ELA-1 literature map**			
	Category-i	**Category-ii**	**Category-iii**	***Total***
1967	-	-	1	***1***
1968	-	-	1	***1***
1992	-	-	2	***2***
1994	-	1	1	***2***
1995	-	-	1	***1***
1996	-	-	2	***2***
1998	1	1	1	***3***
1999	-	1	1	***2***
2000	2	-	3	***5***
2001	-	-	3	***3***
2002	1	-	-	***1***
2003	5	4	5	***14***
2004	1	4	1	***6***
2005	4	3	2	***9***
2006	8	13	10	***31***
2007	6	9	10	***25***
2008	4	14	7	***25***
2009	10	13	11	***34***
2010	12	18	13	***43***
2011	9	10	14	***33***
2012	2	20	5	***27***
Total	***65***	***111***	***94***	***270***

Table 6.12 Temporal characteristics of ELA–2

Year	Count of items in ELA-2 literature map			
	Category-i	**Category-ii**	**Category-iii**	***Total***
1992	-	-	1	***1***
1996	-	-	1	***1***
1997	-	-	1	***1***
1998	1	-	-	***1***
1999	-	1	-	***1***
2000	2	-	1	***3***
2002	1	-	-	***1***
2003	3	3	2	***8***
2004	-	2	1	***3***
2005	1	2	-	***3***
2006	2	6	2	***10***
2007	1	4	4	***9***
2008	4	5	5	***14***
2009	5	7	7	***19***
2010	10	12	3	***25***
2011	2	5	5	***12***
2012	2	5	1	***8***
Total	***34***	***52***	***34***	***120***

Table 6.13 Temporal characteristics of ELA–3

Year	**Count of items in ELA-3 literature map**			
	Category-i	**Category-ii**	**Category-iii**	***Total***
2000	-	-	1	***1***
2001	-	-	1	***1***
2003	1	1	1	***3***
2004	1	1	1	***3***
2005	1	-	2	***3***
2006	5	3	5	***13***
2007	7	5	5	***17***
2008	2	9	3	***14***
2009	3	1	3	***7***
2010	3	3	3	***9***
2011	2	5	8	***15***
2012	-	5	3	***8***
Total	***25***	***33***	***36***	***94***

Table 6.14 Temporal characteristics of the entire literature archive

Year	Count of items in 'Group-A' literature archive			
	Category-i	**Category-ii**	**Category-iii**	***Total***
1967	-	-	1	***1***
1968	-	-	1	***1***
1973	-	-	1	***1***
1981	-	-	1	***1***
1983	-	-	1	***1***
1986	-	-	1	***1***
1987	-	-	1	***1***
1992	-	-	2	***2***
1993	-	-	1	***1***
1994	-	1	1	***2***
1995	-	-	1	***1***
1996	-	-	3	***3***
1997	-	-	4	***4***
1998	1	1	2	***4***
1999	-	1	5	***6***
2000	2	-	8	***10***
2001	-	-	10	***10***
2002	1	-	2	***3***
2003	5	4	19	***28***
2004	1	4	5	***10***
2005	4	3	9	***16***
2006	10	17	25	***52***
2007	11	12	36	***59***
2008	5	17	24	***46***
2009	10	17	20	***47***
2010	14	19	23	***56***
2011	9	13	36	***58***
2012	2	22	15	***39***
Total	***75***	***131***	***258***	***464***

Figure 6.2 Comparison of percent article counts preceding and after the birth of sustainability science

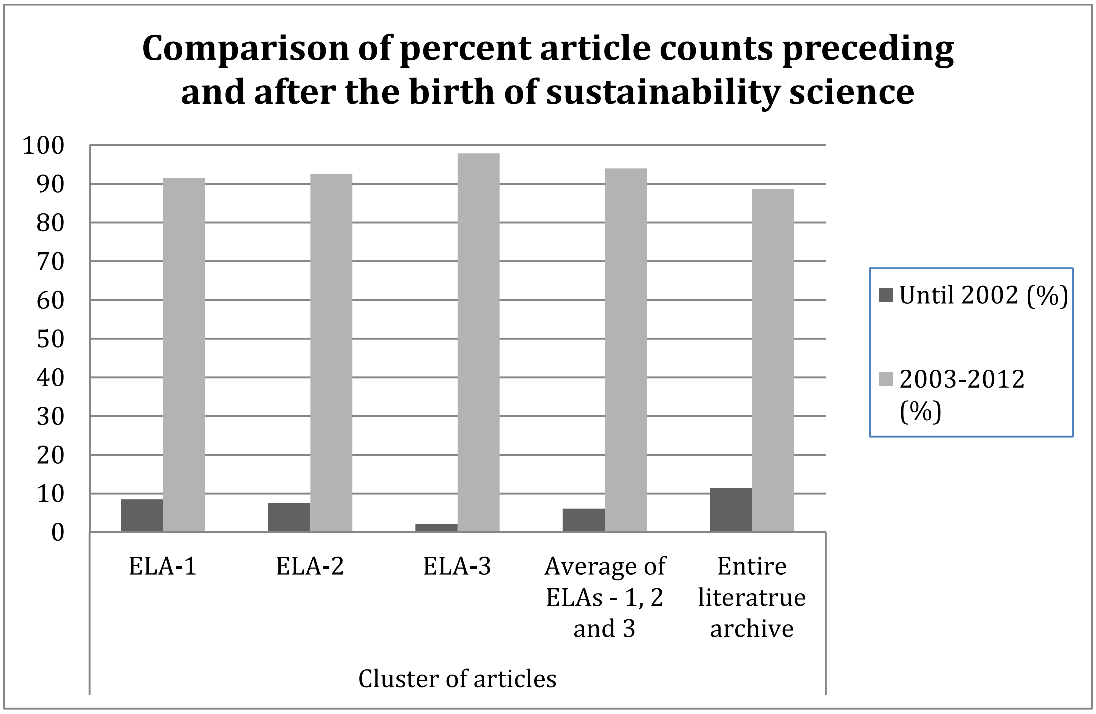


Figure 6.3 Temporal characteristics preceding the birth of sustainability science

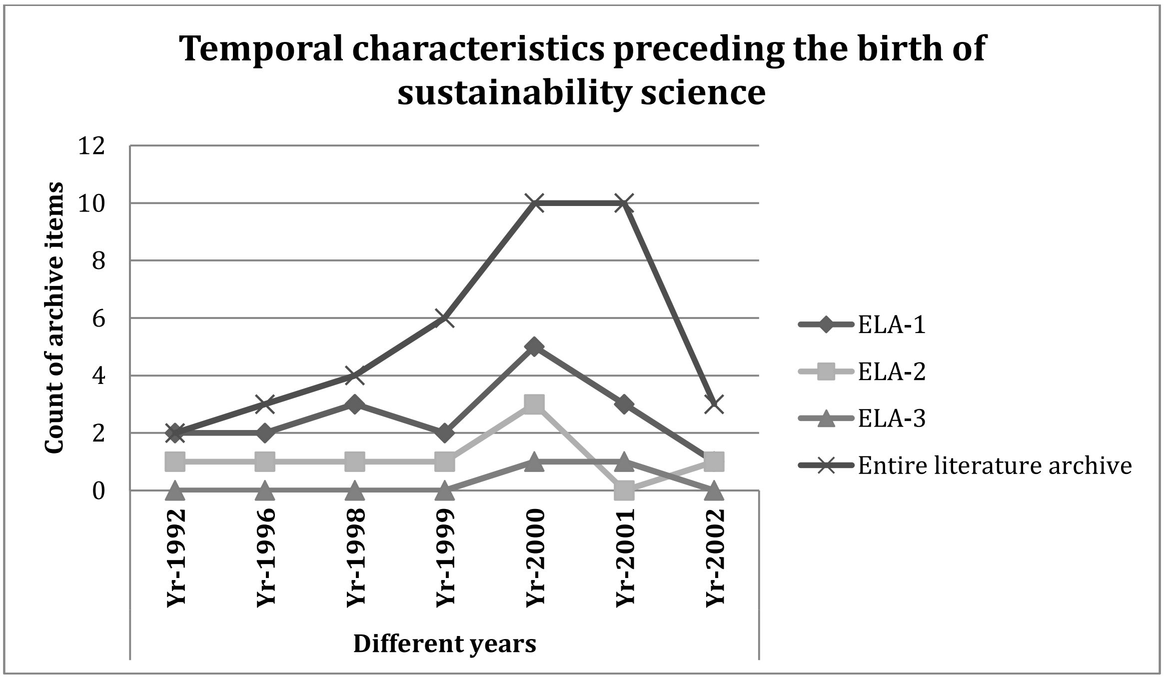
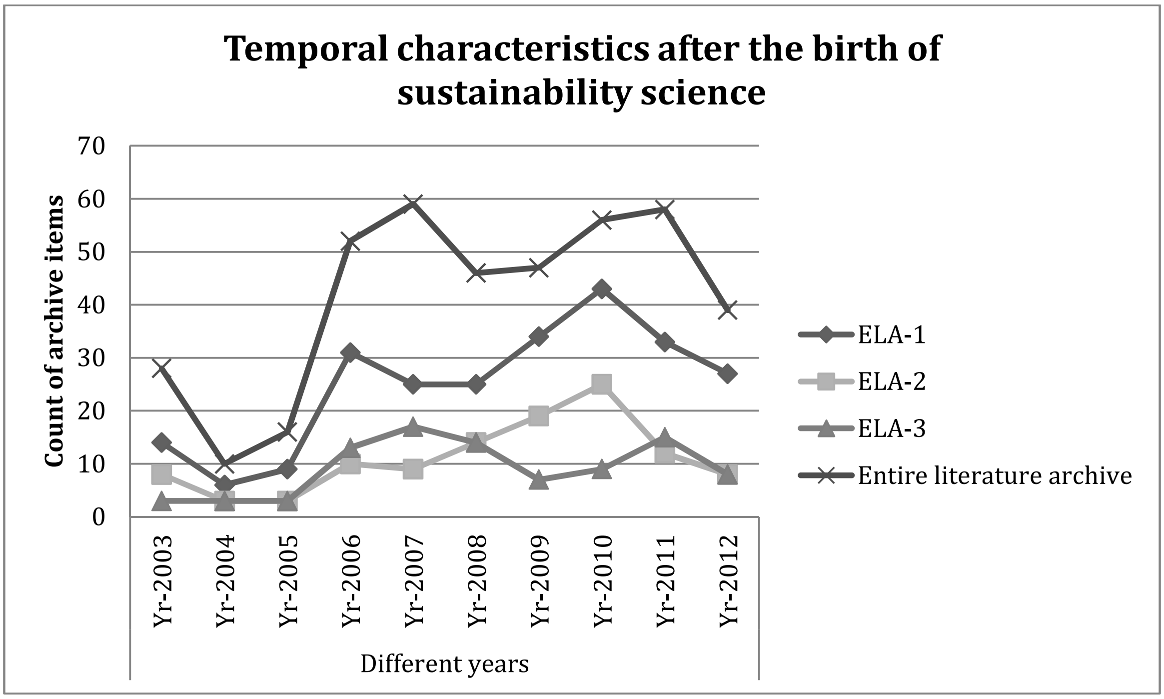


Figure 6.4 Temporal characteristics after the birth of sustainability science



6.4 Discussing the findings

The findings on the scale, place and temporal dimensions of sustainability science are described in a list of 11 characteristics below.

1. Much of sustainability science research is apparently devoid of any specific scale-place characteristic. This goes against the apparent desired characteristic of the practice in terms of connecting to the different scales of given places in conducting its research (**Tables 6.1-6.3**).

2. Taking all scales that do exhibit scale-place characteristics together, the main presence is in the social perspectives of sustainability, with the lowest observed in the sphere representing the central organization of sustainability. The economic and environmental perspectives of sustainability exhibit an averaged position between these (**Table 6.4**). This is in good agreement with the entire literature archive except for the sphere representing the central organization of sustainability, revealing a mere 16.2% share of the researches (**Table 6.5** and **Figure 6.1**), whereas under the empirical literature analyses it is exhibited as 47.7% averaged (SD = 4.7). Such low representation of the research with scale-place characteristics for the sphere representing the central organization of sustainability in the entire literature archive could be explained by the presence of a great number of articles produced to articulate what sustainability science is or should/ could be, which is reflective of efforts trying to hypothetically shape sustainability science instead of more overt scale-place studies.

3. The majority of the places—both in terms of the places the research are concerned with as well as the places of their authorship—not having a pronounced presence reveals a dominantly distributive nature of the sustainability science research (**Tables 6.6-6.9**).

4. The count of articles with global characteristics outnumbers the article counts corresponding to all continents taken together in the entire literature archive as well as in all empirical literature analyses, while the counts with global characteristics remain the highest compared to any given country represented in the articles (**Tables 6.6-6.9**). This reveals an importance ascribed to the global dimensions of sustainability in sustainability science research.

5. In terms of the continents corresponded to in the sustainability science researches, Asia is the most pronounced, followed by Africa and Europe (**Tables 6.6-6.9**). In terms of countries, China, Japan and USA exhibit the most pronounced presence (**Tables 6.6-6.9**). The subsequent pronounced countries follow as India, Australia, Malaysia, Nigeria, Tanzania and Brazil.

6. In terms of the most pronounced places of authorship of the articles, in order, these are: USA, Japan, UK and Germany, while the appearance of USA greatly outnumbering the other three countries taken together (**Tables 6.6-6.9**). The subsequent pronounced places of authorship are: Canada, Australia, Netherlands, Sweden, Austria, France, Italy, China, Belgium, Switzerland, Spain, Kenya, Norway and India.

7. The dataset reveals a steady trend of saturation of the 'place characteristic' with an increase in the counts of studies conducted, i.e. a steady increase in the counts of articles per place with an increase in the article cluster size (**Table 6.10**). This means that the development of research in sustainability science tends to focus more on pronounced places rather than exhibiting a distributive focus.

8. The analysis of the temporal characteristics for the period after the birth of sustainability science includes all years with uniform representation in all article clusters (**Figure 6.4**), whereas for the period before the birth of sustainability science they appear in fragmented forms, with not all of the appeared years being represented in all article clusters (**Tables 6.11-6.14**). This reveals a sustained increase in the awareness and practice in sustainability science research after the practice has been incepted, compared to a sporadic practice of its awareness before its birth.

9. The majority of sustainability science research corresponds to the period after the birth of sustainability science (**Figure 6.2**).

10. After the birth of sustainability science, the research with wider scopes regarding sustainability science are conducted more compared to those with narrower scopes, and vice versa for the period before its birth (**Figure 6.2**).

11. The analysis of the period preceding the birth of sustainability science exhibits a steady increase in terms of the awareness for sustainability science, peaking in the

years 2000 and 2001 (**Figure 6.3**). Following the birth of sustainability science a small peak is observed in the year 2003, which could be attributed to the aftermath of the official birth of sustainability science occurring in 2001 (**Figure 6.4**). Then followed two other peaks around the years 2006–2007 and 2010–2011, where the earlier instance could be attributed to the establishment of the IR3S (Integrated Research Systems for Sustainability Science) in 2006 in Japan, while the latter could be attributed to a combined effort towards sustainability science globally (**Figure 6.4**).

6.4.1 Intermediary summary discussion

The 11 scale, place and temporal characteristics of sustainability science are described in this intermediary discussion in three paragraphs—each discussing one of the three broad analyses—in order to facilitate the logical progression on arriving at the 'summary strong and weak aspects' of the structure of practice in sustainability science, in **Section 6.4.2**.

[1] Although all different scales corresponded to the studies together outnumber the count of the studies being devoid of scale-place characteristics, compared against any particular scale, the highest count of sustainability science studies for most of the sustainability perspectives not being associated with any scale-place characteristic does not reveal a strong desire to connect to the different scales and places in conducting research. In the entire literature archive a mere 16.2% of the studies having scale-place characteristics for the sphere representing the central organization of sustainability is reflective of attempting to 'hypothetically' shape sustainability science instead of more robust measures.

[2] The majority of the places corresponded to in the research not having a pronounced presence communicates a dominantly distributive nature of the practice across the globe, along with an importance ascribed on the global aspect of sustainability in the research. In terms of the continents corresponded to in the research, Asia is revealed as the most pronounced, followed by Africa and Europe; whereas with regard to the countries, China, Japan and USA exhibit the most pronounced presence. In terms of the most pronounced places of authorship of the articles, the practice reveals the places in the order of USA, Japan, UK and Germany, where the appearance of USA greatly outnumbers the other three countries taken together. Besides, a steady trend of saturation of the place characteristic with an increase in the counts of studies conducted (i.e.

increase in the article cluster size) communicates that the development of research in sustainability science tend to focus more on the pronounced places instead of a distributive focus.

[3] The compared temporal characteristics between the periods before and after the birth of sustainability science reveal a sustained increase in the awareness and practice in sustainability science research after the practice has been incepted, compared to a sporadic practice of its awareness before its birth. While the majority of the sustainability science research corresponds to the period after the birth of its practice, in the period after its birth the research with wider scopes regarding sustainability science are conducted more compared to those with narrower scopes, and vice versa for the period before the birth of the practice. A steady increase in terms of the awareness of sustainability science is revealed from the analysis on the period preceding its birth, peaking in the years 2000 and 2001; whereas three peaks are observed in the period following its birth — in the year 2003, during the years 2006-2007, and in 2010-2011. The small peak observed in the year 2003 could be attributed as being the aftermath of the official birth of the practice, whereas the peak appearing in the years 2006-2007 could be attributed to the establishment of IR3S in Japan (Integrated Research Systems for Sustainability Science) in the year 2006, with the peak in 2010-2011 communicating a combined effort towards sustainability science globally.

6.4.2 Summary on the strong and weak aspects of the structure of practice

The strong aspects of the discourse in terms of the contextual qualities are twofold:

1. A dominantly distributive nature of the practice is evident in terms of the places corresponded to in the research, along with an importance ascribed on the global aspect of sustainability.
2. Since the inception of the practice, it has shaped the matters of sustainability in such a way that the research with wider scopes regarding sustainability are conducted in the practice at a greater extent compared to the ones with narrower scopes, a contrary picture to which is portrayed from the period before its birth.

In contrast to the strong aspects of the contextual qualities of the discourse, there are also two weak aspects inherent to it:

1. A characteristic lack in connecting to the different scales and places in conducting research, and
2. The development of research in terms of ‘study cluster sizes’ tending to focus more on the pronounced places instead of a distributive focus.

Chapter 7

Key findings

7.1 Bringing the pieces together

This chapter completes the 'Results & Discussion' component of the thesis through undertaking an integrated discussion, followed by inductive analysis, drawing from the findings from the fundamental analyses carried out in 'Part I' (**Chapters 1-3**) as well as the deductive analyses in **Chapters 4-6**. As the **Chapters 4-6** form part of the 'Results & Discussion' component of the thesis, the findings on the discursive (**Chapter 4**), integrative (**Chapter 5**) and contextual (**Chapter 6**) structures of sustainability science are discussed in these respective chapters. In **Chapter 7** the findings from all these chapters are discussed on their totality in light of addressing the **KRQ 3** and the overall aim of the thesis.

As articulated in **Section 1.6** and reiterated in **Section 3.1**, the overall aim of the thesis is the extraction of a *fundamental intellectual process* that can enquire on a pluralistic orientation and avenue of knowledge, and lead to the laying of an intellectual foundation for *the scholarship of sustainability*. This is reiterated as the culmination of the discussion on the problem definition in **Section 3.1** in terms of an outstanding need for a process that could enable the study of pluralistic knowledge and research structures as well as can epistemologically provide a measure for developing a structured scholarship on sustainability based on a pluralistic orientation of knowledge and effective knowledge integration. This overall aim has been reflected in the identification of the following three Key Research Questions (KRQs).

KRQ 1: How can an intellectual process fundamentally be framed in order to study the pluralistic knowledge and research structures regarding sustainability?

KRQ 2: What are the basic structures of the discourse of sustainability science and how are they structured?

i. *Discursive structure: Fundamental empirical aspects*

   KRQ 2.1: What discursive practices characterize research in sustainability science?

ii. *Integrative structure: Qualitative aspects*

   KRQ 2.2: What qualities are apparent in the ways sustainability science tries to tackle integrative concepts?

iii. *The structure of practice: Spatio-temporal dimensions*

KRQ 2.3: What temporal, spatial and dynamic variations are apparent in the practice of sustainability science?

KRQ 3: How might a *pluralistic knowledge avenue* and the layout of an intellectual foundation for the *scholarship of sustainability* be elicited based on the rationale, framing and application of the *fundamental intellectual process*?

The **KRQ 1** has been addressed in **Chapter 3** in terms of empirically framing the *fundamental intellectual process*, while under the **KRQ 2** this frame of the *fundamental intellectual process* has been applied on the 'example pluralistic knowledge and research body' i.e. the first decade's body of work of sustainability science, in order to elucidate its discursive, integrative and contextual structures as a pluralistic knowledge and research body. These, together with the intellectual perspective of sustainability formed in **Chapter 2**, culminate in the potential for an integrated inductive analysis on eliciting a *pluralistic knowledge avenue* and the layout of an intellectual foundation for the *scholarship of sustainability*, framed under the **KRQ 3**.

Thus, the intellectual perspective on sustainability (formed in **Chapter 2**), the *fundamental intellectual process* for *sustainability scholarship* (framed in **Chapter 3**), the application of the *fundamental intellectual process* on the example pluralistic knowledge and research body (conducted in **Chapters 4-6)**, as well as the intellectual foundation of *sustainability scholarship* (inductively elicited in **Chapter 7**) — together form a continuous thread of inquiry on the intellectual treatment of sustainability. In this continuous thread, it is the framing of the *fundamental intellectual process* in **Chapter 3** and its application throughout the **Chapters 4-6** that connect the intellectual perspective on sustainability to the intellectual foundation of its scholarship through inductively eliciting a *pluralistic knowledge avenue*. In line of this continuous thread of inquiry, the **Sections 7.2 – 7.5** presents an integrated discussion drawing from the findings from **Chapters 1-6** in terms of four key findings arising out of this research, which reveal the different dimensions of the *pluralistic knowledge avenue* as well as latent elements/ characters for an intellectual foundation of the *scholarship of sustainability*.

Following the integrated discussion on the four key findings in light of the **KRQ 3**—i.e. revealing the different dimensions of the *pluralistic knowledge avenue* as well as latent elements/ characters for an intellectual foundation of the *scholarship of sustainability*—the structure of the *pluralistic knowledge avenue*, characterized by the *new mode of enquiry* (see **Sections 2.2** and **2.5**), is elicited through an inductive framing in **Section 7.6**. Together, these lead to constructing an integrated theory on the intellectual foundation of the *scholarship of sustainability* in **Section 7.7**. As treated in **Section 3.4.2**, the methodological challenge of revisiting the literature i.e. the new researches appearing while conducting this research, is addressed through discussing the new literatures in each of the **Sections 7.2 – 7.6**.

7.2 Key finding – 1: Characterization of human-environment system

Details of the finding

The characterization of human-environment system is one of the most important aspects for a scholarship of sustainability. This is addressed through the 'focus analysis – 2' (FA-II) in **Section 5.2**. The findings on FA-II, discussed in **Section 5.5** and summarized in **Sections 5.5.1** and **5.5.2**, reveals 86 different types of use of the concept of 'human-environment system' within a literature map of 141 archive items, 87% of which occurred only once in the map. This revealed an extremely open-ended characterization of the concept in sustainability science research. With the pattern remaining the same across the economic, social and environmental perspectives of sustainability, on one hand, it reveals the great complexity that the 'human-environment system' presents, while on the other hand, it communicates an unsatisfactory integrative structure of sustainability science.

New knowledge

In discussing the problems with the nature, definition and foundation of sustainability science in **Section 1.4,** sustainability science is seen to be proclaimed as having become a new academic discipline. This finding on the characterization of the 'human-environment system' disagrees to such proclamation in terms of the lack of an integrative structure in sustainability science on such a concept that sits at the core of the notion of sustainability. A recent study (Frey 2016) reveals the success or failure of sustainable management of social-ecological systems to be constrained by the inconsistent organization of the relevant variables. This supports the finding in this research on the unsatisfactory integrative structure of sustainability science in terms of the characterization of the concept of the 'human-environment system'.

<u>How does it build on our understanding?</u>

In terms of the development of the practice of sustainability science, this finding reveals the necessity for a sound integrative structure for its discourse. In terms of building a *scholarship of sustainability* based on the *fundamental intellectual process* through the practice of the *new mode of enquiry* (see **Sections 2.2** and **2.5**), this finding reveals the value of a sound integrative structure for the concept of the 'human-environment system'.

7.3 Key finding – 2: The overall contribution of sustainability science in the intellectual treatment of sustainability

<u>Details of the finding</u>

Discursively, the contributions of sustainability science in the intellectual treatment of sustainability can be described in terms of —

(i) its innovative nature in undertaking sustainability research (the strong aspect #1 in **Section 4.4.2**),

(ii) the utilization of a wide range of approaches in its studies (the strong aspect #1 in **Section 4.4.2**),

(iii) the predominant original nature of its research (the strong aspect #1 in **Section 4.4.2**),

(iv) its balanced focus on the different categorical aspects of addressing sustainability (the strong aspect #2 in **Section 4.4.2**), as well as

(v) its well-justified application of a variety of empirical classes (the strong aspect #3 in **Section 4.4.2**).

Weaknesses in the discursive qualities of the discourse include —

(i) its lack in attempting to develop research at the complex interface of the nature and human society (the weak aspect #1 in **Section 4.4.2**),

(ii) a lack in empirical field approaches to try to understand the problems/ issues of sustainability (the weak aspect #3 in **Section 4.4.2**),

(iii) a lack in conjoining the economic, social and environmental perspectives of sustainability (the weak aspect #2 in **Section 4.4.2**), as well as

(iv) a weakness in the study of the economic perspectives of sustainability (the weak aspect #4 in **Section 4.4.2**).

Overall, these discursive qualities of the discourse of sustainability science reveal structural contributions to the intellectual treatment of sustainability. The qualities of sustainability research in terms of utilizing a wide range of approaches, predominant original nature of the researches, balanced focus on the different categorical aspects, as well as the well-justified application of the empirical classes — all these dimensions could potentially be reflected in a given scholastic practice. However, 'the capacity to develop research at the complex interface of the nature and human society', or 'building capability on understanding the problems/ issues of sustainability from the conjoint perspectives of the economic, social and environmental aspects' cannot be accomplished through simple structural improvements, and instead, these require developing fundamental intellectual capabilities.

The contributions of the discourse of sustainability science in terms of its integrative qualities are yet to occur. However, a step forward lies in recognizing the challenges. Weaknesses in the integrative qualities include lack of precision in characterizing the concept of 'human-environment system' along with an extremely open-ended characterization of the concept (the weak aspect #1 in **Section 5.5.2**), and a lack of clarity in addressing the aspect of 'global sustainability' (the weak aspect #2 in **Section 5.5.2**). Given the lack in its functional capacity to produce the intellectual treatment of sustainability, the discourse reveals a maturity in terms of recognizing its challenges (the strong aspects #1-2 in **Section 5.5.2**). This could be considered as a structural contribution similar to the discursive aspect.

Contextually, the discourse of sustainability science contributes into the intellectual treatment of sustainability through building a dominantly distributive nature in terms of the places corresponded to in the research (the strong aspect #1 in **Section 6.4.2**), through ascribing importance to the global aspect of sustainability (the strong aspect #1 in **Section 6.4.2**), as well as through enhancing the scope of sustainability (the strong aspect #2 in **Section 6.4.2**). Consistent with the contributions in the discursive and integrative aspects, these contextual contributions could also be addressed through conducting structural improvements in the scholastic practice, while the drawbacks in its contextual qualities communicate 'a characteristic lack in connecting to the different scales and places in conducting research' (the weak aspect #1 in **Section 6.4.2**) as well as 'the development of research not having a distributive focus' (the weak aspect #2 in **Section 6.4.2**) **–** pointing to the need to develop fundamental intellectual capacities. Moreover, the structural contribution in terms of 'ascribing an importance on the global aspect of sustainability' needs to be viewed together with the drawback in the integrative qualities of the discourse in terms of the practices on global sustainability still largely being at the outset of appreciating the sustainability challenge for the globe.

Therefore, the overall contribution of sustainability science, revealed as consistent across its three different basic structures, lacks intellectual capacities. The interactions among the three different framing approaches (i.e. discursive, integrative and contextual analyses) mutually reinforce capacities and incapacities of the discourse of sustainability science in terms of the intellectual treatment of sustainability. This consistent overall conclusion arising from the three basic qualities of sustainability science—as a pluralistic knowledge and research body—brings in the question of the development of a *fundamental intellectual process* for a *scholarship of sustainability*.

New knowledge

The research reveals a hitherto hidden concern, that the overall contribution of sustainability science lacks intellectual capacity. Revisiting the literature with respect to this key finding brings in recent studies. The review study by Shahadu (2016) tries to devise a new definition of sustainability science in terms of proposing an umbrella science, where the functions of facilitating cross-disciplinary communication as well as addressing the challenge of integrating the different fields of research are proposed by promoting a standard definition of sustainability science as an umbrella science. This, not only confirms the yet unframed identity of sustainability science (i.e. that is open for arbitrary redefinition and newer interpretations), but also tries to promote a structural measure—in terms of simply promoting a new standard definition for the discourse—to be able to impart the functional capacities of facilitating cross-disciplinary communication and the integration of different fields of research. This study exemplifies what is discovered in this thesis in terms of the overall contribution of sustainability science, i.e. imparting structural contributions while lacking in the intellectual capacities to provide the functional aspects to the intellectual treatment of sustainability.

Two more recent studies also proceed in the same direction. Hering (2016) argues whether we need more research, or better implementation through knowledge brokering, as the author proposes the establishment and professionalization of knowledge brokering to be an important step forward. Keeler et al. (2016) propose the utilization of international networks for accelerating research in transformational sustainability science. While the utilization of such approaches can definitely widen the scope for the development of sustainability science research, this signals structural improvement, rather than intellectual scholarship.

Structural contributions could be reflected in a given scholastic practice through undertaking structural improvements, but they would not necessarily produce the required intellectual capabilities within the practice. While being incepted in the year 2001 as a consensus practice (Kates et al. 2001), the identity of sustainability science has not produced the required intellectual capacities, as evidenced from this analysis of its first decade of scholarship. Takeuchi (2017) describes sustainability science as a problem-driven discipline, characterized with its own methods and approaches. However, in assuming sustainability science as a problem-and-solution-driven discipline, if the integration cannot epistemologically, theoretically as well as methodologically take place due to insufficient functional-intellectual capabilities, what difference could the mere structural improvements really make in addressing the complex sustainability issues/ problems and towards finding their solutions? The discourse of sustainability science still needs to meet the challenge of finding an effective answer to this question.

<u>How does it build on our understanding?</u>

The new knowledge produced from this key finding reveals the challenge for the practice of sustainability science in terms of developing its fundamental intellectual capabilities in order to significantly contribute in the intellectual treatment of sustainability.

In terms of building a *scholarship of sustainability* based on the *fundamental intellectual process* through the practice of the *new mode of enquiry*, the new knowledge communicates that the practice of the intellectual process as well as the growth of the *pluralistic knowledge avenue* in light of this *new mode of enquiry* need to develop both structural and functional-intellectual capabilities for effectively contributing into the intellectual treatment of sustainability.

7.4 Key finding – 3: The language of conversation to facilitate knowledge co-production in sustainability research

Details of the finding

A theoretical framework is developed on the language of conversation in sustainability research in **Section 4.2.4**, and subsequently discussed as the second major finding in **Section 4.4.3**. This language of conversation is capable of providing the proper and error-free extent of understanding, where a researcher coming from a given research stream is not able to entirely understand the depths and details embedded in a study arising from a different research stream while there is a necessity for the researcher to understand the research to the extent that would enable him/ her to participate and contribute in the research consortium in addressing the sustainability problem/ issue in question. The postulate with regard to the necessity for this language of conversation — which states that the sustainability researchers need to conduct their research on sustainability within some frame of research consortia, where the research task should begin from examining the reported diverse researches on the similar or fragments of the topic in question, and the researchers participating in the consortia represent the corresponding research streams — has been supported with evidence from the empirical characteristics of sustainability science research, as discussed under the first major finding in **Section 4.4.3**.

The language of conversation is based on a frame of six questions, and therefore, six corresponding aspects, on the ways the studies are conducted in sustainability research (see **Table 4.1**). These six aspects describe — (Q1) – the theme of the study to be learnt, (Q2) – a generalized communication on the overarching method(s) in the conduction of the study, (Q3) – a generalized account on the overarching 'philosophical, theoretical and methodological' issues, (Q4) – communication on the utilized research methods in simplified and universally understandable terms, (Q5) – a simplified view on the quality and rigor issues, and (Q6) – if, any additional aspects to be learnt that are non-generalizable into a common structure.

New knowledge

Takeuchi (2017) mentions the outstanding need for stakeholders in different disciplines and roles to work together, as well as on the development of networks of research groups to enable a trans-disciplinary approach. In this context Westberg and Polk (2016) writes:

“*Transdisciplinary (TD) research is an example of a participatory research approach that has been developed to address the complexity of societal problems through the exchange of knowledge and expertise across diverse groups of societal actors. The concept of knowledge exchange is central to the ability of TD research to produce usable knowledge.*” (p.385) The authors revealed the need for moving from a normative concept to an analytical tool through a practice-based approach in terms of the role of knowledge exchange in trans-disciplinary research, and presented their analysis revealing the problem that when the project teams in question are given the same task and framework, they did not understand or enact trans-disciplinarity in a similar fashion, leading to the creation of different goals, organizations and challenges. These understandings from revisiting the literature reveal the need for effective and error-free methods of knowledge exchange and co-production while working in research consortia in undertaking sustainability research, which is met by the new knowledge produced from this key finding in terms of the conceptualization and extensive exemplification of the language of conversation in sustainability research, a theoretical framework of which is produced in **Table 4.1** based on these.

How does it build on our understanding?

In terms of the manners ‘knowledge sharing’ occurs across different domains, Beers and Bots (2009) describe knowledge sharing from three different aspects — knowledge-modeling, science webs (such as network of networks (Kajikawa and Komiyama 2011)), and communities of practice. A limitation in these modes of knowledge sharing across domains is in their lack of instrument for knowledge co-production across the domains, which is not satisfied by mere knowledge sharing, or else knowledge-modeling. It means, besides knowledge-modeling, instruments for knowledge co-production would also need to be developed, as knowledge co-production across the domains is to become an essential reality of an established *scholarship of sustainability*. In ‘multi-, inter and trans-disciplinary’ sustainability research as the necessity for developing knowledge exchange mechanisms have so far been dealt as arbitrary capabilities, and therefore, knowledge in this regard focusing on building research networks/ consortia and not so much on the methodical procedures for their fruitful interaction, this new knowledge on a consistent and effective language of conversation as exemplified throughout the **Sections 4.2.1 – 4.2.3** could provide new intellectual lens into approaching effective trans-disciplinary sustainability research.

7.5 Key finding – 4: Core empirical characteristics of sustainability research

<u>Details of the finding</u>

Discussed as the first major finding in **Section 4.4.3**, the core empirical characteristics of sustainability research could be articulated in terms of:

(i) strong correlation between the dominant 'original nature' and 'the *Archetype-I* characters'—i.e. 'literature survey' being the mode of conduction of a study, while 'literature archive analysis' being the research method—of the research, as well as

(ii) a characteristic dominance of the *Archetype-I* criteria both in terms of the intensity and the diversity of sustainability research.

These findings also resolve the conventional incompatibility between the '*Archetype-I criteria*' and 'original research', as well as reveals the significance of *Archetype-I* characteristics for sustainability research along with a range of other implications—as discussed in **Section 4.4.3**—for the *scholarship of sustainability*.

<u>New knowledge</u>

In revisiting the literature, Takeuchi (2017) mentions the outstanding need for stakeholders in different disciplines to work together, as well as the development of networks of research groups to enable a trans-disciplinary approach through literature review and shared understanding. The empirical approach undertaken in framing the *fundamental intellectual process* in **Chapter 3** embodies this reality of literature organization and analysis processes becoming the dominant character of sustainability research, leading to in contributing a *fundamental literature organization process* based on a bottom-up approach as well as the resultant *structure of five cross-connected layers of organizations* within a given literature archive on sustainability (see discussion in **Section 4.4**). Thus, the new knowledge arising from this key finding establishes a new orientation of thought with regard to *sustainability scholarship* in terms of it being enabled by fundamental literature organization processes.

<u>How does it build on our understanding?</u>

Fundamental literature organization and analysis processes in sustainability research are critical in brokering common language and understanding, and in breaking the impasse of the so-called conventional incompatibility between original research and literature analysis processes.

7.6 Inductive framing: On eliciting a pluralistic knowledge avenue characterized by the new mode of enquiry

The four key findings discussed in **Sections 7.2 – 7.5** reveal the different dimensions of a *pluralistic knowledge avenue* for *sustainability scholarship*. For example, the key finding on the characterization of human-environment system in **Section 7.2** reveals the value of a sound integrative structure for the pluralistic concept of the 'human-environment system' in the practice of the *pluralistic knowledge avenue*. The key finding – 2 in **Section 7.3** informs on the discursive, integrative and contextual qualities of the potential *pluralistic knowledge avenue* based on practical observations on sustainability science scholarship. In **Section 7.4** the value of a language of conversation is revealed for facilitating knowledge co-production in the practice of the *pluralistic knowledge avenue* through providing a new intellectual lens for approaching effective trans-disciplinary sustainability research. Finally, the key finding – 4 in **Section 7.5** informs on the core empirical characteristics of the practice of the *pluralistic knowledge avenue* in terms of revealing the importance of fundamental literature organization and analysis processes in brokering common language and understanding for enabling *sustainability scholarship*. This section inductively elicits the structure of the *pluralistic knowledge avenue* in terms of its cognitive composition, levels of integration within the cognitive composition, as well as modeling the integration between these in light of the *new mode of enquiry* (see **Sections 2.2** and **2.5**) based on the findings throughout **Chapters 1-3**. This structure of the *pluralistic knowledge avenue* together with the findings in **Sections 7.2 – 7.5** and **Chapters 1-3** project on the intellectual foundation of the *scholarship of sustainability* in **Section 7.7**.

7.6.1 The pluralistic knowledge avenue: role of existing disciplines and 'the new expertise'

As evident from the discussions in **Section 2.3**, the moral conscience of the sustainability crisis resides in the shortcomings of the paradigm of modern rationalism. It follows that these questions need to become the key to sustainability research practice. Based on the discussions in **Section 2.3**, the potential role of humanities in the making of the *pluralistic* *knowledge avenue* for *sustainability scholarship* is in terms of questioning, assessing and reforming (whereupon necessary) the deep-rooted problems in modern rationalism. This is to be regarded as one of the core challenges in resolving the sustainability crisis, as otherwise, the objective nature of the reductionist scientific inquiry and its tendency to try to avoid being contextual could serve to hide the fundamental root of the sustainability crisis embedded in the making of modern society (see **Section 2.2**). As long as the humanities and the social sciences ask questions about the 'self' i.e. the subject and to the degree that they make it the focus of their inquiry, they reveal the fundamental root of the sustainability crisis in the making of modern society. In connecting the subject with the object, the analytical with the integrative, and the universal with the particular, the contributions from these modes of scholarships are essential in the pursuit of sustainability research.

However, the dissimilar nature of the humanities with respect to the natural and the social sciences constructs a methodological inconvenience in terms of the integration of the participating scholarships in producing the *pluralistic knowledge avenue*. A framework, linking the humanities with the 'realm of judgment and practical wisdom oriented social science' (see **Section 2.3**) could provide a methodological convenience in that end, as the participating scholarships need to produce a uniform platform for their integration in the *pluralistic knowledge avenue*. However, the 'realm of judgment and practical wisdom oriented social science' has already been neglected and downplayed in the social sciences (Sato 2011), together with a deep inertia existing in the natural sciences in terms of continuing its reductionist way of inquiry. In such a reality, the utility of these components in the making of the *pluralistic knowledge avenue* seem to exist in a disjointed fashion. Takemura writes, "*The natural sciences develop their findings independently, and the social sciences have lost their philosophical way, being carried away with a utilitarian attitude and calculations of things such as efficiency. In that sense, the humanities are in practice powerless in the face of the out-of-control rush of modern rationalism.*" (Takemura 2011, p.340)

As evident from the discussions in **Sections 2.2 – 2.3**, there are four main kinds of contributions from the natural and social sciences, and the humanities (designated with 'A', 'B & C' and 'D', respectively) to participate in the *pluralistic knowledge avenue*. Besides 'a new expertise' functioning in light of the *new mode of enquiry* (described in **Section 2.5**) would be required in accomplishing the integration for the making of the *pluralistic knowledge avenue*. This new expertise is termed as *integration expertise* (designated with ‘E’) in this discussion.

A – Natural Sciences: The potential contributions from the natural sciences are in terms of providing the understandings, tools and technologies through ‘analysis’, ‘logic’ and the pursuit of the universal, in relevant experimentation and observation on the sustainability issues, as well as in guiding solutions.

B & C – Social Sciences: The roles of the social sciences in the *pluralistic knowledge avenue* are two-fold.

> **B – The social sciences oriented to emulate the natural sciences**: The contributions from this mode of the social sciences are similar to those of the natural sciences, i.e. in providing the understandings, tools and technologies through ‘analysis’, ‘logic’ and the pursuit of the universal, in relevant experimentation and observation on the sustainability issues, as well as in guiding solutions.
>
> **C – The realm of judgment and practical wisdom oriented social science**: The contributions from this mode are in terms of the contextual, ethical and integrative necessities through the practices of ‘integration’ (instead of ‘analysis’), ‘experience’ (instead of ‘logic’), and ‘attention to particular’ (instead of ‘the pursuit of the universal’), in the understanding, observation and deliberation on the realm of sustainability issues, as well as in guiding solutions.

D – Humanities: The roles of humanities in the making of the *pluralistic knowledge avenue* for the *scholarship of sustainability* are in assessing and reforming (whereupon necessary) the paradigm of ‘human existence’ through examining peoples’ ‘sense of values’, ‘thought’, and ‘culture’, as expressed in the languages, semantic structures and verbalization of non-linguistic expressions.

E – The integration expertise: With regard to the *new mode of enquiry* required for the *scholarship of sustainability* (see **Sections 2.2** and **2.5**), the new expertise i.e. *the integration expertise* need to deliver the functions of integrating, correlating and managing the entire pool of scholarships required for the *scholarship of sustainability*. This expertise is not limited to ‘being a philosophical thinker’ (Yoshikawa 2011), although it involves being a ‘knowledge-broker’ or a ‘boundary-spanner’ (Kajikawa and

Komiyama 2011, p.43). Although no attempt is undertaken in this work in trying to heuristically model the dimensions of *the integration expertise*, the characteristics that need to be present within the expertise are outlined below.

Based on the intellectual perspective of sustainability, articulated in **Section 2.5**, *the integration expertise* need to deliver ***the characteristic of sophistication*** in both lateral and vertical means —

(i) The lateral sophistication is in terms of 'spanning wide', for example, identifying and understanding the sustainability problems and the contexts of human-environment system with regard to these problems. It refers to <u>a horizontal comprehension of the integrity of the reality</u>.

(ii) The vertical sophistication is in terms of 'going deep', e.g. accommodating the same (as in lateral) along the vertical shafts of knowledge avenues. This dimension refers to <u>a vertical comprehension of the specificity of the integrated reality</u>.

With regard to the sustainability problems and their contexts in human-environment system, the integration of the lateral and vertical sophistication could take place under *the new expertise* through maintaining a generalizing interpretation of the depths of knowledge within the vertical shafts of the knowledge avenues in a way as if there were no disciplinary divides and the interpretation propagating in absolute lateral continuity along the vertical depths. The line of thought here is that in being a generalizing interpretation, *knowledge* does not have to be reductionist; instead it can also be interpreted in totality. This generalizing characteristic does neither need to be contradictory to obtaining depths, by restrictively referring it to superficial understanding. Instead, it can be as much in providing depth of knowledge as in obtaining superficial understanding where the provision of depth might not be essential. Both of the provisions of 'depth of knowledge' and 'superficial understanding' are resolved here merely as different depths of knowledge vertically, with the same type of lateral continuity. Therefore, this characteristic of *the integration expertise* need to provide totality of knowledge in terms of a seamless interpretation of the depths that also encompasses the lateral expanse due to the absence of the reductionist character of the knowledge.

Thus, ***the characteristic of generalization*** should functionalize the combination of the lateral and vertical dimensions of sophistication in knowledge, where together these two characteristics (i.e., the characteristic of sophistication and the characteristic of generalization) produce the mental paradigm for the necessity of the *sustainability scholarship* to operate between a horizontal comprehension of the integrity of the reality and a vertical comprehension of the specificity of the integrated reality, revealing the manner the research enquiry needs to operate in addressing sustainability (see **Section 2.5**). It is also in the combination of these characteristics that the intellectual orientation of the *new mode of enquiry* as being 'the capacity to produce bricks of knowledge while looking at the whole building' (see **Section 2.5**) could be reflected within *the integration expertise*.

7.6.2 Levels of integration for the scholarship of sustainability

The integration of the participating elements in the *pluralistic knowledge avenue* could be achieved in different manners and degrees. For example, in sustainability research, the need for developing 'transcending' or 'coherent' research methods is unlikely to be required across divergent disciplines, where 'compatible' research methods would be regarded as essential. The first degree of integration is, therefore, taken in the case that involves divergent disciplines, as this reveals the maximum distance to traverse in terms of accomplishing integration. As the transcending or coherent research methods are unlikely to be required in this case, the development of compatible research methods, thus, becomes the lowest level of integration. In another sense, the compatibility represents a level of integration that is symbolic of multi-disciplinarity.

However, among the pluralistic modes of 'multi, inter and trans-disciplinarity' (see **Section 1.3**), multi-disciplinarity constructs the most primitive mode of all. Therefore, apart from the lowest level of integration (i.e. compatibility) representing the most primitive pluralistic mode of multi-disciplinarity in the case of divergent disciplines, the higher levels of integration with respect to more structured modes of plurality remain to be addressed. Two other scenarios are required for considering these.

The first scenario is in the case where the subject matter of a study remains the same in two academic discourses, however, with two different research topics, i.e. the same research topic is not being studied by both of the discourses. In this case, given the subject matter is the same with a difference in the research topics, there would be no need for developing a 'transcending' research method, and instead, the research methods only need to be 'compatible' if not also 'coherent'. This requires treating the research topics from a unit and broader framework than each of their corresponding scopes, which integrates the two discourses from the level of the same subject matter, the research topics belong as subsets to which. When it becomes necessary for the research methods also to be 'coherent', it focuses on the space between the two academic discourses that resides within the same subject matter however sits between the two research topics. This level of integration i.e. the necessity for 'coherency' represents the interdisciplinary character of sustainability research.

In the second scenario, within the same subject matter if it is same research topic to be studied by more than one academic discourse, then it represents the necessity for even a higher level of integration. Examples of such cases can be taken as any complex topic arising from the sustainability crisis, where the research topics have a number of facets to be studied from the perspectives of different knowledge avenues. In this case, the research methods need to be 'coherent' (on top of being 'compatible') if not being 'transcending' as well, across the academic discourses. When it becomes necessary for the research methods also to be 'transcending', this indicates the trans-disciplinary mode of sustainability research.

The three different levels of integration that are discussed insofar are summarized below.

(i) Multi-disciplinarity, being the most primitive mode of plurality in knowledge/ research, reveals the necessity of developing compatible research methods, representing the lowest level of integration.

(ii) Interdisciplinarity, being a more structured mode of plurality in knowledge/ research, requires coherent research methods on top of the necessary compatibility, thus, revealing a higher level of integration.

(iii) Trans-disciplinarity, being the most structured mode of plurality in knowledge/ research requires the development of transcending research methods, the coherency and compatibility are pre-requisites to which. It, therefore, reveals the highest level of integration.

The structures of these three levels of integration are summarized in **Table 7.1**. However, an even higher level of integration is required—to be termed as the fourth level—that is characteristic of integrating, correlating and managing the entire pool of scholarships required for the *scholarship of sustainability*, i.e. referring to the function of *the* *integration expertise* in the making of the *pluralistic knowledge avenue*. By actively processing integration at each of the first three levels, this fourth level reveals the entirety of the *scholarship of sustainability*.

Table 7.1: Three levels of integration for the scholarship of sustainability			
Research methods	**Level 1: Multi-disciplinary sustainability research**	**Level 2: Interdisciplinary sustainability research**	**Level 3: Trans-disciplinary sustainability research**
Compatible	√	√	√
Coherent	—	(√)	√
Transcending	—	—	(√)

7.6.3 Combining cognitive necessities with levels of integration

In terms of the interplay between 'the participating scholarships/ elements in the making of the *pluralistic knowledge avenue*' (**Section 7.6.1**) and 'the different levels of integration for the *scholarship of sustainability*' (**Section 7.6.2)**, the five participating scholarships/ elements (i.e. A-E) present different scenarios for integration in sustainability research. These can be summarized based on four cases.

(i) The scholarship of humanities (i.e. 'D') can only exist in multi-disciplinary integration with the natural (A) and the social sciences (B and C) based on the character of compatibility. Hence, the humanities do not get integrated with the natural and the social sciences in either of the interdisciplinary or trans-disciplinary modes of plurality in knowledge/ research. The multi-disciplinary integration of humanities can suitably occur through its integration in terms of compatibility with the 'realm of judgment and practical wisdom oriented social science' (C) due to the proximity of the two in their study-matters with regard to sustainability.

(ii) Based on the previous case, in interdisciplinarity, it would only be the natural (A) and the social sciences (B and C) to be integrated. In this combination, the 'realm of judgment and practical wisdom oriented social science' (C) possesses characteristics that do not place it in a position to be transcended with the natural sciences (A) and the 'social sciences oriented to emulate the natural sciences' (B) (see **Section 2.3**). Therefore, the 'realm of judgment and practical wisdom oriented social science' (C) remains limited within the multi-disciplinary and interdisciplinary modes of sustainability research.

(iii) Consequently, it becomes only the natural sciences (A) and the 'social sciences oriented to emulate the natural sciences' (B) to be transcended having similar characteristics, and therefore, the integration between these two can exist in all three pluralistic modes of sustainability research (i.e. multi-disciplinarity, interdisciplinarity and trans-disciplinarity).

(iv) However, all these types of relations (i.e. compatibility, coherency and transcendence) in all modes of plurality in knowledge/ research (i.e. multi-disciplinarity, interdisciplinarity and trans-disciplinarity) among the A, B, C and D are to be integrated, correlated and managed by *the integration expertise* (E).

Thus, it represents the fourth level of integration (**Section 7.6.2**) through applying *the integration expertise* (E) to the four participating scholarships (A-D) in the making of the *pluralistic knowledge avenue*.

These scenarios are reflected in the following relational groupings within the five participating scholarships/ elements in the making of the *pluralistic knowledge avenue*.

Multi-disciplinary sustainability research

Based on —

Compatibility of research methods: E (A + B + C + D)

Interdisciplinary sustainability research

Based on —

Compatibility of research methods: E (A + B + C)

Coherency of research methods: E {<A> (+) <B> (+) <C>}

Trans-disciplinary sustainability research

Based on —

Compatibility of research methods: E (A + B)

Coherency of research methods: E (A + B)

Transcendence of research methods: E {<A> (+) <B>}

To summarize these scenarios in terms of the three pluralistic modes of sustainability research, the multi-disciplinary mode involves all five participating scholarships/ elements, and therefore, the research practices from the four disciplinary scholarships (i.e. A, B, C and D) must be compatible to one another. In the case of interdisciplinarity, all disciplinary scholarships except for the humanities (D) are included, hence, their research practices must be compatible to one another, including being coherent. Finally, in the trans-disciplinary mode, the humanities (D) and the 'realm of judgment and practical wisdom oriented social science' (C) are excluded, and therefore, the natural sciences (A) and the 'social sciences oriented to emulate the natural sciences' (B) must be compatible and coherent to each other, including becoming transcending.

Based on the findings insofar, the transcending research methods are required only between 'A' and 'B', whereas coherency in the research methods is required among the 'A', 'B' and 'C', and the compatibility requiring all of 'A', 'B', 'C' and 'D'. *The* *integration expertise* (E) processes these integrations, and correlates and manages the entire pool of scholarships required for the *scholarship of sustainability*. Based on the discussions in **Sections 2.2 – 2.3**, it should be noted here that the general characteristics of sustainability research that need to be maintained in order for these integration processes to take place in these scenarios are —

(i) the nature of enquiry asking on both 'the subject' and 'the object' in a given study instead of making merely objective enquiry,

(ii) accomplishing 'integration' through maintaining 'analytical rigor',

(iii) considering 'experience' consistent and together with the 'logical orientation', and

(iv) providing 'particular focuses' in ways that also add to 'the pursuit of the universal'.

The functional establishment of the *pluralistic knowledge avenue* with the multi-disciplinary, interdisciplinary and trans-disciplinary modes of plurality in knowledge/ research also necessitates the development of the required compatibility, coherency and transcendence in the research methods in order for the studies to take place. These, based on the discussions in **Section 2.2** and **Chapter 3**, must be accompanied by the conjugal establishments of —

(i) ***an epistemological scholarship***, dealing with the philosophical incoherencies with regard to the nature of knowledge required for, as well as acceptable in, sustainability research (referring to **Section 2.2**), and

(ii) ***the scholarship of knowledge-structuring***, working with the theoretical incoherencies standing as bar in advancing the *scholarship of sustainability*.

As the knowledge-structuring scholarship reveals fundamental and systematic literature organization (as exemplified in **Chapter 3**), this scholarship can elucidate the existing theoretical as well as epistemological incoherencies embedded in a given frame of research body. These two scholarships (i.e. the epistemological and the knowledge-structuring scholarships) together can be framed to produce the theoretical map of the *scholarship of sustainability*, under which the empirical studies/ experiments in the nature-society system could be devised. The compatibility, coherency and transcendence in the research methods would be required for conducting these empirical studies/ experiments, besides the necessary 'frameworks' to be provided from the knowledge-structuring scholarship through resolving the relevant theoretical incoherencies. Apart from these, the functional establishment of the *pluralistic knowledge avenue* as well as the *scholarship of sustainability* would require institutional and organizational innovations in order to create the physical space and the intellectual infrastructure for the practice of effective sustainability research.

7.6.4 Modeling the integration

Since the advancement in human knowledge system has been characterized with a reductionist fragmentary knowledge practice, there would essentially be only two basic directions of knowledge expertise regardless of the three pluralistic modes of knowledge/ research (i.e. multi-disciplinarity, interdisciplinarity and trans-disciplinarity). One of these is along with the vertical shafts of reductionism referred to in here as ‘going deep’, whereas the other is noted as ‘spanning wide’ along the horizontal plane, referring to the existing diversity in the fragmentary knowledge practices that grow in reductionist fashion along their vertical shafts. When these two traverse through each other, the integration takes place.

The areas/ avenues of human knowledge system can be sketched as parts of a two-dimensional horizontal platform, such as the solid circular dots on the area of (X × Y) in the left-hand image in **Figure 7.1**. The empty areas among these solid dots, therefore, represent the interdisciplinary areas. The collection of the downward arrows along the Z-axis represents ‘going deep’, whereas the entire plane of (X × Y) represents ‘spanning wide’ in **Figure 7.1**. Therefore, the integration is to take place between this collection of the downward arrows along the Z-axis and the entire plane of (X × Y). The product of this traversing produces the right-hand side image in **Figure 7.1**, which represents the ultimate integrated reality of human knowledge system.

It should be noted here that in **Figure 7.1**, the X and Y are merely two axes of horizontal dimensions, and therefore, they are brought in only in order to define a horizontal plane sufficient for including all existing areas/ avenues of human knowledge system (represented as solid circular dots that grow in reductionist fashion along the Z-axis), as well as all interdisciplinary areas among them (represented as empty areas among the dots). If each solid circular dot on the (X × Y) plane in the left-hand image in **Figure 7.1** represents each knowledge practice in human knowledge system, then other than forming a sufficient horizontal plane for including all of such dots including the empty areas in between, there is no other significance of the two X and Y axes.

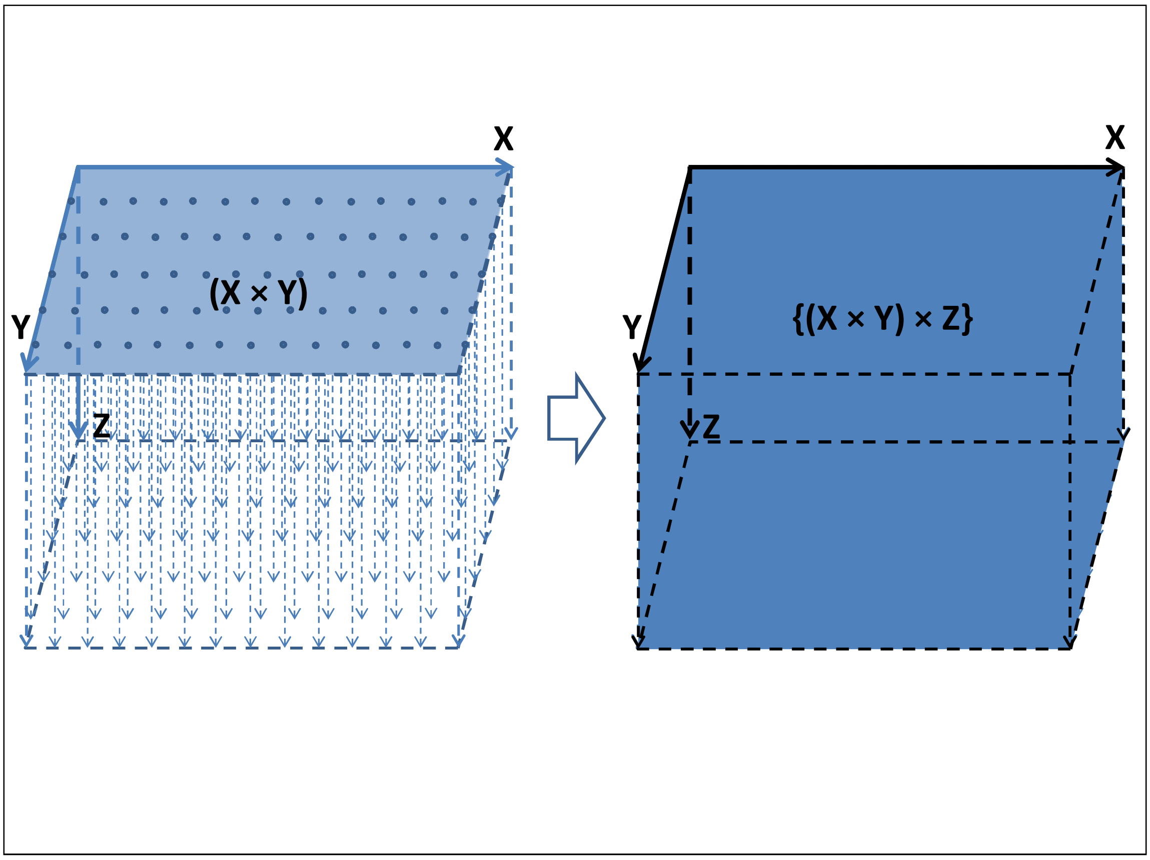


Figure 7.1 Directions of knowledge expertise (left-hand image) and their integration (right-hand image)

In **Figure 7.1**, the collection of all areas of solid circular dots together with their downward projected areas along the Z-axis collectively forms the pluralistic mode of multi-disciplinarity. In this way, the multi-disciplinary mode becomes a function of {(X × Y) × Z}, thereby characteristically representing the integration of both ‘spanning wide’ and ‘going deep’. Similarly, the areas from the horizontal plane of (X × Y) excluding the solid circular dotted areas, and their projected empty areas along the Z-axis collectively form the pluralistic mode of interdisciplinarity, hence, the interdisciplinary mode also becoming a function of {(X × Y) × Z}, representing the integration of both ‘spanning wide’ and ‘going deep’. The trans-disciplinarity involves the entire plane of (X × Y) and their entire downward projection along the Z-axis, thereby the entire three-dimensional space of {(X × Y) × Z} in **Figure 7.1**, which reveal the ultimate integrated reality of human knowledge system with the integration of ‘spanning wide’ and ‘going deep’ to the maximum possible extent. Thus, as modeled from **Figure 7.1**, all three pluralistic modes of sustainability research can and should represent ‘spanning wide’ and ‘going deep’ at the same time, i.e. the products of their integration.

Following from the scenarios of integration for sustainability research developed in **Section 7.6.3**, the multi-disciplinary mode requires the compatibility of research methods among all four disciplinary scholarships (represented as E(A + B + C + D)), referring here to the solid dotted areas for ‘A’, ‘B’, ‘C’ and ‘D’ within the (X × Y) plane together with their respective areas of downward projections along the Z-axis, in a compatible manner. In a similar way, in the interdisciplinary mode, both of compatibility and coherency are required among the ‘A’, ‘B’ and ‘C’ (represented as E(A + B + C) for compatibility and E{<A> (+) <B> (+) <C>} for coherency), where the integration takes place with the interstitial areas among the solid dotted areas for ‘A’, ‘B’ and ‘C’ within the (X × Y) plane together with their respective empty areas of downward projections along the Z-axis, in both compatible and coherent manners. Finally, in the trans-disciplinary mode, all of compatibility, coherency and transcendence among the ‘A’ and ‘B’ become required (represented as E(A + B) for compatibility and coherency, and E{<A> (+) <B>} for transcendence), where the integration takes place between – (i) the solid dotted areas for ‘A’ and ‘B’ together with the interstitial areas among these solid dotted areas of ‘A’ and ‘B’ within the (X × Y) plane, and (ii) the respective downward projected areas of all these along the Z-axis, in all three compatible, coherent and transcending manners.

An insight here would be with respect to the way the interdisciplinary and trans-disciplinary relations are referred to in the model. Although in the interdisciplinary mode it is only the interstitial areas among the solid dotted areas for ‘A’, ‘B’ and ‘C’ to take part in the integration, the expression is made through E(A + B + C) for compatibility and E{<A> (+) <B> (+) <C>} for coherency, instead of representing the interstitial areas. This is due to the studies in the interdisciplinary areas taking place with the conjunction of the relevant disciplinary areas, hence, the interdisciplinary work progressing within the integrated platform of these disciplinary areas. This also explains the similar for trans-disciplinary mode where E(A + B) is expressed for compatibility and coherency, and E{<A> (+) <B>} for transcendence, whereas it involves both of ‘the solid dotted areas for ‘A’ and ‘B’’ and ‘the interstitial areas among these solid dotted areas’ on the (X × Y) plane for representing transcendence. Therefore, the interdisciplinary and trans-disciplinary components are expressed in the ways how the respective works are carried out within the conjunction of the relevant disciplinary areas, thus, the symbolic expressions requiring to be understood in their functional way.

7.6.5 Revisiting the literature

A revisit to the literature brings quite a few new studies with regard to the *pluralistic knowledge avenue* and the *new mode of enquiry*. Stafford-Smith et al. (2016) demonstrates the essential need of greater integration on the inter-linkages among sectors, actors and countries. Addressing needs such as this would require a structured scholarship of sustainability, capable of accomplishing such complex integration, which could also be measured through concrete empirical analytics based on the inter-linkages within the structure. The structure of the *pluralistic knowledge avenue* in light of the *new mode of enquiry* outlines the components of such a structure for an effective *scholarship of sustainability*.

The essential focus on the *new mode of enquiry* that does not operate based on the reductionist procedure of knowledge production i.e. the characteristic reductionist practice of the traditional scientific method, also needs to be emphasized to this end. This is because of the sustainability science literature continuing on the path of scientific methodology, such as, Takeuchi (2017) mentioning sustainability science as a distinct scientific endeavor, together with envisioning to provide scientific knowledge and instruments for the implementation of the SDGs (Sustainable Development Goals), or

Wuelser and Pohl (2016) outlining how the framing of scientific considerations significantly influence research project framing on sustainable development. However, an effective *scholarship of sustainability* need to come out of the reductionist methodology and reflect the intellectual orientation of the *new mode of enquiry* in terms of 'producing bricks of knowledge while looking at the whole building', instead of the 'production of specialized bricks of knowledge at the expense of not seeing the whole building' as reflected in the intellectual orientation of the reductionist scientific methodology (see **Section 2.5**).

With regard to *the integration expertise*, Wittmayer and Schäpke (2014) describes the roles of sustainability researchers in terms of being a change agent, knowledge broker, reflective scientist, self-reflexive scientist, and process facilitator. Although these present some structural identities of the sustainability researcher, an effective integration expertise needs to comprise the characteristics and functions outlined in **Section 7.6.1**.

7.7 The intellectual foundation of the scholarship of sustainability

The discussions in **Sections 7.1 – 7.6** as well as the rationale, framing and application of the *fundamental intellectual process* (presented in **Chapters 1-2**, **3** and **4-6**, respectively) together reveal the latent elements/ characters of an intellectual foundation for the *scholarship of sustainability*. This pluralistic knowledge and research body provide the basis for an integrated theory of 'sustainability scholarship'.

The elements/ characters of the intellectual foundation of the *scholarship of sustainability* are —

(i) the scholarship needs to be built on a *pluralistic knowledge avenue* in human knowledge system that is characterized by the *new mode of enquiry* and comprised of the three pluralistic modes of 'multi-, inter and trans-disciplinarity' (**Section 7.6**),

(ii) the scholarship is enabled by fundamental literature organization processes, characterizing a *fundamental intellectual process* (**Section 7.5**),

(iii) the scholarship needs to operate between a horizontal comprehension of the integrity of the reality and a vertical comprehension of the specificity of the integrated reality (**Section 2.5**),

(iv) the intellectual orientation of the scholarship is in terms of its capacity to produce ‘bricks of knowledge while looking at the whole building’, as opposed to the production of specialized bricks of knowledge at the expense of not seeing the whole building, being characteristic of the reductionist mode of enquiry (**Section 2.5**),

(v) with a research orientation of use-inspired basic research and three pluralistic modes of ‘multi-, inter and trans-disciplinarity’, the *scholarship of sustainability* could combine the elements of concept-oriented, problem/ use-oriented as well as interdisciplinary evolution in its characteristic development as a pluralistic knowledge and research body (**Section 2.5**),

(vi) the scholarship is progressed through knowledge co-production based on effective language of conversation in sustainability research (**Section 7.4**),

(vii) reflecting the *new mode of enquiry*, the scholarship requires an *integration expertise* in order to deliver the functions of integrating, correlating and managing the entire pool of scholarships required for the scholarship (**Section 7.6.1**),

(viii) the scholarship requires an epistemological scholarship as well as a knowledge-structuring scholarship in order to address the philosophical/ epistemological and theoretical incoherencies, respectively; these together creating the theoretical map of the scholarship (**Section 7.6.3**),

(ix) the scholarship requires a component scholarship of research method integration in order to develop the compatibility, coherency and transcendence in the research methods, which, together with ‘frameworks’ provided from the knowledge-structuring scholarship (through resolving relevant theoretical incoherencies) enables the empirical scholarship (**Section 7.6.3**).

Based on these nine elements/ characters of the intellectual foundation of the *scholarship of sustainability*, an integrated theory is developed in **Figure 7.2**.

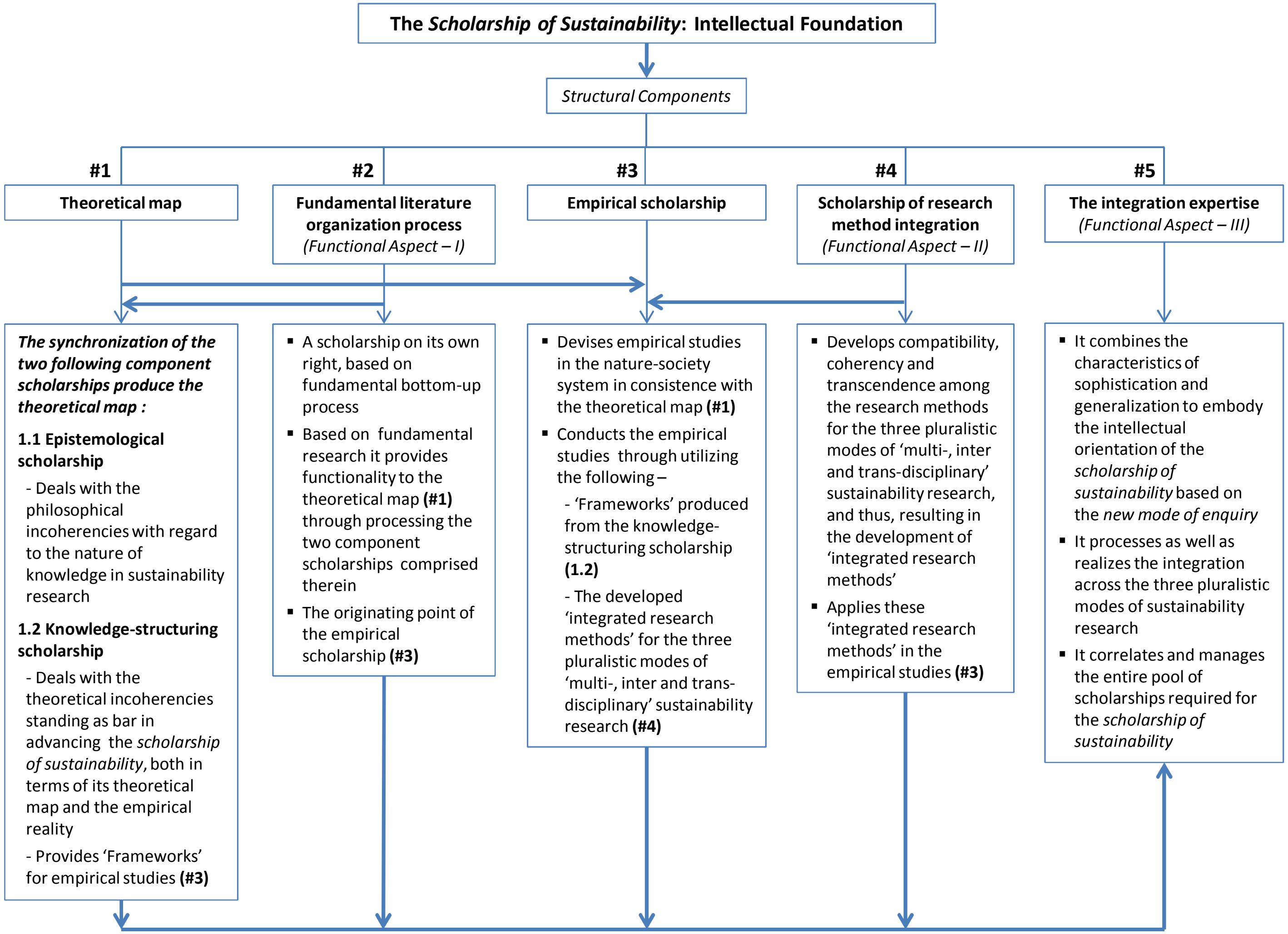


Figure 7.2 Integrated theory on the intellectual foundation of the scholarship of sustainability

The integrated theory, articulated in **Figure 7.2**, is based on the creation of a ‘theoretical map’ for the *scholarship of sustainability* that leads to its ‘empirical scholarship’, in conjunction with three other functional aspects required for these. These functional aspects also create their own structural components in the physical mosaic of the intellectual foundation, besides providing the functionality to it. Therefore, including the two theoretical and empirical components (i.e. the ‘theoretical map’ and the ‘empirical scholarship’), the intellectual foundation of the *scholarship of sustainability* becomes composed of five structural components and three functional aspects.

The ‘theoretical map’ consists of two component scholarships, these being the epistemological scholarship and the knowledge-structuring scholarship. These component scholarships are processed through fundamental research enabled by a *fundamental literature organization process* (see **Section 4.4**), forming the functional aspect – I. The role of the epistemological scholarship in the integrated theory is in terms of addressing the philosophical incoherencies with regard to the nature of knowledge required for, as well as acceptable in, sustainability research, as the epistemological scholarship needs to arbitrate with the complex philosophical reality of knowledge and its production with respect to the multitude of disciplines functioning with multitude of epistemological perspectives (see **Section 2.2**). On the other hand, the knowledge-structuring scholarship addresses the theoretical incoherencies that arise from the incompatible, incoherent, or even conflicting theoretical positions that need to participate and work together in addressing a given sustainability problem/ issue. However, both of these scholarships are to be processed through fundamental research enabled by a *fundamental literature organization process*. This *fundamental literature organization process*, based on a bottom-up approach as well as involving extensive systematic organization, is developed in **Chapter 3**, and established in **Section 4.4**. The fundamental and systematic organization of the literature while employing the bottom-up approach would reveal the existing theoretical incoherencies as well as epistemological mosaic embedded in a given frame of research body. The knowledge-structuring scholarship, operating based on these theoretical incoherencies, attempts to solve these incoherencies and through this, it produces *frameworks* for the conduction of empirical studies. On the other hand, the epistemological scholarship analyzes the epistemological mosaic embedded in the diverse literature, based on which it carries out fundamental research in discerning the required and acceptable nature of knowledge for sustainability research. Subsequently, the synchronization of these epistemological and knowledge-structuring scholarships produces the ‘theoretical map’ of the *scholarship of sustainability*, which is complemented in the ‘empirical scholarship’.

The ‘empirical scholarship’, being the third structural component, devises empirical studies in the nature-society system in consistence with the ‘theoretical map’ of the *scholarship of sustainability*. Besides the *frameworks* produced from the knowledge-structuring scholarship, the conduction of these empirical studies also requires the compatibility, coherency and transcendence among the research methods for the three pluralistic modes of ‘multi-, inter and trans-disciplinary’ sustainability research. The ‘scholarship of research method integration’ develops these integrated research methods, forming the second functional aspect as well as the fourth structural component. Thus, this scholarship of research method integration enables the ‘empirical scholarship’, under which the empirical studies are conducted through utilizing both of ‘the *frameworks* provided from the knowledge-structuring scholarship’, and ‘the developed integrated research methods for the three modes of plurality in sustainability research’.

The ‘theoretical map’ (the first structural component) is functionalized through fundamental research enabled by both of ‘the *fundamental literature organization process*’ (the second structural component and the first functional aspect) and ‘the synchronization of the two component scholarships’ embedded in the theoretical map. The ‘empirical scholarship’ (the third structural component) is functionalized by both of the ‘theoretical map’ (the first structural component) and the ‘scholarship of research method integration’ (the fourth structural component and the second functional aspect). The role of the ‘theoretical map’ in the ‘empirical scholarship’ is both in terms of the empirical studies being devised in consistence with the theoretical map, as well as the conduction of the empirical studies utilizing *frameworks* produced from the knowledge-structuring scholarship.

The integrated mosaic of the first four structural components including the first two functional aspects therein, prepares the reality for the functioning of the fifth structural component i.e. *the integration expertise* (see **Sections 7.6.1**). Also acting as the third functional aspect besides being the fifth structural component, *the integration expertise* serves the purposes of processing the integration based on a combination of the characteristics of sophistication and generalization (see **Section 7.6.1**), as well as functioning to correlate and managing the entire pool of scholarships required for the *scholarship of sustainability*.

Chapter 8

Conclusion

8.1 Summary of findings

This chapter presents a synthesis of the findings and conclusions of the research undertaken in this thesis. The aim of the research was the extraction of a *fundamental intellectual process* that can enquire on a pluralistic orientation and avenue of knowledge, and lead to the laying of an intellectual foundation for *the scholarship of sustainability*. To achieve this aim, the research sought answers to a series of Key Research Questions (KRQs):

KRQ 1: How can an intellectual process fundamentally be framed in order to study the pluralistic knowledge and research structures regarding sustainability?

KRQ 2: What are the basic structures of the discourse of sustainability science and how are they structured?

iv. *Discursive structure: Fundamental empirical aspects*

KRQ 2.1: What discursive practices characterize research in sustainability science?

v. *Integrative structure: Qualitative aspects*

KRQ 2.2: What qualities are apparent in the ways sustainability science tries to tackle integrative concepts?

vi. *The structure of practice: Spatio-temporal dimensions*

KRQ 2.3: What temporal, spatial and dynamic variations are apparent in the practice of sustainability science?

KRQ 3: How might a *pluralistic knowledge avenue* and the layout of an intellectual foundation for the *scholarship of sustainability* be elicited based on the rationale, framing and application of the *fundamental intellectual process*?

The C**hapters 1** and **2** provides the rationale for the KRQs in terms of introducing the fundamental research as well as forming an intellectual perspective on sustainability. The **KRQ 1** is addressed in **Chapter 3** in empirically framing a *fundamental intellectual process*. The frame of this process is applied in **Chapters 4-6** on the first decade's 'body of work' of sustainability science in order to elucidate the discursive, integrative and contextual structures of its discourse as being a pluralistic knowledge and research body, thus, addressing **KRQ 2**. These together form a continuous thread of inquiry on the intellectual treatment of sustainability, leading to addressing **KRQ 3** in **Chapter 7** in terms of eliciting a *pluralistic knowledge avenue* and the layout of an intellectual foundation for the *scholarship of sustainability* based on the rationale, framing and application of the *fundamental intellectual process*.

8.1.1 Summary findings from answering the KRQ 1

The contributions from **Chapter 3** in addressing the **KRQ 1** reside in:

(i) the development of a *fundamental literature organization process* that resulted in a *structure of five cross-connected layers of organization* within the literature archive (**Section 3.4**),

(ii) the development of a full-fledged *discourse analysis mechanism* that produces an analytical process based on a *system of five stages of discourse analysis* (**Section 3.4**), as well as

(iii) these two contributions becoming connected through a fundamental scheme of analyzing the basic structures of pluralistic knowledge/ research in terms of the discursive, integrative and contextual qualities (**Section 3.4**).

Besides these component structural contributions, **Chapter 3** frames the *fundamental intellectual process* required for the intellectual treatment of sustainability.

8.1.2 Summary findings from answering the KRQ 2

While addressing the **KRQ 1** in **Chapter 3** produced structural contributions in terms of the *fundamental intellectual process*, addressing the **KRQ 2** in **Chapters 4-6** produced functional contributions in terms of carrying out the *fundamental intellectual process*. These functional aspects include:

(i) the theoretical framework on the language of conversation in sustainability research (**Section 4.2.4**),

(ii) the significance of *Archetype-I* in sustainability research (**Section 4.2.1**),

(iii) the development of the *Prototype-I theoretical assumption* for sustainability research (**Section 4.2.1**), as well as

(iv) the generation of a vast array of analytics on studying the pluralistic knowledge and research structures in terms of the 'quantitative and discursive', 'qualitative and integrative' as well as 'place/ scale-based' analyses throughout the **Chapters 4-6**.

Addressing the **KRQ 2** also revealed findings on the discursive, integrative and contextual qualities of the discourse of sustainability science, which are discussed and summarized in the **Chapters 4**, **5** and **6**, respectively. The key findings arising from these analyses throughout the **Chapters 4-6**—as elaborated in **Sections 7.2 – 7.5**—are briefly articulated below.

(i) **Key Finding 1:** A lack of precision in characterizing the concept of 'human-environment system' along with an extremely open-ended representation of the concept (**Section 7.2**)

(ii) **Key Finding 2:** The overall contribution of sustainability science—revealed as consistent across its three different basic structures—is with respect to imparting structural contributions while lacking in the intellectual capacities to provide the functional aspects to the intellectual treatment of sustainability (**Section 7.3**)

(iii) **Key Finding 3:** The development of a theoretical framework on the language of conversation in sustainability research—based on conceptualization and extensive exemplification—in order to facilitate knowledge co-production in sustainability research (**Section 7.4**)

(iv) **Key Finding 4:** There is a strong correlation between the dominant 'original nature' and 'the *Archetype-I* characters'—i.e. 'literature survey' being the mode of conduction of a study, while 'literature archive analysis' being the research method—of the research, as well as a characteristic dominance of the *Archetype-I* criteria both in terms of the intensity and the diversity of sustainability science research. (**Section 7.5**)

8.1.3 Summary findings from answering the KRQ 3

Addressing the **KRQ 3** in **Chapter 7** based on inductive analysis produces the following contributions in terms of eliciting the pluralistic knowledge avenue.

(i) **Section 7.6.1** produces a structure of the component scholarships/ elements for the *pluralistic knowledge avenue*, besides inductively projecting the characteristics of an *integration expertise* for integrating, correlating and managing the entire pool of scholarships required for the *scholarship of sustainability*. These characteristics are inductively produced in light of the *new mode of enquiry* required for the *scholarship of sustainability*.

(ii) **Section 7.6.2** elucidates the levels of integration required for the scholarship of sustainability in terms of the different manners and degrees of integration of the participating elements in the *pluralistic knowledge avenue*.

(iii) **Section 7.6.3** produces the different scenarios for integration in sustainability research through analyzing the interplay between 'the participating scholarships/ elements in the making of the *pluralistic knowledge avenue*' (**Section 7.6.1**) and 'the different levels of integration for the *scholarship of sustainability*' (**Section 7.6.2**).

(iv) **Section 7.6.4** produces an in-depth modeling of these integrations.

In terms of eliciting the layout of an intellectual foundation for the *scholarship of sustainability*, the **KRQ 3** is addressed through taking the discussions in **Sections 7.1 – 7.6** as well as the rationale, framing and application of the *fundamental intellectual process* (presented in **Chapters 1-2**, **3** and **4-6**, respectively) together to extract the latent elements/ characters of an intellectual foundation for the *scholarship of sustainability*. Based on the elucidation of a total count of nine elements/ characters, the **Section 7.7** develops an integrated theory (in **Figure 7.2**) on the intellectual foundation of the *scholarship of sustainability*.

8.2 Contribution to knowledge

The **Table 8.1** enlists the new knowledge components of the thesis.

Table 8.1 New knowledge components of the research	
Corresponding section in Chapter 7	**Particulars**
7.2	***Key finding – 1: Characterization of human-environment system***
	In discussing the problems with the nature, definition and foundation of sustainability science in **Section 1.4,** sustainability science is seen to be proclaimed as having become a new academic discipline. This finding on the characterization of the 'human-environment system' disagrees to such proclamation in terms of the lack of an integrative structure in sustainability science on such a concept that sits at the core of the notion of sustainability.
7.3	***Key finding – 2: The overall contribution of sustainability science in the intellectual treatment of sustainability***
	The overall contribution of sustainability science being with respect to imparting structural contributions while lacking in the intellectual capacities to provide the functional aspects to the intellectual treatment of sustainability, communicates a significant discovery on the discourse of sustainability science. With respect to the proclamations on the practice as reviewed in C**hapter 1**, this finding reveals the capacities as well as the incapacities of the practice that were unknown before. As structural contributions could be reflected in a given scholastic practice through undertaking structural improvements, this does not necessarily produce the required intellectual capabilities within the practice. While being incepted in the year 2001 as a consensus practice (Kates et al. 2001), the structural consensus improvement that was framed within the identity of sustainability science could not produce the required intellectual capacities to provide the functional aspects to the intellectual treatment of sustainability, as evidenced from the analysis on its first decade of scholarship.
7.4	***Key finding – 3: The language of conversation to facilitate knowledge co-production in sustainability research***
	The understandings from literature reveal the need for effective and error-free methods of knowledge exchange and co-production while working in research consortia in undertaking sustainability research, which is met by the conceptualization and extensive exemplification of the language of conversation in sustainability research, leading to the development of a theoretical framework on it (in **Table 4.1**).
7.5	***Key finding – 4: Core empirical characteristics of sustainability research***
	In conventional wisdom literature analysis processes are seen not as much compatible with original nature of research, as well as viewed as a necessary measure for forming the background of a research without ascribing much importance to it. Takeuchi (2017) mentioning on the outstanding need for stakeholders in different disciplines to work together, as well as on the development of networks of research groups to enable a trans-disciplinary approach indicates to the necessity of a reality where processes such as literature analysis becomes a significant consideration. This key finding—consistent to the knowledge on the language of conversation in sustainability research (i.e. ***Key finding – 3***)—explicitly demonstrates the importance and dominant role of literature analysis processes in sustainability research.
7.6	***Inductive framing on eliciting the pluralistic knowledge avenue***
	Stafford-Smith et al. (2016) demonstrates the essential need of greater integration on the inter-linkages among sectors, actors and countries. Addressing needs such as this would require a structured scholarship of sustainability, capable of accomplishing such complex integration, which could also be measured through concrete empirical analytics based on the inter-linkages within the structure. The structure of the *pluralistic knowledge avenue* in light of the *new mode of enquiry* outlines the components of such a structure for an effective *scholarship of sustainability*.

8.3 Implications for policy and practice

The implications of the findings out of this research are manifold. In a prevailing reality of treating sustainability scholarship based on normative assumption-based exercises, the thesis produces the structure of a sustainability scholarship—in terms of a *fundamental intellectual process* for the intellectual treatment of sustainability—based on fundamental intellectual justification. This contribution can potentially reorient the chaotic debate around sustainability in terms of the deepening intellectual chaos, and through this, it can also reinvigorate the philosophical and moral basis of sustainability, besides providing a rigid reference to society.

The implications of the results arising from this research for the practice of sustainability science include:

(i) The value of practice that transcends reductionist methodology and reflects the intellectual orientation of the *new mode of enquiry* in terms of 'producing bricks of knowledge while looking at the whole building' in contrast to the 'production of specialized bricks of knowledge at the expense of not seeing the whole building'.

(ii) The potential for fundamental innovations to occur in terms of developing a newly integrative discourse, as well as in harnessing functional-intellectual capabilities in the intellectual treatment of sustainability.

(iii) The opportunity for practice to transcend a normative impulse and to harness fundamental intellectual processes in light of the intellectual perspective of sustainability.

A *sustainability scholarship* based on fundamental intellectual justification together with the establishment of the *pluralistic knowledge avenue* in research practice/ engagement in light of the *new mode of enquiry* offers the potential for research practices to create transformative knowledge of sustainability, in the process providing more value to society.

References

Before providing the list of references, the full table of references for the entire literature archive ('Group-A' literature archive) analyzed in this thesis is provided here. This renders all references in this thesis (including references appearing in all appendices except for **Appendix-6**) be placed together in the reference list following the table.

Item ID	Item	Sphere	Category	Theme ID	Theme
JG11	(Gilbert 2010)	A	i	1	Food security—Agricultural challenges/issues
JH7	(Hara et al. 2011)	A	i	3	Industrialization—Energy—Environment
JB26	(Berkhout et al. 2012)	A	ii	1	Energy policy/innovation
JG2	(Gallagher et al. 2006)	A	ii	1	Energy policy/innovation
JG12	(Gillingham et al. 2006)	A	ii	1	Energy policy/innovation
JG5	(Geels 2002)	A	iii	1	Transition theory
Item ID	Item	Sphere	Category	Theme ID	Theme
JB7	(Bettencourt et al. 2007)	AB	i	4	Urbanization—Consumption—Environment
JG20	(Graedel and Cao 2010)	AB	i	4	Urbanization—Consumption—Environment
JJ12	(Jolly et al. 2012)	AB	ii	1	Energy policy/innovation
JM29	(McCauley and Stephens 2012)	AB	ii	1	Energy policy/innovation
JN9	(Nakamura et al. 2013)	AB	ii	1	Energy policy/innovation
JS44	(Suwa and Jupesta 2012)	AB	ii	1	Energy policy/innovation
JA3	(Adeel and Safriel 2008)	AB	ii	2	Alternative livelihood
JA13	(Arnold et al. 2010)	AB	ii	3	Interventions and development, and conservation
JF1	(Fabusoro 2009)	AB	ii	4	Community involvement
JH32	(Hanaoka and Kainuma 2012)	AB	ii	5	Low-carbon transitions
JT2	(Takiguchi and Morita 2009)	AB	ii	5	Low-carbon transitions
JZ5	(Zhou 2006)	AB	ii	5	Low-carbon transitions
JA18	(Ausubel and Waggoner 2008)	AB	iii	2	Dematerialization
JY5	(Yokoo 2010)	AB	iii	3	"Reuse" as theory
JZ4	(Zhijun and Nailing 2007)	AB	iii	4	Circular economy
JZ9	(Zik and Kulatilaka 2013)	AB	iii	5	Quantitative sustainability
Item ID	Item	Sphere	Category	Theme ID	Theme
JE2	(Ejeta 2010)	AC	i	1	Food security—Agricultural challenges/issues
JF14	(Furuya and Kobayashi 2009)	AC	i	1	Food security—Agricultural challenges/issues
JC8	(Chong and Sunding 2006)	AC	i	2	Water availability/quality
JK31	(Kim 2006)	AC	i	3	Industrialization—Energy—Environment
JS17	(Shi et al. 2011)	AC	i	3	Industrialization—Energy—Environment
JP11	(Peters et al. 2011)	AC	i	5	Air pollution—GHG Emission—Emission transfers
JS35	(Suneetha 2010)	AC	i	6	Biodiversity—Habitat destruction—Trade
JL7	(Lee et al. 2008)	AC	ii	1	Energy policy/innovation

JM21	(Moreira and Goldemberg 1999)	AC	ii	1	Energy policy/innovation
JS27	(Steinfeld 2006)	AC	ii	1	Energy policy/innovation
JS42	(Sovacool and Bulan 2013)	AC	ii	1	Energy policy/innovation
JA20	(Akashi and Hanaoka 2012)	AC	ii	5	Low-carbon transitions
JA21	(Akimoto et al. 2012)	AC	ii	5	Low-carbon transitions
JI2	(Ikkatai et al. 2008)	AC	ii	5	Low-carbon transitions
JM11	(Matsuoka et al. 2008)	AC	ii	5	Low-carbon transitions
JW15	(Wagner et al. 2012)	AC	ii	5	Low-carbon transitions
JT15	(Tsuji et al. 2011)	AC	ii	6	Biodiversity—Agriculture—Poverty
JA9	(Andersen 2007)	AC	iii	4	Circular economy
JD6	(Dasgupta 2008)	AC	iii	6	Natural capital & ecosystem services management/governance
JP31	(Patterson and Glavovic 2013)	AC	iii	7	Ecological economics

Item ID	Item	Sphere	Category	Theme ID	Theme
JA1	(Acuin et al. 2011)	B	i	7	Public health
JC16	(Coker et al. 2011)	B	i	7	Public health
JW6	(WHO 2009)	B	i	7	Public health
JA16	(Aspinall 2005)	B	i	8	Human insecurity—Conflict
JH28	(HSC 2005)	B	i	8	Human insecurity—Conflict
JH29	(HSC 2011, Part I)	B	i	8	Human insecurity—Conflict
JH30	(HSC 2011, Part III)	B	i	8	Human insecurity—Conflict
JU1	(UN-ESC 2009)	B	i	9	Population—Consumption—Environment
JP13	(Phillips et al. 2005)	B	ii	3	Interventions and development, and conservation
JP23	(GF 2009)	B	ii	3	Interventions and development, and conservation
JP24	(GF 2009)	B	ii	3	Interventions and development, and conservation
JP26	(GF 2009)	B	ii	3	Interventions and development, and conservation
JP27	(GF 2009)	B	ii	3	Interventions and development, and conservation
JP28	(GF 2009)	B	ii	3	Interventions and development, and conservation
JP29	(GF 2009)	B	ii	3	Interventions and development, and conservation
JS33	(GF 2009)	B	ii	3	Interventions and development, and conservation
JJ6	(Jarchow et al. 2011)	B	ii	4	Community involvement
JK34	(Kisinza et al. 2008)	B	ii	4	Community involvement
JR1	(Raloff 1998)	B	ii	4	Community involvement
JA10	(Andersson 2008)	B	ii	7	Social learning
JB12	(Bongaarts 1994)	B	ii	8	Population policy
JC18	(Colten et al. 2008)	B	iii	8	Resilience
JL8	(Leiserowitz et al. 2005)	B	iii	9	Value—Attitude—Behavior
JL9	(Leiserowitz et al. 2006)	B	iii	9	Value—Attitude—Behavior

Item ID	Item	Sphere	Category	Theme ID	Theme
JA2	(Struble and Aomari 2003)	BA	i	1	Food security—Agricultural challenges/issues
JB1	(Barrett 2010)	BA	i	1	Food security—Agricultural challenges/issues
JC6	(Godfray et al. 2010)	BA	i	1	Food security—Agricultural challenges/issues
JC19	(Conway 2000)	BA	i	1	Food security—Agricultural challenges/issues
JF9	(2010)	BA	i	1	Food security—Agricultural challenges/issues

JF11	(Frongillo 1999)	BA	i	1	Food security—Agricultural challenges/issues
JM10	(Matsumura et al. 2009)	BA	i	1	Food security—Agricultural challenges/issues
JW2	(Webb 2010)	BA	i	1	Food security—Agricultural challenges/issues
JM8	(Marcotullio 2007)	BA	i	2	Water availability/quality
JH23	(Homs 2007)	BA	i	4	Urbanization—Consumption—Environment
JK10	(Kates 2000b)	BA	i	9	Population—Consumption—Environment
JC17	(Collier 2007)	BA	i	10	African poverty
JP30	(GF 2009)	BA	ii	3	Interventions and development, and conservation
JM2	(Mabogunje 2007)	BA	ii	4	Community involvement
JD17	(Diffenbaugh 2013)	BA	ii	5	Low-carbon transitions
JL2	(Larson and Ribot 2007)	BA	ii	9	Forest management policy/innovation
JT4	(Tester and Langridge 2010)	BA	ii	10	Agricultural policy/innovation
JT14	(Trieb and Müller-Steinhagen 2007)	BA	ii	11	Regional cooperation
JA17	(Auer 2007)	BA	iii	10	Institutional reform
JK5	(Kates 1992)	BA	iii	11	Sustainability challenge
JL13	(Levi-Faur 2005)	BA	iii	12	Regulatory capitalism
JL14	(Levi-Faur and Jordana 2005)	BA	iii	12	Regulatory capitalism
JM13	(McGee 2008)	BA	iii	13	Rural-urban transformation
JR15	(Rosenfeld 2010)	BA	iii	14	Poverty—Development
JT12	(Townsend 2010)	BA	iii	14	Poverty—Development
JS5	(Sanya 2012)	BA	iii	15	Sustainable architecture

Item ID	Item	Sphere	Category	Theme ID	Theme
JR4	(Rarieya and Fortun 2010)	BC	i	1	Food security—Agricultural challenges/issues
JF13	(Funke et al. 2007)	BC	i	2	Water availability/quality
JK25	(Kazama et al. 2012)	BC	i	7	Public health
JI7	(Iwasaki and Shaw 2009)	BC	i	8	Human insecurity—Conflict
JK29	(Khagram and Ali 2006)	BC	i	8	Human insecurity—Conflict
JD12	(Dietz et al. 2003)	BC	i	9	Population—Consumption—Environment
JG13	(Gleick 2003b)	BC	i	9	Population—Consumption—Environment
JO1	(O'Neill et al. 2010)	BC	i	9	Population—Consumption—Environment
JP16	(Popovski and Mundy 2012)	BC	i	11	Climate change problem/impacts
JS16	(Shahbazbegian and Bagheri 2010)	BC	i	12	Drought
JS38	(Syvitski 2008)	BC	i	13	Delta — problems
JH33	(Higgins and Foliente 2013)	BC	ii	3	Interventions and development, and conservation
JP1	(de Palencia and Pérez-Foguet 2011)	BC	ii	3	Interventions and development, and conservation
JP25	(GF 2009)	BC	ii	3	Interventions and development, and conservation
JR17	(Rehman et al. 2012)	BC	ii	3	Interventions and development, and conservation
JT11	(Toth and Hizsnyik 2008)	BC	ii	4	Community involvement
JG17	(Gomi et al. 2007)	BC	ii	5	Low-carbon transitions
JS20	(Snapp et al. 2010)	BC	ii	6	Biodiversity—Agriculture—Poverty
JT7	(Timmer and Juma 2005)	BC	ii	6	Biodiversity—Agriculture—Poverty
JY10	(Yami et al. 2013)	BC	ii	9	Forest management policy/innovation
JI5	(IAC 2004)	BC	ii	10	Agricultural policy/innovation
JT13	(Townsend and Porder 2012)	BC	ii	10	Agricultural policy/innovation
JN1-4	(Ross and Woo 2011)	BC	ii	11	Regional cooperation

JA22	(Antanasijević et al. 2013)	BC	**ii**	**12**	Modeling
JP22	(Preston et al. 2011)	BC	**ii**	**12**	Modeling
JB11	(Black et al. 2011)	BC	**ii**	**13**	Adaptation—Natural Disaster—Migration—Benefits
JG24	(Gray and Mueller 2012)	BC	**ii**	**13**	Adaptation—Natural Disaster—Migration—Benefits
JP2	(Parker et al. 2007)	BC	**ii**	**13**	Adaptation—Natural Disaster—Migration—Benefits
JR16	(Reckien et al. 2013)	BC	**ii**	**13**	Adaptation—Natural Disaster—Migration—Benefits
JS36	(Surjan and Shaw 2008)	BC	**ii**	**14**	Urban policy/innovation
JU3	(UN-Habitat 2012)	BC	**ii**	**14**	Urban policy/innovation
JW9	(Wilbanks et al. 2007)	BC	**ii**	**14**	Urban policy/innovation
JT5	(Thomas 2011)	BC	**ii**	**15**	Reuse—Recycling—Pollution control
JK41	(Kurian et al. 2013)	BC	**iii**	**3**	"Reuse" as theory
JL11	(Lemos and Agrawal 2006)	BC	**iii**	**6**	Natural capital & ecosystem services management/governance
JL22	(Lynam et al. 2007)	BC	**iii**	**6**	Natural capital & ecosystem services management/governance
JS32	(Su et al. 2012)	BC	**iii**	**6**	Natural capital & ecosystem services management/governance
JW4	(White 1967)	BC	**iii**	**11**	Sustainability challenge
JK6	(Kates and Haarmann 1992)	BC	**iii**	**14**	Poverty—Development
JR6	(Raudsepp-Hearne et al. 2010)	BC	**iii**	**14**	Poverty—Development
JK37	(Kosamu 2011)	BC	**iii**	**15**	Sustainable architecture
JN1-3	(Brown 2011)	BC	**iii**	**15**	Sustainable architecture
JB10	(Birkmann et al. 2010)	BC	**iii**	**16**	Urban sustainability and adaptive urban governance
JS9	(Satterthwaite 2007)	BC	**iii**	**16**	Urban sustainability and adaptive urban governance
JS23	(Solecki and Leichenko 2006)	BC	**iii**	**16**	Urban sustainability and adaptive urban governance
JK9	(Kates 2000a)	BC	**iii**	**17**	Adaptation
JM20	(Molua 2011)	BC	**iii**	**17**	Adaptation
JL15	(Lie 2007)	BC	**iii**	**18**	Political ecology
JL17	(Liverman and Vilas 2006)	BC	**iii**	**18**	Political ecology
JM7	(Manson 2006)	BC	**iii**	**19**	Land cover and land use change science
JW13	(Wu et al. 2010)	BC	**iii**	**19**	Land cover and land use change science
JY4	(Yin and Xiang 2010)	BC	**iii**	**19**	Land cover and land use change science
JM31	(Mohamad et al. 2012)	BC	**iii**	**20**	Sustainability—Culture—Religion
JT1	(Tàbara and Ilhan 2008)	BC	**iii**	**20**	Sustainability—Culture—Religion
JR10	(Roberts et al. 2003)	BC	**iii**	**21**	World System theory
JW5	(White et al. 2001)	BC	**iii**	**22**	Learning—Knowledge—Ignorance—Condition

Item ID	**Item**	**Sphere**	**Category**	**Theme ID**	**Theme**
JP17	(Pöschl 2005)	C	**i**	**5**	Air pollution—GHG Emission—Emission transfers
JO8	(Overpeck and Cole 2006)	C	**i**	**11**	Climate change problem/impacts
JP3	(Parkinson 2006)	C	**i**	**11**	Climate change problem/impacts
JK4	(Kasei et al. 2010)	C	**i**	**12**	Drought
JB14	(Boyce et al. 2010)	C	**i**	**14**	Ecological crisis
JG22	(Grainger 2008)	C	**i**	**14**	Ecological crisis
JC9	(Church et al. 2008)	C	**i**	**15**	Coastal vulnerability issues & sea level rise
JJ9	(Jin et al. 2008)	C	**ii**	**12**	Modeling

JL12	(Lenton et al. 2008)	C	iii	23	Earth System analysis and tipping elements/points
JL20	(Lovelock 1986)	C	iii	23	Earth System analysis and tipping elements/points

Item ID	Item	Sphere	Category	Theme ID	Theme
JE5	(Esteban et al. 2009)	CA	i	16	Global warming—Natural disaster
JB8	(Birch et al. 2010)	CA	ii	9	Forest management policy/innovation
JH27	(Hosoda and Hayashi 2010)	CA	ii	11	Regional cooperation
JK24	(Kazama et al. 2010)	CA	ii	12	Modeling
JD11	(Diallo and Brinker 2011)	CA	ii	16	Technology and nanotechnology
JS22	(Socolow et al. 2004)	CA	ii	16	Technology and nanotechnology
JE4	(Esposto 2009)	CA	ii	17	Water policy/innovation
JE6	(Eyckmans and Finus 2007)	CA	ii	18	Treaties—Agreements
JC21	(Costanza et al. 1997)	CA	iii	6	Natural capital & ecosystem services management/governance
JD1	(Daily et al. 2000)	CA	iii	6	Natural capital & ecosystem services management/governance
JA12	(Arndt et al. 2011)	CA	iii	17	Adaptation
JD4	(Dasgupta et al. 1995)	CA	iii	24	Environmental regulation

Item ID	Item	Sphere	Category	Theme ID	Theme
JM3	(MacDonald et al. 2011)	CB	i	1	Food security—Agricultural challenges/issues
JM9	(Marty et al. 2010)	CB	i	1	Food security—Agricultural challenges/issues
JS1	(Sachs et al. 2010)	CB	i	1	Food security—Agricultural challenges/issues
JS8	(Sattari et al. 2012)	CB	i	1	Food security—Agricultural challenges/issues
JM19	(Molina and Molina 2004)	CB	i	5	Air pollution—GHG Emission—Emission transfers
JD13	(Dirzo and Raven 2003)	CB	i	6	Biodiversity—Habitat destruction—Trade
JG8	(Geist and Lambin 2002)	CB	i	6	Biodiversity—Habitat destruction—Trade
JS4	(Sala and Knowlton 2006)	CB	i	6	Biodiversity—Habitat destruction—Trade
JK14	(Kates and Wilbanks 2003)	CB	i	11	Climate change problem/impacts
JN2	(NAS 2008)	CB	i	11	Climate change problem/impacts
JS3	(Sahoo and Schladow 2008)	CB	i	11	Climate change problem/impacts
JP18	(Postel 2005)	CB	i	14	Ecological crisis
JG23	(Gravelle and Mimura 2008)	CB	i	15	Coastal vulnerability issues & sea level rise
JH9	(Harvey and Woodroffe 2008)	CB	i	15	Coastal vulnerability issues & sea level rise
JM15	(Mcleod et al. 2010)	CB	i	15	Coastal vulnerability issues & sea level rise
JN7	(Nicholls et al. 2008)	CB	i	15	Coastal vulnerability issues & sea level rise
JR14	(Romieu et al. 2010)	CB	i	15	Coastal vulnerability issues & sea level rise
JT10	(Torresan et al. 2008)	CB	i	15	Coastal vulnerability issues & sea level rise
JY2	(Yasuhara et al. 2007)	CB	i	15	Coastal vulnerability issues & sea level rise
JY3	(Yasuhara et al. 2011)	CB	i	15	Coastal vulnerability issues & sea level rise
JL19	(Lotze et al. 2006)	CB	i	17	Estuaries & coastal seas — problems
JS18	(Sidle et al. 2007)	CB	i	18	Open water bodies — problems
JS2	(Safriel and Adeel 2008)	CB	ii	2	Alternative livelihood
JB2	(Barthelmie et al. 2008)	CB	ii	5	Low-carbon transitions
JA23	(Azadi et al. 2013)	CB	ii	9	Forest management policy/innovation
JL4	(Lebel et al. 2004)	CB	ii	9	Forest management policy/innovation
JS24	(Sonwa et al. 2011)	CB	ii	9	Forest management policy/innovation
JY8	(Yoshikawa et al. 2011)	CB	ii	9	Forest management policy/innovation
JC4	(Cassman et al. 2003)	CB	ii	10	Agricultural policy/innovation

JC7	(Chen et al. 2011)	CB	ii	**10**	Agricultural policy/innovation
JF4	(Fedoroff et al. 2010)	CB	ii	**10**	Agricultural policy/innovation
JG4	(Gebbers and Adamchuk 2010)	CB	ii	**10**	Agricultural policy/innovation
JG9	(Gewin 2010)	CB	ii	**10**	Agricultural policy/innovation
JH13	(Herdt 2006)	CB	ii	**10**	Agricultural policy/innovation
JH15	(Herrero et al. 2010)	CB	ii	**10**	Agricultural policy/innovation
JR11	(Roberts and Brink 2010)	CB	ii	**10**	Agricultural policy/innovation
JS43	(Spugnoli and Dainelli 2013)	CB	ii	**10**	Agricultural policy/innovation
JT8	(Tollefson 2010)	CB	ii	**10**	Agricultural policy/innovation
JK22	(Katsuyama et al. 2009)	CB	ii	**12**	Modeling
JP21	(Poumadère et al. 2008)	CB	ii	**12**	Modeling
JB9	(Birkmann and von Teichman 2010)	CB	ii	**13**	Adaptation—Natural Disaster—Migration—Benefits
JH11	(Hay and Mimura 2006)	CB	ii	**13**	Adaptation—Natural Disaster—Migration—Benefits
JS30	(von Storch and Woth 2008)	CB	ii	**13**	Adaptation—Natural Disaster—Migration—Benefits
JO3	(Ohyama et al. 2008)	CB	ii	**14**	Urban policy/innovation
JN1-6	(Graedel 2011)	CB	ii	**15**	Reuse—Recycling—Pollution control
JZ2	(Zhang et al. 2006)	CB	ii	**15**	Reuse—Recycling—Pollution control
JD3	(Daniell et al. 2010)	CB	ii	**17**	Water policy/innovation
JG14	(Gleick 2003a)	CB	ii	**17**	Water policy/innovation
JH14	(Hermanowicz 2008)	CB	ii	**17**	Water policy/innovation
JR2	(Ramanathan and Xu 2010)	CB	ii	**18**	Treaties—Agreements
JB15	(Brack et al. 2006)	CB	ii	**19**	Emission estimation/control
JC1	(Caldeira and Davis 2011)	CB	ii	**19**	Emission estimation/control
JH6	(Hara et al. 2010)	CB	ii	**20**	Land use system planning/innovation
JK33	(Kimura et al. 2010)	CB	ii	**20**	Land use system planning/innovation
JK39	(Kumar and Takeuchi 2009)	CB	ii	**20**	Land use system planning/innovation
JL5	(Leclerc et al. 2009)	CB	ii	**20**	Land use system planning/innovation
JH19	(Hoekstra 2012)	CB	ii	**21**	Biodiversity conservation policy/innovation
JL10	(Lejano and Ingram 2007)	CB	ii	**21**	Biodiversity conservation policy/innovation
JS6	(Sarkar et al. 2006)	CB	ii	**21**	Biodiversity conservation policy/innovation
JJ1	(Jack et al. 2008)	CB	ii	**22**	Ecosystem services policy/innovation
JK35	(Komatsuzaki and Ohta 2007)	CB	ii	**22**	Ecosystem services policy/innovation
JT9	(Tomich et al. 2004)	CB	ii	**22**	Ecosystem services policy/innovation
JX1	(Xia and Yan 2012)	CB	ii	**22**	Ecosystem services policy/innovation
JL18	(Longhurst et al. 2009)	CB	ii	**23**	Air quality policy/innovation
JY7	(Yoshida 2007)	CB	ii	**24**	Environmental restoration policies/innovation
JC2	(Carpenter et al. 2009)	CB	iii	**6**	Natural capital & ecosystem services management/governance
JD2	(Daily and Matson 2008)	CB	iii	**6**	Natural capital & ecosystem services management/governance
JD10	(Depietri et al. 2012)	CB	iii	**6**	Natural capital & ecosystem services management/governance
JF5	(Ferraro Jr. and Burztyn 2008)	CB	iii	**6**	Natural capital & ecosystem services management/governance
JG3	(Gardi and Sconosciuto 2007)	CB	iii	**6**	Natural capital & ecosystem services management/governance
JH4	(Halpin 1997)	CB	iii	**6**	Natural capital & ecosystem services management/governance
JB20	(Bueno and Basurto 2009)	CB	iii	**8**	Resilience
JM5	(Mah and Bustami 2012)	CB	iii	**8**	Resilience
JP19	(Potschin and Haines-Young 2006b)	CB	iii	**11**	Sustainability challenge

JS28	(Stocker et al. 2010)	CB	iii	11	Sustainability challenge
JY6	(York et al. 2003)	CB	iii	11	Sustainability challenge
JF15	(Füssel 2007)	CB	iii	17	Adaptation
JD9	(DeFries et al. 2006)	CB	iii	19	Land cover and land use change science
JG1	(Gadda and Gasparatos 2009)	CB	iii	19	Land cover and land use change science
JI4	(Ileva et al. 2009)	CB	iii	19	Land cover and land use change science
JL1	(Lambin et al. 2003)	CB	iii	19	Land cover and land use change science
JP15	(Pontius Jr and Neeti 2010)	CB	iii	19	Land cover and land use change science
JF12	(Fung and O'rourke 2000)	CB	iii	24	Environmental regulation
JC14	(Clark et al. 2006)	CB	iii	25	Environmental assessment
JM24	(Mühlhäusler and Peace 2006)	CB	iii	26	Sustainability related discourses

Item ID	Item	Sphere	Category	Theme ID	Theme
JK20	(Kates and Dasgupta 2007)	D	i	10	African poverty
JI6	(IPCC 2007)	D	i	11	Climate change problem/impacts
JZ7	(Ziv et al. 2012)	D	i	19	River — problems
JN3	(Nautiyal 2011)	D	ii	3	Interventions and development, and conservation
JM18	(Millar et al. 2007)	D	ii	9	Forest management policy/innovation
JA6	(Alcamo et al. 2005)	D	ii	12	Modeling
JG18	(Goodchild 2003)	D	ii	12	Modeling
JJ5	(Janssen and Ostrom 2006)	D	ii	12	Modeling
JM23	(Moser and Ekstrom 2010)	D	ii	13	Adaptation—Natural Disaster—Migration—Benefits
JH31	(Han et al. 2012)	D	ii	14	Urban policy/innovation
JN1-1	(Fink 2011)	D	ii	14	Urban policy/innovation
JS13	(Schmandt 2006)	D	ii	17	Water policy/innovation
JZ8	(Zwane et al. 2009)	D	ii	17	Water policy/innovation
JS21	(Soberon 2004)	D	ii	21	Biodiversity conservation policy/innovation
JG15	(2007)	D	ii	24	Environmental restoration policies/innovation
JA14	(Ascher 2006)	D	ii	25	Sustainable Development strategies/innovation
JM1	(Mabogunje and Kates 2004)	D	ii	25	Sustainable Development strategies/innovation
JN8	(Nidumolu et al. 2009)	D	ii	25	Sustainable Development strategies/innovation
JZ1	(van Zeijl-Rozema et al. 2008)	D	ii	25	Sustainable Development strategies/innovation
JG6	(Geels and Schot 2007)	D	iii	1	Transition theory
JG7	(Geels 2011)	D	iii	1	Transition theory
JZ3	(Zhang et al. 2009)	D	iii	4	Circular economy
JB13	(Boulanger 2008)	D	iii	5	Quantitative sustainability
JF3	(Fan and Qi 2010)	D	iii	5	Quantitative sustainability
JH5	(Hara et al. 2009)	D	iii	5	Quantitative sustainability
JK18	(Kates et al. 2005)	D	iii	5	Quantitative sustainability
JM27	(MacDonald 2005)	D	iii	5	Quantitative sustainability
JN5	(Ness et al. 2007)	D	iii	5	Quantitative sustainability
JO5	(Orecchini 2007)	D	iii	5	Quantitative sustainability
JP4	(Parris and Kates 2003b)	D	iii	5	Quantitative sustainability
JP5	(Parris and Kates 2003a)	D	iii	5	Quantitative sustainability
JP14	(Phillips 2010)	D	iii	5	Quantitative sustainability
JH2	(Haberl et al. 2007)	D	iii	6	Natural capital & ecosystem services management/governance

JH8	(Hardin 1968)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance
JH18	(Hoekstra and Mekonnen 2012)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance
JK26	(Kenward et al. 2011)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance
JO6	(Ostrom and Nagendra 2006)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance
JO7	(Ostrom et al. 2007)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance
JT3	(Tallis and Kareiva 2006)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance
JW11	(Wilderer 2007)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance
JA4	(Adger 2000)	**D**	**iii**	**8**	Resilience
JB16	(Brand and Jax 2007)	**D**	**iii**	**8**	Resilience
JF7	(Folke et al. 2010)	**D**	**iii**	**8**	Resilience
JH21	(Holling 1973)	**D**	**iii**	**8**	Resilience
JS19	(Smith and Stirling 2010)	**D**	**iii**	**8**	Resilience
JK19	(Kates et al. 2006)	**D**	**iii**	**9**	Value—Attitude—Behavior
JA19	(Ayres 2000)	**D**	**iii**	**11**	Sustainability challenge
JB17	(Brewer 2007)	**D**	**iii**	**11**	Sustainability challenge
JB18	(WCED 1987)	**D**	**iii**	**11**	Sustainability challenge
JC11	(Clark 2003b)	**D**	**iii**	**11**	Sustainability challenge
JC13	(Clark et al. 2004a)	**D**	**iii**	**11**	Sustainability challenge
JD5	(Dasgupta 2007)	**D**	**iii**	**11**	Sustainability challenge
JF8	(Folke et al. 2011)	**D**	**iii**	**11**	Sustainability challenge
JG21	(Graffy 2012)	**D**	**iii**	**11**	Sustainability challenge
JH20	(Holdren 2008)	**D**	**iii**	**11**	Sustainability challenge
JI1	(ICSU 2002)	**D**	**iii**	**11**	Sustainability challenge
JK7	(Kates 1996)	**D**	**iii**	**11**	Sustainability challenge
JK8	(Kates and Torrie 1998)	**D**	**iii**	**11**	Sustainability challenge
JK11	(Kates 2001a)	**D**	**iii**	**11**	Sustainability challenge
JK13	(Kates et al. 2001)	**D**	**iii**	**11**	Sustainability challenge
JK16	(Kates 2003b)	**D**	**iii**	**11**	Sustainability challenge
JK17	(Kates and Parris 2003)	**D**	**iii**	**11**	Sustainability challenge
JM26	(Munasinghe 2010)	**D**	**iii**	**11**	Sustainability challenge
JP10	(Perrings 2007)	**D**	**iii**	**11**	Sustainability challenge
JR5	(Raskin et al. 2010)	**D**	**iii**	**11**	Sustainability challenge
JR7	(Raven 2002)	**D**	**iii**	**11**	Sustainability challenge
JR12	(Rockström et al. 2009)	**D**	**iii**	**11**	Sustainability challenge
JS10	(Savage 2006)	**D**	**iii**	**11**	Sustainability challenge
JS34	(Suneetha 2010)	**D**	**iii**	**11**	Sustainability challenge
JS39	(Doran et al. 2012)	**D**	**iii**	**11**	Sustainability challenge
JW8	(Wilbanks and Kates 1999)	**D**	**iii**	**11**	Sustainability challenge
JP9	(Peet and Peet 2000)	**D**	**iii**	**14**	Poverty—Development
JM14	(McGranahan and Satterthwaite 2003)	**D**	**iii**	**16**	Urban sustainability and adaptive urban governance
JN1-2	(Daigger 2011)	**D**	**iii**	**16**	Urban sustainability and adaptive urban governance
JN1-5	(Bai 2011)	**D**	**iii**	**16**	Urban sustainability and adaptive urban governance
JW10	(Wilbanks and Kates 2010)	**D**	**iii**	**17**	Adaptation
JB19	(Bryant 1998)	**D**	**iii**	**18**	Political ecology
JC20	(Cox 1981)	**D**	**iii**	**18**	Political ecology
JH16	(Hersperger et al. 2010)	**D**	**iii**	**19**	Land cover and land use change science
JR9	(Rindfuss et al. 2004)	**D**	**iii**	**19**	Land cover and land use change science
JS11	(Schaldach and Priess 2008)	**D**	**iii**	**19**	Land cover and land use change science
JT18	(Turner et al. 2007a)	**D**	**iii**	**19**	Land cover and land use change science
JB22	(Burns et al. 2003)	**D**	**iii**	**21**	World System theory

JH25	(Hornborg 1998)	D	iii	21	World System theory
JM6	(Mann 2010)	D	iii	21	World System theory
JH12	(Henry 2009)	D	iii	22	Learning—Knowledge—Ignorance—Condition
JS12	(Schellnhuber 2009)	D	iii	23	Earth System analysis and tipping elements/points
JK3	(Kajikawa et al. 2011)	D	iii	25	Environmental assessment
JP6	(Parson 1997)	D	iii	25	Environmental assessment
JA5	(Adger et al. 2001)	D	iii	26	Sustainability related discourses
JH34	(Hugé et al. 2013)	D	iii	26	Sustainability related discourses
JA7	(Allenby 2006)	D	iii	27	Ethics
JD16	(Dwyer 2008)	D	iii	27	Ethics
JA8	(Allenby et al. 2009)	D	iii	28	Sustainable engineering education
JS15	(Segalas et al. 2009)	D	iii	28	Sustainable engineering education
JA11	(Andersson et al. 2008)	D	iii	29	Sustainability Science education/curriculum
JB24	(Barth and Michelsen 2013)	D	iii	29	Sustainability Science education/curriculum
JE3	(Epstein et al. 2009)	D	iii	29	Sustainability Science education/curriculum
JF2	(Fadeeva and Mochizuki 2010)	D	iii	29	Sustainability Science education/curriculum
JO4	(Onuki and Mino 2009)	D	iii	29	Sustainability Science education/curriculum
JP12	(Petry et al. 2011)	D	iii	29	Sustainability Science education/curriculum
JT21	(Tamura and Uegaki 2012)	D	iii	29	Sustainability Science education/curriculum
JU2	(Uwasu et al. 2009)	D	iii	29	Sustainability Science education/curriculum
JW7	(Wiek et al. 2011)	D	iii	29	Sustainability Science education/curriculum
JW12	(Wright et al. 2009)	D	iii	29	Sustainability Science education/curriculum
JY11	(Yarime et al. 2012)	D	iii	29	Sustainability Science education/curriculum
JA15	(Ascher 2007)	D	iii	30	Policy science
JR13	(Rodriguez and Montalvo 2007)	D	iii	30	Policy science
JB3	(Beck 2010b)	D	iii	31	Cosmopolitanism
JB4	(Beck 2010a)	D	iii	31	Cosmopolitanism
JB5	(Beratan 2007)	D	iii	32	Decision making
JB6	(Berger et al. 2001)	D	iii	33	Ecological modernization
JJ4	(Jänicke 2008)	D	iii	33	Ecological modernization
JB21	(Burian 2001)	D	iii	34	Case studies for sustainability science
JB23	(Bursztyn 2008)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JB25	(Benessia et al. 2012)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JB27	(Buter and Van Raan 2013)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JC3	(Cash et al. 2003)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JC10	(Clark 2003a)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JC12	(Clark and Dickson 2003)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JC22	(Costa and Kropp 2013)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JE1	(Eakin and Luers 2006)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JG10	(Gieryn 1983)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JG16	(Goldman and Schurman 2000)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JG19	(Gotts 2007)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JG27	(Gardner 2013)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JH1	(Haapasaari et al. 2012)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research

JH3	(Hadorn 2004)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JH17	(Hiramatsu et al. 2008)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JJ2	(Jäger 2006)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JJ3	(Jäger 2011)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JK1	(Kajikawa et al. 2007)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JK23	(Kauffman 2009)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JK36	(Komiyama and Takeuchi 2006)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JL23	(Lang et al. 2012)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JL24	(van der Leeuw et al. 2012)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JM4	(MacMynowski 2007)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JM17	(Mihelcic et al. 2003)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JM22	(Morioka et al. 2006)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JM25	(Mulder 2007)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JN4	(Nelson 2006)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JO9	(Orecchini et al. 2012)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JP8	(Pauwels 2011)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JR3	(Rapport 2007)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JR8	(Reitan 2005)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JS14	(Schoolman et al. 2012)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JS41	(Shiroyama et al. 2012)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JW1	(Wallerstein 2010)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JW3	(Westley et al. 2011)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JW14	(Wuelser et al. 2012)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JW17	(Wiek et al. 2012b)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JY1	(Yarime et al. 2010)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JC5	(Chapin III et al. 2011)	D	iii	36	Anthropocene and Earth stewardship
JS26	(Steffen et al. 2011)	D	iii	36	Anthropocene and Earth stewardship
JS29	(2011)	D	iii	36	Anthropocene and Earth stewardship
JT16	(Turner et al. 1994)	D	iii	36	Anthropocene and Earth stewardship
JC15	(Clark 2007)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JF16	(Forsyth 2001)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JH26	(Hornborg 2003)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JJ8	(Jerneck et al. 2011)	D	iii	37	Ontology and/or epistemology of Sustainability Science

JK2	(Kajikawa 2008)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JK12	(Kates 2001b)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JK21	(Kates 2011)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JK27	(Kerkhoff and Lebel 2006)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JK30	(Khagram et al. 2010)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JK38	(Kristjanson et al. 2009)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JK40	(Kumazawa et al. 2009)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JM12	(Max-Neef 2005)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JM28	(Marsden 2013)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JM30	(Miller 2013)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JN6	(Ness et al. 2010)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JS7	(Sato 2007)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JS25	(Steffen 2006)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JS31	(Strunz 2012)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JS40	(Salas-Zapata et al. 2013)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JT19	(Turner and Robbins 2008)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JT20	(Tushman and O'Reilly 2007)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JW16	(Wiek et al. 2012a)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JZ6	(Ziegler and Ott 2011)	D	iii	37	Ontology and/or epistemology of Sustainability Science
JD7	(Davis 2006)	D	iii	38	Complex systems, analysis, and adaptive planning/management
JD8	(Dearing et al. 2010)	D	iii	38	Complex systems, analysis, and adaptive planning/management
JF6	(Folke et al. 2007)	D	iii	38	Complex systems, analysis, and adaptive planning/management
JH22	(Holling 2001)	D	iii	38	Complex systems, analysis, and adaptive planning/management
JH24	(Horan et al. 2011)	D	iii	38	Complex systems, analysis, and adaptive planning/management
JI3	(Iles 1996)	D	iii	38	Complex systems, analysis, and adaptive planning/management
JJ10	(Johnson 1999)	D	iii	38	Complex systems, analysis, and adaptive planning/management
JL6	(Lee 1999)	D	iii	38	Complex systems, analysis, and adaptive planning/management
JL16	(Liu et al. 2007)	D	iii	38	Complex systems, analysis, and adaptive planning/management
JM16	(Meadows 1999)	D	iii	38	Complex systems, analysis, and adaptive planning/management
JP7	(Parsons 2007)	D	iii	38	Complex systems, analysis, and adaptive planning/management
JT17	(Turner et al. 2003)	D	iii	38	Complex systems, analysis, and adaptive planning/management

JY9	(Young et al. 2006)	D	iii	38	Complex systems, analysis, and adaptive planning/management
JD14	(Douglas 2007)	D	iii	39	Cultural theory
JO2	(O'Riordan and Jordan 1999)	D	iii	39	Cultural theory
JT6	(Thompson 1997)	D	iii	39	Cultural theory
JD15	(Drechsel and Dongus 2010)	D	iii	40	Urban agriculture
JF10	(Fotopoulos 2007)	D	iii	41	De-growth
JK28	(Kerschner 2010)	D	iii	41	De-growth
JL3	(Latouche 2007)	D	iii	41	De-growth
JG25	(Grey 1993)	D	iii	42	Anthropocentrism vs. deep ecology
JG26	(Gruen et al. 2008)	D	iii	43	Sustainable health
JH10	(von Hauff and Wilderer 2008)	D	iii	44	Industrial ecology
JJ7	(Jerneck and Olsson 2011)	D	iii	45	Reframing
JJ11	(Jorgenson and Kick 2003)	D	iii	46	Globalization
JK15	(Kates 2003a)	D	iii	46	Globalization
JK32	(Kim and Oki 2011)	D	iii	47	Scenario analysis—Visioneering
JS37	(Kosamu 2011)	D	iii	47	Scenario analysis—Visioneering
JL21	(Lüdeke et al. 2004)	D	iii	48	Syndromes
JP20	(Potschin and Haines-Young 2006a)	D	iii	49	Landscape ecology

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Appendix 1

Full list of the 'Themes' (1, 2, 3 …) under the 'Categories' (i, ii, iii)

The color variation of entries (blue, black, green and yellow) represent the first emergence of the themes in the sequence of the broad spheres of A—'Economic perspectives of sustainability', B—'Social perspectives of sustainability' and C—'Environmental perspectives of sustainability', and D—'Central organization of sustainability', respectively. Once the themes occur, they potentially share archive items from the subsequent broad spheres.

Full list of the Themes (1, 2, 3 …) under the Categories (i, ii, iii)

i		ii		iii	
i	Problem/ issue/ challenge/ syndrome-sphere	ii	Action/ approach-sphere	iii	Academic-sphere
i 1	Food security—Agricultural challenges/issues	ii 1	Energy policy/innovation	iii 1	Transition theory
i 2	Water availability/quality	ii 2	Alternative livelihood	iii 2	Dematerialization
i 3	Industrialization—Energy—Environment	ii 3	Interventions and development, and conservation	iii 3	"Reuse" as theory
i 4	Urbanization—Consumption—Environment	ii 4	Community involvement	iii 4	Circular economy
i 5	Air pollution—GHG Emission—Emission transfers	ii 5	Low-carbon transitions	iii 5	Quantitative sustainability
i 6	Biodiversity—Habitat destruction—Trade	ii 6	Biodiversity—Agriculture—Poverty	iii 6	Natural capital & ecosystem services management/governance
i 7	Public health	ii 7	Social learning	iii 7	Ecological economics
i 8	Human insecurity—Conflict	ii 8	Population policy	iii 8	Resilience
i 9	Population—Consumption—Environment	ii 9	Forest management policy/innovation	iii 9	Value—Attitude—Behavior
i 10	African poverty	ii 10	Agricultural policy/innovation	iii 10	Institutional reform
i 11	Climate change problem/impacts	ii 11	Regional cooperation	iii 11	Sustainability challenge
i 12	Drought	ii 12	Modeling	iii 12	Regulatory capitalism
i 13	Delta — problems	ii 13	Adaptation—Natural Disaster—Migration—Benefits	iii 13	Rural-urban transformation
i 14	Ecological crisis	ii 14	Urban policy/innovation	iii 14	Poverty—Development
i 15	Coastal vulnerability issues & sea level rise	ii 15	Reuse—Recycling—Pollution control	iii 15	Sustainable architecture
i 16	Global warming—Natural disaster	ii 16	Technology and nanotechnology	iii 16	Urban sustainability and adaptive urban governance
i 17	Estuaries & coastal seas — problems	ii 17	Water policy/innovation	iii 17	Adaptation
i 18	Open water bodies — problems	ii 18	Treaties—Agreements	iii 18	Political ecology
i 19	River — problems	ii 19	Emission estimation/control	iii 19	Land cover and land use change science
		ii 20	Land use system planning/innovation	iii 20	Sustainability—Culture—Religion
		ii 21	Biodiversity conservation policy/innovation	iii 21	World System theory
		ii 22	Ecosystem services policy/innovation	iii 22	Learning—Knowledge—Ignorance—Condition
		ii 23	Air quality policy/innovation	iii 23	Earth System analysis and tipping elements/points
		ii 24	Environmental restoration policies/innovation	iii 24	Environmental regulation
		ii 25	Sustainable Development strategies/innovation	iii 25	Environmental assessment
				iii 26	Sustainability related discourses
				iii 27	Ethics
				iii 28	Sustainable engineering education
				iii 29	Sustainability Science education/curriculum
				iii 30	Policy science
				iii 31	Cosmopolitanism
				iii 32	Decision making
				iii 33	Ecological modernization
				iii 34	Case studies for sustainability science
				iii 35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
				iii 36	Anthropocene and Earth stewardship
				iii 37	Ontology and/or epistemology of Sustainability Science
				iii 38	Complex systems, analysis, and adaptive planning/management
				iii 39	Cultural theory
				iii 40	Urban agriculture
				iii 41	De-growth
				iii 42	Anthropocentrism vs. deep ecology
				iii 43	Sustainable health
				iii 44	Industrial ecology
				iii 45	Reframing
				iii 46	Globalization
				iii 47	Scenario analysis—Visioneering
				iii 48	Syndromes
				iii 49	Landscape ecology

Appendix 2

The full literature map, continued in the consecutive sequence of the broad spheres of 'A' (= A + AB + AC), 'B' (= B + BA + BC), 'C' (= C + CA + CB), and D; where the broad sphere 'A' stands for the economic perspectives of sustainability, 'B' stands for the social perspectives of sustainability, 'C' referring to the environmental perspectives of sustainability, and 'D' representing the central organization of sustainability.

In the literature map, the descriptor "i/ii/iii" is for the three 'Categories' (i—'Problem/ issue/ challenge/ syndrome-sphere', ii—'Action/ approach-sphere', and iii—Academic-sphere) and "1/2/3/4/.." is for the 'Themes' under each 'Category'. The association of individual items with the particular 'empirical literature analyses' and/ or 'focus analyses into the quality of sustainability science' are briefly coded as 'Dev3rd', 'Agri', 'Urban', 'Water', 'SusSD', 'Hum-Env', 'Cmplx', and 'Global' to represent the topics of 'empirical literature analysis – 1', 'empirical literature analysis – 2', 'empirical literature analysis – 3', 'empirical literature analysis – 4', 'focus analysis – I', 'focus analysis – II', 'focus analysis – III', and 'focus analysis – IV', respectively. The archive items corresponding to the respective 'empirical literature analysis' and/ or focus analysis topics are expressed with the symbol '1'.

A	Qualifier	Dev3rd	Agri	Urban	Water	[Hum-Env]	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JG11	A	1	1				i	1	Food security—Agricultural challenges/issues
JH7	A	1					i	3	Industrialization—Energy—Environment
JB26	A	1		1			ii	1	Energy policy/innovation
JG2	A	1					ii	1	Energy policy/innovation
JG12	A	1		1			ii	1	Energy policy/innovation
JG5	A	1					iii	1	Transition theory

A (AB)	Qualifier	Dev3rd	Agri	Urban	Water	[Hum-Env]	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JB7	AB			1			i	4	Urbanization—Consumption—Environment
JG20	AB	1					i	4	Urbanization—Consumption—Environment
JJ12	AB	1					ii	1	Energy policy/innovation
JM29	AB						ii	1	Energy policy/innovation
JN9	AB						ii	1	Energy policy/innovation
JS44	AB	1					ii	1	Energy policy/innovation
JA3	AB	1					ii	2	Alternative livelihood
JA13	AB	1					ii	3	Interventions and development, and conservation
JF1	AB	1	1				ii	4	Community involvement
JH32	AB	1					ii	5	Low-carbon transitions
JT2	AB			1			ii	5	Low-carbon transitions
JZ5	AB	1					ii	5	Low-carbon transitions
JA18	AB	1					iii	2	Dematerialization
JY5	AB	1					iii	3	"Reuse" as theory
JZ4	AB	1					iii	4	Circular economy
JZ9	AB	1					iii	5	Quantitative sustainability

A (AC)	Qualifier	Dev3rd	Agri	Urban	Water	Hum-Env	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JE2	AC	1	1				i	1	Food security—Agricultural challenges/issues
JF14	AC	1	1			1	i	1	Food security—Agricultural challenges/issues
JC8	AC	1		1	1	1	i	2	Water availability/quality
JK31	AC			1	1	1	i	3	Industrialization—Energy—Environment
JS17	AC	1		1			i	3	Industrialization—Energy—Environment
JP11	AC	1	1				i	5	Air pollution—GHG Emission—Emission transfers
JS35	AC	1	1			1	i	6	Biodiversity—Habitat destruction—Trade
JL7	AC	1	1			1	ii	1	Energy policy/innovation
JM21	AC	1	1			1	ii	1	Energy policy/innovation
JS27	AC	1		1			ii	1	Energy policy/innovation
JS42	AC	1				1	ii	1	Energy policy/innovation

A (AC)	Qualifier	Dev3rd	Agri	Urban	Water	Hum-Env	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JA20	AC	1					ii	5	Low-carbon transitions
JA21	AC	1					ii	5	Low-carbon transitions
JI2	AC						ii	5	Low-carbon transitions
JM11	AC			1			ii	5	Low-carbon transitions
JW15	AC	1					ii	5	Low-carbon transitions
JT15	AC	1	1				ii	6	Biodiversity—Agriculture—Poverty
JA9	AC	1				1	iii	4	Circular economy
JD6	AC	1				1	iii	6	Natural capital & ecosystem services management/governance
JP31	AC	1		1		1	iii	7	Ecological economics

B	Qualifier	Dev3rd	Agri	Urban	Water	[Hum-Env]	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JA1	B	1					i	7	Public health
JC16	B	1					i	7	Public health
JW6	B	1					i	7	Public health
JA16	B	1					i	8	Human insecurity—Conflict
JH28	B	1					i	8	Human insecurity—Conflict
JH29	B	1					i	8	Human insecurity—Conflict
JH30	B	1					i	8	Human insecurity—Conflict
JU1	B	1					i	9	Population—Consumption—Environment
JP13	B	1					ii	3	Interventions and development, and conservation
JP23	B	1					ii	3	Interventions and development, and conservation
JP24	B	1					ii	3	Interventions and development, and conservation
JP26	B	1					ii	3	Interventions and development, and conservation
JP27	B	1					ii	3	Interventions and development, and conservation
JP28	B	1					ii	3	Interventions and development, and conservation
JP29	B	1					ii	3	Interventions and development, and conservation
JS33	B	1					ii	3	Interventions and development, and conservation
JJ6	B						ii	4	Community involvement
JK34	B	1					ii	4	Community involvement
JR1	B	1					ii	4	Community involvement
JA10	B	1					ii	7	Social learning
JB12	B	1					ii	8	Population policy
JC18	B			1			iii	8	Resilience
JL8	B						iii	9	Value—Attitude—Behavior
JL9	B						iii	9	Value—Attitude—Behavior

B (BA)	Qualifier	Dev3rd	Agri	Urban	Water	[Hum-Env]	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JA2	BA	1	1				i	1	Food security—Agricultural challenges/issues
JB1	BA	1	1				i	1	Food security—Agricultural challenges/issues

B (BA)	Qualifier	Dev3rd	Agri	Urban	Water	[Hum-Env]	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JC6	BA	1	1				i	1	Food security—Agricultural challenges/issues
JC19	BA	1	1				i	1	Food security—Agricultural challenges/issues
JF9	BA	1	1				i	1	Food security—Agricultural challenges/issues
JF11	BA	1	1				i	1	Food security—Agricultural challenges/issues
JM10	BA	1	1				i	1	Food security—Agricultural challenges/issues
JW2	BA	1	1				i	1	Food security—Agricultural challenges/issues
JM8	BA	1		1	1		i	2	Water availability/quality
JH23	BA			1			i	4	Urbanization—Consumption—Environment
JK10	BA	1	1				i	9	Population—Consumption—Environment
JC17	BA	1					i	10	African poverty
JP30	BA	1	1				ii	3	Interventions and development, and conservation
JM2	BA	1					ii	4	Community involvement
JD17	BA	1		1			ii	5	Low-carbon transitions
JL2	BA	1	1				ii	9	Forest management policy/innovation
JT4	BA	1	1				ii	10	Agricultural policy/innovation
JT14	BA	1		1	1		ii	11	Regional cooperation
JA17	BA	1					iii	10	Institutional reform
JK5	BA	1	1				iii	11	Sustainability challenge
JL13	BA						iii	12	Regulatory capitalism
JL14	BA						iii	12	Regulatory capitalism
JM13	BA	1		1			iii	13	Rural-urban transformation
JR15	BA	1					iii	14	Poverty—Development
JT12	BA	1					iii	14	Poverty—Development
JS5	BA	1		1			iii	15	Sustainable architecture

B (BC)	Qualifier	Dev3rd	Agri	Urban	Water	Hum-Env	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JR4	BC	1	1				i	1	Food security—Agricultural challenges/issues
JF13	BC				1	1	i	2	Water availability/quality
JK25	BC	1		1	1	1	i	7	Public health
JI7	BC	1				1	i	8	Human insecurity—Conflict
JK29	BC	1				1	i	8	Human insecurity—Conflict
JD12	BC	1				1	i	9	Population—Consumption—Environment
JG13	BC	1	1	1	1	1	i	9	Population—Consumption—Environment
JO1	BC	1		1			i	9	Population—Consumption—Environment
JP16	BC	1					i	11	Climate change problem/impacts
JS16	BC	1	1	1	1	1	i	12	Drought
JS38	BC	1		1		1	i	13	Delta — problems
JH33	BC	1		1		1	ii	3	Interventions and development, and conservation
JP1	BC	1			1		ii	3	Interventions and development, and conservation
JP25	BC	1					ii	3	Interventions and development, and conservation

B (BC)	Qualifier	Dev3rd	Agri	Urban	Water	Hum-Env	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JR17	BC	1					ii	**3**	Interventions and development, and conservation
JT11	BC	1		1			ii	**4**	Community involvement
JG17	BC			1		1	ii	**5**	Low-carbon transitions
JS20	BC	1	1				ii	**6**	Biodiversity—Agriculture—Poverty
JT7	BC	1	1			1	ii	**6**	Biodiversity—Agriculture—Poverty
JY10	BC	1	1			1	ii	**9**	Forest management policy/innovation
JI5	BC	1	1				ii	**10**	Agricultural policy/innovation
JT13	BC	1	1			1	ii	**10**	Agricultural policy/innovation
JN1-4	BC			1			ii	**11**	Regional cooperation
JA22	BC	1		1	1		ii	**12**	Modeling
JP22	BC	1					ii	**12**	Modeling
JB11	BC	1				1	ii	**13**	Adaptation—Natural Disaster—Migration—Benefits
JG24	BC	1				1	ii	**13**	Adaptation—Natural Disaster—Migration—Benefits
JP2	BC	1					ii	**13**	Adaptation—Natural Disaster—Migration—Benefits
JR16	BC	1					ii	**13**	Adaptation—Natural Disaster—Migration—Benefits
JS36	BC	1		1		1	ii	**14**	Urban policy/innovation
JU3	BC	1		1	1		ii	**14**	Urban policy/innovation
JW9	BC	1		1	1	1	ii	**14**	Urban policy/innovation
JT5	BC	1					ii	**15**	Reuse—Recycling—Pollution control
JK41	BC	1	1	1	1	1	iii	**3**	"Reuse" as theory
JL11	BC						iii	**6**	Natural capital & ecosystem services management/governance
JL22	BC	1	1		1	1	iii	**6**	Natural capital & ecosystem services management/governance
JS32	BC	1	1	1		1	iii	**6**	Natural capital & ecosystem services management/governance
JW4	BC	1				1	iii	**11**	Sustainability challenge
JK6	BC	1				1	iii	**14**	Poverty—Development
JR6	BC	1	1			1	iii	**14**	Poverty—Development
JK37	BC	1		1		1	iii	**15**	Sustainable architecture
JN1-3	BC			1			iii	**15**	Sustainable architecture
JB10	BC	1		1		1	iii	**16**	Urban sustainability and adaptive urban governance
JS9	BC	1		1	1	1	iii	**16**	Urban sustainability and adaptive urban governance
JS23	BC	1		1		1	iii	**16**	Urban sustainability and adaptive urban governance
JK9	BC	1	1	1		1	iii	**17**	Adaptation
JM20	BC	1	1			1	iii	**17**	Adaptation
JL15	BC						iii	**18**	Political ecology
JL17	BC					1	iii	**18**	Political ecology
JM7	BC	1				1	iii	**19**	Land cover and land use change science
JW13	BC	1	1			1	iii	**19**	Land cover and land use change science
JY4	BC	1	1			1	iii	**19**	Land cover and land use change science
JM31	BC	1		1			iii	**20**	Sustainability—Culture—Religion
JT1	BC	1		1	1	1	iii	**20**	Sustainability—Culture—Religion
JR10	BC	1					iii	**21**	World System theory
JW5	BC	1		1			iii	**22**	Learning—Knowledge—Ignorance—Condition

C	Qualifier	Dev3rd	Agri	Urban	Water	[Hum-Env]	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JP17	C	1		1			i	5	Air pollution—GHG Emission—Emission transfers
JO8	C	1	1	1			i	11	Climate change problem/impacts
JP3	C						i	11	Climate change problem/impacts
JK4	C	1	1				i	12	Drought
JB14	C		1				i	14	Ecological crisis
JG22	C	1	1				i	14	Ecological crisis
JC9	C			1			i	15	Coastal vulnerability issues & sea level rise
JJ9	C	1	1				ii	12	Modeling
JL12	C						iii	23	Earth System analysis and tipping elements/points
JL20	C						iii	23	Earth System analysis and tipping elements/points

C (CA)	Qualifier	Dev3rd	Agri	Urban	Water	Hum-Env	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JE5	CA	1		1		1	i	16	Global warming—Natural disaster
JB8	CA	1	1				ii	9	Forest management policy/innovation
JH27	CA						ii	11	Regional cooperation
JK24	CA			1	1	1	ii	12	Modeling
JD11	CA	1	1	1	1		ii	16	Technology and nanotechnology
JS22	CA	1					ii	16	Technology and nanotechnology
JE4	CA	1		1	1		ii	17	Water policy/innovation
JE6	CA						ii	18	Treaties—Agreements
JC21	CA		1			1	iii	6	Natural capital & ecosystem services management/governance
JD1	CA					1	iii	6	Natural capital & ecosystem services management/governance
JA12	CA	1				1	iii	17	Adaptation
JD4	CA	1					iii	24	Environmental regulation

C (CB)	Qualifier	Dev3rd	Agri	Urban	Water	Hum-Env	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JM3	CB	1	1				i	1	Food security—Agricultural challenges/issues
JM9	CB		1				i	1	Food security—Agricultural challenges/issues
JS1	CB	1	1			1	i	1	Food security—Agricultural challenges/issues
JS8	CB	1	1				i	1	Food security—Agricultural challenges/issues
JM19	CB	1		1		1	i	5	Air pollution—GHG Emission—Emission transfers
JD13	CB	1	1				i	6	Biodiversity—Habitat destruction—Trade
JG8	CB	1	1			1	i	6	Biodiversity—Habitat destruction—Trade
JS4	CB	1	1			1	i	6	Biodiversity—Habitat destruction—Trade
JK14	CB	1					i	11	Climate change problem/impacts
JN2	CB	1	1	1	1		i	11	Climate change problem/impacts
JS3	CB	1	1				i	11	Climate change problem/impacts
JP18	CB	1	1				i	14	Ecological crisis

C (CB)	Qualifier	Dev3rd	Agri	Urban	Water	Hum-Env	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JG23	CB			1			i	15	Coastal vulnerability issues & sea level rise
JH9	CB			1			i	15	Coastal vulnerability issues & sea level rise
JM15	CB	1		1			i	15	Coastal vulnerability issues & sea level rise
JN7	CB	1		1			i	15	Coastal vulnerability issues & sea level rise
JR14	CB	1	1	1			i	15	Coastal vulnerability issues & sea level rise
JT10	CB	1		1			i	15	Coastal vulnerability issues & sea level rise
JY2	CB	1		1	1		i	15	Coastal vulnerability issues & sea level rise
JY3	CB	1		1	1		i	15	Coastal vulnerability issues & sea level rise
JL19	CB	1			1		i	17	Estuaries & coastal seas — problems
JS18	CB	1			1	1	i	18	Open water bodies — problems
JS2	CB	1	1	1		1	ii	2	Alternative livelihood
JB2	CB	1		1			ii	5	Low-carbon transitions
JA23	CB	1	1				ii	9	Forest management policy/innovation
JL4	CB	1	1				ii	9	Forest management policy/innovation
JS24	CB	1	1				ii	9	Forest management policy/innovation
JY8	CB	1	1			1	ii	9	Forest management policy/innovation
JC4	CB	1	1			1	ii	10	Agricultural policy/innovation
JC7	CB	1	1				ii	10	Agricultural policy/innovation
JF4	CB	1	1				ii	10	Agricultural policy/innovation
JG4	CB	1	1				ii	10	Agricultural policy/innovation
JG9	CB	1	1				ii	10	Agricultural policy/innovation
JH13	CB	1	1				ii	10	Agricultural policy/innovation
JH15	CB	1	1				ii	10	Agricultural policy/innovation
JR11	CB	1	1			1	ii	10	Agricultural policy/innovation
JS43	CB	1	1			1	ii	10	Agricultural policy/innovation
JT8	CB	1	1			1	ii	10	Agricultural policy/innovation
JK22	CB		1			1	ii	12	Modeling
JP21	CB	1					ii	12	Modeling
JB9	CB	1		1			ii	13	Adaptation—Natural Disaster—Migration—Benefits
JH11	CB	1					ii	13	Adaptation—Natural Disaster—Migration—Benefits
JS30	CB			1			ii	13	Adaptation—Natural Disaster—Migration—Benefits
JO3	CB	1	1	1		1	ii	14	Urban policy/innovation
JN1-6	CB	1		1			ii	15	Reuse—Recycling—Pollution control
JZ2	CB	1	1			1	ii	15	Reuse—Recycling—Pollution control
JD3	CB			1	1		ii	17	Water policy/innovation
JG14	CB	1	1	1	1		ii	17	Water policy/innovation
JH14	CB	1	1	1	1		ii	17	Water policy/innovation
JR2	CB	1					ii	18	Treaties—Agreements
JB15	CB	1	1			1	ii	19	Emission estimation/control
JC1	CB	1					ii	19	Emission estimation/control
JH6	CB	1	1	1		1	ii	20	Land use system planning/innovation
JK33	CB		1			1	ii	20	Land use system planning/innovation

C (CB)	Qualifier	Dev3rd	Agri	Urban	Water	Hum-Env	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JK39	CB		1			1	ii	20	Land use system planning/innovation
JL5	CB	1	1				ii	20	Land use system planning/innovation
JH19	CB	1	1				ii	21	Biodiversity conservation policy/innovation
JL10	CB	1	1			1	ii	21	Biodiversity conservation policy/innovation
JS6	CB	1	1				ii	21	Biodiversity conservation policy/innovation
JJ1	CB	1	1		1		ii	22	Ecosystem services policy/innovation
JK35	CB	1	1				ii	22	Ecosystem services policy/innovation
JT9	CB	1	1	1		1	ii	22	Ecosystem services policy/innovation
JX1	CB	1	1			1	ii	22	Ecosystem services policy/innovation
JL18	CB	1		1			ii	23	Air quality policy/innovation
JY7	CB	1					ii	24	Environmental restoration policies/innovation
JC2	CB	1	1				iii	6	Natural capital & ecosystem services management/governance
JD2	CB	1	1			1	iii	6	Natural capital & ecosystem services management/governance
JD10	CB	1		1	1	1	iii	6	Natural capital & ecosystem services management/governance
JF5	CB	1	1			1	iii	6	Natural capital & ecosystem services management/governance
JG3	CB		1				iii	6	Natural capital & ecosystem services management/governance
JH4	CB	1	1				iii	6	Natural capital & ecosystem services management/governance
JB20	CB	1	1				iii	8	Resilience
JM5	CB	1	1				iii	8	Resilience
JP19	CB	1		1			iii	11	Sustainability challenge
JS28	CB			1			iii	11	Sustainability challenge
JY6	CB	1				1	iii	11	Sustainability challenge
JF15	CB	1					iii	17	Adaptation
JD9	CB	1	1	1		1	iii	19	Land cover and land use change science
JG1	CB		1			1	iii	19	Land cover and land use change science
JI4	CB		1		1	1	iii	19	Land cover and land use change science
JL1	CB	1	1			1	iii	19	Land cover and land use change science
JP15	CB	1	1	1			iii	19	Land cover and land use change science
JF12	CB	1					iii	24	Environmental regulation
JC14	CB						iii	25	Environmental assessment
JM24	CB						iii	26	Sustainability related discourses

D	No Qual.	Dev3rd	Agri	Urban	Water	SusSD	Hum-Env	Cmplx	Global	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names	D
JK20		1				1		1		i	10	African poverty	JK20
JI6		1	1			1	1	1		i	11	Climate change problem/impacts	JI6
JZ7		1	1			1	1	1		i	19	River — problems	JZ7
JN3		1	1			1	1	1		ii	3	Interventions and development, and conservation	JN3
JM18		1	1			1		1		ii	9	Forest management policy/innovation	JM18
JA6		1	1						1	ii	12	Modeling	JA6
JG18		1				1			1	ii	12	Modeling	JG18
JJ5						1		1		ii	12	Modeling	JJ5
JM23		1				1		1		ii	13	Adaptation—Natural Disaster—Migration—Benefits	JM23
JH31		1		1		1	1	1		ii	14	Urban policy/innovation	JH31
JN1-1				1		1			1	ii	14	Urban policy/innovation	JN1-1
JS13		1			1	1	1	1		ii	17	Water policy/innovation	JS13
JZ8		1	1	1	1	1	1	1		ii	17	Water policy/innovation	JZ8
JS21		1	1			1		1		ii	21	Biodiversity conservation policy/innovation	JS21
JG15						1				ii	24	Environmental restoration policies/innovation	JG15
JA14						1		1		ii	25	Sustainable Development strategies/innovation	JA14
JM1		1				1		1		ii	25	Sustainable Development strategies/innovation	JM1
JN8		1				1		1		ii	25	Sustainable Development strategies/innovation	JN8
JZ1		1				1		1		ii	25	Sustainable Development strategies/innovation	JZ1
JG6						1				iii	1	Transition theory	JG6
JG7						1		1		iii	1	Transition theory	JG7
JZ3		1		1		1	1	1		iii	4	Circular economy	JZ3
JB13						1		1		iii	5	Quantitative sustainability	JB13
JF3		1		1		1				iii	5	Quantitative sustainability	JF3

D	No Qual.	Dev3rd	Agri	Urban	Water	SusSD	Hum-Env	Cmplx	Global	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names	D
JH5						1		1		iii	5	Quantitative sustainability	JH5
JK18						1		1		iii	5	Quantitative sustainability	JK18
JM27						1		1		iii	5	Quantitative sustainability	JM27
JN5						1		1		iii	5	Quantitative sustainability	JN5
JO5						1		1		iii	5	Quantitative sustainability	JO5
JP4						1		1		iii	5	Quantitative sustainability	JP4
JP5						1		1		iii	5	Quantitative sustainability	JP5
JP14						1		1		iii	5	Quantitative sustainability	JP14
JH2		1	1				1		1	iii	6	Natural capital & ecosystem services management/governance	JH2
JH8		1				1	1			iii	6	Natural capital & ecosystem services management/governance	JH8
JH18		1			1		1		1	iii	6	Natural capital & ecosystem services management/governance	JH18
JK26		1	1			1		1		iii	6	Natural capital & ecosystem services management/governance	JK26
JO6		1	1			1	1	1		iii	6	Natural capital & ecosystem services management/governance	JO6
JO7						1	1	1		iii	6	Natural capital & ecosystem services management/governance	JO7
JT3		1				1	1	1	1	iii	6	Natural capital & ecosystem services management/governance	JT3
JW11		1		1	1	1		1		iii	6	Natural capital & ecosystem services management/governance	JW11
JA4						1	1			iii	8	Resilience	JA4
JB16						1	1			iii	8	Resilience	JB16
JF7						1	1	1		iii	8	Resilience	JF7
JH21						1	1			iii	8	Resilience	JH21
JS19		1				1		1		iii	8	Resilience	JS19
JK19						1				iii	9	Value—Attitude—Behavior	JK19
JA19						1			1	iii	11	Sustainability challenge	JA19
JB17						1		1		iii	11	Sustainability challenge	JB17
JB18						1				iii	11	Sustainability challenge	JB18
JC11						1		1		iii	11	Sustainability challenge	JC11

D	No Qual.	Dev3rd	Agri	Urban	Water	SusSD	Hum-Env	Cmplx	Global	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names	D
JC13						1		1	1	**iii**	**11**	Sustainability challenge	JC13
JD5						1		1		**iii**	**11**	Sustainability challenge	JD5
JF8						1	1	1		**iii**	**11**	Sustainability challenge	JF8
JG21			1	1		1				**iii**	**11**	Sustainability challenge	JG21
JH20						1		1		**iii**	**11**	Sustainability challenge	JH20
JI1						1		1		**iii**	**11**	Sustainability challenge	JI1
JK7						1	1	1		**iii**	**11**	Sustainability challenge	JK7
JK8									1	**iii**	**11**	Sustainability challenge	JK8
JK11		1				1	1	1		**iii**	**11**	Sustainability challenge	JK11
JK13						1		1		**iii**	**11**	Sustainability challenge	JK13
JK16						1		1		**iii**	**11**	Sustainability challenge	JK16
JK17						1			1	**iii**	**11**	Sustainability challenge	JK17
JM26		1				1		1		**iii**	**11**	Sustainability challenge	JM26
JP10						1		1		**iii**	**11**	Sustainability challenge	JP10
JR5						1	1	1	1	**iii**	**11**	Sustainability challenge	JR5
JR7						1		1	1	**iii**	**11**	Sustainability challenge	JR7
JR12		1				1				**iii**	**11**	Sustainability challenge	JR12
JS10		1		1		1	1			**iii**	**11**	Sustainability challenge	JS10
JS34		1		1		1		1		**iii**	**11**	Sustainability challenge	JS34
JS39						1		1	1	**iii**	**11**	Sustainability challenge	JS39
JW8		1				1	1	1	1	**iii**	**11**	Sustainability challenge	JW8
JP9		1				1		1		**iii**	**14**	Poverty—Development	JP9
JM14		1		1		1		1		**iii**	**16**	Urban sustainability and adaptive urban governance	JM14
JN1-2		1		1	1	1				**iii**	**16**	Urban sustainability and adaptive urban governance	JN1-2
JN1-5		1		1		1		1		**iii**	**16**	Urban sustainability and adaptive urban governance	JN1-5
JW10		1				1	1	1		**iii**	**17**	Adaptation	JW10

D	No Qual.	Dev3rd	Agri	Urban	Water	SusSD	Hum-Env	Cmplx	Global	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names	D
JB19		1				1		1		**iii**	**18**	Political ecology	JB19
JC20						1				**iii**	**18**	Political ecology	JC20
JH16		1				1	1			**iii**	**19**	Land cover and land use change science	JH16
JR9		1	1	1		1	1	1		**iii**	**19**	Land cover and land use change science	JR9
JS11		1	1	1		1	1	1	1	**iii**	**19**	Land cover and land use change science	JS11
JT18		1	1	1		1	1	1	1	**iii**	**19**	Land cover and land use change science	JT18
JB22		1	1			1				**iii**	**21**	World System theory	JB22
JH25						1	1			**iii**	**21**	World System theory	JH25
JM6						1	1	1		**iii**	**21**	World System theory	JM6
JH12						1		1		**iii**	**22**	Learning—Knowledge—Ignorance—Condition	JH12
JS12						1	1	1	1	**iii**	**23**	Earth System analysis and tipping elements/points	JS12
JK3						1		1		**iii**	**25**	Environmental assessment	JK3
JP6						1		1		**iii**	**25**	Environmental assessment	JP6
JA5						1				**iii**	**26**	Sustainability related discourses	JA5
JH34		1				1	1	1		**iii**	**26**	Sustainability related discourses	JH34
JA7						1				**iii**	**27**	Ethics	JA7
JD16						1				**iii**	**27**	Ethics	JD16
JA8						1		1		**iii**	**28**	Sustainable engineering education	JA8
JS15						1		1		**iii**	**28**	Sustainable engineering education	JS15
JA11						1		1		**iii**	**29**	Sustainability Science education/curriculum	JA11
JB24						1		1		**iii**	**29**	Sustainability Science education/curriculum	JB24
JE3						1		1		**iii**	**29**	Sustainability Science education/curriculum	JE3
JF2						1		1		**iii**	**29**	Sustainability Science education/curriculum	JF2
JO4						1		1		**iii**	**29**	Sustainability Science education/curriculum	JO4
JP12		1				1		1		**iii**	**29**	Sustainability Science education/curriculum	JP12
JT21						1		1		**iii**	**29**	Sustainability Science education/curriculum	JT21

D	No Qual.	Dev3rd	Agri	Urban	Water	SusSD	Hum-Env	Cmplx	Global	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names	D
JU2						1		1		iii	29	Sustainability Science education/curriculum	JU2
JW7						1		1		iii	29	Sustainability Science education/curriculum	JW7
JW12						1		1		iii	29	Sustainability Science education/curriculum	JW12
JY11						1		1		iii	29	Sustainability Science education/curriculum	JY11
JA15						1		1		iii	30	Policy science	JA15
JR13								1		iii	30	Policy science	JR13
JB3		1				1				iii	31	Cosmopolitanism	JB3
JB4						1				iii	31	Cosmopolitanism	JB4
JB5						1	1	1		iii	32	Decision making	JB5
JB6						1				iii	33	Ecological modernization	JB6
JJ4						1	1			iii	33	Ecological modernization	JJ4
JB21										iii	34	Case studies for sustainability science	JB21
JB23						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JB23
JB25						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JB25
JB27						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JB27
JC3						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JC3
JC10						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JC10
JC12						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JC12
JC22						1	1	1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JC22
JE1						1	1			iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JE1
JG10						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JG10
JG16						1	1			iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JG16
JG19						1	1	1	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JG19
JG27						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JG27
JH1						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JH1
JH3						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JH3

D	No Qual.	Dev3rd	Agri	Urban	Water	SusSD	Hum-Env	Cmplx	Global	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names	D
JH17						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JH17
JJ2						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JJ2
JJ3						1				iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JJ3
JK1						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JK1
JK23						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JK23
JK36						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JK36
JL23						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JL23
JL24						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JL24
JM4						1	1	1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JM4
JM17						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JM17
JM22						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JM22
JM25						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JM25
JN4						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JN4
JO9						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JO9
JP8						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JP8
JR3		1				1	1	1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JR3
JR8						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JR8
JS14						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JS14
JS41		1				1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JS41
JW1						1	1	1	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JW1
JW3						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JW3
JW14						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JW14
JW17						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JW17
JY1						1		1		iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	JY1
JC5		1				1	1			iii	36	Anthropocene and Earth stewardship	JC5
JS26		1				1	1	1	1	iii	36	Anthropocene and Earth stewardship	JS26

D	No Qual.	Dev3rd	Agri	Urban	Water	SusSD	Hum-Env	Cmplx	Global	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names	D
JS29		1				1		1	1	iii	36	Anthropocene and Earth stewardship	JS29
JT16		1				1	1	1	1	iii	36	Anthropocene and Earth stewardship	JT16
JC15						1		1		iii	37	Ontology and/or epistemology of Sustainability Science	JC15
JF16						1				iii	37	Ontology and/or epistemology of Sustainability Science	JF16
JH26						1				iii	37	Ontology and/or epistemology of Sustainability Science	JH26
JJ8						1		1	1	iii	37	Ontology and/or epistemology of Sustainability Science	JJ8
JK2						1		1		iii	37	Ontology and/or epistemology of Sustainability Science	JK2
JK12						1	1	1		iii	37	Ontology and/or epistemology of Sustainability Science	JK12
JK21						1	1	1	1	iii	37	Ontology and/or epistemology of Sustainability Science	JK21
JK27						1		1		iii	37	Ontology and/or epistemology of Sustainability Science	JK27
JK30						1		1		iii	37	Ontology and/or epistemology of Sustainability Science	JK30
JK38		1	1			1			1	iii	37	Ontology and/or epistemology of Sustainability Science	JK38
JK40						1		1		iii	37	Ontology and/or epistemology of Sustainability Science	JK40
JM12						1		1		iii	37	Ontology and/or epistemology of Sustainability Science	JM12
JM28		1	1	1		1	1	1		iii	37	Ontology and/or epistemology of Sustainability Science	JM28
JM30						1		1		iii	37	Ontology and/or epistemology of Sustainability Science	JM30
JN6						1		1		iii	37	Ontology and/or epistemology of Sustainability Science	JN6
JS7						1		1		iii	37	Ontology and/or epistemology of Sustainability Science	JS7
JS25						1		1		iii	37	Ontology and/or epistemology of Sustainability Science	JS25
JS31						1	1	1		iii	37	Ontology and/or epistemology of Sustainability Science	JS31
JS40						1		1		iii	37	Ontology and/or epistemology of Sustainability Science	JS40
JT19						1	1	1		iii	37	Ontology and/or epistemology of Sustainability Science	JT19
JT20						1	1	1		iii	37	Ontology and/or epistemology of Sustainability Science	JT20
JW16						1		1		iii	37	Ontology and/or epistemology of Sustainability Science	JW16
JZ6						1		1		iii	37	Ontology and/or epistemology of Sustainability Science	JZ6
JD7								1		iii	38	Complex systems, analysis, and adaptive planning/management	JD7

D	No Qual.	Dev3rd	Agri	Urban	Water	SusSD	Hum-Env	Cmplx	Global	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names	D
JD8		1	1			1	1	1		iii	38	Complex systems, analysis, and adaptive planning/management	JD8
JF6						1	1			iii	38	Complex systems, analysis, and adaptive planning/management	JF6
JH22						1	1	1		iii	38	Complex systems, analysis, and adaptive planning/management	JH22
JH24		1				1	1			iii	38	Complex systems, analysis, and adaptive planning/management	JH24
JI3		1				1	1	1		iii	38	Complex systems, analysis, and adaptive planning/management	JI3
JJ10						1	1	1		iii	38	Complex systems, analysis, and adaptive planning/management	JJ10
JL6						1	1	1		iii	38	Complex systems, analysis, and adaptive planning/management	JL6
JL16						1	1	1		iii	38	Complex systems, analysis, and adaptive planning/management	JL16
JM16						1		1		iii	38	Complex systems, analysis, and adaptive planning/management	JM16
JP7						1		1		iii	38	Complex systems, analysis, and adaptive planning/management	JP7
JT17						1	1	1		iii	38	Complex systems, analysis, and adaptive planning/management	JT17
JY9		1		1		1	1	1	1	iii	38	Complex systems, analysis, and adaptive planning/management	JY9
JD14						1				iii	39	Cultural theory	JD14
JO2						1		1		iii	39	Cultural theory	JO2
JT6						1		1		iii	39	Cultural theory	JT6
JD15		1	1	1	1	1	1	1		iii	40	Urban agriculture	JD15
JF10		1				1				iii	41	De-growth	JF10
JK28						1				iii	41	De-growth	JK28
JL3						1				iii	41	De-growth	JL3
JG25						1	1			iii	42	Anthropocentrism vs. deep ecology	JG25
JG26		1				1		1		iii	43	Sustainable health	JG26
JH10						1				iii	44	Industrial ecology	JH10
JJ7						1			1	iii	45	Reframing	JJ7
JJ11									1	iii	46	Globalization	JJ11
JK15						1			1	iii	46	Globalization	JK15
JK32						1		1		iii	47	Scenario analysis—Visioneering	JK32

D	No Qual.	Dev3rd	Agri	Urban	Water	SusSD	Hum-Env	Cmplx	Global	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names	D
JS37						1		1	1	iii	47	Scenario analysis—Visioneering	JS37
JL21						1		1	1	iii	48	Syndromes	JL21
JP20				1		1	1	1		iii	49	Landscape ecology	JP20

Appendix 3

Literature maps for the empirical literature analyses and focus analyses

In the literature maps, the descriptor “i/ii/iii” is for the three ‘Categories’ (i—‘Problem/ issue/ challenge/ syndrome-sphere’, ii—‘Action/ approach-sphere’, and iii—Academic-sphere) and “1/2/3/4/..” is for the ‘Themes’ under each ‘Category’. The association of individual items with the particular ‘empirical literature analyses’ and/ or ‘focus analyses into the quality of sustainability science’ are briefly coded as ‘Dev3rd’, ‘Agri’, ‘Urban’, ‘Water’, ‘SusSD’, ‘Hum-Env’, ‘Cmplx’, and ‘Global’ to represent the topics of ‘empirical literature analysis – 1’, ‘empirical literature analysis – 2’, ‘empirical literature analysis – 3’, ‘empirical literature analysis – 4’, ‘focus analysis – I’, ‘focus analysis – II’, ‘focus analysis – III’, and ‘focus analysis – IV’, respectively. The archive items corresponding to the respective ‘empirical literature analysis’ and/ or focus analysis topics are expressed with the symbol ‘1’. These literature maps present the archive items in the sequence of the broad spheres of ‘A’ (= A + AB + AC), ‘B’ (= B + BA + BC), ‘C’ (= C + CA + CB), and D; where the broad sphere ‘A’ stands for the economic perspectives of sustainability, ‘B’ stands for the social perspectives of sustainability, ‘C’ referring to the environmental perspectives of sustainability, and ‘D’ representing the central organization of sustainability.

Literature map for ‘Empirical literature analysis – 1’

A	Qualifier	Dev3rd	i/ii/iii	1/2/3/4/..	Description of ‘1/2/3/4/..’ standard names
JG11	A	1	i	1	Food security—Agricultural challenges/issues
JH7	A	1	i	3	Industrialization—Energy—Environment
JB26	A	1	ii	1	Energy policy/innovation
JG2	A	1	ii	1	Energy policy/innovation
JG12	A	1	ii	1	Energy policy/innovation
JG5	A	1	iii	1	Transition theory

A (AB)	Qualifier	Dev3rd	i/ii/iii	1/2/3/4/..	Description of ‘1/2/3/4/..’ standard names
JG20	AB	1	i	4	Urbanization—Consumption—Environment
JJ12	AB	1	ii	1	Energy policy/innovation
JS44	AB	1	ii	1	Energy policy/innovation
JA3	AB	1	ii	2	Alternative livelihood
JA13	AB	1	ii	3	Interventions and development, and conservation
JF1	AB	1	ii	4	Community involvement
JH32	AB	1	ii	5	Low-carbon transitions
JZ5	AB	1	ii	5	Low-carbon transitions
JA18	AB	1	iii	2	Dematerialization
JY5	AB	1	iii	3	"Reuse" as theory
JZ4	AB	1	iii	4	Circular economy
JZ9	AB	1	iii	5	Quantitative sustainability

A (AC)	Qualifier	Dev3rd	i/ii/iii	1/2/3/4/..	Description of ‘1/2/3/4/..’ standard names
JE2	AC	1	i	1	Food security—Agricultural challenges/issues
JF14	AC	1	i	1	Food security—Agricultural challenges/issues
JC8	AC	1	i	2	Water availability/quality
JS17	AC	1	i	3	Industrialization—Energy—Environment
JP11	AC	1	i	5	Air pollution—GHG Emission—Emission transfers
JS35	AC	1	i	6	Biodiversity—Habitat destruction—Trade
JL7	AC	1	ii	1	Energy policy/innovation
JM21	AC	1	ii	1	Energy policy/innovation
JS27	AC	1	ii	1	Energy policy/innovation
JS42	AC	1	ii	1	Energy policy/innovation
JA20	AC	1	ii	5	Low-carbon transitions
JA21	AC	1	ii	5	Low-carbon transitions
JW15	AC	1	ii	5	Low-carbon transitions
JT15	AC	1	ii	6	Biodiversity—Agriculture—Poverty

A (AC)	**Qualifier**	**Dev3rd**	**i/ii/iii**	**1/2/3/4/..**	**Description of '1/2/3/4/..' standard names**
JA9	AC	1	**iii**	**4**	Circular economy
JD6	AC	1	**iii**	**6**	Natural capital & ecosystem services management/governance
JP31	AC	1	**iii**	**7**	Ecological economics

B	**Qualifier**	**Dev3rd**	**i/ii/iii**	**1/2/3/4/..**	**Description of '1/2/3/4/..' standard names**
JA1	B	1	**i**	**7**	Public health
JC16	B	1	**i**	**7**	Public health
JW6	B	1	**i**	**7**	Public health
JA16	B	1	**i**	**8**	Human insecurity—Conflict
JH28	B	1	**i**	**8**	Human insecurity—Conflict
JH29	B	1	**i**	**8**	Human insecurity—Conflict
JH30	B	1	**i**	**8**	Human insecurity—Conflict
JU1	B	1	**i**	**9**	Population—Consumption—Environment
JP13	B	1	**ii**	**3**	Interventions and development, and conservation
JP23	B	1	**ii**	**3**	Interventions and development, and conservation
JP24	B	1	**ii**	**3**	Interventions and development, and conservation
JP26	B	1	**ii**	**3**	Interventions and development, and conservation
JP27	B	1	**ii**	**3**	Interventions and development, and conservation
JP28	B	1	**ii**	**3**	Interventions and development, and conservation
JP29	B	1	**ii**	**3**	Interventions and development, and conservation
JS33	B	1	**ii**	**3**	Interventions and development, and conservation
JK34	B	1	**ii**	**4**	Community involvement
JR1	B	1	**ii**	**4**	Community involvement
JA10	B	1	**ii**	**7**	Social learning
JB12	B	1	**ii**	**8**	Population policy

B (BA)	**Qualifier**	**Dev3rd**	**i/ii/iii**	**1/2/3/4/..**	**Description of '1/2/3/4/..' standard names**
JA2	BA	1	**i**	**1**	Food security—Agricultural challenges/issues
JB1	BA	1	**i**	**1**	Food security—Agricultural challenges/issues
JC6	BA	1	**i**	**1**	Food security—Agricultural challenges/issues
JC19	BA	1	**i**	**1**	Food security—Agricultural challenges/issues
JF9	BA	1	**i**	**1**	Food security—Agricultural challenges/issues
JF11	BA	1	**i**	**1**	Food security—Agricultural challenges/issues
JM10	BA	1	**i**	**1**	Food security—Agricultural challenges/issues
JW2	BA	1	**i**	**1**	Food security—Agricultural challenges/issues
JM8	BA	1	**i**	**2**	Water availability/quality
JK10	BA	1	**i**	**9**	Population—Consumption—Environment
JC17	BA	1	**i**	**10**	African poverty

B (BA)	Qualifier	Dev3rd	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JP30	BA	1	ii	3	Interventions and development, and conservation
JM2	BA	1	ii	4	Community involvement
JD17	BA	1	ii	5	Low-carbon transitions
JL2	BA	1	ii	9	Forest management policy/innovation
JT4	BA	1	ii	10	Agricultural policy/innovation
JT14	BA	1	ii	11	Regional cooperation
JA17	BA	1	iii	10	Institutional reform
JK5	BA	1	iii	11	Sustainability challenge
JM13	BA	1	iii	13	Rural-urban transformation
JR15	BA	1	iii	14	Poverty—Development
JT12	BA	1	iii	14	Poverty—Development
JS5	BA	1	iii	15	Sustainable architecture

B (BC)	Qualifier	Dev3rd	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JR4	BC	1	i	1	Food security—Agricultural challenges/issues
JK25	BC	1	i	7	Public health
JI7	BC	1	i	8	Human insecurity—Conflict
JK29	BC	1	i	8	Human insecurity—Conflict
JD12	BC	1	i	9	Population—Consumption—Environment
JG13	BC	1	i	9	Population—Consumption—Environment
JO1	BC	1	i	9	Population—Consumption—Environment
JP16	BC	1	i	11	Climate change problem/impacts
JS16	BC	1	i	12	Drought
JS38	BC	1	i	13	Delta — problems
JH33	BC	1	ii	3	Interventions and development, and conservation
JP1	BC	1	ii	3	Interventions and development, and conservation
JP25	BC	1	ii	3	Interventions and development, and conservation
JR17	BC	1	ii	3	Interventions and development, and conservation
JT11	BC	1	ii	4	Community involvement
JS20	BC	1	ii	6	Biodiversity—Agriculture—Poverty
JT7	BC	1	ii	6	Biodiversity—Agriculture—Poverty
JY10	BC	1	ii	9	Forest management policy/innovation
JI5	BC	1	ii	10	Agricultural policy/innovation
JT13	BC	1	ii	10	Agricultural policy/innovation
JA22	BC	1	ii	12	Modeling
JP22	BC	1	ii	12	Modeling
JB11	BC	1	ii	13	Adaptation—Natural Disaster—Migration—Benefits
JG24	BC	1	ii	13	Adaptation—Natural Disaster—Migration—Benefits
JP2	BC	1	ii	13	Adaptation—Natural Disaster—Migration—Benefits
JR16	BC	1	ii	13	Adaptation—Natural Disaster—Migration—Benefits
JS36	BC	1	ii	14	Urban policy/innovation

B (BC)	Qualifier	Dev3rd	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JU3	BC	1	ii	14	Urban policy/innovation
JW9	BC	1	ii	14	Urban policy/innovation
JT5	BC	1	ii	15	Reuse—Recycling—Pollution control
JK41	BC	1	iii	3	"Reuse" as theory
JL22	BC	1	iii	6	Natural capital & ecosystem services management/governance
JS32	BC	1	iii	6	Natural capital & ecosystem services management/governance
JW4	BC	1	iii	11	Sustainability challenge
JK6	BC	1	iii	14	Poverty—Development
JR6	BC	1	iii	14	Poverty—Development
JK37	BC	1	iii	15	Sustainable architecture
JB10	BC	1	iii	16	Urban sustainability and adaptive urban governance
JS9	BC	1	iii	16	Urban sustainability and adaptive urban governance
JS23	BC	1	iii	16	Urban sustainability and adaptive urban governance
JK9	BC	1	iii	17	Adaptation
JM20	BC	1	iii	17	Adaptation
JM7	BC	1	iii	19	Land cover and land use change science
JW13	BC	1	iii	19	Land cover and land use change science
JY4	BC	1	iii	19	Land cover and land use change science
JM31	BC	1	iii	20	Sustainability—Culture—Religion
JT1	BC	1	iii	20	Sustainability—Culture—Religion
JR10	BC	1	iii	21	World System theory
JW5	BC	1	iii	22	Learning—Knowledge—Ignorance—Condition

C	Qualifier	Dev3rd	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JP17	C	1	i	5	Air pollution—GHG Emission—Emission transfers
JO8	C	1	i	11	Climate change problem/impacts
JK4	C	1	i	12	Drought
JB14	C		i	14	Ecological crisis
JG22	C	1	i	14	Ecological crisis
JJ9	C	1	ii	12	Modeling

C (CA)	Qualifier	Dev3rd	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JE5	CA	1	i	16	Global warming—Natural disaster
JB8	CA	1	ii	9	Forest management policy/innovation
JD11	CA	1	ii	16	Technology and nanotechnology
JS22	CA	1	ii	16	Technology and nanotechnology
JE4	CA	1	ii	17	Water policy/innovation

C (CA)	Qualifier	Dev3rd	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JA12	CA	1	iii	17	Adaptation
JD4	CA	1	iii	24	Environmental regulation

C (CB)	Qualifier	Dev3rd	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JM3	CB	1	i	1	Food security—Agricultural challenges/issues
JS1	CB	1	i	1	Food security—Agricultural challenges/issues
JS8	CB	1	i	1	Food security—Agricultural challenges/issues
JM19	CB	1	i	5	Air pollution—GHG Emission—Emission transfers
JD13	CB	1	i	6	Biodiversity—Habitat destruction—Trade
JG8	CB	1	i	6	Biodiversity—Habitat destruction—Trade
JS4	CB	1	i	6	Biodiversity—Habitat destruction—Trade
JK14	CB	1	i	11	Climate change problem/impacts
JN2	CB	1	i	11	Climate change problem/impacts
JS3	CB	1	i	11	Climate change problem/impacts
JP18	CB	1	i	14	Ecological crisis
JM15	CB	1	i	15	Coastal vulnerability issues & sea level rise
JN7	CB	1	i	15	Coastal vulnerability issues & sea level rise
JR14	CB	1	i	15	Coastal vulnerability issues & sea level rise
JT10	CB	1	i	15	Coastal vulnerability issues & sea level rise
JY2	CB	1	i	15	Coastal vulnerability issues & sea level rise
JY3	CB	1	i	15	Coastal vulnerability issues & sea level rise
JL19	CB	1	i	17	Estuaries & coastal seas — problems
JS18	CB	1	i	18	Open water bodies — problems
JS2	CB	1	ii	2	Alternative livelihood
JB2	CB	1	ii	5	Low-carbon transitions
JA23	CB	1	ii	9	Forest management policy/innovation
JL4	CB	1	ii	9	Forest management policy/innovation
JS24	CB	1	ii	9	Forest management policy/innovation
JY8	CB	1	ii	9	Forest management policy/innovation
JC4	CB	1	ii	10	Agricultural policy/innovation
JC7	CB	1	ii	10	Agricultural policy/innovation
JF4	CB	1	ii	10	Agricultural policy/innovation
JG4	CB	1	ii	10	Agricultural policy/innovation
JG9	CB	1	ii	10	Agricultural policy/innovation
JH13	CB	1	ii	10	Agricultural policy/innovation
JH15	CB	1	ii	10	Agricultural policy/innovation
JR11	CB	1	ii	10	Agricultural policy/innovation
JS43	CB	1	ii	10	Agricultural policy/innovation
JT8	CB	1	ii	10	Agricultural policy/innovation
JP21	CB	1	ii	12	Modeling
JB9	CB	1	ii	13	Adaptation—Natural Disaster—Migration—Benefits
JH11	CB	1	ii	13	Adaptation—Natural Disaster—Migration—Benefits

C (CB)	Qualifier	Dev3rd	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JO3	CB	1	**ii**	**14**	Urban policy/innovation
JN1-6	CB	1	**ii**	**15**	Reuse—Recycling—Pollution control
JZ2	CB	1	**ii**	**15**	Reuse—Recycling—Pollution control
JG14	CB	1	**ii**	**17**	Water policy/innovation
JH14	CB	1	**ii**	**17**	Water policy/innovation
JR2	CB	1	**ii**	**18**	Treaties—Agreements
JB15	CB	1	**ii**	**19**	Emission estimation/control
JC1	CB	1	**ii**	**19**	Emission estimation/control
JH6	CB	1	**ii**	**20**	Land use system planning/innovation
JL5	CB	1	**ii**	**20**	Land use system planning/innovation
JH19	CB	1	**ii**	**21**	Biodiversity conservation policy/innovation
JL10	CB	1	**ii**	**21**	Biodiversity conservation policy/innovation
JS6	CB	1	**ii**	**21**	Biodiversity conservation policy/innovation
JJ1	CB	1	**ii**	**22**	Ecosystem services policy/innovation
JK35	CB	1	**ii**	**22**	Ecosystem services policy/innovation
JT9	CB	1	**ii**	**22**	Ecosystem services policy/innovation
JX1	CB	1	**ii**	**22**	Ecosystem services policy/innovation
JL18	CB	1	**ii**	**23**	Air quality policy/innovation
JY7	CB	1	**ii**	**24**	Environmental restoration policies/innovation
JC2	CB	1	**iii**	**6**	Natural capital & ecosystem services management/governance
JD2	CB	1	**iii**	**6**	Natural capital & ecosystem services management/governance
JD10	CB	1	**iii**	**6**	Natural capital & ecosystem services management/governance
JF5	CB	1	**iii**	**6**	Natural capital & ecosystem services management/governance
JH4	CB	1	**iii**	**6**	Natural capital & ecosystem services management/governance
JB20	CB	1	**iii**	**8**	Resilience
JM5	CB	1	**iii**	**8**	Resilience
JP19	CB	1	**iii**	**11**	Sustainability challenge
JY6	CB	1	**iii**	**11**	Sustainability challenge
JF15	CB	1	**iii**	**17**	Adaptation
JD9	CB	1	**iii**	**19**	Land cover and land use change science
JL1	CB	1	**iii**	**19**	Land cover and land use change science
JP15	CB	1	**iii**	**19**	Land cover and land use change science
JF12	CB	1	**iii**	**24**	Environmental regulation

D	No Qual.	Dev3rd	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JK20		1	**i**	**10**	African poverty
JI6		1	**i**	**11**	Climate change problem/impacts
JZ7		1	**i**	**19**	River — problems
JN3		1	**ii**	**3**	Interventions and development, and conservation
JM18		1	**ii**	**9**	Forest management policy/innovation

D	No Qual.	Dev3rd	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JA6		1	ii	12	Modeling
JG18		1	ii	12	Modeling
JM23		1	ii	13	Adaptation—Natural Disaster—Migration—Benefits
JH31		1	ii	14	Urban policy/innovation
JS13		1	ii	17	Water policy/innovation
JZ8		1	ii	17	Water policy/innovation
JS21		1	ii	21	Biodiversity conservation policy/innovation
JM1		1	ii	25	Sustainable Development strategies/innovation
JN8		1	ii	25	Sustainable Development strategies/innovation
JZ1		1	ii	25	Sustainable Development strategies/innovation
JZ3		1	iii	4	Circular economy
JF3		1	iii	5	Quantitative sustainability
JH2		1	iii	6	Natural capital & ecosystem services management/governance
JH8		1	iii	6	Natural capital & ecosystem services management/governance
JH18		1	iii	6	Natural capital & ecosystem services management/governance
JK26		1	iii	6	Natural capital & ecosystem services management/governance
JO6		1	iii	6	Natural capital & ecosystem services management/governance
JT3		1	iii	6	Natural capital & ecosystem services management/governance
JW11		1	iii	6	Natural capital & ecosystem services management/governance
JS19		1	iii	8	Resilience
JK11		1	iii	11	Sustainability challenge
JM26		1	iii	11	Sustainability challenge
JR12		1	iii	11	Sustainability challenge
JS10		1	iii	11	Sustainability challenge
JS34		1	iii	11	Sustainability challenge
JW8		1	iii	11	Sustainability challenge
JP9		1	iii	14	Poverty—Development
JM14		1	iii	16	Urban sustainability and adaptive urban governance
JN1-2		1	iii	16	Urban sustainability and adaptive urban governance
JN1-5		1	iii	16	Urban sustainability and adaptive urban governance
JW10		1	iii	17	Adaptation
JB19		1	iii	18	Political ecology
JH16		1	iii	19	Land cover and land use change science
JR9		1	iii	19	Land cover and land use change science
JS11		1	iii	19	Land cover and land use change science
JT18		1	iii	19	Land cover and land use change science
JB22		1	iii	21	World System theory
JH34		1	iii	26	Sustainability related discourses
JP12		1	iii	29	Sustainability Science education/curriculum
JB3		1	iii	31	Cosmopolitanism
JR3		1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JS41		1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research

D	No Qual.	Dev3rd	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JC5		1	iii	**36**	Anthropocene and Earth stewardship
JS26		1	iii	**36**	Anthropocene and Earth stewardship
JS29		1	iii	**36**	Anthropocene and Earth stewardship
JT16		1	iii	**36**	Anthropocene and Earth stewardship
JK38		1	iii	**37**	Ontology and/or epistemology of Sustainability Science
JM28		1	iii	**37**	Ontology and/or epistemology of Sustainability Science
JD8		1	iii	**38**	Complex systems, analysis, and adaptive planning/management
JH24		1	iii	**38**	Complex systems, analysis, and adaptive planning/management
JI3		1	iii	**38**	Complex systems, analysis, and adaptive planning/management
JY9		1	iii	**38**	Complex systems, analysis, and adaptive planning/management
JD15		1	iii	**40**	Urban agriculture
JF10		1	iii	**41**	De-growth
JG26		1	iii	**43**	Sustainable health

Literature map for 'Empirical literature analysis – 2'

A	Qualifier	Agri	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JG11	A	1	i	1	Food security—Agricultural challenges/issues

A (AB)	Qualifier	Agri	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JF1	AB	1	ii	4	Community involvement

A (AC)	Qualifier	Agri	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JE2	AC	1	i	1	Food security—Agricultural challenges/issues
JF14	AC	1	i	1	Food security—Agricultural challenges/issues
JP11	AC	1	i	5	Air pollution—GHG Emission—Emission transfers
JS35	AC	1	i	6	Biodiversity—Habitat destruction—Trade
JL7	AC	1	ii	1	Energy policy/innovation
JM21	AC	1	ii	1	Energy policy/innovation
JT15	AC	1	ii	6	Biodiversity—Agriculture—Poverty

B	Qualifier	Agri	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names

B (BA)	Qualifier	Agri	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JA2	BA	1	i	1	Food security—Agricultural challenges/issues
JB1	BA	1	i	1	Food security—Agricultural challenges/issues
JC6	BA	1	i	1	Food security—Agricultural challenges/issues
JC19	BA	1	i	1	Food security—Agricultural challenges/issues
JF9	BA	1	i	1	Food security—Agricultural challenges/issues
JF11	BA	1	i	1	Food security—Agricultural challenges/issues
JM10	BA	1	i	1	Food security—Agricultural challenges/issues
JW2	BA	1	i	1	Food security—Agricultural challenges/issues
JK10	BA	1	i	9	Population—Consumption—Environment
JP30	BA	1	ii	3	Interventions and development, and conservation
JL2	BA	1	ii	9	Forest management policy/innovation
JT4	BA	1	ii	10	Agricultural policy/innovation

B (BA)	Qualifier	Agri	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JK5	BA	1	iii	11	Sustainability challenge

B (BC)	Qualifier	Agri	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JR4	BC	1	i	1	Food security—Agricultural challenges/issues
JG13	BC	1	i	9	Population—Consumption—Environment
JS16	BC	1	i	12	Drought
JS20	BC	1	ii	6	Biodiversity—Agriculture—Poverty
JT7	BC	1	ii	6	Biodiversity—Agriculture—Poverty
JY10	BC	1	ii	9	Forest management policy/innovation
JI5	BC	1	ii	10	Agricultural policy/innovation
JT13	BC	1	ii	10	Agricultural policy/innovation
JK41	BC	1	iii	3	"Reuse" as theory
JL22	BC	1	iii	6	Natural capital & ecosystem services management/governance
JS32	BC	1	iii	6	Natural capital & ecosystem services management/governance
JR6	BC	1	iii	14	Poverty—Development
JK9	BC	1	iii	17	Adaptation
JM20	BC	1	iii	17	Adaptation
JW13	BC	1	iii	19	Land cover and land use change science
JY4	BC	1	iii	19	Land cover and land use change science

C	Qualifier	Agri	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JO8	C	1	i	11	Climate change problem/impacts
JK4	C	1	i	12	Drought
JB14	C	1	i	14	Ecological crisis
JG22	C	1	i	14	Ecological crisis
JJ9	C	1	ii	12	Modeling

C (CA)	Qualifier	Agri	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JB8	CA	1	ii	9	Forest management policy/innovation
JD11	CA	1	ii	16	Technology and nanotechnology
JC21	CA	1	iii	6	Natural capital & ecosystem services management/governance

C (CB)	Qualifier	Agri	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JM3	CB	1	i	1	Food security—Agricultural challenges/issues
JM9	CB	1	i	1	Food security—Agricultural challenges/issues
JS1	CB	1	i	1	Food security—Agricultural challenges/issues

C (CB)	Qualifier	Agri	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JS8	CB	1	i	1	Food security—Agricultural challenges/issues
JD13	CB	1	i	6	Biodiversity—Habitat destruction—Trade
JG8	CB	1	i	6	Biodiversity—Habitat destruction—Trade
JS4	CB	1	i	6	Biodiversity—Habitat destruction—Trade
JN2	CB	1	i	11	Climate change problem/impacts
JS3	CB	1	i	11	Climate change problem/impacts
JP18	CB	1	i	14	Ecological crisis
JR14	CB	1	i	15	Coastal vulnerability issues & sea level rise
JS2	CB	1	ii	2	Alternative livelihood
JA23	CB	1	ii	9	Forest management policy/innovation
JL4	CB	1	ii	9	Forest management policy/innovation
JS24	CB	1	ii	9	Forest management policy/innovation
JY8	CB	1	ii	9	Forest management policy/innovation
JC4	CB	1	ii	10	Agricultural policy/innovation
JC7	CB	1	ii	10	Agricultural policy/innovation
JF4	CB	1	ii	10	Agricultural policy/innovation
JG4	CB	1	ii	10	Agricultural policy/innovation
JG9	CB	1	ii	10	Agricultural policy/innovation
JH13	CB	1	ii	10	Agricultural policy/innovation
JH15	CB	1	ii	10	Agricultural policy/innovation
JR11	CB	1	ii	10	Agricultural policy/innovation
JS43	CB	1	ii	10	Agricultural policy/innovation
JT8	CB	1	ii	10	Agricultural policy/innovation
JK22	CB	1	ii	12	Modeling
JO3	CB	1	ii	14	Urban policy/innovation
JZ2	CB	1	ii	15	Reuse—Recycling—Pollution control
JG14	CB	1	ii	17	Water policy/innovation
JH14	CB	1	ii	17	Water policy/innovation
JB15	CB	1	ii	19	Emission estimation/control
JH6	CB	1	ii	20	Land use system planning/innovation
JK33	CB	1	ii	20	Land use system planning/innovation
JK39	CB	1	ii	20	Land use system planning/innovation
JL5	CB	1	ii	20	Land use system planning/innovation
JH19	CB	1	ii	21	Biodiversity conservation policy/innovation
JL10	CB	1	ii	21	Biodiversity conservation policy/innovation
JS6	CB	1	ii	21	Biodiversity conservation policy/innovation
JJ1	CB	1	ii	22	Ecosystem services policy/innovation
JK35	CB	1	ii	22	Ecosystem services policy/innovation
JT9	CB	1	ii	22	Ecosystem services policy/innovation
JX1	CB	1	ii	22	Ecosystem services policy/innovation
JC2	CB	1	iii	6	Natural capital & ecosystem services management/governance
JD2	CB	1	iii	6	Natural capital & ecosystem services management/governance

C (CB)	Qualifier	Agri	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JF5	CB	1	iii	6	Natural capital & ecosystem services management/governance
JG3	CB	1	iii	6	Natural capital & ecosystem services management/governance
JH4	CB	1	iii	6	Natural capital & ecosystem services management/governance
JB20	CB	1	iii	8	Resilience
JM5	CB	1	iii	8	Resilience
JD9	CB	1	iii	19	Land cover and land use change science
JG1	CB	1	iii	19	Land cover and land use change science
JI4	CB	1	iii	19	Land cover and land use change science
JL1	CB	1	iii	19	Land cover and land use change science
JP15	CB	1	iii	19	Land cover and land use change science

D	No Qual.	Agri	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JI6		1	i	11	Climate change problem/impacts
JZ7		1	i	19	River — problems
JN3		1	ii	3	Interventions and development, and conservation
JM18		1	ii	9	Forest management policy/innovation
JA6		1	ii	12	Modeling
JZ8		1	ii	17	Water policy/innovation
JS21		1	ii	21	Biodiversity conservation policy/innovation
JH2		1	iii	6	Natural capital & ecosystem services management/governance
JK26		1	iii	6	Natural capital & ecosystem services management/governance
JO6		1	iii	6	Natural capital & ecosystem services management/governance
JG21		1	iii	11	Sustainability challenge
JR9		1	iii	19	Land cover and land use change science
JS11		1	iii	19	Land cover and land use change science
JT18		1	iii	19	Land cover and land use change science
JB22		1	iii	21	World System theory
JK38		1	iii	37	Ontology and/or epistemology of Sustainability Science
JM28		1	iii	37	Ontology and/or epistemology of Sustainability Science
JD8		1	iii	38	Complex systems, analysis, and adaptive planning/management
JD15		1	iii	40	Urban agriculture

Literature map for 'Empirical literature analysis – 3'

A	Qualifier	Urban	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JB26	A	1	ii	1	Energy policy/innovation
JG12	A	1	ii	1	Energy policy/innovation

A (AB)	Qualifier	Urban	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JB7	AB	1	i	4	Urbanization—Consumption—Environment
JT2	AB	1	ii	5	Low-carbon transitions

A (AC)	Qualifier	Urban	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JC8	AC	1	i	2	Water availability/quality
JK31	AC	1	i	3	Industrialization—Energy—Environment
JS17	AC	1	i	3	Industrialization—Energy—Environment
JS27	AC	1	ii	1	Energy policy/innovation
JM11	AC	1	ii	5	Low-carbon transitions
JP31	AC	1	iii	7	Ecological economics

B	Qualifier	Urban	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JC18	B	1	iii	8	Resilience

B (BA)	Qualifier	Urban	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JM8	BA	1	i	2	Water availability/quality
JH23	BA	1	i	4	Urbanization—Consumption—Environment
JD17	BA	1	ii	5	Low-carbon transitions
JT14	BA	1	ii	11	Regional cooperation
JM13	BA	1	iii	13	Rural-urban transformation
JS5	BA	1	iii	15	Sustainable architecture

B (BC)	Qualifier	Urban	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JK25	BC	1	i	**7**	Public health
JG13	BC	1	i	**9**	Population—Consumption—Environment
JO1	BC	1	i	**9**	Population—Consumption—Environment
JS16	BC	1	i	**12**	Drought
JS38	BC	1	i	**13**	Delta — problems
JH33	BC	1	ii	**3**	Interventions and development, and conservation
JT11	BC	1	ii	**4**	Community involvement
JG17	BC	1	ii	**5**	Low-carbon transitions
JN1-4	BC	1	ii	**11**	Regional cooperation
JA22	BC	1	ii	**12**	Modeling
JS36	BC	1	ii	**14**	Urban policy/innovation
JU3	BC	1	ii	**14**	Urban policy/innovation
JW9	BC	1	ii	**14**	Urban policy/innovation
JK41	BC	1	iii	**3**	"Reuse" as theory
JS32	BC	1	iii	**6**	Natural capital & ecosystem services management/governance
JK37	BC	1	iii	**15**	Sustainable architecture
JN1-3	BC	1	iii	**15**	Sustainable architecture
JB10	BC	1	iii	**16**	Urban sustainability and adaptive urban governance
JS9	BC	1	iii	**16**	Urban sustainability and adaptive urban governance
JS23	BC	1	iii	**16**	Urban sustainability and adaptive urban governance
JK9	BC	1	iii	**17**	Adaptation
JM31	BC	1	iii	**20**	Sustainability—Culture—Religion
JT1	BC	1	iii	**20**	Sustainability—Culture—Religion
JW5	BC	1	iii	**22**	Learning—Knowledge—Ignorance—Condition

C	Qualifier	Urban	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JP17	C	1	i	**5**	Air pollution—GHG Emission—Emission transfers
JO8	C	1	i	**11**	Climate change problem/impacts
JC9	C	1	i	**15**	Coastal vulnerability issues & sea level rise

C (CA)	Qualifier	Urban	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JE5	CA	1	i	**16**	Global warming—Natural disaster
JK24	CA	1	ii	**12**	Modeling
JD11	CA	1	ii	**16**	Technology and nanotechnology
JE4	CA	1	ii	**17**	Water policy/innovation

C (CB)	Qualifier	Urban	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JM19	CB	1	i	5	Air pollution—GHG Emission—Emission transfers
JN2	CB	1	i	11	Climate change problem/impacts
JG23	CB	1	i	15	Coastal vulnerability issues & sea level rise
JH9	CB	1	i	15	Coastal vulnerability issues & sea level rise
JM15	CB	1	i	15	Coastal vulnerability issues & sea level rise
JN7	CB	1	i	15	Coastal vulnerability issues & sea level rise
JR14	CB	1	i	15	Coastal vulnerability issues & sea level rise
JT10	CB	1	i	15	Coastal vulnerability issues & sea level rise
JY2	CB	1	i	15	Coastal vulnerability issues & sea level rise
JY3	CB	1	i	15	Coastal vulnerability issues & sea level rise
JS2	CB	1	ii	2	Alternative livelihood
JB2	CB	1	ii	5	Low-carbon transitions
JB9	CB	1	ii	13	Adaptation—Natural Disaster—Migration—Benefits
JS30	CB	1	ii	13	Adaptation—Natural Disaster—Migration—Benefits
JO3	CB	1	ii	14	Urban policy/innovation
JN1-6	CB	1	ii	15	Reuse—Recycling—Pollution control
JD3	CB	1	ii	17	Water policy/innovation
JG14	CB	1	ii	17	Water policy/innovation
JH14	CB	1	ii	17	Water policy/innovation
JH6	CB	1	ii	20	Land use system planning/innovation
JT9	CB	1	ii	22	Ecosystem services policy/innovation
JL18	CB	1	ii	23	Air quality policy/innovation
JD10	CB	1	iii	6	Natural capital & ecosystem services management/governance
JP19	CB	1	iii	11	Sustainability challenge
JS28	CB	1	iii	11	Sustainability challenge
JD9	CB	1	iii	19	Land cover and land use change science
JP15	CB	1	iii	19	Land cover and land use change science

D	No Qual.	Urban	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JH31		1	ii	14	Urban policy/innovation
JN1-1		1	ii	14	Urban policy/innovation
JZ8		1	ii	17	Water policy/innovation
JZ3		1	iii	4	Circular economy
JF3		1	iii	5	Quantitative sustainability
JW11		1	iii	6	Natural capital & ecosystem services management/governance
JG21		1	iii	11	Sustainability challenge
JS10		1	iii	11	Sustainability challenge
JS34		1	iii	11	Sustainability challenge

D	No Qual.	Urban	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JM14		1	**iii**	**16**	Urban sustainability and adaptive urban governance
JN1-2		1	**iii**	**16**	Urban sustainability and adaptive urban governance
JN1-5		1	**iii**	**16**	Urban sustainability and adaptive urban governance
JR9		1	**iii**	**19**	Land cover and land use change science
JS11		1	**iii**	**19**	Land cover and land use change science
JT18		1	**iii**	**19**	Land cover and land use change science
JM28		1	**iii**	**37**	Ontology and/or epistemology of Sustainability Science
JY9		1	**iii**	**38**	Complex systems, analysis, and adaptive planning/management
JD15		1	**iii**	**40**	Urban agriculture
JP20		1	**iii**	**49**	Landscape ecology

Literature map for 'Empirical literature analysis – 4'

A	Qualifier	Water	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names

A (AB)	Qualifier	Water	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names

A (AC)	Qualifier	Water	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JC8	AC	1	i	2	Water availability/quality
JK31	AC	1	i	3	Industrialization—Energy—Environment

B	Qualifier	Water	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names

B (BA)	Qualifier	Water	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JM8	BA	1	i	2	Water availability/quality
JT14	BA	1	ii	11	Regional cooperation

B (BC)	Qualifier	Water	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JF13	BC	1	i	2	Water availability/quality
JK25	BC	1	i	7	Public health
JG13	BC	1	i	9	Population—Consumption—Environment
JS16	BC	1	i	12	Drought
JP1	BC	1	ii	3	Interventions and development, and conservation
JA22	BC	1	ii	12	Modeling
JU3	BC	1	ii	14	Urban policy/innovation
JW9	BC	1	ii	14	Urban policy/innovation
JK41	BC	1	iii	3	"Reuse" as theory
JL22	BC	1	iii	6	Natural capital & ecosystem services management/governance
JS9	BC	1	iii	16	Urban sustainability and adaptive urban governance
JT1	BC	1	iii	20	Sustainability—Culture—Religion

C	Qualifier	Water	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names

C (CA)	Qualifier	Water	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JK24	CA	1	ii	12	Modeling
JD11	CA	1	ii	16	Technology and nanotechnology
JE4	CA	1	ii	17	Water policy/innovation

C (CB)	Qualifier	Water	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JN2	CB	1	i	11	Climate change problem/impacts
JY2	CB	1	i	15	Coastal vulnerability issues & sea level rise
JY3	CB	1	i	15	Coastal vulnerability issues & sea level rise
JL19	CB	1	i	17	Estuaries & coastal seas — problems
JS18	CB	1	i	18	Open water bodies — problems
JD3	CB	1	ii	17	Water policy/innovation
JG14	CB	1	ii	17	Water policy/innovation
JH14	CB	1	ii	17	Water policy/innovation
JJ1	CB	1	ii	22	Ecosystem services policy/innovation
JD10	CB	1	iii	6	Natural capital & ecosystem services management/governance
JI4	CB	1	iii	19	Land cover and land use change science

D	No Qual.	Water	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JS13		1	ii	17	Water policy/innovation
JZ8		1	ii	17	Water policy/innovation
JH18		1	iii	6	Natural capital & ecosystem services management/governance
JW11		1	iii	6	Natural capital & ecosystem services management/governance
JN1-2		1	iii	16	Urban sustainability and adaptive urban governance
JD15		1	iii	40	Urban agriculture

Literature map for 'Focus analysis – I'

D	SusSD	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JK20	1	i	10	African poverty
JI6	1	i	11	Climate change problem/impacts
JZ7	1	i	19	River — problems
JN3	1	ii	3	Interventions and development, and conservation
JM18	1	ii	9	Forest management policy/innovation
JG18	1	ii	12	Modeling
JJ5	1	ii	12	Modeling
JM23	1	ii	13	Adaptation—Natural Disaster—Migration—Benefits
JH31	1	ii	14	Urban policy/innovation
JN1-1	1	ii	14	Urban policy/innovation
JS13	1	ii	17	Water policy/innovation
JZ8	1	ii	17	Water policy/innovation
JS21	1	ii	21	Biodiversity conservation policy/innovation
JG15	1	ii	24	Environmental restoration policies/innovation
JA14	1	ii	25	Sustainable Development strategies/innovation
JM1	1	ii	25	Sustainable Development strategies/innovation
JN8	1	ii	25	Sustainable Development strategies/innovation
JZ1	1	ii	25	Sustainable Development strategies/innovation
JG6	1	iii	1	Transition theory
JG7	1	iii	1	Transition theory
JZ3	1	iii	4	Circular economy
JB13	1	iii	5	Quantitative sustainability
JF3	1	iii	5	Quantitative sustainability
JH5	1	iii	5	Quantitative sustainability
JK18	1	iii	5	Quantitative sustainability
JM27	1	iii	5	Quantitative sustainability
JN5	1	iii	5	Quantitative sustainability
JO5	1	iii	5	Quantitative sustainability
JP4	1	iii	5	Quantitative sustainability
JP5	1	iii	5	Quantitative sustainability
JP14	1	iii	5	Quantitative sustainability
JH8	1	iii	6	Natural capital & ecosystem services management/governance
JK26	1	iii	6	Natural capital & ecosystem services management/governance
JO6	1	iii	6	Natural capital & ecosystem services management/governance
JO7	1	iii	6	Natural capital & ecosystem services management/governance
JT3	1	iii	6	Natural capital & ecosystem services management/governance
JW11	1	iii	6	Natural capital & ecosystem services management/governance
JA4	1	iii	8	Resilience
JB16	1	iii	8	Resilience

D	SusSD	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JF7	1	iii	8	Resilience
JH21	1	iii	8	Resilience
JS19	1	iii	8	Resilience
JK19	1	iii	9	Value—Attitude—Behavior
JA19	1	iii	11	Sustainability challenge
JB17	1	iii	11	Sustainability challenge
JB18	1	iii	11	Sustainability challenge
JC11	1	iii	11	Sustainability challenge
JC13	1	iii	11	Sustainability challenge
JD5	1	iii	11	Sustainability challenge
JF8	1	iii	11	Sustainability challenge
JG21	1	iii	11	Sustainability challenge
JH20	1	iii	11	Sustainability challenge
JI1	1	iii	11	Sustainability challenge
JK7	1	iii	11	Sustainability challenge
JK11	1	iii	11	Sustainability challenge
JK13	1	iii	11	Sustainability challenge
JK16	1	iii	11	Sustainability challenge
JK17	1	iii	11	Sustainability challenge
JM26	1	iii	11	Sustainability challenge
JP10	1	iii	11	Sustainability challenge
JR5	1	iii	11	Sustainability challenge
JR7	1	iii	11	Sustainability challenge
JR12	1	iii	11	Sustainability challenge
JS10	1	iii	11	Sustainability challenge
JS34	1	iii	11	Sustainability challenge
JS39	1	iii	11	Sustainability challenge
JW8	1	iii	11	Sustainability challenge
JP9	1	iii	14	Poverty—Development
JM14	1	iii	16	Urban sustainability and adaptive urban governance
JN1-2	1	iii	16	Urban sustainability and adaptive urban governance
JN1-5	1	iii	16	Urban sustainability and adaptive urban governance
JW10	1	iii	17	Adaptation
JB19	1	iii	18	Political ecology
JC20	1	iii	18	Political ecology
JH16	1	iii	19	Land cover and land use change science
JR9	1	iii	19	Land cover and land use change science
JS11	1	iii	19	Land cover and land use change science
JT18	1	iii	19	Land cover and land use change science
JB22	1	iii	21	World System theory
JH25	1	iii	21	World System theory
JM6	1	iii	21	World System theory
JH12	1	iii	22	Learning—Knowledge—Ignorance—Condition
JS12	1	iii	23	Earth System analysis and tipping elements/points

D	SusSD	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JK3	1	iii	25	Environmental assessment
JP6	1	iii	25	Environmental assessment
JA5	1	iii	26	Sustainability related discourses
JH34	1	iii	26	Sustainability related discourses
JA7	1	iii	27	Ethics
JD16	1	iii	27	Ethics
JA8	1	iii	28	Sustainable engineering education
JS15	1	iii	28	Sustainable engineering education
JA11	1	iii	29	Sustainability Science education/curriculum
JB24	1	iii	29	Sustainability Science education/curriculum
JE3	1	iii	29	Sustainability Science education/curriculum
JF2	1	iii	29	Sustainability Science education/curriculum
JO4	1	iii	29	Sustainability Science education/curriculum
JP12	1	iii	29	Sustainability Science education/curriculum
JT21	1	iii	29	Sustainability Science education/curriculum
JU2	1	iii	29	Sustainability Science education/curriculum
JW7	1	iii	29	Sustainability Science education/curriculum
JW12	1	iii	29	Sustainability Science education/curriculum
JY11	1	iii	29	Sustainability Science education/curriculum
JA15	1	iii	30	Policy science
JB3	1	iii	31	Cosmopolitanism
JB4	1	iii	31	Cosmopolitanism
JB5	1	iii	32	Decision making
JB6	1	iii	33	Ecological modernization
JJ4	1	iii	33	Ecological modernization
JB23	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JB25	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JB27	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JC3	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JC10	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JC12	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JC22	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JE1	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JG10	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JG16	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JG19	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JG27	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JH1	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JH3	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JH17	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JJ2	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JJ3	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JK1	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JK23	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research

D	SusSD	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JK36	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JL23	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JL24	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JM4	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JM17	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JM22	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JM25	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JN4	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JO9	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JP8	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JR3	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JR8	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JS14	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JS41	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JW1	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JW3	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JW14	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JW17	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JY1	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JC5	1	iii	36	Anthropocene and Earth stewardship
JS26	1	iii	36	Anthropocene and Earth stewardship
JS29	1	iii	36	Anthropocene and Earth stewardship
JT16	1	iii	36	Anthropocene and Earth stewardship
JC15	1	iii	37	Ontology and/or epistemology of Sustainability Science
JF16	1	iii	37	Ontology and/or epistemology of Sustainability Science
JH26	1	iii	37	Ontology and/or epistemology of Sustainability Science
JJ8	1	iii	37	Ontology and/or epistemology of Sustainability Science
JK2	1	iii	37	Ontology and/or epistemology of Sustainability Science
JK12	1	iii	37	Ontology and/or epistemology of Sustainability Science
JK21	1	iii	37	Ontology and/or epistemology of Sustainability Science
JK27	1	iii	37	Ontology and/or epistemology of Sustainability Science
JK30	1	iii	37	Ontology and/or epistemology of Sustainability Science
JK38	1	iii	37	Ontology and/or epistemology of Sustainability Science
JK40	1	iii	37	Ontology and/or epistemology of Sustainability Science
JM12	1	iii	37	Ontology and/or epistemology of Sustainability Science
JM28	1	iii	37	Ontology and/or epistemology of Sustainability Science
JM30	1	iii	37	Ontology and/or epistemology of Sustainability Science
JN6	1	iii	37	Ontology and/or epistemology of Sustainability Science
JS7	1	iii	37	Ontology and/or epistemology of Sustainability Science
JS25	1	iii	37	Ontology and/or epistemology of Sustainability Science
JS31	1	iii	37	Ontology and/or epistemology of Sustainability Science
JS40	1	iii	37	Ontology and/or epistemology of Sustainability Science
JT19	1	iii	37	Ontology and/or epistemology of Sustainability Science
JT20	1	iii	37	Ontology and/or epistemology of Sustainability Science

D	SusSD	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JW16	1	iii	37	Ontology and/or epistemology of Sustainability Science
JZ6	1	iii	37	Ontology and/or epistemology of Sustainability Science
JD8	1	iii	38	Complex systems, analysis, and adaptive planning/management
JF6	1	iii	38	Complex systems, analysis, and adaptive planning/management
JH22	1	iii	38	Complex systems, analysis, and adaptive planning/management
JH24	1	iii	38	Complex systems, analysis, and adaptive planning/management
JI3	1	iii	38	Complex systems, analysis, and adaptive planning/management
JJ10	1	iii	38	Complex systems, analysis, and adaptive planning/management
JL6	1	iii	38	Complex systems, analysis, and adaptive planning/management
JL16	1	iii	38	Complex systems, analysis, and adaptive planning/management
JM16	1	iii	38	Complex systems, analysis, and adaptive planning/management
JP7	1	iii	38	Complex systems, analysis, and adaptive planning/management
JT17	1	iii	38	Complex systems, analysis, and adaptive planning/management
JY9	1	iii	38	Complex systems, analysis, and adaptive planning/management
JD14	1	iii	39	Cultural theory
JO2	1	iii	39	Cultural theory
JT6	1	iii	39	Cultural theory
JD15	1	iii	40	Urban agriculture
JF10	1	iii	41	De-growth
JK28	1	iii	41	De-growth
JL3	1	iii	41	De-growth
JG25	1	iii	42	Anthropocentrism vs. deep ecology
JG26	1	iii	43	Sustainable health
JH10	1	iii	44	Industrial ecology
JJ7	1	iii	45	Reframing
JK15	1	iii	46	Globalization
JK32	1	iii	47	Scenario analysis—Visioneering
JS37	1	iii	47	Scenario analysis—Visioneering
JL21	1	iii	48	Syndromes
JP20	1	iii	49	Landscape ecology

Literature map for 'Focus analysis – II'

A (AC)	Qualifier	Hum-Env	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JF14	AC	1	i	1	Food security—Agricultural challenges/issues
JC8	AC	1	i	2	Water availability/quality
JK31	AC	1	i	3	Industrialization—Energy—Environment
JS35	AC	1	i	6	Biodiversity—Habitat destruction—Trade
JL7	AC	1	ii	1	Energy policy/innovation
JM21	AC	1	ii	1	Energy policy/innovation
JS42	AC	1	ii	1	Energy policy/innovation
JA9	AC	1	iii	4	Circular economy
JD6	AC	1	iii	6	Natural capital & ecosystem services management/governance
JP31	AC	1	iii	7	Ecological economics

B (BC)	Qualifier	Hum-Env	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JF13	BC	1	i	2	Water availability/quality
JK25	BC	1	i	7	Public health
JI7	BC	1	i	8	Human insecurity—Conflict
JK29	BC	1	i	8	Human insecurity—Conflict
JD12	BC	1	i	9	Population—Consumption—Environment
JG13	BC	1	i	9	Population—Consumption—Environment
JS16	BC	1	i	12	Drought
JS38	BC	1	i	13	Delta — problems
JH33	BC	1	ii	3	Interventions and development, and conservation
JG17	BC	1	ii	5	Low-carbon transitions
JT7	BC	1	ii	6	Biodiversity—Agriculture—Poverty
JY10	BC	1	ii	9	Forest management policy/innovation
JT13	BC	1	ii	10	Agricultural policy/innovation
JB11	BC	1	ii	13	Adaptation—Natural Disaster—Migration—Benefits
JG24	BC	1	ii	13	Adaptation—Natural Disaster—Migration—Benefits
JS36	BC	1	ii	14	Urban policy/innovation
JW9	BC	1	ii	14	Urban policy/innovation
JK41	BC	1	iii	3	"Reuse" as theory
JL22	BC	1	iii	6	Natural capital & ecosystem services management/governance
JS32	BC	1	iii	6	Natural capital & ecosystem services management/governance
JW4	BC	1	iii	11	Sustainability challenge
JK6	BC	1	iii	14	Poverty—Development
JR6	BC	1	iii	14	Poverty—Development
JK37	BC	1	iii	15	Sustainable architecture

B (BC)	Qualifier	Hum-Env	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JB10	BC	1	**iii**	**16**	Urban sustainability and adaptive urban governance
JS9	BC	1	**iii**	**16**	Urban sustainability and adaptive urban governance
JS23	BC	1	**iii**	**16**	Urban sustainability and adaptive urban governance
JK9	BC	1	**iii**	**17**	Adaptation
JM20	BC	1	**iii**	**17**	Adaptation
JL17	BC	1	**iii**	**18**	Political ecology
JM7	BC	1	**iii**	**19**	Land cover and land use change science
JW13	BC	1	**iii**	**19**	Land cover and land use change science
JY4	BC	1	**iii**	**19**	Land cover and land use change science
JT1	BC	1	**iii**	**20**	Sustainability—Culture—Religion

C (CA)	Qualifier	Hum-Env	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JE5	CA	1	**i**	**16**	Global warming—Natural disaster
JK24	CA	1	**ii**	**12**	Modeling
JC21	CA	1	**iii**	**6**	Natural capital & ecosystem services management/governance
JD1	CA	1	**iii**	**6**	Natural capital & ecosystem services management/governance
JA12	CA	1	**iii**	**17**	Adaptation

C (CB)	Qualifier	Hum-Env	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JS1	CB	1	**i**	**1**	Food security—Agricultural challenges/issues
JM19	CB	1	**i**	**5**	Air pollution—GHG Emission—Emission transfers
JG8	CB	1	**i**	**6**	Biodiversity—Habitat destruction—Trade
JS4	CB	1	**i**	**6**	Biodiversity—Habitat destruction—Trade
JS18	CB	1	**i**	**18**	Open water bodies — problems
JS2	CB	1	**ii**	**2**	Alternative livelihood
JY8	CB	1	**ii**	**9**	Forest management policy/innovation
JC4	CB	1	**ii**	**10**	Agricultural policy/innovation
JR11	CB	1	**ii**	**10**	Agricultural policy/innovation
JS43	CB	1	**ii**	**10**	Agricultural policy/innovation
JT8	CB	1	**ii**	**10**	Agricultural policy/innovation
JK22	CB	1	**ii**	**12**	Modeling
JO3	CB	1	**ii**	**14**	Urban policy/innovation
JZ2	CB	1	**ii**	**15**	Reuse—Recycling—Pollution control
JB15	CB	1	**ii**	**19**	Emission estimation/control
JH6	CB	1	**ii**	**20**	Land use system planning/innovation
JK33	CB	1	**ii**	**20**	Land use system planning/innovation
JK39	CB	1	**ii**	**20**	Land use system planning/innovation
JL10	CB	1	**ii**	**21**	Biodiversity conservation policy/innovation
JT9	CB	1	**ii**	**22**	Ecosystem services policy/innovation

C (CB)	Qualifier	Hum-Env	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JX1	CB	1	ii	22	Ecosystem services policy/innovation
JD2	CB	1	iii	6	Natural capital & ecosystem services management/governance
JD10	CB	1	iii	6	Natural capital & ecosystem services management/governance
JF5	CB	1	iii	6	Natural capital & ecosystem services management/governance
JY6	CB	1	iii	11	Sustainability challenge
JD9	CB	1	iii	19	Land cover and land use change science
JG1	CB	1	iii	19	Land cover and land use change science
JI4	CB	1	iii	19	Land cover and land use change science
JL1	CB	1	iii	19	Land cover and land use change science

D	No Qual.	Hum-Env	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JI6		1	i	11	Climate change problem/impacts
JZ7		1	i	19	River — problems
JN3		1	ii	3	Interventions and development, and conservation
JH31		1	ii	14	Urban policy/innovation
JS13		1	ii	17	Water policy/innovation
JZ8		1	ii	17	Water policy/innovation
JZ3		1	iii	4	Circular economy
JH2		1	iii	6	Natural capital & ecosystem services management/governance
JH8		1	iii	6	Natural capital & ecosystem services management/governance
JH18		1	iii	6	Natural capital & ecosystem services management/governance
JO6		1	iii	6	Natural capital & ecosystem services management/governance
JO7		1	iii	6	Natural capital & ecosystem services management/governance
JT3		1	iii	6	Natural capital & ecosystem services management/governance
JA4		1	iii	8	Resilience
JB16		1	iii	8	Resilience
JF7		1	iii	8	Resilience
JH21		1	iii	8	Resilience
JF8		1	iii	11	Sustainability challenge
JK7		1	iii	11	Sustainability challenge
JK11		1	iii	11	Sustainability challenge
JR5		1	iii	11	Sustainability challenge
JS10		1	iii	11	Sustainability challenge
JW8		1	iii	11	Sustainability challenge
JW10		1	iii	17	Adaptation
JH16		1	iii	19	Land cover and land use change science
JR9		1	iii	19	Land cover and land use change science
JS11		1	iii	19	Land cover and land use change science
JT18		1	iii	19	Land cover and land use change science

D	No Qual.	Hum-Env	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JH25		1	iii	21	World System theory
JM6		1	iii	21	World System theory
JS12		1	iii	23	Earth System analysis and tipping elements/points
JH34		1	iii	26	Sustainability related discourses
JB5		1	iii	32	Decision making
JJ4		1	iii	33	Ecological modernization
JC22		1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JE1		1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JG16		1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JG19		1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JM4		1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JR3		1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JW1		1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JC5		1	iii	36	Anthropocene and Earth stewardship
JS26		1	iii	36	Anthropocene and Earth stewardship
JT16		1	iii	36	Anthropocene and Earth stewardship
JK12		1	iii	37	Ontology and/or epistemology of Sustainability Science
JK21		1	iii	37	Ontology and/or epistemology of Sustainability Science
JM28		1	iii	37	Ontology and/or epistemology of Sustainability Science
JS31		1	iii	37	Ontology and/or epistemology of Sustainability Science
JT19		1	iii	37	Ontology and/or epistemology of Sustainability Science
JT20		1	iii	37	Ontology and/or epistemology of Sustainability Science
JD8		1	iii	38	Complex systems, analysis, and adaptive planning/management
JF6		1	iii	38	Complex systems, analysis, and adaptive planning/management
JH22		1	iii	38	Complex systems, analysis, and adaptive planning/management
JH24		1	iii	38	Complex systems, analysis, and adaptive planning/management
JI3		1	iii	38	Complex systems, analysis, and adaptive planning/management
JJ10		1	iii	38	Complex systems, analysis, and adaptive planning/management
JL6		1	iii	38	Complex systems, analysis, and adaptive planning/management
JL16		1	iii	38	Complex systems, analysis, and adaptive planning/management
JT17		1	iii	38	Complex systems, analysis, and adaptive planning/management
JY9		1	iii	38	Complex systems, analysis, and adaptive planning/management
JD15		1	iii	40	Urban agriculture
JG25		1	iii	42	Anthropocentrism vs. deep ecology
JP20		1	iii	49	Landscape ecology

Literature map for ‘Focus analysis – III’

D	Cmplx	i/ii/iii	1/2/3/4/..	Description of ‘1/2/3/4/..’ standard names
JK20	1	i	10	African poverty
JI6	1	i	11	Climate change problem/impacts
JZ7	1	i	19	River — problems
JN3	1	ii	3	Interventions and development, and conservation
JM18	1	ii	9	Forest management policy/innovation
JJ5	1	ii	12	Modeling
JM23	1	ii	13	Adaptation—Natural Disaster—Migration—Benefits
JH31	1	ii	14	Urban policy/innovation
JS13	1	ii	17	Water policy/innovation
JZ8	1	ii	17	Water policy/innovation
JS21	1	ii	21	Biodiversity conservation policy/innovation
JA14	1	ii	25	Sustainable Development strategies/innovation
JM1	1	ii	25	Sustainable Development strategies/innovation
JN8	1	ii	25	Sustainable Development strategies/innovation
JZ1	1	ii	25	Sustainable Development strategies/innovation
JG7	1	iii	1	Transition theory
JZ3	1	iii	4	Circular economy
JB13	1	iii	5	Quantitative sustainability
JH5	1	iii	5	Quantitative sustainability
JK18	1	iii	5	Quantitative sustainability
JM27	1	iii	5	Quantitative sustainability
JN5	1	iii	5	Quantitative sustainability
JO5	1	iii	5	Quantitative sustainability
JP4	1	iii	5	Quantitative sustainability
JP5	1	iii	5	Quantitative sustainability
JP14	1	iii	5	Quantitative sustainability
JK26	1	iii	6	Natural capital & ecosystem services management/governance
JO6	1	iii	6	Natural capital & ecosystem services management/governance
JO7	1	iii	6	Natural capital & ecosystem services management/governance
JT3	1	iii	6	Natural capital & ecosystem services management/governance
JW11	1	iii	6	Natural capital & ecosystem services management/governance
JF7	1	iii	8	Resilience
JS19	1	iii	8	Resilience
JB17	1	iii	11	Sustainability challenge
JC11	1	iii	11	Sustainability challenge
JC13	1	iii	11	Sustainability challenge
JD5	1	iii	11	Sustainability challenge
JF8	1	iii	11	Sustainability challenge
JH20	1	iii	11	Sustainability challenge

D	Cmplx	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JI1	1	iii	11	Sustainability challenge
JK7	1	iii	11	Sustainability challenge
JK11	1	iii	11	Sustainability challenge
JK13	1	iii	11	Sustainability challenge
JK16	1	iii	11	Sustainability challenge
JM26	1	iii	11	Sustainability challenge
JP10	1	iii	11	Sustainability challenge
JR5	1	iii	11	Sustainability challenge
JR7	1	iii	11	Sustainability challenge
JS34	1	iii	11	Sustainability challenge
JS39	1	iii	11	Sustainability challenge
JW8	1	iii	11	Sustainability challenge
JP9	1	iii	14	Poverty—Development
JM14	1	iii	16	Urban sustainability and adaptive urban governance
JN1-5	1	iii	16	Urban sustainability and adaptive urban governance
JW10	1	iii	17	Adaptation
JB19	1	iii	18	Political ecology
JR9	1	iii	19	Land cover and land use change science
JS11	1	iii	19	Land cover and land use change science
JT18	1	iii	19	Land cover and land use change science
JM6	1	iii	21	World System theory
JH12	1	iii	22	Learning—Knowledge—Ignorance—Condition
JS12	1	iii	23	Earth System analysis and tipping elements/points
JK3	1	iii	25	Environmental assessment
JP6	1	iii	25	Environmental assessment
JH34	1	iii	26	Sustainability related discourses
JA8	1	iii	28	Sustainable engineering education
JS15	1	iii	28	Sustainable engineering education
JA11	1	iii	29	Sustainability Science education/curriculum
JB24	1	iii	29	Sustainability Science education/curriculum
JE3	1	iii	29	Sustainability Science education/curriculum
JF2	1	iii	29	Sustainability Science education/curriculum
JO4	1	iii	29	Sustainability Science education/curriculum
JP12	1	iii	29	Sustainability Science education/curriculum
JT21	1	iii	29	Sustainability Science education/curriculum
JU2	1	iii	29	Sustainability Science education/curriculum
JW7	1	iii	29	Sustainability Science education/curriculum
JW12	1	iii	29	Sustainability Science education/curriculum
JY11	1	iii	29	Sustainability Science education/curriculum
JA15	1	iii	30	Policy science
JR13	1	iii	30	Policy science
JB5	1	iii	32	Decision making
JB23	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JB25	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research

D	Cmplx	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JB27	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JC3	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JC10	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JC12	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JC22	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JG10	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JG19	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JG27	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JH1	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JH3	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JH17	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JJ2	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JK1	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JK23	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JK36	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JL23	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JL24	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JM4	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JM17	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JM22	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JM25	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JN4	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JO9	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JP8	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JR3	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JR8	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JS14	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JS41	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JW1	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JW3	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JW14	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JW17	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JY1	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JS26	1	iii	36	Anthropocene and Earth stewardship
JS29	1	iii	36	Anthropocene and Earth stewardship
JT16	1	iii	36	Anthropocene and Earth stewardship
JC15	1	iii	37	Ontology and/or epistemology of Sustainability Science
JJ8	1	iii	37	Ontology and/or epistemology of Sustainability Science
JK2	1	iii	37	Ontology and/or epistemology of Sustainability Science
JK12	1	iii	37	Ontology and/or epistemology of Sustainability Science
JK21	1	iii	37	Ontology and/or epistemology of Sustainability Science
JK27	1	iii	37	Ontology and/or epistemology of Sustainability Science
JK30	1	iii	37	Ontology and/or epistemology of Sustainability Science
JK40	1	iii	37	Ontology and/or epistemology of Sustainability Science

D	Cmplx	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JM12	1	iii	37	Ontology and/or epistemology of Sustainability Science
JM28	1	iii	37	Ontology and/or epistemology of Sustainability Science
JM30	1	iii	37	Ontology and/or epistemology of Sustainability Science
JN6	1	iii	37	Ontology and/or epistemology of Sustainability Science
JS7	1	iii	37	Ontology and/or epistemology of Sustainability Science
JS25	1	iii	37	Ontology and/or epistemology of Sustainability Science
JS31	1	iii	37	Ontology and/or epistemology of Sustainability Science
JS40	1	iii	37	Ontology and/or epistemology of Sustainability Science
JT19	1	iii	37	Ontology and/or epistemology of Sustainability Science
JT20	1	iii	37	Ontology and/or epistemology of Sustainability Science
JW16	1	iii	37	Ontology and/or epistemology of Sustainability Science
JZ6	1	iii	37	Ontology and/or epistemology of Sustainability Science
JD7	1	iii	38	Complex systems, analysis, and adaptive planning/management
JD8	1	iii	38	Complex systems, analysis, and adaptive planning/management
JH22	1	iii	38	Complex systems, analysis, and adaptive planning/management
JI3	1	iii	38	Complex systems, analysis, and adaptive planning/management
JJ10	1	iii	38	Complex systems, analysis, and adaptive planning/management
JL6	1	iii	38	Complex systems, analysis, and adaptive planning/management
JL16	1	iii	38	Complex systems, analysis, and adaptive planning/management
JM16	1	iii	38	Complex systems, analysis, and adaptive planning/management
JP7	1	iii	38	Complex systems, analysis, and adaptive planning/management
JT17	1	iii	38	Complex systems, analysis, and adaptive planning/management
JY9	1	iii	38	Complex systems, analysis, and adaptive planning/management
JO2	1	iii	39	Cultural theory
JT6	1	iii	39	Cultural theory
JD15	1	iii	40	Urban agriculture
JG26	1	iii	43	Sustainable health
JK32	1	iii	47	Scenario analysis—Visioneering
JS37	1	iii	47	Scenario analysis—Visioneering
JL21	1	iii	48	Syndromes
JP20	1	iii	49	Landscape ecology

Literature map for 'Focus analysis – IV'

D	Global	i/ii/iii	1/2/3/4/..	Description of '1/2/3/4/..' standard names
JA6	1	ii	12	Modeling
JG18	1	ii	12	Modeling
JN1-1	1	ii	14	Urban policy/innovation
JH2	1	iii	6	Natural capital & ecosystem services management/governance
JH18	1	iii	6	Natural capital & ecosystem services management/governance
JT3	1	iii	6	Natural capital & ecosystem services management/governance
JA19	1	iii	11	Sustainability challenge
JC13	1	iii	11	Sustainability challenge
JK8	1	iii	11	Sustainability challenge
JK17	1	iii	11	Sustainability challenge
JR5	1	iii	11	Sustainability challenge
JR7	1	iii	11	Sustainability challenge
JS39	1	iii	11	Sustainability challenge
JW8	1	iii	11	Sustainability challenge
JS11	1	iii	19	Land cover and land use change science
JT18	1	iii	19	Land cover and land use change science
JS12	1	iii	23	Earth System analysis and tipping elements/points
JG19	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JW1	1	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
JS26	1	iii	36	Anthropocene and Earth stewardship
JS29	1	iii	36	Anthropocene and Earth stewardship
JT16	1	iii	36	Anthropocene and Earth stewardship
JJ8	1	iii	37	Ontology and/or epistemology of Sustainability Science
JK21	1	iii	37	Ontology and/or epistemology of Sustainability Science
JK38	1	iii	37	Ontology and/or epistemology of Sustainability Science
JY9	1	iii	38	Complex systems, analysis, and adaptive planning/management
JJ7	1	iii	45	Reframing
JJ11	1	iii	46	Globalization
JK15	1	iii	46	Globalization
JS37	1	iii	47	Scenario analysis—Visioneering
JL21	1	iii	48	Syndromes

Appendix 4

Representation of ‘Themes’ (under the three ‘Categories’) corresponding to the archive items present in the literature maps for the empirical literature analyses 1-4, and focus analyses I-IV.

The descriptor “i/ii/iii” stands for the three ‘Categories’ (i—‘Problem/ issue/ challenge/ syndrome-sphere’, ii—‘Action/ approach-sphere’, and iii—Academic-sphere), while “1/2/3/4/..” stands for the ‘Themes’ under each ‘Category’. Only the yellow-highlighted ‘Themes’ correspond to the archive items present in the literature maps for the empirical literature analyses and focus analyses. The rest of the Themes (un-highlighted) reveal comparison with respect to the represented ‘Themes’ in the thematic map.

‘Empirical literature analysis – 1’ literature map

i			ii			iii		
i		Problem/issue/challenge/syndrome sphere	ii		Action/approach sphere	iii		Academic sphere
i	1	Food security—Agricultural challenges/issues	ii	1	Energy policy/innovation	iii	1	Transition theory
i	2	Water availability/quality	ii	2	Alternative livelihood	iii	2	Dematerialization
i	3	Industrialization—Energy—Environment	ii	3	Interventions and development, and conservation	iii	3	"Reuse" as theory
i	4	Urbanization—Consumption—Environment	ii	4	Community involvement	iii	4	Circular economy
i	5	Air pollution—GHG Emission—Emission transfers	ii	5	Low-carbon transitions	iii	5	Quantitative sustainability
i	6	Biodiversity—Habitat destruction—Trade	ii	6	Biodiversity—Agriculture—Poverty	iii	6	Natural capital & ecosystem services management/governance
i	7	Public health	ii	7	Social learning	iii	7	Ecological economics
i	8	Human insecurity—Conflict	ii	8	Population policy	iii	8	Resilience
i	9	Population—Consumption—Environment	ii	9	Forest management policy/innovation	iii	9	Value—Attitude—Behavior
i	10	African poverty	ii	10	Agricultural policy/innovation	iii	10	Institutional reform
i	11	Climate change problem/impacts	ii	11	Regional cooperation	iii	11	Sustainability challenge
i	12	Drought	ii	12	Modeling	iii	12	Regulatory capitalism
i	13	Delta — problems	ii	13	Adaptation—Natural Disaster—Migration—Benefits	iii	13	Rural-urban transformation
i	14	Ecological crisis	ii	14	Urban policy/innovation	iii	14	Poverty—Development
i	15	Coastal vulnerability issues & sea level rise	ii	15	Reuse—Recycling—Pollution control	iii	15	Sustainable architecture
i	16	Global warming—Natural disaster	ii	16	Technology and nanotechnology	iii	16	Urban sustainability and adaptive urban governance
i	17	Estuaries & coastal seas — problems	ii	17	Water policy/innovation	iii	17	Adaptation
i	18	Open water bodies — problems	ii	18	Treaties—Agreements	iii	18	Political ecology
i	19	River — problems	ii	19	Emission estimation/control	iii	19	Land cover and land use change science
			ii	20	Land use system planning/innovation	iii	20	Sustainability—Culture—Religion
			ii	21	Biodiversity conservation policy/innovation	iii	21	World System theory
			ii	22	Ecosystem services policy/innovation	iii	22	Learning—Knowledge—Ignorance—Condition
			ii	23	Air quality policy/innovation	iii	23	Earth System analysis and tipping elements/points
			ii	24	Environmental restoration policies/innovation	iii	24	Environmental regulation
			ii	25	Sustainable Development strategies/innovation	iii	25	Environmental assessment
						iii	26	Sustainability related discourses
						iii	27	Ethics
						iii	28	Sustainable engineering education
						iii	29	Sustainability Science education/curriculum
						iii	30	Policy science
						iii	31	Cosmopolitanism
						iii	32	Decision making
						iii	33	Ecological modernization
						iii	34	Case studies for sustainability science
						iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
						iii	36	Anthropocene and Earth stewardship
						iii	37	Ontology and/or epistemology of Sustainability Science
						iii	38	Complex systems, analysis, and adaptive planning/management
						iii	39	Cultural theory
						iii	40	Urban agriculture
						iii	41	De-growth
						iii	42	Anthropocentrism vs. deep ecology
						iii	43	Sustainable health
						iii	44	Industrial ecology
						iii	45	Reframing
						iii	46	Globalization
						iii	47	Scenario analysis—Visioneering
						iii	48	Syndromes
						iii	49	Landscape ecology

'Empirical literature analysis – 2' literature map

i			ii			iii		
i		Problem/issue/challenge/syndrome sphere	ii		Action/approach sphere	iii		Academic sphere
i	1	Food security—Agricultural challenges/issues	ii	1	Energy policy/innovation	iii	1	Transition theory
i	2	Water availability/quality	ii	2	Alternative livelihood	iii	2	Dematerialization
i	3	Industrialization—Energy—Environment	ii	3	Interventions and development, and conservation	iii	3	"Reuse" as theory
i	4	Urbanization—Consumption—Environment	ii	4	Community involvement	iii	4	Circular economy
i	5	Air pollution—GHG Emission—Emission transfers	ii	5	Low-carbon transitions	iii	5	Quantitative sustainability
i	6	Biodiversity—Habitat destruction—Trade	ii	6	Biodiversity—Agriculture—Poverty	iii	6	Natural capital & ecosystem services management/governance
i	7	Public health	ii	7	Social learning	iii	7	Ecological economics
i	8	Human insecurity—Conflict	ii	8	Population policy	iii	8	Resilience
i	9	Population—Consumption—Environment	ii	9	Forest management policy/innovation	iii	9	Value—Attitude—Behavior
i	10	African poverty	ii	10	Agricultural policy/innovation	iii	10	Institutional reform
i	11	Climate change problem/impacts	ii	11	Regional cooperation	iii	11	Sustainability challenge
i	12	Drought	ii	12	Modeling	iii	12	Regulatory capitalism
i	13	Delta — problems	ii	13	Adaptation—Natural Disaster—Migration—Benefits	iii	13	Rural-urban transformation
i	14	Ecological crisis	ii	14	Urban policy/innovation	iii	14	Poverty—Development
i	15	Coastal vulnerability issues & sea level rise	ii	15	Reuse—Recycling—Pollution control	iii	15	Sustainable architecture
i	16	Global warming—Natural disaster	ii	16	Technology and nanotechnology	iii	16	Urban sustainability and adaptive urban governance
i	17	Estuaries & coastal seas — problems	ii	17	Water policy/innovation	iii	17	Adaptation
i	18	Open water bodies — problems	ii	18	Treaties—Agreements	iii	18	Political ecology
i	19	River — problems	ii	19	Emission estimation/control	iii	19	Land cover and land use change science
			ii	20	Land use system planning/innovation	iii	20	Sustainability—Culture—Religion
			ii	21	Biodiversity conservation policy/innovation	iii	21	World System theory
			ii	22	Ecosystem services policy/innovation	iii	22	Learning—Knowledge—Ignorance—Condition
			ii	23	Air quality policy/innovation	iii	23	Earth System analysis and tipping elements/points
			ii	24	Environmental restoration policies/innovation	iii	24	Environmental regulation
			ii	25	Sustainable Development strategies/innovation	iii	25	Environmental assessment
						iii	26	Sustainability related discourses
						iii	27	Ethics
						iii	28	Sustainable engineering education
						iii	29	Sustainability Science education/curriculum
						iii	30	Policy science
						iii	31	Cosmopolitanism
						iii	32	Decision making
						iii	33	Ecological modernization
						iii	34	Case studies for sustainability science
						iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
						iii	36	Anthropocene and Earth stewardship
						iii	37	Ontology and/or epistemology of Sustainability Science
						iii	38	Complex systems, analysis, and adaptive planning/management
						iii	39	Cultural theory
						iii	40	Urban agriculture
						iii	41	De-growth
						iii	42	Anthropocentrism vs. deep ecology
						iii	43	Sustainable health
						iii	44	Industrial ecology
						iii	45	Reframing
						iii	46	Globalization
						iii	47	Scenario analysis—Visioneering
						iii	48	Syndromes
						iii	49	Landscape ecology

‘Empirical literature analysis – 3’ literature map

i			ii			iii		
i		Problem/issue/challenge/syndrome sphere	ii		Action/approach sphere	iii		Academic sphere
i	1	Food security—Agricultural challenges/issues	ii	1	Energy policy/innovation	iii	1	Transition theory
i	2	Water availability/quality	ii	2	Alternative livelihood	iii	2	Dematerialization
i	3	Industrialization—Energy—Environment	ii	3	Interventions and development, and conservation	iii	3	"Reuse" as theory
i	4	Urbanization—Consumption—Environment	ii	4	Community involvement	iii	4	Circular economy
i	5	Air pollution—GHG Emission—Emission transfers	ii	5	Low-carbon transitions	iii	5	Quantitative sustainability
i	6	Biodiversity—Habitat destruction—Trade	ii	6	Biodiversity—Agriculture—Poverty	iii	6	Natural capital & ecosystem services management/governance
i	7	Public health	ii	7	Social learning	iii	7	Ecological economics
i	8	Human insecurity—Conflict	ii	8	Population policy	iii	8	Resilience
i	9	Population—Consumption—Environment	ii	9	Forest management policy/innovation	iii	9	Value—Attitude—Behavior
i	10	African poverty	ii	10	Agricultural policy/innovation	iii	10	Institutional reform
i	11	Climate change problem/impacts	ii	11	Regional cooperation	iii	11	Sustainability challenge
i	12	Drought	ii	12	Modeling	iii	12	Regulatory capitalism
i	13	Delta — problems	ii	13	Adaptation—Natural Disaster—Migration—Benefits	iii	13	Rural-urban transformation
i	14	Ecological crisis	ii	14	Urban policy/innovation	iii	14	Poverty—Development
i	15	Coastal vulnerability issues & sea level rise	ii	15	Reuse—Recycling—Pollution control	iii	15	Sustainable architecture
i	16	Global warming—Natural disaster	ii	16	Technology and nanotechnology	iii	16	Urban sustainability and adaptive urban governance
i	17	Estuaries & coastal seas — problems	ii	17	Water policy/innovation	iii	17	Adaptation
i	18	Open water bodies — problems	ii	18	Treaties—Agreements	iii	18	Political ecology
i	19	River — problems	ii	19	Emission estimation/control	iii	19	Land cover and land use change science
			ii	20	Land use system planning/innovation	iii	20	Sustainability—Culture—Religion
			ii	21	Biodiversity conservation policy/innovation	iii	21	World System theory
			ii	22	Ecosystem services policy/innovation	iii	22	Learning—Knowledge—Ignorance—Condition
			ii	23	Air quality policy/innovation	iii	23	Earth System analysis and tipping elements/points
			ii	24	Environmental restoration policies/innovation	iii	24	Environmental regulation
			ii	25	Sustainable Development strategies/innovation	iii	25	Environmental assessment
						iii	26	Sustainability related discourses
						iii	27	Ethics
						iii	28	Sustainable engineering education
						iii	29	Sustainability Science education/curriculum
						iii	30	Policy science
						iii	31	Cosmopolitanism
						iii	32	Decision making
						iii	33	Ecological modernization
						iii	34	Case studies for sustainability science
						iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
						iii	36	Anthropocene and Earth stewardship
						iii	37	Ontology and/or epistemology of Sustainability Science
						iii	38	Complex systems, analysis, and adaptive planning/management
						iii	39	Cultural theory
						iii	40	Urban agriculture
						iii	41	De-growth
						iii	42	Anthropocentrism vs. deep ecology
						iii	43	Sustainable health
						iii	44	Industrial ecology
						iii	45	Reframing
						iii	46	Globalization
						iii	47	Scenario analysis—Visioneering
						iii	48	Syndromes
						iii	49	Landscape ecology

'Empirical literature analysis – 4' literature map

i			ii			iii		
i		Problem/issue/challenge/syndrome sphere	ii		Action/approach sphere	iii		Academic sphere
i	1	Food security—Agricultural challenges/issues	ii	1	Energy policy/innovation	iii	1	Transition theory
i	2	Water availability/quality	ii	2	Alternative livelihood	iii	2	Dematerialization
i	3	Industrialization—Energy—Environment	ii	3	Interventions and development, and conservation	iii	3	"Reuse" as theory
i	4	Urbanization—Consumption—Environment	ii	4	Community involvement	iii	4	Circular economy
i	5	Air pollution—GHG Emission—Emission transfers	ii	5	Low-carbon transitions	iii	5	Quantitative sustainability
i	6	Biodiversity—Habitat destruction—Trade	ii	6	Biodiversity—Agriculture—Poverty	iii	6	Natural capital & ecosystem services management/governance
i	7	Public health	ii	7	Social learning	iii	7	Ecological economics
i	8	Human insecurity—Conflict	ii	8	Population policy	iii	8	Resilience
i	9	Population—Consumption—Environment	ii	9	Forest management policy/innovation	iii	9	Value—Attitude—Behavior
i	10	African poverty	ii	10	Agricultural policy/innovation	iii	10	Institutional reform
i	11	Climate change problem/impacts	ii	11	Regional cooperation	iii	11	Sustainability challenge
i	12	Drought	ii	12	Modeling	iii	12	Regulatory capitalism
i	13	Delta — problems	ii	13	Adaptation—Natural Disaster—Migration—Benefits	iii	13	Rural-urban transformation
i	14	Ecological crisis	ii	14	Urban policy/innovation	iii	14	Poverty—Development
i	15	Coastal vulnerability issues & sea level rise	ii	15	Reuse—Recycling—Pollution control	iii	15	Sustainable architecture
i	16	Global warming—Natural disaster	ii	16	Technology and nanotechnology	iii	16	Urban sustainability and adaptive urban governance
i	17	Estuaries & coastal seas — problems	ii	17	Water policy/innovation	iii	17	Adaptation
i	18	Open water bodies — problems	ii	18	Treaties—Agreements	iii	18	Political ecology
i	19	River — problems	ii	19	Emission estimation/control	iii	19	Land cover and land use change science
			ii	20	Land use system planning/innovation	iii	20	Sustainability—Culture—Religion
			ii	21	Biodiversity conservation policy/innovation	iii	21	World System theory
			ii	22	Ecosystem services policy/innovation	iii	22	Learning—Knowledge—Ignorance—Condition
			ii	23	Air quality policy/innovation	iii	23	Earth System analysis and tipping elements/points
			ii	24	Environmental restoration policies/innovation	iii	24	Environmental regulation
			ii	25	Sustainable Development strategies/innovation	iii	25	Environmental assessment
						iii	26	Sustainability related discourses
						iii	27	Ethics
						iii	28	Sustainable engineering education
						iii	29	Sustainability Science education/curriculum
						iii	30	Policy science
						iii	31	Cosmopolitanism
						iii	32	Decision making
						iii	33	Ecological modernization
						iii	34	Case studies for sustainability science
						iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
						iii	36	Anthropocene and Earth stewardship
						iii	37	Ontology and/or epistemology of Sustainability Science
						iii	38	Complex systems, analysis, and adaptive planning/management
						iii	39	Cultural theory
						iii	40	Urban agriculture
						iii	41	De-growth
						iii	42	Anthropocentrism vs. deep ecology
						iii	43	Sustainable health
						iii	44	Industrial ecology
						iii	45	Reframing
						iii	46	Globalization
						iii	47	Scenario analysis—Visioneering
						iii	48	Syndromes
						iii	49	Landscape ecology

'Focus analysis – I' literature map

i			ii			iii		
i		Problem/issue/challenge/syndrome sphere	ii		Action/approach sphere	iii		Academic sphere
i	1	Food security—Agricultural challenges/issues	ii	1	Energy policy/innovation	iii	1	Transition theory
i	2	Water availability/quality	ii	2	Alternative livelihood	iii	2	Dematerialization
i	3	Industrialization—Energy—Environment	ii	3	Interventions and development, and conservation	iii	3	"Reuse" as theory
i	4	Urbanization—Consumption—Environment	ii	4	Community involvement	iii	4	Circular economy
i	5	Air pollution—GHG Emission—Emission transfers	ii	5	Low-carbon transitions	iii	5	Quantitative sustainability
i	6	Biodiversity—Habitat destruction—Trade	ii	6	Biodiversity—Agriculture—Poverty	iii	6	Natural capital & ecosystem services management/governance
i	7	Public health	ii	7	Social learning	iii	7	Ecological economics
i	8	Human insecurity—Conflict	ii	8	Population policy	iii	8	Resilience
i	9	Population—Consumption—Environment	ii	9	Forest management policy/innovation	iii	9	Value—Attitude—Behavior
i	10	African poverty	ii	10	Agricultural policy/innovation	iii	10	Institutional reform
i	11	Climate change problem/impacts	ii	11	Regional cooperation	iii	11	Sustainability challenge
i	12	Drought	ii	12	Modeling	iii	12	Regulatory capitalism
i	13	Delta — problems	ii	13	Adaptation—Natural Disaster—Migration—Benefits	iii	13	Rural-urban transformation
i	14	Ecological crisis	ii	14	Urban policy/innovation	iii	14	Poverty—Development
i	15	Coastal vulnerability issues & sea level rise	ii	15	Reuse—Recycling—Pollution control	iii	15	Sustainable architecture
i	16	Global warming—Natural disaster	ii	16	Technology and nanotechnology	iii	16	Urban sustainability and adaptive urban governance
i	17	Estuaries & coastal seas — problems	ii	17	Water policy/innovation	iii	17	Adaptation
i	18	Open water bodies — problems	ii	18	Treaties—Agreements	iii	18	Political ecology
i	19	River — problems	ii	19	Emission estimation/control	iii	19	Land cover and land use change science
			ii	20	Land use system planning/innovation	iii	20	Sustainability—Culture—Religion
			ii	21	Biodiversity conservation policy/innovation	iii	21	World System theory
			ii	22	Ecosystem services policy/innovation	iii	22	Learning—Knowledge—Ignorance—Condition
			ii	23	Air quality policy/innovation	iii	23	Earth System analysis and tipping elements/points
			ii	24	Environmental restoration policies/innovation	iii	24	Environmental regulation
			ii	25	Sustainable Development strategies/innovation	iii	25	Environmental assessment
						iii	26	Sustainability related discourses
						iii	27	Ethics
						iii	28	Sustainable engineering education
						iii	29	Sustainability Science education/curriculum
						iii	30	Policy science
						iii	31	Cosmopolitanism
						iii	32	Decision making
						iii	33	Ecological modernization
						iii	34	Case studies for sustainability science
						iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
						iii	36	Anthropocene and Earth stewardship
						iii	37	Ontology and/or epistemology of Sustainability Science
						iii	38	Complex systems, analysis, and adaptive planning/management
						iii	39	Cultural theory
						iii	40	Urban agriculture
						iii	41	De-growth
						iii	42	Anthropocentrism vs. deep ecology
						iii	43	Sustainable health
						iii	44	Industrial ecology
						iii	45	Reframing
						iii	46	Globalization
						iii	47	Scenario analysis—Visioneering
						iii	48	Syndromes
						iii	49	Landscape ecology

‘Focus analysis – II’ literature map

i			ii			iii		
i		Problem/issue/challenge/syndrome sphere	ii		Action/approach sphere	iii		Academic sphere
i	1	Food security—Agricultural challenges/issues	ii	1	Energy policy/innovation	iii	1	Transition theory
i	2	Water availability/quality	ii	2	Alternative livelihood	iii	2	Dematerialization
i	3	Industrialization—Energy—Environment	ii	3	Interventions and development, and conservation	iii	3	"Reuse" as theory
i	4	Urbanization—Consumption—Environment	ii	4	Community involvement	iii	4	Circular economy
i	5	Air pollution—GHG Emission—Emission transfers	ii	5	Low-carbon transitions	iii	5	Quantitative sustainability
i	6	Biodiversity—Habitat destruction—Trade	ii	6	Biodiversity—Agriculture—Poverty	iii	6	Natural capital & ecosystem services management/governance
i	7	Public health	ii	7	Social learning	iii	7	Ecological economics
i	8	Human insecurity—Conflict	ii	8	Population policy	iii	8	Resilience
i	9	Population—Consumption—Environment	ii	9	Forest management policy/innovation	iii	9	Value—Attitude—Behavior
i	10	African poverty	ii	10	Agricultural policy/innovation	iii	10	Institutional reform
i	11	Climate change problem/impacts	ii	11	Regional cooperation	iii	11	Sustainability challenge
i	12	Drought	ii	12	Modeling	iii	12	Regulatory capitalism
i	13	Delta — problems	ii	13	Adaptation—Natural Disaster—Migration—Benefits	iii	13	Rural-urban transformation
i	14	Ecological crisis	ii	14	Urban policy/innovation	iii	14	Poverty—Development
i	15	Coastal vulnerability issues & sea level rise	ii	15	Reuse—Recycling—Pollution control	iii	15	Sustainable architecture
i	16	Global warming—Natural disaster	ii	16	Technology and nanotechnology	iii	16	Urban sustainability and adaptive urban governance
i	17	Estuaries & coastal seas — problems	ii	17	Water policy/innovation	iii	17	Adaptation
i	18	Open water bodies — problems	ii	18	Treaties—Agreements	iii	18	Political ecology
i	19	River — problems	ii	19	Emission estimation/control	iii	19	Land cover and land use change science
			ii	20	Land use system planning/innovation	iii	20	Sustainability—Culture—Religion
			ii	21	Biodiversity conservation policy/innovation	iii	21	World System theory
			ii	22	Ecosystem services policy/innovation	iii	22	Learning—Knowledge—Ignorance—Condition
			ii	23	Air quality policy/innovation	iii	23	Earth System analysis and tipping elements/points
			ii	24	Environmental restoration policies/innovation	iii	24	Environmental regulation
			ii	25	Sustainable Development strategies/innovation	iii	25	Environmental assessment
						iii	26	Sustainability related discourses
						iii	27	Ethics
						iii	28	Sustainable engineering education
						iii	29	Sustainability Science education/curriculum
						iii	30	Policy science
						iii	31	Cosmopolitanism
						iii	32	Decision making
						iii	33	Ecological modernization
						iii	34	Case studies for sustainability science
						iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
						iii	36	Anthropocene and Earth stewardship
						iii	37	Ontology and/or epistemology of Sustainability Science
						iii	38	Complex systems, analysis, and adaptive planning/management
						iii	39	Cultural theory
						iii	40	Urban agriculture
						iii	41	De-growth
						iii	42	Anthropocentrism vs. deep ecology
						iii	43	Sustainable health
						iii	44	Industrial ecology
						iii	45	Reframing
						iii	46	Globalization
						iii	47	Scenario analysis—Visioneering
						iii	48	Syndromes
						iii	49	Landscape ecology

'Focus analysis – III' literature map

i			ii			iii		
i		Problem/issue/challenge/syndrome sphere	ii		Action/approach sphere	iii		Academic sphere
i	1	Food security—Agricultural challenges/issues	ii	1	Energy policy/innovation	iii	1	Transition theory
i	2	Water availability/quality	ii	2	Alternative livelihood	iii	2	Dematerialization
i	3	Industrialization—Energy—Environment	ii	3	Interventions and development, and conservation	iii	3	"Reuse" as theory
i	4	Urbanization—Consumption—Environment	ii	4	Community involvement	iii	4	Circular economy
i	5	Air pollution—GHG Emission—Emission transfers	ii	5	Low-carbon transitions	iii	5	Quantitative sustainability
i	6	Biodiversity—Habitat destruction—Trade	ii	6	Biodiversity—Agriculture—Poverty	iii	6	Natural capital & ecosystem services management/governance
i	7	Public health	ii	7	Social learning	iii	7	Ecological economics
i	8	Human insecurity—Conflict	ii	8	Population policy	iii	8	Resilience
i	9	Population—Consumption—Environment	ii	9	Forest management policy/innovation	iii	9	Value—Attitude—Behavior
i	10	African poverty	ii	10	Agricultural policy/innovation	iii	10	Institutional reform
i	11	Climate change problem/impacts	ii	11	Regional cooperation	iii	11	Sustainability challenge
i	12	Drought	ii	12	Modeling	iii	12	Regulatory capitalism
i	13	Delta — problems	ii	13	Adaptation—Natural Disaster—Migration—Benefits	iii	13	Rural-urban transformation
i	14	Ecological crisis	ii	14	Urban policy/innovation	iii	14	Poverty—Development
i	15	Coastal vulnerability issues & sea level rise	ii	15	Reuse—Recycling—Pollution control	iii	15	Sustainable architecture
i	16	Global warming—Natural disaster	ii	16	Technology and nanotechnology	iii	16	Urban sustainability and adaptive urban governance
i	17	Estuaries & coastal seas — problems	ii	17	Water policy/innovation	iii	17	Adaptation
i	18	Open water bodies — problems	ii	18	Treaties—Agreements	iii	18	Political ecology
i	19	River — problems	ii	19	Emission estimation/control	iii	19	Land cover and land use change science
			ii	20	Land use system planning/innovation	iii	20	Sustainability—Culture—Religion
			ii	21	Biodiversity conservation policy/innovation	iii	21	World System theory
			ii	22	Ecosystem services policy/innovation	iii	22	Learning—Knowledge—Ignorance—Condition
			ii	23	Air quality policy/innovation	iii	23	Earth System analysis and tipping elements/points
			ii	24	Environmental restoration policies/innovation	iii	24	Environmental regulation
			ii	25	Sustainable Development strategies/innovation	iii	25	Environmental assessment
						iii	26	Sustainability related discourses
						iii	27	Ethics
						iii	28	Sustainable engineering education
						iii	29	Sustainability Science education/curriculum
						iii	30	Policy science
						iii	31	Cosmopolitanism
						iii	32	Decision making
						iii	33	Ecological modernization
						iii	34	Case studies for sustainability science
						iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
						iii	36	Anthropocene and Earth stewardship
						iii	37	Ontology and/or epistemology of Sustainability Science
						iii	38	Complex systems, analysis, and adaptive planning/management
						iii	39	Cultural theory
						iii	40	Urban agriculture
						iii	41	De-growth
						iii	42	Anthropocentrism vs. deep ecology
						iii	43	Sustainable health
						iii	44	Industrial ecology
						iii	45	Reframing
						iii	46	Globalization
						iii	47	Scenario analysis—Visioneering
						iii	48	Syndromes
						iii	49	Landscape ecology

‘Focus analysis – IV’ literature map

i			ii			iii		
i		Problem/issue/challenge/syndrome sphere	ii		Action/approach sphere	iii		Academic sphere
i	1	Food security—Agricultural challenges/issues	ii	1	Energy policy/innovation	iii	1	Transition theory
i	2	Water availability/quality	ii	2	Alternative livelihood	iii	2	Dematerialization
i	3	Industrialization—Energy—Environment	ii	3	Interventions and development, and conservation	iii	3	"Reuse" as theory
i	4	Urbanization—Consumption—Environment	ii	4	Community involvement	iii	4	Circular economy
i	5	Air pollution—GHG Emission—Emission transfers	ii	5	Low-carbon transitions	iii	5	Quantitative sustainability
i	6	Biodiversity—Habitat destruction—Trade	ii	6	Biodiversity—Agriculture—Poverty	iii	6	Natural capital & ecosystem services management/governance
i	7	Public health	ii	7	Social learning	iii	7	Ecological economics
i	8	Human insecurity—Conflict	ii	8	Population policy	iii	8	Resilience
i	9	Population—Consumption—Environment	ii	9	Forest management policy/innovation	iii	9	Value—Attitude—Behavior
i	10	African poverty	ii	10	Agricultural policy/innovation	iii	10	Institutional reform
i	11	Climate change problem/impacts	ii	11	Regional cooperation	iii	11	Sustainability challenge
i	12	Drought	ii	12	Modeling	iii	12	Regulatory capitalism
i	13	Delta — problems	ii	13	Adaptation—Natural Disaster—Migration—Benefits	iii	13	Rural-urban transformation
i	14	Ecological crisis	ii	14	Urban policy/innovation	iii	14	Poverty—Development
i	15	Coastal vulnerability issues & sea level rise	ii	15	Reuse—Recycling—Pollution control	iii	15	Sustainable architecture
i	16	Global warming—Natural disaster	ii	16	Technology and nanotechnology	iii	16	Urban sustainability and adaptive urban governance
i	17	Estuaries & coastal seas — problems	ii	17	Water policy/innovation	iii	17	Adaptation
i	18	Open water bodies — problems	ii	18	Treaties—Agreements	iii	18	Political ecology
i	19	River — problems	ii	19	Emission estimation/control	iii	19	Land cover and land use change science
			ii	20	Land use system planning/innovation	iii	20	Sustainability—Culture—Religion
			ii	21	Biodiversity conservation policy/innovation	iii	21	World System theory
			ii	22	Ecosystem services policy/innovation	iii	22	Learning—Knowledge—Ignorance—Condition
			ii	23	Air quality policy/innovation	iii	23	Earth System analysis and tipping elements/points
			ii	24	Environmental restoration policies/innovation	iii	24	Environmental regulation
			ii	25	Sustainable Development strategies/innovation	iii	25	Environmental assessment
						iii	26	Sustainability related discourses
						iii	27	Ethics
						iii	28	Sustainable engineering education
						iii	29	Sustainability Science education/curriculum
						iii	30	Policy science
						iii	31	Cosmopolitanism
						iii	32	Decision making
						iii	33	Ecological modernization
						iii	34	Case studies for sustainability science
						iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research
						iii	36	Anthropocene and Earth stewardship
						iii	37	Ontology and/or epistemology of Sustainability Science
						iii	38	Complex systems, analysis, and adaptive planning/management
						iii	39	Cultural theory
						iii	40	Urban agriculture
						iii	41	De-growth
						iii	42	Anthropocentrism vs. deep ecology
						iii	43	Sustainable health
						iii	44	Industrial ecology
						iii	45	Reframing
						iii	46	Globalization
						iii	47	Scenario analysis—Visioneering
						iii	48	Syndromes
						iii	49	Landscape ecology

Appendix 5

Appendix 5 provides sphere-wise (based on the 10 spheres within A/B/C/D) thematic comparison across the three categories (i, ii and iii) for each of the empirical literature analyses and focus analyses (**Tables A5.1–A5.4** for the four 'empirical literature analyses' and **Tables A5.5–A5.8** for the four 'focus analyses into the quality of sustainability science'). For pairing purpose, a full list of the titles of the empirical literature analyses and the focus analyses into the quality of sustainability science precedes the **Tables A5.1–A5.8**.

[Empirical literature analysis - 1]: Ecologically-benign development pathways in 'Global South'

[Empirical literature analysis - 2]: Hunger and food insecurity in human societies and the agricultural production issues

[Empirical literature analysis - 3]: Sustainability science issues in urban planning

[Empirical literature analysis - 4]: Sustainability science issues in water security syndrome

[Focus analysis - I]: Existing 'philosophical, theoretical and methodological' avenues in sustainability science

[Focus analysis - II]: Characterization of 'human-environment system' in sustainability science

[Focus analysis - III]: Nature of complexity in sustainability science

[Focus analysis - IV]: Analysis of practices on 'global sustainability'

The 10 Spheres within (A/B/C/D)	Table A5.1: List of 'Themes' under the three 'Categories' (i/ii/iii) represented by the corresponding archive items present in the 'empirical literature analysis – 1' literature map		
	(i) Problem/ issue/ challenge/ syndrome-sphere	(ii) Action/ approach-sphere	(iii) Academic-sphere
A	[Food security—Agricultural challenges/issues] [Industrialization—Energy—Environment]	[Energy policy/innovation]	[Transition theory]
A(AB)	[Urbanization—Consumption—Environment]	[Energy policy/innovation] [Alternative livelihood] [Interventions and development, and conservation] [Community involvement] [Low-carbon transitions]	[Dematerialization] ["Reuse" as theory] [Circular economy] [Quantitative sustainability]
A(AC)	[Food security—Agricultural challenges/issues] [Water availability/quality] [Industrialization—Energy—Environment] [Air pollution—GHG Emission—Emission transfers] [Biodiversity—Habitat destruction—Trade]	[Energy policy/innovation] [Low-carbon transitions] [Biodiversity—Agriculture—Poverty]	[Circular economy] [Natural capital & ecosystem services management/governance] [Ecological economics]
B	[Public health] [Human insecurity—Conflict] [Population—Consumption—Environment]	[Interventions and development, and conservation] [Community involvement] [Social learning] [Population policy]	-
B(BA)	[Food security—Agricultural challenges/issues] [Water availability/quality] [Population—Consumption—Environment] [African poverty]	[Interventions and development, and conservation] [Community involvement] [Low-carbon transitions] [Forest management policy/innovation] [Agricultural policy/innovation] [Regional cooperation]	[Institutional reform] [Sustainability challenge] [Rural-urban transformation] [Poverty—Development] [Sustainable architecture]
B(BC)	[Food security—Agricultural challenges/issues] [Public health] [Human insecurity—Conflict] [Population—Consumption—Environment] [Climate change problem/impacts] [Drought] [Delta —problems]	[Interventions and development, and conservation] [Community involvement] [Biodiversity—Agriculture—Poverty] [Forest management policy/innovation] [Agricultural policy/innovation] [Modeling] [Adaptation—Natural Disaster—Migration—Benefits] [Urban policy/innovation] [Reuse—Recycling—Pollution control]	["Reuse" as theory] [Natural capital & ecosystem services management/governance] [Sustainability challenge] [Poverty—Development] [Sustainable architecture] [Urban sustainability and adaptive urban governance] [Adaptation] [Land cover and land use change science] [Sustainability—Culture—Religion] [World System theory] [Learning—Knowledge—Ignorance—Condition]
C	[Air pollution—GHG Emission—Emission transfers] [Climate change problem/impacts] [Drought] [Ecological crisis]	[Modeling]	-
C(CA)	[Global warming—Natural disaster]	[Forest management policy/innovation] [Technology and nanotechnology] [Water policy/innovation]	[Adaptation] [Environmental regulation]
C(CB)	[Food security—Agricultural challenges/issues] [Air pollution—GHG Emission—Emission transfers] [Biodiversity—Habitat destruction—Trade] [Climate change problem/impacts] [Ecological crisis] [Coastal vulnerability issues & sea level rise] [Estuaries & coastal seas —	[Alternative livelihood] [Low-carbon transitions] [Forest management policy/innovation] [Agricultural policy/innovation] [Modeling] [Adaptation—Natural Disaster—Migration—Benefits] [Urban policy/innovation] [Reuse—	[Natural capital & ecosystem services management/governance] [Resilience] [Sustainability challenge] [Adaptation] [Land cover and land use change science] [Environmental regulation]

	problems] [Open water bodies — problems]	Recycling—Pollution control] [Water policy/innovation] [Treaties—Agreements] [Emission estimation/control] [Land use system planning/innovation] [Biodiversity conservation policy/innovation] [Ecosystem services policy/innovation] [Air quality policy/innovation] [Environmental restoration policies/innovation]	
D	[African poverty] [Climate change problem/impacts] [River — problems]	[Interventions and development, and conservation] [Forest management policy/innovation] [Modeling] [Adaptation—Natural Disaster—Migration—Benefits] [Urban policy/innovation] [Water policy/innovation] [Biodiversity conservation policy/innovation] [Sustainable Development strategies/innovation]	[Circular economy] [Quantitative sustainability] [Natural capital & ecosystem services management/governance] [Resilience] [Sustainability challenge] [Poverty—Development] [Urban sustainability and adaptive urban governance] [Adaptation] [Political ecology] [Land cover and land use change science] [World System theory] [Sustainability related discourses] [Sustainability Science education/curriculum] [Cosmopolitanism] [Inter-/multi-/trans-/Disciplinarity of Sustainability Science research] [Anthropocene and Earth stewardship] [Ontology and/or epistemology of Sustainability Science] [Complex systems, analysis, and adaptive planning/management] [Urban agriculture] [De-growth] [Sustainable health]

The 10 Spheres within (A/B/C/D)	**Table A5.2: List of 'Themes' under the three 'Categories' (i/ii/iii) represented by the corresponding archive items present in the 'empirical literature analysis – 2' literature map**		
	(i) Problem/ issue/ challenge/ syndrome-sphere	**(ii) Action/ approach-sphere**	**(iii) Academic-sphere**
A	-	-	-
A(AB)	-	[Community involvement]	-
A(AC)	[Food security—Agricultural challenges/issues] [Air pollution—GHG Emission—Emission transfers] [Biodiversity—Habitat destruction—Trade]	[Energy policy/innovation] [Biodiversity—Agriculture—Poverty]	-
B	-	-	-
B(BA)	[Food security—Agricultural challenges/issues] [Population—Consumption—Environment]	[Interventions and development, and conservation] [Forest management policy/innovation] [Agricultural policy/innovation]	[Sustainability challenge]
B(BC)	[Food security—Agricultural challenges/issues] [Population—Consumption—Environment] [Drought]	[Biodiversity—Agriculture—Poverty] [Forest management policy/innovation] [Agricultural policy/innovation]	["Reuse" as theory] [Natural capital & ecosystem services management/governance] [Poverty—Development] [Adaptation] [Land cover and land use change science]
C	[Climate change problem/impacts] [Drought] [Ecological crisis]	[Modeling]	-
C(CA)	-	[Forest management policy/innovation] [Technology and nanotechnology]	[Natural capital & ecosystem services management/governance]
C(CB)	[Food security—Agricultural challenges/issues] [Biodiversity—Habitat destruction—Trade] [Climate change problem/impacts] [Ecological crisis] [Coastal vulnerability issues & sea level rise]	[Alternative livelihood] [Forest management policy/innovation] [Agricultural policy/innovation] [Modeling] [Urban policy/innovation] [Reuse—Recycling—Pollution control] [Water policy/innovation] [Emission estimation/control] [Land use system planning/innovation] [Biodiversity conservation policy/innovation] [Ecosystem services policy/innovation]	[Natural capital & ecosystem services management/governance] [Resilience] [Land cover and land use change science]
D	[Climate change problem/impacts] [River — problems]	[Interventions and development, and conservation] [Forest management policy/innovation] [Modeling] [Water policy/innovation] [Biodiversity conservation policy/innovation]	[Natural capital & ecosystem services management/governance] [Sustainability challenge] [Land cover and land use change science] [World System theory] [Ontology and/or epistemology of Sustainability Science] [Complex systems, analysis, and adaptive planning/management] [Urban agriculture]

The 10 Spheres within (A/B/C/D)	Table A5.3: List of 'Themes' under the three 'Categories' (i/ii/iii) represented by the corresponding archive items present in the 'empirical literature analysis – 3' literature map		
	(i) Problem/ issue/ challenge/ syndrome-sphere	**(ii) Action/ approach-sphere**	**(iii) Academic-sphere**
A	-	[Energy policy/innovation]	-
A(AB)	[Urbanization—Consumption—Environment]	[Low-carbon transitions]	-
A(AC)	[Water availability/quality] [Industrialization—Energy—Environment]	[Energy policy/innovation] [Low-carbon transitions]	[Ecological economics]
B	-	-	[Resilience]
B(BA)	[Water availability/quality] [Urbanization—Consumption—Environment]	[Low-carbon transitions] [Regional cooperation]	[Rural-urban transformation] [Sustainable architecture]
B(BC)	[Public health] [Population—Consumption—Environment] [Drought] [Delta — problems]	[Interventions and development, and conservation] [Community involvement] [Low-carbon transitions] [Regional cooperation] [Modeling] [Urban policy/innovation]	["Reuse" as theory] [Natural capital & ecosystem services management/governance] [Sustainable architecture] [Urban sustainability and adaptive urban governance] [Adaptation] [Sustainability—Culture—Religion] [Learning—Knowledge—Ignorance—Condition]
C	[Air pollution—GHG Emission—Emission transfers] [Climate change problem/impacts] [Coastal vulnerability issues & sea level rise]	-	-
C(CA)	[Global warming—Natural disaster]	[Modeling] [Technology and nanotechnology] [Water policy/innovation]	-
C(CB)	[Air pollution—GHG Emission—Emission transfers] [Climate change problem/impacts] [Coastal vulnerability issues & sea level rise]	[Alternative livelihood] [Low-carbon transitions] [Adaptation—Natural Disaster—Migration—Benefits] [Urban policy/innovation] [Reuse—Recycling—Pollution control] [Water policy/innovation] [Land use system planning/innovation] [Ecosystem services policy/innovation] [Air quality policy/innovation]	[Natural capital & ecosystem services management/governance] [Sustainability challenge] [Land cover and land use change science]
D	-	[Urban policy/innovation] [Water policy/innovation]	[Circular economy] [Quantitative sustainability] [Natural capital & ecosystem services management/governance] [Sustainability challenge] [Urban sustainability and adaptive urban governance] [Land cover and land use change science] [Ontology and/or epistemology of Sustainability Science] [Complex systems, analysis, and adaptive planning/management] [Urban agriculture] [Landscape ecology]

The 10 Spheres within (A/B/C/D)	**Table A5.4: List of 'Themes' under the three 'Categories' (i/ii/iii) represented by the corresponding archive items present in the 'empirical literature analysis – 4' literature map**		
	(i) Problem/ issue/ challenge/ syndrome-sphere	**(ii) Action/ approach-sphere**	**(iii) Academic-sphere**
A	-	-	-
A(AB)	-	-	-
A(AC)	[Water availability/quality] [Industrialization—Energy—Environment]	-	-
B	-	-	-
B(BA)	[Water availability/quality]	[Regional cooperation]	-
B(BC)	[Water availability/quality] [Public health] [Population—Consumption—Environment] [Drought]	[Interventions and development, and conservation] [Modeling] [Urban policy/innovation]	["Reuse" as theory] [Natural capital & ecosystem services management/governance] [Urban sustainability and adaptive urban governance] [Sustainability—Culture—Religion]
C	-	-	-
C(CA)	-	[Modeling] [Technology and nanotechnology] [Water policy/innovation]	-
C(CB)	[Climate change problem/impacts] [Coastal vulnerability issues & sea level rise] [Estuaries & coastal seas — problems] [Open water bodies — problems]	[Water policy/innovation] [Ecosystem services policy/innovation]	[Natural capital & ecosystem services management/governance] [Land cover and land use change science]
D	-	[Water policy/innovation]	[Natural capital & ecosystem services management/governance] [Urban sustainability and adaptive urban governance] [Urban agriculture]

The 10 Spheres within (A/B/C/D)	**Table A5.5: List of 'Themes' under the three 'Categories' (i/ii/iii) represented by the corresponding archive items present in the 'focus analysis – I' literature map**		
	(i) Problem/ issue/ challenge/ syndrome-sphere	**(ii) Action/ approach-sphere**	**(iii) Academic-sphere**
D	[African poverty] [Climate change problem/impacts] [River — problems]	[Interventions and development, and conservation] [Forest management policy/innovation] [Modeling] [Adaptation—Natural Disaster—Migration—Benefits] [Urban policy/innovation] [Water policy/innovation] [Biodiversity conservation policy/innovation] [Environmental restoration policies/innovation] [Sustainable Development strategies/innovation]	[Transition theory] [Circular economy] [Quantitative sustainability] [Natural capital & ecosystem services management/governance] [Resilience] [Value—Attitude—Behavior] [Sustainability challenge] [Poverty—Development] [Urban sustainability and adaptive urban governance] [Adaptation] [Political ecology] [Land cover and land use change science] [World System theory] [Learning—Knowledge—Ignorance—Condition] [Earth System analysis and tipping elements/points] [Environmental assessment] [Sustainability related discourses] [Ethics] [Sustainable engineering education] [Sustainability Science education/curriculum] [Policy science] [Cosmopolitanism] [Decision making] [Ecological modernization] [Inter-/multi-/trans-/Disciplinarity of Sustainability Science research] [Anthropocene and Earth stewardship] [Ontology and/or epistemology of Sustainability Science] [Complex systems, analysis, and adaptive planning/management] [Cultural theory] [Urban agriculture] [De-growth] [Anthropocentrism vs. deep ecology] [Sustainable health] [Industrial ecology] [Reframing] [Globalization] [Scenario analysis—Visioneering] [Syndromes] [Landscape ecology]

The 10 Spheres within (A/B/C/D)	Table A5.6: List of 'Themes' under the three 'Categories' (i/ii/iii) represented by the corresponding archive items present in the 'focus analysis – II' literature map		
	(i) Problem/ issue/ challenge/ syndrome-sphere	**(ii) Action/ approach-sphere**	**(iii) Academic-sphere**
A(AC)	[Food security—Agricultural challenges/issues] [Water availability/quality] [Industrialization—Energy—Environment] [Biodiversity—Habitat destruction—Trade]	[Energy policy/innovation]	[Circular economy] [Natural capital & ecosystem services management/governance] [Ecological economics]
B(BC)	[Water availability/quality] [Public health] [Human insecurity—Conflict] [Population—Consumption—Environment] [Drought] [Delta — problems]	[Interventions and development, and conservation] [Low-carbon transitions] [Biodiversity—Agriculture—Poverty] [Forest management policy/innovation] [Agricultural policy/innovation] [Adaptation—Natural Disaster—Migration—Benefits] [Urban policy/innovation]	["Reuse" as theory] [Natural capital & ecosystem services management/governance] [Sustainability challenge] [Poverty—Development] [Sustainable architecture] [Urban sustainability and adaptive urban governance] [Adaptation] [Political ecology] [Land cover and land use change science] [Sustainability—Culture—Religion]
C(CA)	[Global warming—Natural disaster]	[Modeling]	[Natural capital & ecosystem services management/governance] [Adaptation]
C(CB)	[Food security—Agricultural challenges/issues] [Air pollution—GHG Emission—Emission transfers] [Biodiversity—Habitat destruction—Trade] [Open water bodies — problems]	[Alternative livelihood] [Forest management policy/innovation] [Agricultural policy/innovation] [Modeling] [Urban policy/innovation] [Reuse—Recycling—Pollution control] [Emission estimation/control] [Land use system planning/innovation] [Biodiversity conservation policy/innovation] [Ecosystem services policy/innovation]	[Natural capital & ecosystem services management/governance] [Sustainability challenge] [Land cover and land use change science]
D	[Climate change problem/impacts] [River — problems]	[Interventions and development, and conservation] [Urban policy/innovation] [Water policy/innovation]	[Circular economy] [Natural capital & ecosystem services management/governance] [Resilience] [Sustainability challenge] [Adaptation] [Land cover and land use change science] [World System theory] [Earth System analysis and tipping elements/points] [Sustainability related discourses] [Decision making] [Ecological modernization] [Inter-/multi-/trans-/Disciplinarity of Sustainability Science research] [Anthropocene and Earth stewardship] [Ontology and/or epistemology of Sustainability Science] [Complex systems, analysis, and adaptive planning/management] [Urban agriculture] [Anthropocentrism vs. deep ecology] [Landscape ecology]

The 10 Spheres within (A/B/C/D)	**Table A5.7: List of 'Themes' under the three 'Categories' (i/ii/iii) represented by the corresponding archive items present in the 'focus analysis – III' literature map**		
	(i) Problem/ issue/ challenge/ syndrome-sphere	**(ii) Action/ approach-sphere**	**(iii) Academic-sphere**
D	[African poverty] [Climate change problem/impacts] [River — problems]	[Interventions and development, and conservation] [Forest management policy/innovation] [Modeling] [Adaptation—Natural Disaster—Migration—Benefits] [Urban policy/innovation] [Water policy/innovation] [Biodiversity conservation policy/innovation] [Sustainable Development strategies/innovation]	[Transition theory] [Circular economy] [Quantitative sustainability] [Natural capital & ecosystem services management/governance] [Resilience] [Sustainability challenge] [Poverty—Development] [Urban sustainability and adaptive urban governance] [Adaptation] [Political ecology] [Land cover and land use change science] [World System theory] [Learning—Knowledge—Ignorance—Condition] [Earth System analysis and tipping elements/points] [Environmental assessment] [Sustainability related discourses] [Sustainable engineering education] [Sustainability Science education/curriculum] [Policy science] [Decision making] [Inter-/multi-/trans-/Disciplinarity of Sustainability Science research] [Anthropocene and Earth stewardship] [Ontology and/or epistemology of Sustainability Science] [Complex systems, analysis, and adaptive planning/management] [Cultural theory] [Urban agriculture] [Sustainable health] [Scenario analysis—Visioneering] [Syndromes] [Landscape ecology]

The 10 Spheres within (A/B/C/D)	**Table A5.8: List of 'Themes' under the three 'Categories' (i/ii/iii) represented by the corresponding archive items present in the 'focus analysis – IV' literature map**		
	(i) Problem/ issue/ challenge/ syndrome-sphere	**(ii) Action/ approach-sphere**	**(iii) Academic-sphere**
D	-	[Modeling] [Urban policy/innovation]	[Natural capital & ecosystem services management/governance] [Sustainability challenge] [Land cover and land use change science] [Earth System analysis and tipping elements/points] [Inter-/multi-/trans-/Disciplinarity of Sustainability Science research] [Anthropocene and Earth stewardship] [Ontology and/or epistemology of Sustainability Science] [Complex systems, analysis, and adaptive planning/management] [Reframing] [Globalization] [Scenario analysis—Visioneering] [Syndromes]

Appendix 6

Megacity Dhaka: ‘water security syndrome’ and implications for the scholarship of sustainability

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Abstract
The potentials of the scholarship of sustainability present new possibilities for integrated analysis to address syndromes in human-environment systems. A syndrome here means a big-picture complex problem or issue with sustainability implications, such as urban sprawl, land contamination, mass tourism, waste dumping, etc. Through a case history – that of a 'water security syndrome' – this paper explores key conceptual aspects for the potential scholarship of sustainability. First, it outlines the scope of this syndrome within the context of one megacity, Dhaka (Bangladesh). Through a holistic literature analysis utilizing system's approach six themes are then elucidated, including patterns of change, sectoral impacts, climate change implications, and opportunities to capitalize. A model is constructed representing a 'water security syndrome' in the perspective of developing world, and implications are drawn for the potential scholarship of sustainability.

1. Introduction
The negative impacts of anthropogenic utilization of the Earth's resources have become so numerous and entangled that they often overwhelm policy-making and thus limit planning for sustainable futures (Ayres 2000). In an attempt to describe this problem the German Advisory Council on Global Change (WGBU 1996) identified categories or archetypical patterns in the complex problems of human-environment relationships we now face. Each of these categories of problems, termed sustainability 'syndromes', is a 'core problem of global change' being "the product of characteristic constellations of socioeconomic, geographical and political trends … and can be identified in many regions of the world" (ibid. 1). In response, various transdisciplinary contributions from both natural and human sciences are advocated to trace the complexity and indicating areas for solutions (Raven 2002, Kates et al. 2001). The potential scholarship of sustainability is expected to provide concepts and methods for undertaking integrated analysis in transdisciplinary research (Kates et al. 2001; Clark et al. 2004; Clark 2007). This case history demonstrates a way in which the syndrome of water security in megacities of developing world may be investigated, with implications for the potential scholarship of sustainability.

From the 1700s to 1950, rural to urban migration and industrialization were associated with significant demographic shifts in Europe and North America. During the latter half of the 20th century, urbanization in the developing world accelerated (Jones and Kandel

1992). By 1996, 17 of the largest 20 cities were in developing countries, up from seven in 1950 (Domeisen and Palm 1996). In 2010 the world's population living in urban areas crossed the 50 per cent threshold, and it is predicted to reach 70% by 2050 (UN-HABITAT 2012). The developing countries are expected to cross the 50% urban threshold by 2017 (United Nations 2004).

As one of the 'new' megacities (Karn and Harada 2001), Dhaka became the ninth largest megacity in the world in 2007 with 13.5 million inhabitants, and it is expected to become the fourth largest by 2025 with 22 million inhabitants (United Nations 2008). Facing systemic challenges with water supply and management, Dhaka is presented as an example of a 'water security syndrome', where 'syndrome' is intended as a neutral concept describing a big-picture cluster of problems and/or issues in sustainability (WGBU 1996).

In this study, we systematically analyzed the available literature on water management and water bodies in Dhaka, and identified different layers of organizations described as 'themes'. Using a 'bottom-up approach', these layers are interconnected in patterns through employing system's approach, referencing secondary data from the literature. The equivalent 'water security syndrome' of selected other developing world megacities are also summarized, and the general issues relating to the development of a sustainability scholarship are identified.

As we argue in this paper, a clear challenge for the potential scholarship of sustainability is in epistemological, theoretical and methodological incompatibilities, incoherence and cleavages that arise from the fragmentary nature of discipline-based knowledge within and between the natural and human sciences. Synthesizing knowledge for a pluralistic approach such as the potential scholarship of sustainability requires fundamental innovations in epistemological, theoretical and methodological avenues. This case history, thus, puts forth the example of 'water security syndrome' of Dhaka to reveal the complexity that the scholarship of sustainability must address in pursuit of integrative sustainability innovation.

2. Water problems in megacities and the need for integrative water security research

The lack of material and human resources in developing country megacities, such as Dhaka, is a distinguishing factor in water-related problems. For example, lack of water distribution systems is considered a major concern for water managers in the developing world (UN-HABITAT 2003), especially in informal settlements. Moreover, due to lack of data on urban provision of water and sanitation in the developing world, the reality is likely to be far worse than most international statistics suggest (UN-HABITAT 2003). Therefore, municipal authorities in such megacities face serious challenges that will worsen, given the projected increases in urban populations discharging ever increasing quantities of waste into freshwater bodies, threatening water quality and aquatic ecosystems (Cohen 2006). **Table 1** showcases the types of problems that other developing world megacities face with respect to sustainable water management.

[Insert Table 1 here]

Table 1 reveals the interlocking root causes and impacts of water insecurity in developing world megacities, which include:

- Rapid urban expansion
- Chemical and microbial water pollution
- Poor, or lack of, sewerage facilities
- Shortage of safe drinking water
- Flooding, which can combine with sewerage to the detriment of public health, and impact on economic activities
- Limited water infrastructure
- Excessive groundwater extraction causing risks of land subsidence and salt water intrusion
- Industrial and domestic pollution into water bodies
- Eutrophication, and
- Poor urban governance

All these issues are also characteristic to the 'water security syndrome' of Dhaka, articulated throughout **Section 3**. Besides, in recent time the linkage between water security and the science agenda has come to question. Wheater and Gober (2016) summarize the situation with the following:

> "*The freshwater environment is facing unprecedented global pressures. Unsustainable use of surface and groundwater is ubiquitous. Gross pollution is seen in developing economies, nutrient pollution is a global threat to aquatic ecosystems, and flood damage is increasing. Droughts have severe local consequences, but effects on food can be global. These current pressures are set in the context of rapid environmental change and socio-economic development, population growth, and weak and fragmented governance. We ask what should be the role of the water science community in addressing water security challenges. Deeper understanding of aquatic and terrestrial environments and their interactions with the climate system is needed, along with trans-disciplinary analysis of vulnerabilities to environmental and societal change. The human dimension must be fully integrated into water science research and viewed as an endogenous component of water system dynamics. Land and water management are inextricably linked, and thus more cross-sector coordination of research and policy is imperative.*" (p. 5406)

Similar question has been asked by Zeitoun et al. (2016) in contrasting between reductionist and integrative research approaches to complex water security challenge. The authors elucidate the advantages of an integrative approach over the reductionist approach in terms of the capabilities of addressing a range of uncertainties otherwise unaddressed, as well as recognizing diversity in society and environment, incorporating water resources that are less-easily controlled, and the consideration of adaptive approaches to move beyond the conventional supply-side prescriptions.

Given these recent concerns resulting in 'water security' to emerge as a rapidly developing new research area (Huai and Chai, 2016), holistic research on elucidating the water security syndrome in the context of megacities holds much promise for advancing deeper understanding and treatment of the issues associated with promoting water security in urban areas. In this light, Schenk et al. (2009) criticize the prevailing Integrated Water Resources Management (IWRM) methodology as IWRM does not provide a clear definition of what should be integrated as well as the various water-related issues addressed separately although well encompassed in the literature. Therefore, the authors argue on the necessity of a holistic, system-based description of water management that emphasizes on the interrelations of the issues. Thus, Schenk et al. (2009) have constructed a system model for water management that includes a graphical representation and textual descriptions of the various water issues and their components and interactions, followed by the demonstration of its utility with two case studies

(Birmingham, England, and Belo Horizonte, Brazil). In a similar way, Chen and Wei (2014) applied the concept of system dynamics to water security research and revealed the utility of it in terms of elucidating the progress and deficiencies in the current research based on flood security, water resource security, and water environment security as the three basic elements of a water security system. System's approach is also undertaken in elucidating the links between water and health in cities (Rietveld et al. 2016) using case studies from a range of urban socioeconomic and regional contexts. In addressing the holistic need of elucidating a megacity water security syndrome in the perspective of developing world, similar methodology is adopted in the present study. The utility of system's approach for water management, as articulated by Rietveld et al. (2016) follows as:

> "*Decision-makers at all levels face new challenges related to both the scale of service provision and the increasing complexity of cities and the networks that connect them. These challenges may take on unique aspects in cities with different cultures, political and institutional frameworks, and at different levels of development, but they frequently have in common an origin in the interaction of human and environmental systems and the feedback relationships that govern their dynamic evolution. Accordingly, systems approaches are becoming recognized as critical to understanding and addressing such complex problems, including those related to human health and wellbeing. Management of water resources in and for cities is one area where such approaches hold real promise.*" (p. 151)

3. Holistic analysis of the Dhaka water security syndrome

Bangladesh is a lower-riparian country lying between the Ganges, Brahmaputra, and Meghna (GBM) rivers, and comprises approximately seven per cent of the GBM basin. Externally-generated runoff in upper catchments of the basin provide up to 80 per cent of the water in Bangladesh, while the rest comes from local rainfall (Chowdhury 2007).

Founded as a provincial capital in the sub-continent in 1608 and emerging as the capital of Bangladesh through independence in 1971, Dhaka has been witnessing an increase in population at an annual rate of over five per cent (Khondoker 2006). It is bordered by four rivers, the Buriganga (South), Turag (West), Balu (East), and Tongi (North), into which the city's drainage pours. Canals (*khals*) criss-cross the city, collecting runoff, wastewater and drainage as do the several permanent lakes. However, these surface water bodies are used much less as sources of water than the city's groundwater storage. The main source of groundwater in the city is Dupi Tila sands aquifer, underlying Madhupur

Clay with an average 10 meter thickness, whereas the thickness of the aquifer varies from 100 to 200 meters. This aquifer is exposed along the riverbeds of the peripheral rivers which facilitates recharge in the aquifer, and the groundwater becomes available at a depth of 15 to 20 meters at these peripheries while not any lesser than 25 to 30 meters at the central part of the city (Banglapedia, 2006).

Dhaka is characterized with subtropical, humid climate with an annual mean rainfall of 1920 mm, approximately 87.5 per cent of which falls during May to October, with June–August being the period of the heaviest rainfall (**Figure 1**) (BBC 2010). This seasonal rain distribution provides context for many of the city's water problems, as excessive water pours during some part of the year, causing flood and other associated problems, while drastic decrease in rainfall leads to drying up and other associated problems in the other parts of the year.

[Insert Figure 1 here]

Outlined in **Figure 2** and elucidated in detail in the following sections, the holistic analysis of 'water security syndrome' exhibits a highly complex and complicated mosaic of interlocking connections. Some of these connections are summarized in **Tables 3** and **4**. Substantiated by detail secondary data (**Table SM1**, supplementary material), these insights are generated through the merit of systematic literature analysis designed in a 'bottom-up' manner. Through laying down these insights with interconnecting patterns using system's approach (see **Section 2**), the 'water security syndrome' with respect to Dhaka is synthesized, organized, and presented in **Figure 6**. The syndrome details the causes and impacts in a number of entangled feedback loops illustrating how such problems should overwhelm policy-making, thus otherwise limiting sustainable future planning (Ayres 2000). In situations as complex as the syndrome presented in the **Figure 6**, decision-making is not a straightforward process. The conventional fragmentary approach can be greatly limiting in such situations, given that a single change in the cause-impact mosaic might trigger other impacts, with the possibility of worsening the overall balance.

The analysis reveals six major themes constituting the water security syndrome (**A–F** in **Figure 2**; all substantiated by secondary data). The list of these themes also structures the holistic analysis presented throughout the remainder of this section.

[Insert Figure 2 here]

A. Sources of Dhaka's water supply and use

With surface water becoming increasingly polluted and costly to purify, public water utilities and other water users have turned to groundwater as a potential source of cheaper and safer supply. Deep-tube wells are heavily used by public institutions as well as private owners (*The Daily Star* 2009), providing over 86 per cent of Dhaka's water supply in the year 2007 (DWASA 2007). Groundwater extraction has a number of severe environmental and social consequences, and urban growth in the city is leading to a situation where the ensuing water demand could not anymore be met by groundwater extraction alone (IFCDR 1996). Therefore, it is pivotal to maximize use of surface waters.

B. Patterns of change

The most pronounced changes include: deteriorating aquifer characteristics, drastic lowering of groundwater levels, microbial contamination of groundwater (UNEP 2005), and hydrocarbon contaminants from chemical hazards and industrial pollution (DWASA 2006). Severe organic, inorganic and microbial contaminations have occurred to all river waters (Rahman 2004). The tannery complex in Hazaribagh is polluting groundwater, canals and rivers through discharge of solid wastes and effluents. The previously confined aquifer is increasingly becoming unconfined with a drastic drop in piezometric surface over the last three decades (Haque 2004). The groundwater table of the upper aquifer has been declining by two to three meters per year (DWASA 2006), with drastic lowering of groundwater levels at some locations (see **Figure 3**). Anthropogenic encroachment and infra-structural and industrial activities have also led to shrinking of drainage channels.

The **Figure 3** traces rapid lowering of groundwater table at different locations in the city. Associated with this are significant shrinkage of inland water bodies and open waters. During the period 1968–2001, there was a 54.54 per cent, 10.18 per cent and 6.44 per cent shrinkage in inland water bodies, open waters and fluvial bodies, respectively (Sultana 2005). A linkage is suspected between the groundwater lowering and the rapid rate at which wetlands have been drying up over the last four decades. The open water bodies and wetlands in eastern and western Dhaka have become substantially reduced and sporadic (Sultana 2005), coupled with filling-up and elevation of low-lying areas.

[Insert Figure 3 here]

These extensive shrinkages of water sources have been accompanied by widespread organic, inorganic and microbial pollution of all waters. The primary causes are linked to increased urbanization, which has resulted in — severe organic pollution of Buriganga River (Karn and Harada 2001), extremely severe water pollution in the city in dry season (WARPO 1999), and also high levels of pollution in the city's storm water from residential areas (Khan and Chowdhury 1997). The widespread lack of sewerage treatment systems and the deterioration of existing facilities have substantially polluted the surface water bodies. Over 20 per cent of Dhaka's residents do not have any acceptable sanitary disposal system while leaking, damaged, and broken trunk sewerage lines are polluting the groundwater (*The Daily Star* 2003), resulting in more than two-thirds of Dhaka's sewage being discharged into rivers (*The Daily Star* 2008a). **Figure 4** presents the alarming picture of Dhaka's surface water pollution and its hotspots.

[Insert Figure 4 here]

C. Causes of the negative impacts

There are eight main contributors to the deterioration of Dhaka's water supplies.

C1. Population growth and urbanization

Population growth mainly due to urban migration from other parts of the country to Dhaka has been the main reason for the negative impacts on urban water supplies and quality. Between 1975 and 2000, Dhaka experienced a seven per cent annual population growth compared to 2.1 per cent for the whole country within the same period (United Nations 2000). **Figure 5** shows urbanization in Dhaka compared to the rest of the country. While it is associated with centralization policies of governments (BBS 2001; Jahan and Rouf 2007), the continued growth of Dhaka did not only have deleterious effects on groundwater availability and sanitation but also on aesthetic aspects of the city and its ecological and human health status.

[Insert Figure 5 here]

C2. Excessive groundwater extraction

Groundwater extraction has sharply increased over a 40 year period (1963–2001) (see **Table 2**). Dhaka's water requirements have increased more than ten-fold during the period, with a similar increase in the number of operating deep-tube wells, while the shortfall in supply still increased from 20 to 380 million liters (DWASA 2001). Excessive groundwater extraction can have severe impacts on groundwater availability and water treatment and supply; while IFCDR (1996) predicted that by 2020 Dhaka's water demand will extend beyond groundwater availability, raising risks of land subsidence, earthquakes, and arsenic poisoning (see **Section 3 –** 'D. Sectoral impacts').

[Insert Table 2 here]

C3. Impervious surface from urban developments, resulting in impeded groundwater recharge

The impervious surfaces resulted from urban developments have impeded groundwater recharge with resultant increase in surface runoff. The residential areas result in higher runoff than commercial areas (Chowdhury et al. 1998).

C4. Pollution sources

Figure 4 exhibits pollution 'hotspots' in Dhaka's river and canal system in dry seasons as well as concentrated industrial zones and scattered industries and factories. Tanneries, textiles, pulp and paper mills, fertilizer, industrial chemical production and refineries are the most problematic for water in the city. Extensive pollution has occurred in all rivers around Dhaka. The Hazaribagh tannery area contributes the most in the pollution, greatly impacting the Buringanga River water quality (Zahid et al. 2004; Hossain et al. 2007). A long stretch of the Turag River is being encroached on and filled-up for business purposes (*The Daily Star* 2008a), while illegal encroachment on the Buriganga River is reducing the city's natural drainage capacity (Tawhid 2004). The Balu River is badly contaminated by urban and industrial wastes from Tongi and effluents emanating from the Tejgaon industrial area transported through the Begunbari *Khal*.

The concern of local residents, increasingly depending on polluting industries for their livelihood, tends to overwhelm concerns about the environmental effects of the industries. Although industrial pollution has been the major pollution source, unauthorized domestic sewer connections and poor municipal waste disposal pollute the rivers, inland and open water bodies as well as storm water. Waste dumping on roadsides, near water bodies, and into 'open surface drains' also contribute to pollution, sometimes through blocking the drains. The pollution of catchments is becoming more complex by transfers of polluted waters through connecting trunks (Rahman and Chowdhury 1999). A very small fraction of municipal solid waste is guided through DWASA's (Dhaka Water Supply and Sewerage Authority) sewerage network for treatment (UNIDO 2000).

C5. Expansion of city area

Expansion of the city area has: (a) filled-up low-lying areas and depressions (Shams 1999), (b) increased groundwater demand, waterlogging and flooding, in turn disrupting and challenging living conditions of the local inhabitants, as well as with (c) fishery and biodiversity of the waters impacted.

C6. Encroachment and filling-up

Encroachment and filling-up of water bodies has cost loss of nearly half the number of drainage canals that Dhaka had in the 1960s (The Daily Inqilab 2004), while the major hydrologic feature of the city was the volume of crisscrossing and well distributed drainage canals. The continued violation of 'Wetland Conservation Act, 2000' has resulted in dramatic increase in waterlogging (Tawhid 2004), while water stagnancy also causes building foundation failures (Chowdhury et al. 2001). Encroachment has taken place on rivers, resulting in reduced carrying capacity and causing additional secondary problems (listed in **Table 3**).

C7. Siltation from debris from urban development activities

Dhaka's water bodies and reservoirs have been impacted by construction materials, leaves, household waste, street sweepings, and so on, being carried out by rain water and causing siltation. In addition, flood control embankments and sluice gates across the rivers and canals, coupled with debris flowing from urban development activities results in raised riverbeds and reduced drainage and runoff capacity (Tawhid 2004).

C8. Change in land-use

In 1980s Dhaka had numerous wetlands, *Khals* (i.e. drainage canals), and channels (JICA 1991), however, urbanization has caused massive deterioration in its hydrographic features, wetlands, and natural storm drainage, due to the resultant land-use changes. Raised constructions, built to avoid waterlogging and flooding have, ironically, contributed to more waterlogging and flooding in the city. Land-use changes have had adverse effects on wetlands and natural storm drainage (Chowdhury et al. 2001), while suspended particles originating from agricultural activities and deforestation have led to pollution and siltation of water bodies. Filling-up of wetlands have also caused impaired natural drainage.

All these eight processes identified so far have had secondary impacts; adversely affecting the sectors (impact sectors) listed in **Table 3**.

[Insert Table 3 here]

D. Sectoral impacts

The water security issue of the megacity Dhaka with particulars of sources and patterns of changes as well as factors causing such changes are adversely affecting a number of sectors in a number of ways. Through utilizing a bottom-up approach with the data from relevant literature, these adverse effects can be grouped based on 10 sectors; therefore, the adverse effects being described with these 10 sectoral impacts.

D1. Water treatment and supply

Increased pollution of surface water bodies is making surface water treatment costlier. The increasing demand for water, contributing to enhance pollution of water bodies and excessive groundwater dependency, and greatly outpacing its natural recharge capacity, limits its availability for future. Managing groundwater can only provide a partial solution. The main solution, however, must center on management of surface water bodies, and improved and efficient water treatment and methods of supply.

D2. Groundwater availability

Dhaka had only 21.57 per cent open space remaining by the turn of the year 2006, projected to reduce alarmingly with continual land occupation and encroachment (Haque 2006). Such reduction in open space can greatly limit groundwater recharge, leading to increased lowering of groundwater level.

D3. Waterlogging, flood and living conditions of inhabitants

Conventional inadequate drainage system, uncontrolled siltation from urban sources (often being ignored), ill-developed inlets and outlets, over-disposal of solid wastes, and lack of proper maintenance are the prime reasons of drainage system blockage and waterlogging. Seasonal tidal effect also causes waterlogging, as flooding in Dhaka occurs in two forms: (i) high water levels in the peripheral rivers rendering any natural drainage impossible, and (ii) high intensity rainfall runoff, causing flood even in situations where natural drainage could have been possible. However, in recent times the increasingly impaired natural drainage in Dhaka due to uncontrolled-and-over-urbanization has been the main reason of waterlogging leading to flood. The filling up activities due to urbanization irrespective to the landform results in obstructed wetlands and depressions which previously were acting as drainage basins, thereby resulting in water congestion (Chowdhury et al. 1998).

Flood in Dhaka can create large infrastructural problems for the city and a huge economical loss in production (Mark and Chusit 2002). Disruption of traffic movement and normal life, damage to structures, destruction of vegetation and aquatic habitats, and loss in income potential are some of the effects on city life.

D4. Public health

Pollution of storm water with solid wastes, domestic waters, clinical wastes, silts, and a range of anthropogenic contamination sources contribute in causing water-borne diseases. Stagnant water acts as breeding sites for disease-vectors.

D5. Sanitation

The water-borne sewerage system in Dhaka provides sanitation facilities to a mere 30 per cent of the inhabitants, while 20 per cent among the rest use separate sewerage system, 11 per cent using septic tank, 18 per cent with pit sanitation, and the rest of the people not having any acceptable sanitary disposal system (The Daily Star 2003). A study by the World Bank revealed that a modern waterborne waste disposal system replacing the existing one, broken or leaked at many points, would cost US$ 300 per city dweller (The Daily Star 2003). Annual flooding has become a challenge for adequately designing sealed latrine systems, while poor management of wellhead areas contributes to fecal contamination (apart from direct aquifer pollution).

D6. Fishery and biodiversity

Pollution levels have been reported to be too high in the Buriganga River and most parts of the Turag River to support survival of living organisms, except for some invertebrates and small organisms, even during the rainy season high water flow period (The Daily Star 2008b).

D7. Ecology and environmental health

The clayish layer on which Dhaka city stands varies from less than 1m to more than 45m in thickness, and may become dried up due to the excessive groundwater withdrawal (Haque 2003). The Dhanmondi Lake is polluted in part due to its hydraulic connections with the Satmosjid Road catchment, such that an estimated one-third of storm runoff from the catchment goes into the lake (Hossain et al. 2001).

D8. Risks of geo-hazards (e.g. land subsidence, earthquake)

As Dhaka is situated on clay soil, the declining groundwater trend (revealed in **Figure 3**) can greatly increase associated risks during earthquakes. A government study reveals that some 78,323 buildings in Dhaka would be completely destroyed by a deep 6-magnitude earthquake, whereas a 7.5-magnitude earthquake originating from Madhupur Fault could destroy some 72,316 buildings and damage a further 53,166 buildings with a resultant economic loss of about US$ 1,112 million in structural damage alone (The Daily Star 2010). The shrinking of clay underneath Dhaka due to rapid lowering of the groundwater table could exacerbate the likelihood and strength of an earthquake along the Madhupur clay Fault.

D9. Increase in arsenic in groundwater

'Iron- and arsenate-reducing' bacteria have been found to be associated with elevated groundwater arsenic levels (Weldon 2007). Iron reducing bacteria can be stimulated by the addition of organic carbon to release arsenic into the water phase (Islam et al. 2004). Thus, groundwater contamination by hydrocarbons can trigger arsenic contamination in Dhaka's water. Although Dhaka has previously been considered mostly safe in this regard (GoB 2000), the decreasing groundwater level could promote alteration of oxidation-reduction conditions, triggering the reducing microorganisms to act to release more arsenic.

D10. Aesthetic aspects and recreation

The seasonal stored monsoon waters in Ashulia in Savar charge the Turag River system and thus, provide recreational resources for the residents of Dhaka (Khan et al. 2007).

The **Figure 2** lists the 10 impact sectors elucidated so far, while their linkages are described in **Section 3** ('C. Causes of negative impacts'), classified under eight major causes. The current section (**Section 3 –** 'D. Sectoral impacts') elucidates the cause-effect relations. **Table 4** presents a map of relations between the impact sectors and the causes impacting them. These are grouped together in **Table 4** instead of repeating in the above discussions on the 10 impact sectors. The **Sections 3** and **4** also elucidate various types of cross-sectoral linkages among the impact sectors. These cross-sectoral linkages impart further complexity in the water security syndrome as they create feedback loops among the triggering causes and the resultant problems. This cross-connectedness of the impact sectors are indicated by connecting these impact sectors with broken lines in **Figure 6**, referring to the reinforcing potentials among the impact sectors.

[Insert Table 4 here]

E. Climate change dimensions

The **Figure 2** lists three climate change dimensions with definitive linkages to the impact sectors, which impart further complexity into the interactive matrix of the holistic analysis. Here three examples of these processes are briefly described.

E1. Temperature fluctuation and fish life cycle

Fish larvae are very sensitive to temperature. Depending on the adaptive capacity of different species, fish larvae can be affected by temperature fluctuations in a changing climate. Khan et al. (2007) have shown that the seasonal open water bodies in Dhaka had a temperature range suitable for optimal growth of fish larvae.

E2. Effects of temperature and seasonal pattern, linked with dry season water flow and water quality for treatment and supply

Dhaka has witnessed an increase of 1.8°C in average temperatures over the past 100 years, with the greatest increases in the busiest parts of the city (The Daily Prothom Alo 2008). This may be a result of various contributing factors such as decreases in the groundwater level, the heat island effect and climate change. Delays in onset of seasons are becoming pronounced, offering another indication of changing climate. Such changes in temperature and seasons can affect both dry season water flow and its quality, reducing suitability of its use and cost-effectiveness of techniques for water treatment and supply. Given the excessive groundwater extraction in the city, surface water bodies are likely to be increasingly sought and exploited, although the existing surface waters are already polluted and are expected to be affected further by changes in temperature and seasonal patterns, especially in dry periods. The dry season water flow can be adversely implicated with the impact sectors of water treatment and supply, fishery and biodiversity, as well as aesthetic, amenity and recreation; while the dry season water quality is mainly implicated with water treatment and supply.

E3. Precipitation pattern linked with — flood and waterlogging, rainy season water flow and groundwater recharge

During May to October (the monsoon period) the surrounding rivers' water levels remain higher than the inland drainage levels in the city (Mark and Chusit 2002). The degree of severity of monsoonal rain can be a major contributing factor to the severity of flooding and waterlogging. Climate change is generally expected to make wet zones wetter and dry zones drier. Any such change in precipitation patterns due to a changing climate could adversely affect flooding and waterlogging; while on the other side of the same coin such being advantageous for increased water flow and groundwater recharge. Thus, flood and waterlogging due to any potential future change in precipitation pattern can be linked to five impact sectors (see **Figure 6**), while the rainy season water flow linked to three, and the groundwater recharge to four impact sectors.

F. Opportunities

As identified from the literature, there are three known opportunities to address Dhaka's water problem. The first involves harnessing the rainy season conditions to the advantages of water management. As more than 80 per cent of the annual rainfall occurs during June to October (Chowdhury 2007), this could be utilized as an extremely significant opportunity for recharging groundwater table. Instead of merely considering monsoon rains as disadvantageous, the development of giant underground structures such as in Tokyo might seem appropriate (CNN 2012), which could also partially offset the rainy season stress. The second opportunity involves establishing fisheries in seasonal open water bodies, following Khan et al. (2007) for Ashulia. This might assist in enhancing biodiversity, ecological and environmental health, as well as providing an economic return to the local community, and thus, could also be connected to economic imperatives to maintain surface water quality. A third opportunity belongs to the plan already underway for shifting the Hazaribagh tanning area. Operating for over 50 years, the Hazaribagh tanning area has been identified as the principal water pollution source in Dhaka. Of course, this is contingent upon a successful clean-up project.

[Insert Figure 6 here]

4. Implications for the potential scholarship of sustainability

Sustainability innovation requires interconnectivity of components. With regard to the water security syndrome developed in this case history, the focus on interconnectivity reveals issues and provides ways forward for their resolution, as articulated in **Section 3**. However, five general issues regarding the syndrome are also identified and described in this section, raising implications for the potential scholarship of sustainability.

Duh et al. (2008) pointed out that some regions are better represented than others in the growing literature linking urbanization and environmental quality. In proceeding with the potential scholarship of sustainability, the practice has to identify gaps and under-representations in the existing knowledge base, including regions – such as Dhaka. This is particularly required for addressing as well as integrating unique, complex and fragmentary pools of knowledge across various bodies of literature.

In turn, this illuminates the importance of globalization, which increasingly affects the resilience, vulnerability, and adaptability of coupled human-environment systems as reflected in the mega-trends such as the rise of megacities (Young et al. 2006). Economic globalization has become a major concern to planners and governments with regard to global-city-making (Han 2005). As cities increasingly become central to sustainability concerns, they must reconcile between the global-city tensions and the city's needs (Egger 2006). In accounting for scale, the scholarship of sustainability needs to address such multi-scalar phenomena.

A third issue is that of urban development as a competitive, unregulated and unplanned enterprise in the global economic system (Yulong and Hamnett 2002). Taking the Asia-Pacific region as a case study, Marcotullio (2001) uses the idea of a 'functional city system' acting as the engine of urban growth, and in so doing differentiating the urban, environmental and social issues among the rapidly developing cities. In the rush for development it is estimated that over 70 per cent of contemporary growth happens outside the planning process (McLearn et al. 2005), thus, creating significant challenges in addressing various sustainability problems.

Fourth, sustainability knowledge in the urban field rests upon underdeveloped understanding of the complexity of urban systems. Bettencourt et al. (2007) have called for predictive and quantitative theories of urban organization and sustainable development, given the majority of the world's population now living in cities. Offering urban simulations as a useful approach to understanding the consequences of current planning policies or their incompleteness, Barredo and Demicheli (2003) have stressed the need for such simulations to involve tools embracing the complexity of an urban system. The general point here is that urban theory—although interdisciplinary in nature—is underdeveloped.

Finally, the scholarship of sustainability is ultimately about the social needs, rather than resolving technical and/or environmental problems per se. Thus, it is partly through examining and addressing the social disadvantage and resources that sustainable systems could be established. For example, in a model for Tokyo in Japan, Uitto (1998) stresses the importance of including social vulnerabilities in vulnerability assessments of mega-cities, along with the usual human statistics and economic dimensions, so that 'special needs' groups such as the homeless—who are at risk in megacities—are included in such assessments.

These issues raise a range of implications for the scholarship of sustainability and also point to fields that are fertile territory for addressing such issues. Some already proposed frontier components of sustainability scholarship include: 'tipping' elements in Earth system analysis (Hornborg and Crumley 2007; Schellnhuber 2009), land cover and land use change science (Turner et al. 2007), and sustainable health (Bloom 2007; Gruen et al. 2008). Along with water management challenges, the 'urban system' — for example — presents a range of crucial sustainability issues that require serious focus. Considered as 'hot spots' of unsustainability, and driving environmental change at scales of great elasticity (Grimm et al. 2008; Moran 2010), urban areas invite the need for the development of a comprehensive approach to act as a platform for innovations and system of organization for new knowledge with regard to urban issues.

Valentine and Heiken (2000) propose the scientific community embraces 'urban system science' as an important and credible field of research. Through emphasizing on the increasing effects of cities on Earth, they proposed more collaboration among physical and biological scientists, social scientists, economists and engineers, as well as recognition for the need of government laboratories harnessing their interdisciplinary power for the goal of improving urban conditions. Aware of the reality that such a task would not be easy given the inertia built up over the twentieth century, Valentine and Heiken (2000) proposed 'urban system science' as a new mode of knowledge organization, and advocated interdisciplinary research for integrated management from a number of perspectives that are currently segregated. They hoped that future scientists would be interested in coming out of 'working in a box' to engage in urban studies from a multidisciplinary perspective, and thus, offering—what we recognize as—an approach for the scholarship of sustainability with regard to urban areas. Addressing the city's economy, environment and society through an innovative collaboration of natural and human sciences and technologies does conform to the necessity of the potential scholarship of sustainability, although cleavages and gaps in knowledge — and as integrated theories and research methods evolve — could greatly limit innovation. In the development of the scholarship of sustainability, as eclectic add-ons rarely conform to holistic goals, the scholarship needs to develop pluralistic manifestations in epistemological, theoretical and methodological avenues.

6. Conclusion

Exploring solutions to complex sustainability problems requires the development of a scholarship of sustainability. In complex integrated megacity studies, the particulars of geography and climate are critical. However, we argue that defining and analyzing the Dhaka water security syndrome yields insights for both the local management and the broader development of the scholarship of sustainability.

Portraying a simplified picture of a syndrome in the form of a set of problems and a set of solutions — as has been in conventional practice — presents inevitable constraints. Articulating a 'water security syndrome' takes more than a set of problems and potential solutions. It includes all interactions and feedback loops as important as individual causes and potential solutions. The holistic analysis—summarized in schematic of the syndrome in **Figure 6**—reveals this. Synthesizing this syndrome guides the scope of developing as well as applying the potential scholarship of sustainability in exploring options for the sustainable management of water and water bodies. However, in bridging the gap between 'the conventional practice of dealing with a set of causes and a set of potential solutions', and 'taking consideration of the interactions and feedback loops being as important as individual causes and potential solutions', the scholarship of sustainability faces challenges in developing coherent epistemological, theoretical and methodological identities. Future research should actively advance the agenda of developing the scholarship of sustainability in these regards, along with taking in consideration the urban, or 'urban system science' as a critical spatial dimension.

Acknowledgment

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Table 1: Unsustainability of water and water bodies in some megacities	
Coastal megacities in Asia (Yeung 2001)	▪ Stressed by environmental risks due to rapid expansion, and leading to widespread bacterial pollution of near-shore waters as sewage treatment is an exception
Megacity Mumbai in India (Pacione 2006)	▪ One-third of households not having access to safe drinking water, major infra-structural deficiency; as well as water pollution becoming a serious environmental problem ▪ Contamination and inadequate sewerage leads to spread of diseases ▪ Prone to flooding; a July 2005 flood paralyzed the city for days and resulted in hundreds of deaths
Megacity Calcutta in India (Basu and Main 2001)	▪ Despite a natural abundance of water, the contamination, and limits of the authority's water sources and supply leave millions prone to health risks from drawing water directly from natural sources
Hong-Kong, in connection to China (Cullinane and Cullinane 2003)	▪ Water pollution and sewage disposal are serious problems as nearly 80 per cent of this megacity's water comes from mainland China, needing to be sterilized in order to meet WHO standards, while most sewage is only screened in a preliminary way before being discharged into Victoria Harbor
Jakarta Bandung Region (Firman 2009)	▪ Excessive groundwater extraction is a severe environmental problem as a result of socio-economic development over the past three decades ▪ Neither economically nor environmentally sustainable, groundwater extraction causes land subsidence and salt water intrusion, especially in coastal areas
Metropolitan Cairo (Araby 2002)	▪ Various kinds of untreated industrial and domestic pollutants from the city pour into the Nile River, which has become dangerously polluted, with the level of dissolved oxygen at almost zero. ▪ Around 1.5 million m^3 of wastewater is released every day ▪ Urban governance and policies for water management are not comprehensive
Megacity Istanbul (Baykal et al. 2000)	▪ The six major water sources of drinking water undergoing 'eutrophication' as: sources close to denser settlements with greatest urban land use within their watershed have already exceeded the eutrophic limit, while those further away from industry and dense settlement are in mesotrophic phase.

Table 2: Groundwater extraction over a 40-year period (Source: DWASA 2001)

Year	Population, in million	Water requirement, in million liters	Deficit in supply, in million liters	Deep tube-well number in operation
1963	0.85	150	20	30
1980	3.03	550	250	87
2001	10	1600	380	336

Table 3: Causes of negative impacts and the sectors of impact

Causes—(C)	**Impact sectors—(D)**
C1 (Population growth, urban translocation and carrying capacity)	D2 (Groundwater availability), D5 (Sanitation), D7 (Ecology and environmental health), D8 (Risks of geo-hazards (e.g. land subsidence, earthquake)), and D10 (Aesthetic aspects and recreation)
C2 (Excessive groundwater extraction)	D1 (Water treatment and supply), D2 (Groundwater availability), D8 (Risks of geo-hazards (e.g. land subsidence, earthquake)), and D9 (Increase in arsenic in groundwater)
C3 (Impervious surface from urban developments, resulting in impeded groundwater recharge)	D2 (Groundwater availability), D3 (Waterlogging, flood and living conditions of inhabitants), and D8 (Risks of geo-hazards (e.g. land subsidence, earthquake))
C4 (Pollution sources)	D1 (Water treatment and supply), D4 (Public health), D6 (Fishery and biodiversity), D7 (Ecology and environmental health), and D10 (Aesthetic aspects and recreation)
C5 (Expansion of city area)	D7 (Ecology and environmental health), and D10 (Aesthetic aspects and recreation)
C6 (Encroachment and filling-up)	D1 (Water treatment and supply), D3 (Waterlogging, flood and living conditions of inhabitants), D6 (Fishery and biodiversity), D7 (Ecology and environmental health), and D10 (Aesthetic aspects and recreation)
C7 (Siltation from debris from urban development activities)	D1 (Water treatment and supply), D3 (Waterlogging, flood and living conditions of inhabitants), and D6 (Fishery and biodiversity)
C8 (Change in land-use)	D1 (Water treatment and supply), D3 (Waterlogging, flood and living conditions of inhabitants), D6 (Fishery and biodiversity), and D10 (Aesthetic aspects and recreation)

Table 4: Map of relations between the impact sectors and the causes impacting them

Impact sectors—(D)	**Causes—(C)**
D1 (Water treatment and supply)	C2 (Excessive groundwater extraction), C4 (Pollution sources), C6 (Encroachment and filling-up), C7 (Siltation from debris from urban development activities), and C8 (Change in land-use)
D2 (Groundwater availability)	C1 (Population growth, urban translocation and carrying capacity), C2 (Excessive groundwater extraction), C3 (Impervious surface from urban developments, resulting in impeded groundwater recharge), and C5 (Expansion of city area)
D3 (Waterlogging, flood and living conditions of inhabitants)	C3 (Impervious surface from urban developments, resulting in impeded groundwater recharge), C5 (Expansion of city area), C6 (Encroachment and filling-up), C7 (Siltation from debris from urban development activities), and C8 (Change in land-use)
D4 (Public health)	C4 (Pollution sources)
D5 (Sanitation)	C1 (Population growth, urban translocation and carrying capacity)
D6 (Fishery and biodiversity)	C4 (Pollution sources), C5 (Expansion of city area), C7 (Siltation from debris from urban development activities), and C8 (Change in land-use)
D7 (Ecology and environmental health)	C1 (Population growth, urban translocation and carrying capacity), C4 (Pollution sources), C5 (Expansion of city area), and C6 (Encroachment and filling-up)
D8 (Risks of geo-hazards (e.g. land subsidence, earthquake))	C1 (Population growth, urban translocation and carrying capacity), C2 (Excessive groundwater extraction), and C3 (Impervious surface from urban developments, resulting in impeded groundwater recharge)
D9 (Increase in arsenic in groundwater)	C2 (Excessive groundwater extraction)
D10 (Aesthetic aspects and recreation)	C1 (Population growth, urban translocation and carrying capacity), C4 (Pollution sources), C5 (Expansion of city area), C6 (Encroachment and filling-up), and C8 (Change in land-use)

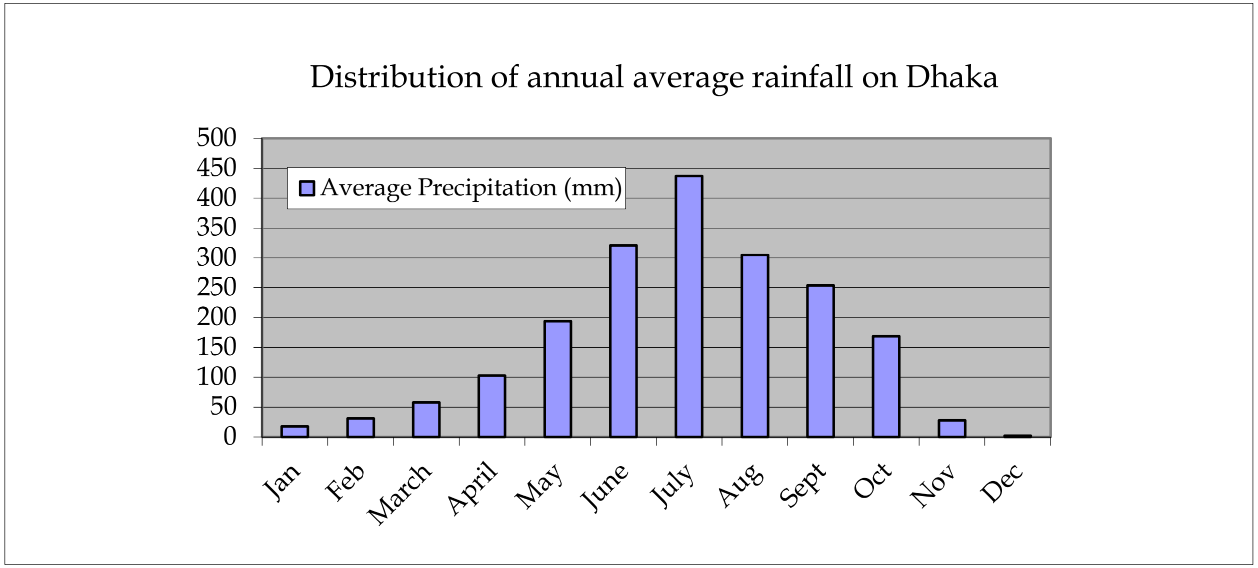

Figure 1: Distribution of annual average rainfall on Dhaka (BBC 2010)

Figure 2: Overall structure of the holistic analysis	
A. Sources of water supply and use in the city	
B. Patterns of change	
B1.	*Groundwater storage and pollution*
B2.	*Shrinkage and pollution of surface water bodies*
C. Causes of the changes	
C1.	*Population growth, urban translocation and carrying capacity*
C2.	*Excessive groundwater extraction*
C3.	*Impervious surface from urban developments, resulting in impeded groundwater recharge*
C4.	*Pollution sources*
C5.	*Expansion of city area*
C6.	*Encroachment and filling-up*
C7.	*Siltation from debris from urban development activities*
C8.	*Change in land-use*
D. Sectoral impacts	
D1.	*Water treatment and supply*
D2.	*Groundwater availability*
D3.	*Waterlogging, flood and living conditions of inhabitants*
D4.	*Public health*
D5.	*Sanitation*
D6.	*Fishery and biodiversity*
D7.	*Ecology and environmental health*
D8.	*Risks of geo-hazards (e.g. land subsidence, earthquake)*
D9.	*Increase in arsenic in groundwater*
D10.	*Aesthetic aspects and recreation*
E. Climate change dimensions	
E1.	*Temperature fluctuation and fish life cycles*
E2.	*Effects of temperature and seasonal pattern, linked with dry season water flow and water quality for treatment and supply*
E3.	*Precipitation pattern linked with — flood and waterlogging, rainy season water flow and groundwater recharge*
F. Opportunities	
F1.	*Rainy season phenomena*
F2.	*Suitability of seasonal open water bodies for fishery*
F3.	*Shifting of Hazaribagh tanning area underway*

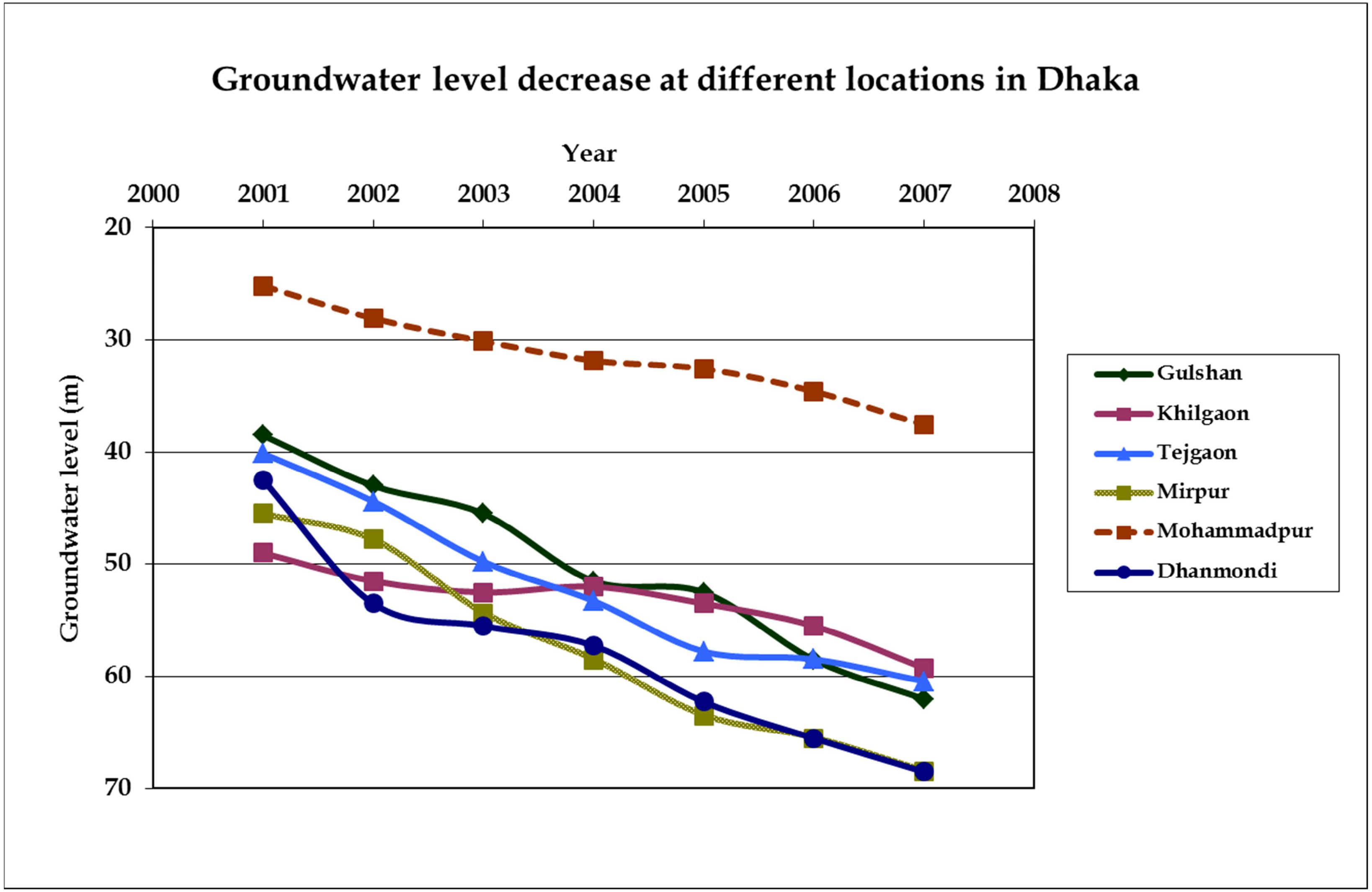

Figure 3: Groundwater levels at various locations in Dhaka between 2001 and 2007

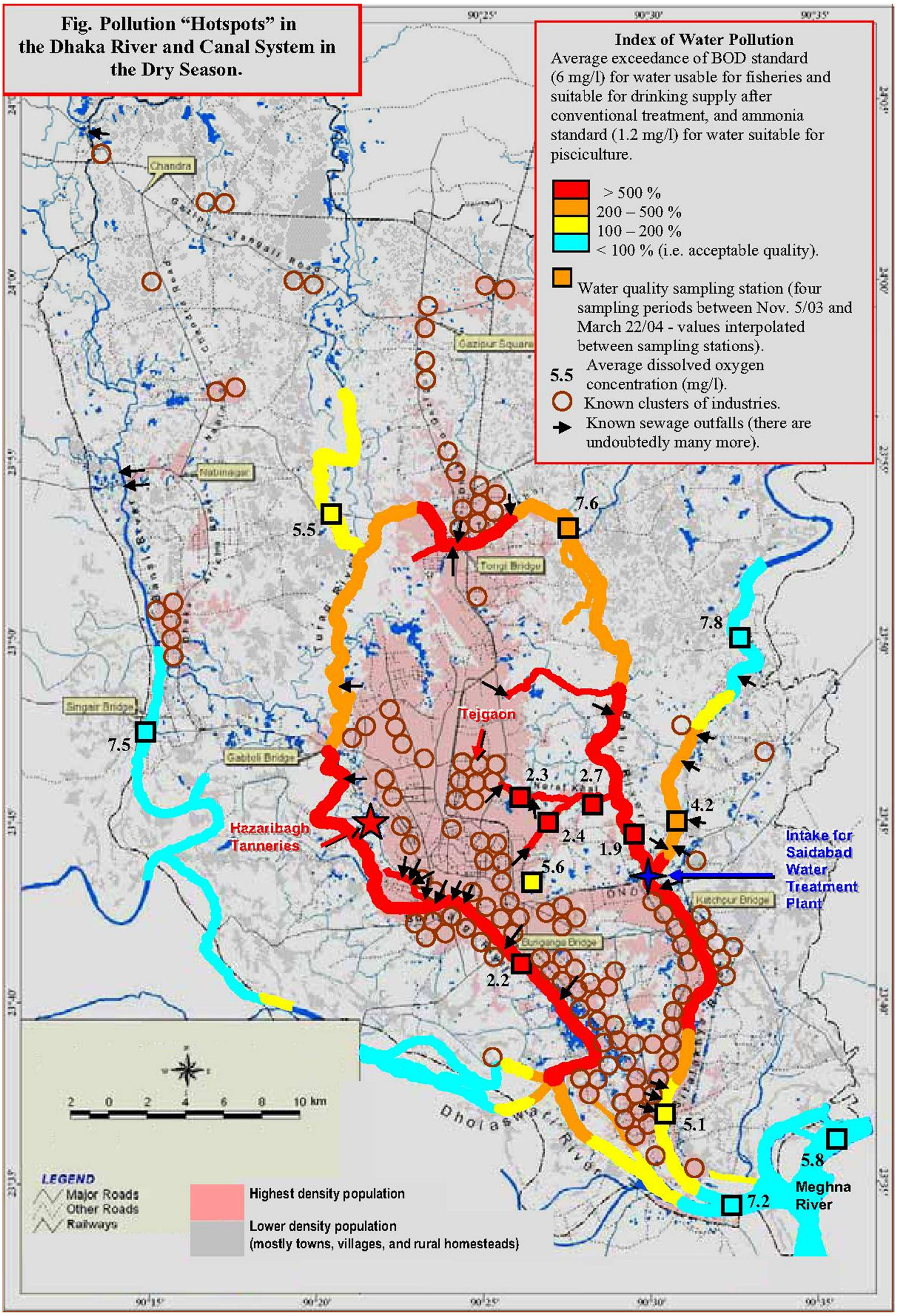

Figure 4: Pollution "Hotspots" in Dhaka's river and canal system in dry season (World Bank 2006)

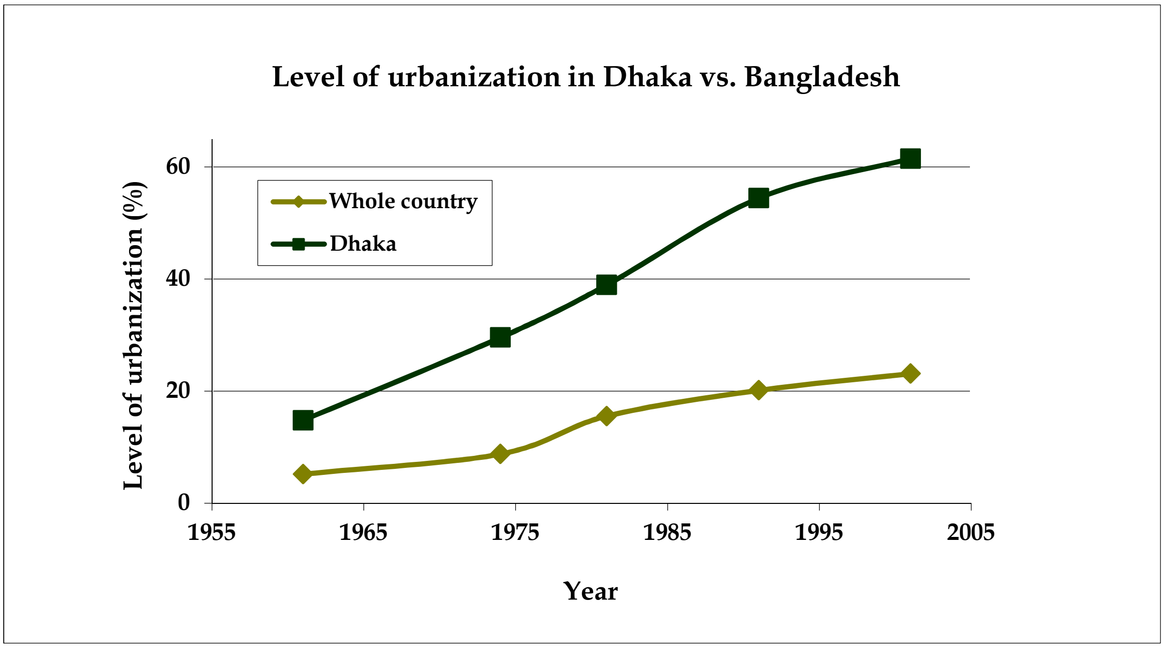

Figure 5: Level of urbanization in Dhaka vs. the whole country

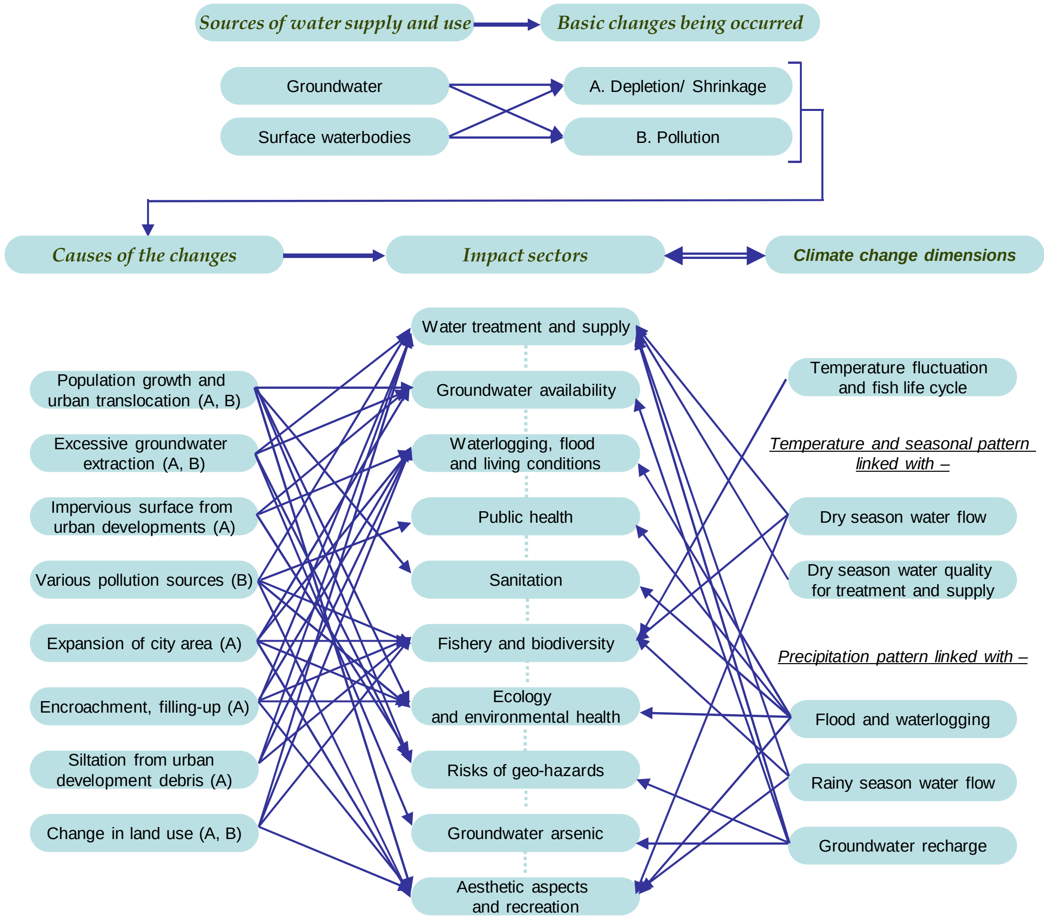

Figure 6: Water security syndrome of Dhaka

Supplementary material [Table SM1]

Table SM1 is comprised of detail quantitative description of the data presented in **Section 3**, and therefore all references in **Table SM1** remain the same as they have appeared in **Section 3** and subsequently occurred in full form in the list of references.

<table>
<tr><th colspan="3">Table SM1: Detail data for the ‘water security syndrome’ of Dhaka</th></tr>
<tr><th colspan="3">SM1(A) Sources of water supply and use in the city</th></tr>
<tr><td colspan="3">
In 2009, Dhaka Water Supply and Sewerage Authority (DWASA) was producing around 1200 ML/day urban water supply from about 423 deep tube wells, with an addition of over 500 private tube wells of different depths estimated to supply about 300 ML/day, mainly to commercial and industrial users (The Daily Star 2009).
In 1995, the total water requirement of the city was 262 IMGD (Imperial Million Gallons per day), of which only 181 IMGD was being supplied by DWASA. It was predicted that the total demand of the city will increase to 534 IMGD by the year 2020, which would be impossible if only groundwater is to be used (IFCDR 1996).
With surface water near the city becoming increasingly polluted and costly to purify, public water utilities and other water users have turned to groundwater as a potential source of cheaper and safer supply. By the year 2007, groundwater sources were used to provide the majority (86.26%) of water in Dhaka while only the remaining 13.74% was from surface water sources from different water treatment plants of DWASA (DWASA 2007).
</td></tr>
<tr><th colspan="3">SM1(B) Basic changes being occurred</th></tr>
<tr><td>B1.</td><td>Groundwater storage and pollution</td><td>
The groundwater aquifer under Dhaka is increasingly becoming unconfined due to a more than 50m drop in piezometric surface over the last three decades. Prior to that it was a confined aquifer due to capping by a clay silt layer (Haque 2004).
The groundwater table of the upper aquifer (<170 m depth) under Dhaka has been declining by around 2m to 3m per year (DWASA 2006). The drastic lowering of the groundwater level at different locations in Dhaka over a very short period is evident from Figure 3 [Data source: Bangladesh Water Development Board (BWDB), Bangladesh Agricultural Development Corporation (BADC)].
The falling groundwater table can be associated with drying up of wetlands, which can be observed in some wetlands with water surface at or slightly above the ground.
DWASA has already found microbial contamination in groundwater of old Dhaka (UNEP 2005).
Hydrocarbons, as deadly contaminants for groundwater, are assumed to already have occurred in Dhaka’s groundwater (DWASA 2006).
The over half a century old tannery complex in Hazaribagh discharges its solid wastes and effluents directly to the natural canals, low lying areas, road sides, and water bodies between nearby dike and residential area without proper treatment. Contaminants seep from there into soil to pollute groundwater and continue through natural canals, ultimately mixing with the river waters of Buriganga and Turag.
</td></tr>
</table>

B2.	**Shrinkage and pollution of surface water bodies**	▪ During the period between 1968 and 2001 inland water bodies have shrunk by 54.54% while open-waters and fluvial water bodies have shrunk by 10.18% and 6.44% respectively (Sultana 2005). ▪ The coverage of the water bodies in the eastern part and western edge of the city have been substantially reduced and became sporadic (Sultana 2005). Reduction in open water bodies mostly occurred in Boro-maghbazar, Eskatan, Motijheel, Jatrabari over the south-eastern corner of the city. Wetlands in south-western corner of the city retreated towards river in areas over Mirpur and Mohammadpur. Minor reductions of the wetlands occurred in Pallabi – Cantonment area as well, where low lying areas were filled and leveled for urban extension. *Drainage channels shrink over the catchments* ▪ The shrunken drainage channels over the five major catchments result from overuse by anthropogenic activities like encroachment or impeded by infra-structural and industrial activities. ▪ Specifically, changes mostly occurred in Gulshan (East-Central Catchment), Motijheel and Jatrabari (South-Central Catchment), and Mohammadpur (West-Central Catchment) area of the city as the majority of urbanization occurred in these areas in recent times. *Pollution of surface water bodies* ▪ The contamination of all river waters in Dhaka during dry season has been presented by Rahman (2004) reporting severe contamination with DO (dissolved oxygen), coliform bacteria, orthophosphate, NO_3^-, Al, Cr; and mild contamination of Cd, Pb, and Hg. ▪ An international study regarding river water pollution of three countries reveals that, the Buriganga River was suffering from severe pollution (Karn and Harada 2001). The reported dry season average BOD ranged between 20-30 mg/L while the total coliform was as high as 104-105 MPN/100 mL, per capita pollution load discharge of urban areas was estimated to be about 25 g BOD/capita/day in Buriganga River, and DO level was found to decline at the average annual rate of nearly 0.3 mg/liter/year. It was also shown that pollution loads steadily increased nearly in step with the trend in urbanization. ▪ The river faces very low to non-existent dissolved oxygen levels in dry season (WARPO 1999). ▪ Figure 4 (World Bank 2006) represents the contamination scenario and pollution hotspots of water bodies around Dhaka city. ▪ In storm water, among different land uses coliform counts were reported to be higher in residential areas (1.20×10^4 to 1.96×10^8 per 100 mL) with relatively high BOD_5 values (96.1 mg/L to 142.6 mg/L) over the city (Khan and Chowdhury 1997). ▪ The only sewage treatment plant in the country serves a part of Dhaka. More than two-thirds of the city sewage falls into rivers, thereby deteriorating water quality for decades (The Daily Star 2008a). ▪ More than 20% people in Dhaka do not have any acceptable sanitary disposal system (The Daily Star 2003). As the existing trunk sewerage lines from Tejgaon to Pagla either have leakage or damaged or broken at many points, any planning is likely to be unfeasible without replacing the entire Tejgaon-Pagla trunk line. The severity of the problem can be understood by the fact that, Baridhara and Uttara are environmentally less polluted than Gulshan and Dhanmondi as the former do not have waterborne sewerage whereas the latter have.

SM1(C) Causes of the changes		
C1.	**Population growth, urban translocation and carrying capacity**	▪ Figure 5 shows level of urbanization in Dhaka compared with the rest of the country (BBS 2001; Jahan and Rouf 2007). By the year 2001 over 61% of Dhaka has been urbanized. The continued trend of urbanization is becoming a major phenomenon in outstripping the carrying capacity of the mega-city. The centralization policy of the governments in recent past contributed a lot in building up the trend. ▪ Tables 1 and 4 represent the trend in population growth in Dhaka with prediction in near future. Between 1975 and 2000, Dhaka grew in population by an annual average of nearly 7% in comparison to 2.1% for Bangladesh as a whole (United Nations 2000).
C2.	**Excessive groundwater extraction**	▪ Table 4 presents groundwater extraction scenario for a 40 year period (DWASA 2001). Efforts in trying to making up the deficit led to vigorous increase in groundwater extraction as can be seen from the Table.
C3.	**Impervious surface from urban developments, resulting in impeded groundwater recharge**	▪ The high level of urbanization in Dhaka (as presented in Figure 5) has been resulting in more and more impervious surfaces. This impedes groundwater recharge, also through increasing surface runoffs. ▪ It was reported that runoff ratios in commercial areas can be as high as 80% in comparison to that of residential areas (Chowdhury et al. 1998).

C4.	**Pollution sources**	▪ There are three designated industrial zones within Dhaka City Corporation area, viz. Hazaribagh, Tejgaon and Shyampur. Different types of industries including tannery, dyeing and textile, printing, metals, rubber, chemicals and pesticides, battery, distillery, plastics, brick manufacturing, jute, etc are a few mentionable ones. The scattered presence of a number of industries or factories can also be seen in Figure 4 (World Bank 2006). ▪ The most problematic industries for the water sector are tanneries, textiles, pulp and paper mills, fertilizer, industrial chemical production and refineries. ▪ Concern over surface water quality gradually merges due to the dispersed locations of polluting industries and their subsequent impact on the livelihood of local communities. The extreme examples of this effect are seen at Konabari and Savar, where the industrial effluents are discharged into nearby land and water bodies without any treatment. ▪ Buriganga River has been facing the worst problem, where the most significant source of pollution appears to be the tannery wastes from Hazaribagh area. ▪ Water of the river Balu is badly contaminated by urban and industrial wastes from Tongi and the effluent flowing out through Begunbari *Khal*, most of which emanates from Tejgaon industrial area. ▪ Unauthorized connection of domestic sewers with the storm sewers and with the receiving water bodies is the major way of stormwater pollution, sometimes resulting in comparable pollution to domestic wastewater. ▪ Dumping of wastes on roadsides, near water bodies, and into open surface drains constitute the other causes of stormwater pollution, also resulting in hampered drainage. ▪ High sediment loads washed away from construction sites has also been reported to pollute stormwater (Khan and Chowdhury 1997). ▪ Rahman and Chowdhury (1999) reported higher pollutant load (higher than secondary effluent treatment standards) in Zigatola catchment than in other catchments, which was ascribed to the transport of tannery wastes from Hazaribagh area through Zigatola trunk. ▪ UNIDO have (United Nations Industrial Development Organization) estimated the generation of about 5000 tons of municipal solid wastes and nearly 750 tons of BOD every day in Dhaka where only 120 tons used to be guided through DWASA's sewerage network for treatment (UNIDO 2000). ▪ The rest uncontrolled dumping of huge industrial wastes of point and non-point sources remains as another significant pollution source in the city. ▪ One of the most important point source for solid wastes has been the tannery industries of Hazaribagh, releasing 600 – 1000 Kg of solid waste resulting from production of each metric ton processed hide (Zahid et al. 2004). Due to the massive use of chrome tanning, the highest chromium content of the solid waste was reported to be 3.2 % (Hossain et al. 2007). Other than the chromium, higher concentrations of Fe, Mn, S, Ni, Pb, Na^+, Mg^{2+},Ca^{2+}, NH_4^+, K^+, Cl^-, and SO_4^{2-} have also been reported (Zahid et al. 2004). ▪ The agricultural chemicals and fertilizers are also one of the potential sources of water body pollution which, with increase of irrigated areas and cultivation of HYV (high yield variety) rice, can increase.

C5.	**Expansion of city area**	▪ Newly developed areas in the city such as Demra, Jurain, Dolaipar, Maniknagar, Mugdapara, Manda, Goran, Rampura, Badda, Baridhara, Mohammadpur, Rair Bazar, Kamrangirchar, Abdullahpur, etc. were developed by filling-up low-lying areas and depressions (Shams 1999). Therefore, expansion of city area can be a link to many related problems.
C6.	**Encroachment and filling-up**	▪ From around 50 *khals* during 1960s in Dhaka City with a total length of 256 km, there are only 26 *Khals* remaining with the total length of as less as 125 Km (The Daily Inqilab 2004). ▪ Filling-up depressions and abandoned channels in the city is a major reason of added water stagnancy, sometimes resulting in foundation failure problems (Chowdhury et al. 2001). ▪ In spite of the 'Wetland Conservation Act, 2000', filling-up vast areas in Ashulia, Banashree, Aftabnagar, Meradia, Baunia, Badda, Amin Bazar, and Hatirjheel, known as water catchments results in increased waterlogging swamping much of the city (Tawhid 2004). ▪ A long stretch of the Turag River is also reported to being encroached and filled-up to be used for business purposes (The Daily Star 2008a), while illegal encroachment on Buriganga River is resulting in reducing carrying capacity of natural drainage system in Dhaka City (Tawhid 2004).
C7.	**Siltation from debris from urban development activities**	▪ Construction materials like bricks, sands, stones, and leaves, household wastes, street sweepings, etc. can be carried out by rain water, thereby reducing runoff capacity of drainage system. ▪ Flood control embankment and sluice gates across the rivers and canals can result in raised riverbed and reduced carrying capacity due to enhanced debris flow from urban development activities (Tawhid 2004).
C8.	**Change in land-use**	▪ In the 1980's, Dhaka city consisted numerous wetlands, *Khals*, and channels within and around the city that would drain the city area efficiently (JICA 1991). In recent times, urbanization took place irrespective to the landform which led filling up many channels and depressions. Such activities have been more pronounced within and nearby the more developed areas of the city. With continuation of such urbanization trend, the city is on the verge of losing its hydrographic features. ▪ Chowdhury et al. (2001) reported adverse impacts of land-use changes on wetlands and natural storm drainage. ▪ Inorganic and organic suspended particles originating from agricultural practices and land-use change (such as deforestation) can lead to pollution and siltation of water bodies. ▪ People have a tendency to develop residential, commercial and industrial areas by raising the ground level to protect them from waterlogging or flooding. Such choices in land use can exaggerate other problems like waterlogging, flooding, etc. Some wetlands are also being filled up for settlements and infra-structures, thereby impairing natural drainage.

SM1(D) Impact sectors		
D1.	**Water treatment and supply**	▪ With increasing pollution of the surface water bodies, it is becoming more and more costly to treat surface waters. The increasing population is in one hand pressing increasingly higher demand for water, and in the other hand also contributing in enhanced pollution of the water bodies. ▪ The present situation of excessive groundwater dependency is pushing the city on the verge of severe dreadful consequences. Natural recharge rates of ground water bodies are being exceedingly outpaced by its extraction, thereby making it less available for future needs. Such destructive and extreme unsustainable trend can only find partial solution in managing the ground water bodies. ▪ However, the larger part of the solution must come from the management of surface water bodies with improved and efficient water treatment and supply methods.
D2.	**Groundwater availability**	▪ Out of the land area under Dhaka city Corporation (DCC) only 21.57% were left as open space by the year 2006, which would have been reduced to as lower as only 4% by the end of 2010 with continual current trend of occupation and encroachment (Haque 2006). Such striking reduction in open space is severely limiting the available scopes of groundwater recharge, leading to increased lowering rate in groundwater level.
D3.	**Waterlogging, flood and living conditions of inhabitants**	▪ Conventional and inadequate drainage system, uncontrolled siltation from urban sources (often being ignored), ill-developed inlets and outlets, over disposal of solid wastes, and lack of proper maintenance are accounted to be the prime reasons of blockage in drainage system and waterlogging. ▪ In addition, seasonal tidal effect also causes waterlogging. Flooding in Dhaka can be from two sources: (i) high water levels in the peripheral rivers rendering any natural drainage impossible, or (ii) high intensity rainfall runoff, causing flood even in situations where natural drainage might be possible. ▪ However, the increasingly impaired natural drainage in Dhaka due to uncontrolled and over-urbanization has been the main reason of worse waterlogging and flooding situations in recent years. The filling up activities due to urbanization irrespective to the landform results in obstructed wetlands and depressions which previously were acting as drainage basins, thereby resulting in miserable water congestion problem (Chowdhury et al. 1998). ▪ Flood in Dhaka can create large infrastructural problems for the city and a huge economical loss in production (Mark and Chusit 2002). Disruption of traffic movement and normal life, damage to structures, destruction of vegetation and aquatic habitats, loss in income potential are some of the effects on city life resulting from these.
D4.	**Public health**	▪ Pollution of storm water by solid wastes, domestic waters, clinical wastes, silts, and a range of anthropogenic contamination sources are contributing in significantly increased water-borne diseases. ▪ Stagnant water in flood or water congestion situations acts as breeding site for disease-vectors. It results in health hazards to inhabitants, and unsightly and foul smelling.

D5.	**Sanitation**	▪ The water-borne sewerage system in Dhaka covers only 30% of the inhabitants; while 20% uses separate sewerage system, 11% septic tank, 18% pit sanitation, and the rest of the people do not have any acceptable sanitary disposal system (The Daily Star 2003). ▪ World Bank study showed that a modern waterborne waste disposal system replacing the existing one, broken or leaked at many points, would cost US$ 300 per city dweller (The Daily Star 2003). ▪ Annual flooding has been a challenge for adequately designing sealed latrine system in some areas, while poor management of wellhead areas would be the most contributing reason to fecal contamination in contrast to direct aquifer pollution.
D6.	**Fishery and biodiversity**	▪ Pollution levels have been reported to be too high in the Buriganga and most parts of Turag River to support survival of living organisms, except for some invertebrates and small organisms during rainy season high water flow period (The Daily Star 2008b). The DO level of these rivers even after the monsoon has been reported to be less than 1 mg/L, while a level of 4-6 mg/L is required for fish survival.
D7.	**Ecology and environmental health**	▪ The clayish layer, varying from less than 1m to more than 45m on which Dhaka city stands, may become dried up and shrunk due to excessive withdrawal of groundwater (Haque 2003), which can become direct physical impediment adversely affecting ecology and environmental health. ▪ The Dhanmondi Lake has been reported to have become polluted due to its hydraulic connections with a catchment, namely, Satmosjid Road catchment. An estimated one-third of storm runoff from the catchment goes into the lake (Hossain et al. 2001). Storm sewer samples from the catchment to the lake yielded pollution with regard to alkaline pH, high BOD_5 and very low DO levels, very high TDS and TSS values, even presence of tannery waste indicating a major influence of tannery outlets within the catchment.
D8.	**Risks of geo-hazards (e.g. land subsidence, earthquake)**	▪ As Dhaka is situated on clay soil plate, the declining groundwater trend as detailed out in Figure 3 can increase risks during earthquake greatly. Government study says that, some 78,323 buildings in Dhaka would be completely destroyed by a 6-magnitude earthquake from its beneath, whereas a 7.5-magnitude earthquake originating from *Madhupur* Fault can damage 72,316 buildings completely and 53,166 buildings partially with a resultant economic loss of about US$ 1,112 million only due to structural damage (The Daily Star 2010). ▪ The *Madhupur* clay fault underneath Dhaka might also be triggered by continual shrinking of the clay due to rapid lowering of groundwater table.

D9.	**Increase in arsenic in groundwater**	▪ Iron and arsenate reducing bacteria have been found to be associated with elevated groundwater arsenic levels (Weldon 2007). Iron reducing bacteria can be stimulated by the addition of organic carbon to release arsenic into the water phase (Islam et al. 2004). Thus, groundwater contamination by hydrocarbons can worsen arsenic contamination. Although Dhaka has been considered mostly in safe limit in terms of arsenic contamination of groundwater (<10 ppb, with a few spots in the range of >10 ppb and <50 ppb) (GoB 2000), the decreasing groundwater level with resultant hydrostatic change of confined aquifer to unconfined aquifer can certainly promote alteration of oxidation-reduction conditions. This can trigger the reducing microorganisms to contribute in releasing more arsenic. ▪ Moreover, groundwater contamination by hydrocarbons can also worsen arsenic contamination.
D10.	**Aesthetic aspects and recreation**	▪ Some seasonal stored monsoon waters in Ashulia in Savar, having definite relation with the Turag River system during monsoon have been reported to be still suitable for aesthetic applications (Khan et al. 2007). With results from a 6 month long study, it was concluded that the waters were still suitable for aesthetic infra-structure development with regard to a number of physical, chemical, and biological aspects, in spite of a number of factors working to adversely affect such. ▪ Developing the existing sporadic aesthetic infrastructures in Ashulia further under an integrated infrastructure development initiative can provide safe recreational facility for city dwellers. However, increasing recreational activity by increasing crowds also has to be carefully watched for any adverse effects on the environment.
SM1(E) Climate change dimensions		
E1.	**Temperature fluctuation and fish life cycle**	▪ Fish larvae are very sensitive to temperature difference and depending on adaptive capacity of different species fish larvae can be affected by temperature fluctuation in a changing climate. Study shows that the seasonal open water bodies in Dhaka still have temperature ranges suitable for optimal growth of fish larvae (Khan et al. 2007), which can be deleterious if enhanced warming happens over a shorter period of time due to changing climate.
E2.	**Effects of temperature and seasonal pattern linked with dry season water flows and water quality on water treatment and supply**	▪ Dhaka has witnessed an increase of 1.8°C in average temperature over the past 100 years, with unusual increase of temperature in the busiest parts of the city including Motijheel, Tejgaon, Farmgate and Old Dhaka (The Daily Prothom Alo 2008). This can be a combined effect of decrease in groundwater level, heat island effects, and climate change. ▪ In recent times delay in onset of the seasons are getting more pronounced, which is also another indication of a changing climate. ▪ Such changes in temperature and seasonal pattern can affect both dry season water flow and the quality of that water for its suitability and cost-effectiveness in treatment and supply. ▪ On the verge of accumulated risk associated with excessive groundwater extraction, surface water bodies are looming to get more attention in near future which might have implications with changes in temperature and seasonal pattern, especially in dry season.

E3.	**Precipitation patterns linked with floods and waterlogging, rainy season water flows and groundwater recharge**	▪ During May to October (monsoon period) the surrounding rivers' water levels remain higher than inland drainage levels (Mark and Chusit 2002), therefore the severity of monsoon rainfall can be a major contributing factor for the severity of flood and waterlogging. Such has special implication as climate change is generally supposed to turn wet zones wetter and dry zones drier. Change in precipitation pattern due to changing climate can be adversely linked to flood and waterlogging problem, while having advantages for water flow and groundwater recharge phenomena.
SM1(F) Opportunities to capitalize		
F1.	**Rainy season phenomena**	▪ As more than 80% of annual rainfall occurs during the period June to October (Chowdhury 2007), the availability of water during this period holds enormous significance for recharging the alarmingly decreasing groundwater table. Such a phenomenon can be targeted to take added advantage in management planning and technology adoption, instead of merely considering monsoon rains as disadvantageous for the city. Development of giant underground structures as have been done in Tokyo can be noted with importance in developing appropriate solutions.
F2.	**Suitability of seasonal open water bodies for fishery**	▪ As the seasonal open water bodies in Ashulia have been reported to be suitable for aesthetic infrastructure development, the suitability of the same (Khan et al. 2007) can also be utilized for reintroducing and developing fishery with an integrated plan with the Turag River system. With proper management of S and Cu (Khan et al. 2007), fishery development can help in enhancing biodiversity, ecology and environmental health, as well as support regional economy.
F3.	**Shifting of Hazaribagh tanning area underway**	▪ Hazaribagh tanning area which has been operating for over 50 years, perhaps being the foremost pollution source for Dhaka's water bodies, is being planned to move away in order to limit pollution resulting from it. Implementation of such plan can be capitalized in adopting integrated plans in order to reduce pollution at significant levels within different time scales.

<u>Appendix 7</u>

Observed data on the empirical literature analyses (ELAs) – 1, 2 and 3

Each of the three ELAs contain 10 tables of observed data, **Tables A7.1.1 – A7.1.10** being for 'ELA – 1', **Tables A7.2.1 – A7.2.10** for 'ELA – 2', and **Tables A7.3.1 – A7.3.10** for 'ELA – 3'. For detail explanation on the column headings in the tables, see **Section 4.3** of the thesis. These 10 tables for each ELA are designed as per the 10 spheres (sphere A[Economy], AB[Socio-economy], AC[Environo-economy], B[Society], BA[Econo-society], BC[Environo-society], C[Environment], CA[Econo-environment], CB[Socio-environment], and D[Central organization of sustainability]). These 10 spheres construct the second layer of organization within the 'Group-A' literature archive, the details of which are provided in the thesis in **Section 3.4.3**.

Table A7.1.1: Observed data on ELA-1 (sphere A, Economy)													
Item ID	**Item**	**Sphere**	**Category**	**Theme ID**	**Theme**	**Article type**	**Scale**	**Place**	**Place of authorship (corresponding author)**	**Temporal**	**Q1**	**Q2**	**Archetype (1) / Prototype (2)**
JG11	(Gilbert 2010)	A	i	1	Food security—Agricultural challenges/issues	Report	-	N/A	UK	2010	Agricultural biotechnology	Reporting	
JH7	(Hara et al. 2011)	A	i	3	Industrialization—Energy—Environment	Original	Local	China	Japan	2010	Energy intensity trends/scenarios	Literature survey	1
JB26	(Berkhout et al. 2012)	A	ii	1	Energy policy/innovation	Editorial	-	N/A	Netherlands	2012	Energy transitions	Editorial	
JG2	(Gallagher et al. 2006)	A	ii	1	Energy policy/innovation	Review	-	N/A	USA	2006	Energy-Technology Innovation	Review	
JG12	(Gillingham et al. 2006)	A	ii	1	Energy policy/innovation	Review	-	N/A	USA	2006	Energy efficiency policies	Review	
JG5	(Geels 2002)	A	iii	1	Transition theory	Original	-	N/A	Netherlands	2001	Technological transitions	Literature survey and case study	

Table A7.1.2: Observed data on ELA-1 (sphere AB, Socio-economy)													
Item ID	**Item**	**Sphere**	**Category**	**Theme ID**	**Theme**	**Article type**	**Scale**	**Place**	**Place of authorship (corresponding author)**	**Temporal**	**Q1**	**Q2**	**Archetype (1) / Prototype (2)**
JG20	(Graedel and Cao 2010)	AB	i	4	Urbanization—Consumption—Environment	Original	Global	Global	USA	2010	Metal spectra, indicator of development	Literature survey	1
JJ12	(Jolly et al. 2012)	AB	ii	1	Energy policy/innovation	Original	Country	India	Netherlands	2012	Solar energy upscaling in Indian society	Literature survey	1
JS44	(Suwa and Jupesta 2012)	AB	ii	1	Energy policy/innovation	Original	Country	Japan	Japan	2012	Renewable energy technology diffusion in Japan society	Literature survey and case study	
JA3	(Adeel and Safriel 2008)	AB	ii	2	Alternative livelihood	Original	Regional	Asia	Canada	2007	Introducing alternative livelihood	Literature survey and case study	
JA13	(Arnold et al. 2010)	AB	ii	3	Interventions and development, and conservation	Original	Local	India	USA	2010	Study of development interventions with casual inference methods	Literature survey and empirical field study	
JF1	(Fabusoro 2009)	AB	ii	4	Community involvement	Original	Local	Nigeria	Japan	2009	Collective action for land accessibility among agro-pastoralists	Field survey	
JH32	(Hanaoka and Kainuma 2012)	AB	ii	5	Low-carbon transitions	Original	Global	Global	Japan	2012	Comparison of technological mitigation potential and costs across the world	Literature survey	1
JZ5	(Zhou 2006)	AB	ii	5	Low-carbon transitions	Overview	Country	China	Japan	2006	GHG reduction with regard to China	Literature survey and case study	
JA18	(Ausubel and Waggoner 2008)	AB	iii	2	Dematerialization	Original	-	N/A	USA	2008	Characteristics of dematerialization	Literature survey	1
JY5	(Zhou 2006)	AB	iii	3	"Reuse" as theory	Report	-	N/A	Japan	2009	Economic theory of reuse	Modeling	
JZ4	(Zhijun and Nailing 2007)	AB	iii	4	Circular economy	Overview	Country	China	China	2006	Conceptualizing circular economy practice in China	Literature survey	1
JZ9	(Zik and Kulatilaka 2013)	AB	iii	5	Quantitative sustainability	Note	-	N/A	USA	2012	Quantitative measure of sustainability	Literature survey	1

Table A7.1.3: Observed data on ELA-1 (sphere AC, Environo-economy)

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JE2	(Ejeta 2010)	AC	i	1	Food security—Agricultural challenges/issues	Perspective	Continent	Africa	USA	2010	African green revolution	Literature survey	1
JF14	(Furuya and Kobayashi 2009)	AC	i	1	Food security—Agricultural challenges/issues	Original	Global	Global	Japan	2008	Global warming affecting global food markets	Literature survey	1
JC8	(Chong and Sunding 2006)	AC	i	2	Water availability/quality	Review	Local	USA	USA	2006	Complications of water supply-demand-markets-trading	Literature survey	1
JS17	(Shi et al. 2011)	AC	i	3	Industrialization—Energy—Environment	Original	Country	China	China	2011	Real cost of economic growth in China	Literature survey	1
JP11	(Peters et al. 2011)	AC	i	5	Air pollution—GHG Emission—Emission transfers	Original	Global	Global	Norway	2011	Emission transfers via international trade	Literature survey	1
JS35	(Suneetha 2010)	AC	i	6	Biodiversity—Habitat destruction—Trade	Original	-	N/A	Japan	2009	Biodiversity business issues with regard to sustainability	Literature survey	1
JL7	(Lee et al. 2008)	AC	ii	1	Energy policy/innovation	Report	-	N/A	USA	2008	Biofuels with regard to sustainable development	Summary report on multi-stake executive session	
JM21	(Moreira and Goldemberg 1999)	AC	ii	1	Energy policy/innovation	Original	Country	Brazil	Brazil	1999	Biofuel program	Literature survey	1
JS27	(Steinfeld 2006)	AC	ii	1	Energy policy/innovation	Note	-	N/A	USA	2006	Green chemistry and future of energy	Literature survey	1

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JS42	(Sovacool and Bulan 2013)	AC	ii	1	Energy policy/innovation	Report	Local	Malaysia	USA	2012	Malaysian Sarawak Corridor of Renewable Energy with regard to sustainability	Field survey	
JA20	(Akashi and Hanaoka 2012)	AC	ii	5	Low-carbon transitions	Original	Global	Global	Japan	2012	Feasibility and cost of 50% GHG emission reduction by 2050	Literature survey	1
JA21	(Akimoto et al. 2012)	AC	ii	5	Low-carbon transitions	Original	Global	Global	Japan	2012	Marginal abatement costs and GHG emission reductions	Literature survey	1
JW15	(Wagner et al. 2012)	AC	ii	5	Low-carbon transitions	Original	-	N/A	Austria	2012	Sectoral marginal abatement cost curves for Annex I countries	Literature survey	1
JT15	(Tsuji et al. 2011)	AC	ii	6	Biodiversity—Agriculture—Poverty	Original	Local	China	Japan	2010	Biodiversity for sustainable pest management	Field survey and simulation	
JA9	(Andersen 2007)	AC	iii	4	Circular economy	Note	-	N/A	Denmark	2006	Environmental economics of circular economy	Literature survey	1
JD6	(Dasgupta 2008)	AC	iii	6	Natural capital & ecosystem services management/governance	Original	-	N/A	UK	2008	Natural capital and economic growth	Literature survey	1
JP31	(Patterson and Glavovic 2013)	AC	iii	7	Ecological economics	Original	-	N/A	New Zealand	2012	Ecological economics of oceans and coasts	Literature survey	1

Table A7.1.4: Observed data on ELA-1 (sphere B, Society)

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JA1	(Acuin et al. 2011)	B	i	7	Public health	Original	Regional	Asia	Philippines	2011	Maternal, neonatal and child health in southeast Asia	Literature survey	1
JC16	(Coker et al. 2011)	B	i	7	Public health	Original	Regional	Asia	Thailand	2011	Emerging infectious diseases in southeast Asia	Literature survey	1
JW6	(Wilbanks and Kates 1999)	B	i	7	Public health	Report	Global	Global	Switzerland	2009	Global health risks	Literature survey	1
JA16	(Aspinall 2005)	B	i	8	Human insecurity—Conflict	Review	Local	Indonesia	Australia	2005	Systemic conflict transformation in Aceh, Indonesia	Literature review	
JH28	(HSC 2005, Part-I)	B	i	8	Human insecurity—Conflict	Report	Global	Global	Canada	2005	Change in global violence	Literature survey	1
JH29	(HSC 2011, Part-I)	B	i	8	Human insecurity—Conflict	Report	Global	Global	Canada	2011	Causes of peace	Literature survey	1
JH30	(HSC 2011, Part-III)	B	i	8	Human insecurity—Conflict	Report	Global	Global	Canada	2011	Human insecurity trends	Literature survey	1
JU1	(UN-ESC 2009)	B	i	9	Population—Consumption—Environment	Report	Global	Global	USA	2009	World demographic trends	Literature survey	1
JP13	(Phillips et al. 2005)	B	ii	3	Interventions and development, and conservation	Report	Country	Ghana	USA	2005	Navrongo initiative in Ghana	Literature survey	1
JP23	(GF 2009)	B	ii	3	Interventions and development, and conservation	Report	Global	Global	USA	2009	Progress against HIV/AIDS	Case reporting	
JP24	(GF 2009)	B	ii	3	Interventions and development, and conservation	Report	Global	Global	USA	2009	Progress against Malaria	Case reporting	
JP26	(GF 2009)	B	ii	3	Interventions and development, and conservation	Report	Global	Global	USA	2009	Progress against Polio	Case reporting	
JP27	(GF 2009)	B	ii	3	Interventions and development, and conservation	Report	Global	Global	USA	2009	Progress against Tuberculosis	Case reporting	

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JP28	(GF 2009)	B	ii	3	Interventions and development, and conservation	Report	Global	Global	USA	2009	Progress towards immunization	Case reporting	
JP29	(GF 2009)	B	ii	3	Interventions and development, and conservation	Report	Global	Global	USA	2009	Progress towards maternal, newborn and child health	Case reporting	
JS33	(GF 2009)	B	ii	3	Interventions and development, and conservation	Report	Global	Global	USA	2009	Progress in global health	Case reporting	
JK34	(Sumi 2007)	B	ii	4	Community involvement	Original	Local	Tanzania	Tanzania	2008	Community directed health interventions in Tanzania	Field survey	
JR1	(Raloff 1998)	B	ii	4	Community involvement	Note	Local	USA	USA	1998	Democratizing science	Case reporting	
JA10	(Andersson 2008)	B	ii	7	Social learning	Original	Local	Sweden	USA	2008	Institutional analysis on social learning	Case study	
JB12	(Bongaarts 1994)	B	ii	8	Population policy	Original	Global	Global	USA	1994	Population policy options in developing world	Literature survey	1

Table A7.1.5: Observed data on ELA-1 (sphere BA, Econo-society)

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JA2	(Struble and Aomari 2003)	BA	i	1	Food security—Agricultural challenges/issues	Report	Global	Global	USA	2003	American Dietetic Association's position on global food insecurity	Literature survey	
JB1	(Barrett 2010)	BA	i	1	Food security—Agricultural challenges/issues	Note	-	N/A	USA	2010	Measuring food insecurity	Literature survey	1
JC6	(Godfray et al. 2010)	BA	i	1	Food security—Agricultural challenges/issues	Review	Global	Global	UK	2010	Food security	Literature survey	1
JC19	(Conway 2000)	BA	i	1	Food security—Agricultural challenges/issues	Original	Global	Global	USA	2000	Food security	Literature survey	1
JF9	(2010)	BA	i	1	Food security—Agricultural challenges/issues	Report	Global	Global	UK	2010	Food security	Literature review	
JF11	(Frongillo 1999)	BA	i	1	Food security—Agricultural challenges/issues	Original	Country	USA	USA	1998	Measuring food insecurity	Literature survey	1
JM10	(Matsumura et al. 2009)	BA	i	1	Food security—Agricultural challenges/issues	Report	Global	Global	Japan	2009	Mapping global demand and supply of rice	Literature survey	1
JW2	(Webb 2010)	BA	i	1	Food security—Agricultural challenges/issues	Original	Global	Global	USA	2010	Implications of high food price for global nutrition	Literature survey	1
JM8	(Marcotullio 2007)	BA	i	2	Water availability/quality	Original	Regional	Asia	USA	2006	Urban water-environmental transitions in southeast Asia	Literature survey	1
JK10	(Kates 2000b)	BA	i	9	Population—Consumption—Environment	Original	-	N/A	USA	2000	Population and consumption	Literature survey	1
JC17	(Collier 2007)	BA	i	10	African poverty	Original	Continent	Africa	UK	2007	Reduction of African poverty	Literature survey	1

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JP30	(GF 2009)	BA	ii	3	Interventions and development, and conservation	Report	Global	Global	USA	2009	Progress towards nutrition	Case reporting	
JM2	(Mabogunje 2007)	BA	ii	4	Community involvement	Original	Local	Nigeria	Nigeria	2007		Field study	
JD17	(Diffenbaug h 2013)	BA	ii	5	Low-carbon transitions	Note	Global	Global	USA	2012	Global GHG emissions debt and human well-being	Literature survey	1
JL2	(Larson and Ribot 2007)	BA	ii	9	Forest management policy/innovation	Original	Regional	Honduras-Senegal	USA	2007	Poverty of forestry policy	Literature survey and case study	
JT4	(Tester and Langridge 2010)	BA	ii	10	Agricultural policy/innovation	Review	-	N/A	Australia	2010	Breeding technologies to increase crop production	Literature review	
JT14	(Tester and Langridge 2010)	BA	ii	11	Regional cooperation	Original	Regional	Eu-ME-NA	Germany	2007	Electricity and water cooperation among Europe-Middle East-North Africa	Literature survey	1
JA17	(Auer 2007)	BA	iii	10	Institutional reform	Original	-	N/A	USA	2007	Aid versus institutions	Literature survey	1
JK5	(Kates 1992)	BA	iii	11	Sustainability challenge	Keynote address	Global	Global	USA	1992	Meeting human needs in changing world	Opinion	
JM13	(McGee 2008)	BA	iii	13	Rural-urban transformation	Overvie w	Regional	Asia	Canada	2007	Rural-urban transformation in East Asia	Literature survey and case study	
JR15	(Rosenfeld 2010)	BA	iii	14	Poverty—Development	Original	-	N/A	USA	2009	Meaning of poverty	Literature survey	1
JT12	(Townsend 2010)	BA	iii	14	Poverty—Development	Original	-	N/A	UK	2010	Meaning of poverty	Literature survey	1
JS5	(Sanya 2012)	BA	iii	15	Sustainable architecture	Original	Country	Uganda	South Africa	2011		Literature survey	1

Table A7.1.6: Observed data on ELA-1 (sphere BC, Environo-society)

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JR4	(Rarieya and Fortun 2010)	BC	i	1	Food security—Agricultural challenges/issues	Original	Local	Kenya	USA	2009	Food security in climate-vulnerable area	Literature survey and field survey	
JK25	(Kazama et al. 2012)	BC	i	7	Public health	Original	Country	Cambodia	Japan	2011	Risk assessment of inundation waterborne infectious disease	Risk modeling	
JI7	(Iwasaki and Shaw 2009)	BC	i	8	Human insecurity—Conflict	Report	Local	India	Japan	2009	Connection between human security and natural resources	Literature survey and case study	
JK29	(Khagram and Ali 2006)	BC	i	8	Human insecurity—Conflict	Original	-	N/A	USA	2006	Environment and security	Literature survey	1
JD12	(Dietz et al. 2003)	BC	i	9	Population—Consumption—Environment	Review	-	N/A	USA	2003	Governance of the commons	Literature review	
JG13	(Gleick 2003b)	BC	i	9	Population—Consumption—Environment	Review	Global	Global	USA	2003	Water use	Literature survey	1
JO1	(O'Neill et al. 2010)	BC	i	9	Population—Consumption—Environment	Original	Global	Global	USA	2010	Demographic trends and future carbon emissions	Literature survey	1
JP16	(Popovski and Mundy 2012)	BC	i	11	Climate change problem/impacts	Original	-	N/A	Japan	2011	Human-induced climate-change victims	Literature survey	1
JS16	(Shahbazbegian and Bagheri 2010)	BC	i	12	Drought	Original	Local	Iran	Iran	2009	Assessment of drought impacts	Systemic assessment	
JS38	(Syvitski 2008)	BC	i	13	Delta — problems	Original	Global	Global	USA	2007	Vulnerability of deltas	Literature survey	1
JH33	(Higgins and Foliente 2013)	BC	ii	3	Interventions and development, and conservation	Original	Local	Australia	Australia	2012	Evaluation of intervention options for environmental benefits in residential sector	Literature survey and case study	

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JP1	(de Palencia and Pérez-Foguet 2011)	BC	ii	3	Interventions and development, and conservation	Original	Local	Tanzania	Spain	2010	Rural water supply and sanitation program in Tanzania	Policy analysis	
JP25	(GF 2009)	BC	ii	3	Interventions and development, and conservation	Report	Global	Global	USA	2009	Progress against neglected tropical diseases	Case reporting	
JR17	(Rehman et al. 2012)	BC	ii	3	Interventions and development, and conservation	Original	Local	India	India	2012	Distribution of improved cook stoves	Empirical field study	
JT11	(Toth and Hizsnyik 2008)	BC	ii	4	Community involvement	Original	-	N/A	Austria	2008	Participatory assessments of extreme climate change impacts and responses	Literature survey	1
JS20	(Snapp et al. 2010)	BC	ii	6	Biodiversity—Agriculture—Poverty	Original	Country	Malawi	USA	2010	Biodiversity to support greener revolution in Africa	Empirical field study	
JT7	(Timmer and Juma 2005)	BC	ii	6	Biodiversity—Agriculture—Poverty	Original	-	N/A	Canada	2005	Biodiversity conservation and poverty reduction in Tropics	Literature survey	1
JY10	(Yami et al. 2013)	BC	ii	9	Forest management policy/innovation	Original	Local	Ethiopia	Ethiopia	2012	Village bylaws in management of community managed exclosures	Literature survey and field survey	
JI5	(IAC 2004)	BC	ii	10	Agricultural policy/innovation	Report	Continent	Africa	Netherlands	2006	Realizing the potential of African agriculture	Reporting	
JT13	(Townsend and Porder 2012)	BC	ii	10	Agricultural policy/innovation	Commentary	-	N/A	USA	2012	Agricultural production and environmental consequences	Commentary	
JA22	(Antanasijević et al. 2013)	BC	ii	12	Modeling	Original	Continent	Europe	Serbia	2011	Forecasting of municipal waste generation	Modeling	

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JP22	(Preston et al. 2011)	BC	**ii**	**12**	Modeling	Review	-	N/A	USA	2011	Mapping vulnerability to climate change	Literature review	
JB11	(Black et al. 2011)	BC	**ii**	**13**	Adaptation—Natural Disaster—Migration—Benefits	Comment	Country	Bangladesh	UK	2011	Migration as adaptation	Opinion	
JG24	(Gray and Mueller 2012)	BC	**ii**	**13**	Adaptation—Natural Disaster—Migration—Benefits	Original	Local	Bangladesh	USA	2012	Natural disasters and population mobility	Field survey	
JP2	(Parker et al. 2007)	BC	**ii**	**13**	Adaptation—Natural Disaster—Migration—Benefits	Original	Country	UK	UK	2007	Human benefits of flood warnings	Literature survey and field survey	
JR16	(Reckien et al. 2013)	BC	**ii**	**13**	Adaptation—Natural Disaster—Migration—Benefits	Original	Local	India	USA	2012	Subjective reality of climate change	Field survey	
JS36	(Surjan and Shaw 2008)	BC	**ii**	**14**	Urban policy/innovation	Report	Local	India	Japan	2008	Eco-city to disaster-resilient eco-community	Literature survey	1
JU3	(UN-Habitat 2012)	BC	**ii**	**14**	Urban policy/innovation	Report	Global	Global	Kenya	2012	Urban planning	Literature survey	1
JW9	(Wilbanks et al. 2007)	BC	**ii**	**14**	Urban policy/innovation	Original	Local	India	USA	2007	Climate change vulnerabilities and responses	Literature survey	1
JT5	(Thomas 2011)	BC	**ii**	**15**	Reuse—Recycling—Pollution control	Original	Country	USA	USA	2010	Environmental potential of book reuse	Case study	
JK41	(Kurian et al. 2013)	BC	**iii**	**3**	"Reuse" as theory	Original	Local	India	UK	2011	Wastewater reuse for peri-urban agriculture	Literature survey and empirical field study	
JL22	(Lynam et al. 2007)	BC	**iii**	**6**	Natural capital & ecosystem services management/governance	Original	-	N/A	Zimbabwe	2007	Decision making in natural resources management	Literature survey	1
JS32	(Su et al. 2012)	BC	**iii**	**6**	Natural capital & ecosystem services management/governance	Original	Local	China	China	2011	Managing ecosystem based on ecosystem services and human activities	Case study	

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JW4	(White 1967)	BC	**iii**	**11**	Sustainability challenge	Perspective	-	N/A	USA	1967	Historical root of ecological crisis	Opinion	
JK6	(Kates 1992)	BC	**iii**	**14**	Poverty—Development	Original	-	N/A	USA	1992	The residing place of the poor	Literature survey	1
JR6	(Raudsepp-Hearne et al. 2010)	BC	**iii**	**14**	Poverty—Development	Original	-	N/A	Canada	2010	Untangling the environmentalist's paradox	Literature survey	1
JK37	(Kosamu 2011)	BC	**iii**	**15**	Sustainable architecture	Original	Country	Malawi	Malawi	2010	Application of environmental impact assessment in infrastructural projects	Literature survey and field survey	
JB10	(Birkmann et al. 2010)	BC	**iii**	**16**	Urban sustainability and adaptive urban governance	Original	-	N/A	Germany	2010	Adaptive urban governance	Literature survey	1
JS9	(Satterthwaite 2007)	BC	**iii**	**16**	Urban sustainability and adaptive urban governance	Original	-	N/A	UK	2007	Urban challenge	Literature survey	1
JS23	(Solecki and Leichenko 2006)	BC	**iii**	**16**	Urban sustainability and adaptive urban governance	Original	-	N/A	USA	2006	Urbanization and metropolitan environment	Literature survey	
JK9	(Kates 2000a)	BC	**iii**	**17**	Adaptation	Original	Global	Global	USA	2000	Adaptation and the global poor	Literature survey	1
JM20	(Molua 2011)	BC	**iii**	**17**	Adaptation	Original	Country	Cameroon	Cameroon	2010	Typology of male and female adaptation to climate change	Literature survey and field survey	
JM7	(Manson 2006)	BC	**iii**	**19**	Land cover and land use change science	Original	Local	Mexico	USA	2005	Population and institutional change in land use	Empirical field study and modeling	
JW13	(Wu et al. 2010)	BC	**iii**	**19**	Land cover and land use change science	Original	Regional	Asia	Japan	2009	Modeling changes in rice-sown areas in Asia	Modeling, empirical field study and simulation	2
JY4	(Yin and Xiang 2010)	BC	**iii**	**19**	Land cover and land use change science	Original	Local	China	USA	2009	Modeling land use changes	Literature survey and modeling	2

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JM31	(Mohamad et al. 2012)	BC	**iii**	**20**	Sustainability—Culture—Religion	Original	Country	Malaysia	Malaysia	2012	Religious community in solid waste management	Literature survey	1
JT1	(Tàbara and Ilhan 2008)	BC	**iii**	**20**	Sustainability—Culture—Religion	Original	Country	Spain	Spain	2007	Role of culture in triggering sustainability transition in water domain	Literature survey	1
JR10	(Roberts et al. 2003)	BC	**iii**	**21**	World System theory	Original	Global	Global	USA	2003	Social roots of global environmental change	Literature survey	1
JW5	(White et al. 2001)	BC	**iii**	**22**	Learning—Knowledge—Ignorance—Condition	Original	-	N/A	USA	2001	Use of knowledge in hazards management	Literature survey	1

Table A7.1.7: Observed data on ELA-1 (sphere C, Environment)													
Item ID	**Item**	**Sphere**	**Category**	**Theme ID**	**Theme**	**Article type**	**Scale**	**Place**	**Place of authorship (corresponding author)**	**Temporal**	**Q1**	**Q2**	**Archetype (1) / Prototype (2)**
JP17	(Pöschl 2005)	C	**i**	**5**	Air pollution—GHG Emission—Emission transfers	Review	-	N/A	Germany	2005	Atmospheric aerosols	Literature review	
JO8	(Overpeck and Cole 2006)	C	**i**	**11**	Climate change problem/impacts	Review	Global	Global	USA	2006	Abrupt climate change	Literature review	
JK4	(Kasei et al. 2010)	C	**i**	**12**	Drought	Original	Regional	Africa	Germany	2009	Drought frequency in Volta basin	Literature survey	1
JG22	(Grainger 2008)	C	**i**	**14**	Ecological crisis	Original	Global	Global	UK	2008	Long-term global trend in tropical forest	Literature survey	1
JJ9	(Jin et al. 2008)	C	**ii**	**12**	Modeling	Original	-	N/A	USA	2008	ENSO prediction skill in coupled ocean-atmosphere models	Literature survey	1

Table A7.1.8: Observed data on ELA-1 (sphere CA, Econo-environment)													
Item ID	**Item**	**Sphere**	**Category**	**Theme ID**	**Theme**	**Article type**	**Scale**	**Place**	**Place of authorship (corresponding author)**	**Temporal**	**Q1**	**Q2**	**Archetype (1) / Prototype (2)**
JE5	(Esteban et al. 2009)	CA	**i**	**16**	Global warming—Natural disaster	Original	Country	Taiwan	Japan	2009	Global warming, typhoon intensity and urban productivity	Simulation	
JB8	(Birch et al. 2010)	CA	**ii**	**9**	Forest management policy/innovation	Original	Regional	North and South America	UK	2010	Dryland forest restoration and ecosystem services	Literature survey, scenario study and field survey	
JD11	(Diallo and Brinker 2011)	CA	**ii**	**16**	Technology and nanotechnology	Report	-	N/A	USA	2011	Nanotechnologies for environment, water, food, minerals and climate	Literature survey	1
JS22	(Socolow et al. 2004)	CA	**ii**	**16**	Technology and nanotechnology	Original	-	N/A	USA	2004	Technologies for curbing carbon dioxide emissions	Literature survey	1
JE4	(Esposto 2009)	CA	**ii**	**17**	Water policy/innovation	Report	Local	Iraq	Switzerland	2008	Water treatment plant design with regard to sustainability in Iraq	Case reporting	
JA12	(Arndt et al. 2011)	CA	**iii**	**17**	Adaptation	Original	Country	Mozambique	Finland	2010	Integrated assessment for climate change adaptation	Literature survey	1
JD4	(Dasgupta et al. 1995)	CA	**iii**	**24**	Environmental regulation	Report	-	N/A	USA	1995	Environmental regulation and development	Literature survey	1

Table A7.1.9: Observed data on ELA-1 (sphere CB, Socio-environment)

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JM3	(MacDonald et al. 2011)	CB	i	1	Food security—Agricultural challenges/issues	Original	Global	Global	Canada	2011	Global phosphorus imbalance in croplands	Literature survey	1
JS1	(Sachs et al. 2010)	CB	i	1	Food security—Agricultural challenges/issues	Report	Global	Global	USA	2010	Monitoring global agriculture	Opinion	
JS8	(Sattari et al. 2012)	CB	i	1	Food security—Agricultural challenges/issues	Original	Global	Global	Netherlands	2012	Residual soil phosphorus and global phosphorus crisis	Literature survey	1
JM19	(Molina and Molina 2004)	CB	i	5	Air pollution—GHG Emission—Emission transfers	Review	Global	Global	USA	2004	Megacities and atmospheric pollution	Literature survey	1
JD13	(Dirzo and Raven 2003)	CB	i	6	Biodiversity—Habitat destruction—Trade	Original	Global	Global	Mexico	2003	State of global biodiversity	Literature survey	1
JG8	(Geist and Lambin 2002)	CB	i	6	Biodiversity—Habitat destruction—Trade	Original	Global	Global	Belgium	2002	Causes and driving forces of tropical deforestation	Literature survey	1
JS4	(Sala and Knowlton 2006)	CB	i	6	Biodiversity—Habitat destruction—Trade	Review	Global	Global	USA	2006	Global marine biodiversity trends	Literature review	
JK14	(Kates and Wilbanks 2003)	CB	i	11	Climate change problem/impacts	Original	Local	USA	USA	2003	Local response to climate change	Literature survey	1
JN2	(NAS 2008)	CB	i	11	Climate change problem/impacts	Review	Global	Global	USA	2008	Understanding on and responding to climate change	Literature review	
JS3	(Sahoo and Schladow 2008)	CB	i	11	Climate change problem/impacts	Original	Local	USA	USA	2008	Climate change impacts on lakes and reservoir dynamics	Literature survey and simulation	

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JP18	(Postel 2005)	CB	i	14	Ecological crisis	Original	-	N/A	USA	2005	Protecting freshwater ecosystems	Literature survey	1
JM15	(Mcleod et al. 2010)	CB	i	15	Coastal vulnerability issues & sea level rise	Report	Regional	Asia	USA	2010	Vulnerability assessment of sea level rise	Literature survey	1
JN7	(Nicholls et al. 2008)	CB	i	15	Coastal vulnerability issues & sea level rise	Original	-	N/A	UK	2007	Coastal vulnerability assessment	Literature survey	1
JR14	(Romieu et al. 2010)	CB	i	15	Coastal vulnerability issues & sea level rise	Original	-	N/A	France	2010	Vulnerability assessments between climate change and natural hazards context	Literature survey	1
JT10	(Torresan et al. 2008)	CB	i	15	Coastal vulnerability issues & sea level rise	Original	-	N/A	Italy	2007	Coastal vulnerability assessment	Literature survey	1
JY2	(Yasuhara et al. 2007)	CB	i	15	Coastal vulnerability issues & sea level rise	Original	Regional	Asia	Japan	2006	Coastal infrastructural instability due to global warming	Modeling and case histories	
JY3	(Yasuhara et al. 2011)	CB	i	15	Coastal vulnerability issues & sea level rise	Overview	Country	Japan	Japan	2009	Climate change effects on coastal disasters	Literature survey	1
JL19	(Lotze et al. 2006)	CB	i	17	Estuaries & coastal seas — problems	Report	Global	Global	Canada	2006	Deterioration and recovery of estuaries and coastal seas	Literature survey	1
JS18	(Sidle et al. 2007)	CB	i	18	Open water bodies — problems	Original	Local	Myanmar	Japan	2006	Change in open water surface in Lake Inle, Myanmar	Literature survey and field survey	
JS2	(Safriel and Adeel 2008)	CB	ii	2	Alternative livelihood	Original	Global	Global	Canada	2007	Dryland development pathways	Literature survey	1

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JB2	(Barthelmie et al. 2008)	CB	ii	5	Low-carbon transitions	Report	Local	Scotland	UK	2008	Renewable energy options for carbon footprint reduction	Literature survey and modeling	
JA23	(Azadi et al. 2013)	CB	ii	9	Forest management policy/innovation	Original	Local	Iran	Belgium	2012	Forest management in Iran	Literature survey and field survey	
JL4	(Lebel et al. 2004)	CB	ii	9	Forest management policy/innovation	Original	Regional	Asia	Thailand	2003	Forest management and governance in southeast Asia	Literature survey	1
JS24	(Sonwa et al. 2011)	CB	ii	9	Forest management policy/innovation	Review	Regional	Africa	Cameroon	2010	Forestry efforts and climate change mitigation	Literature review	
JY8	(Yoshikawa et al. 2011)	CB	ii	9	Forest management policy/innovation	Original	Global	Global	Japan	2011	Quantitative assessment of global forest biodiversity	Literature survey	1
JC4	(Cassman et al. 2003)	CB	ii	10	Agricultural policy/innovation	Original	-	N/A	USA	2003	Agricultural production with protecting natural resources and improving environmental quality	Literature survey	1
JC7	(Chen et al. 2011)	CB	ii	10	Agricultural policy/innovation	Original	Local	China	China	2011	Integrated soil-crop system management	Literature survey, field survey and empirical field study	
JF4	(Fedoroff et al. 2010)	CB	ii	10	Agricultural policy/innovation	Perspective	Global	Global	USA	2010	Rethinking agriculture	Opinion	
JG4	(Gebbers and Adamchuk 2010)	CB	ii	10	Agricultural policy/innovation	Perspective	-	N/A	Germany	2010	Precision agriculture	Literature survey	1

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JG9	(Gewin 2010)	CB	**ii**	**10**	Agricultural policy/innovation	Report	-	N/A	USA	2010	Root-based agricultural revolution	Reporting	
JH13	(Herdt 2006)	CB	**ii**	**10**	Agricultural policy/innovation	Original	-	N/A	USA	2006	Biotechnology in agriculture	Literature survey	1
JH15	(Herrero et al. 2010)	CB	**ii**	**10**	Agricultural policy/innovation	Perspective	-	N/A	Kenya	2010	Mixed crop-livestock systems	Literature survey	1
JR11	(Roberts and Brink 2010)	CB	**ii**	**10**	Agricultural policy/innovation	Original	Global	Global	USA	2010	Marine resources management	Literature survey	1
JS43	(Spugnoli and Dainelli 2013)	CB	**ii**	**10**	Agricultural policy/innovation	Original	-	N/A	Italy	2012	Draught animal and tractor power in agriculture	Literature survey	1
JT8	(Tollefson 2010)	CB	**ii**	**10**	Agricultural policy/innovation	Report	Country	Brazil	USA	2010	Giant-scale agriculture	Reporting	
JP21	(Poumadère et al. 2008)	CB	**ii**	**12**	Modeling	Original	Local	France	France	2008	Risk perception analysis regarding climate change induced sea level rise	Literature survey and field survey	
JB9	(Birkmann and von Teichman 2010)	CB	**ii**	**13**	Adaptation—Natural Disaster—Migration—Benefits	Original	-	N/A	Germany	2010	Disaster risk reduction and climate change adaptation	Literature survey	1
JH11	(Hay and Mimura 2006)	CB	**ii**	**13**	Adaptation—Natural Disaster—Migration—Benefits	Original	Regional	Asia	Japan	2006	Climate change vulnerability and adaptation assessments	Literature survey	1
JO3	(Ohyama et al. 2008)	CB	**ii**	**14**	Urban policy/innovation	Report	-	N/A	Japan	2008	Urban horticulture and environmental conservation	Literature survey	1
JN1-6	(Graedel 2011)	CB	**ii**	**15**	Reuse—Recycling—Pollution control	Original	-	N/A	USA	2011	Urban mining	Literature survey	1

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JZ2	(Zhang et al. 2006)	CB	**ii**	**15**	Reuse—Recycling—Pollution control	Original	Local	China	China	2006	Non-point-source pollution control by rural resource recycling	Field survey and modeling	
JG14	(Gleick 2003a)	CB	**ii**	**17**	Water policy/innovation	Original	Global	Global	USA	2003	Soft-path solutions for global freshwater resources	Literature survey	1
JH14	(Hermanowicz 2008)	CB	**ii**	**17**	Water policy/innovation	Original	-	N/A	USA	2008	Perception in water resources management	Literature survey	1
JR2	(Ramanathan and Xu 2010)	CB	**ii**	**18**	Treaties—Agreements	Perspective	Global	Global	USA	2010	Avenues in the Copenhagen accord	Literature survey	1
JB15	(Brack et al. 2006)	CB	**ii**	**19**	Emission estimation/control	Overview	Country	Australia	Australia	2006	Integrated GHG emission estimation from land systems	Literature survey and modeling	
JC1	(Caldeira and Davis 2011)	CB	**ii**	**19**	Emission estimation/control	Commentary	-	N/A	USA	2011	Accounting carbon dioxide emissions	Opinion	
JH6	(Hara et al. 2010)	CB	**ii**	**20**	Land use system planning/innovation	Original	Local	Thailand	Japan	2010	Mixed land-use planning on large city periphery in Thailand	Case study	
JL5	(Leclerc et al. 2009)	CB	**ii**	**20**	Land use system planning/innovation	Report	Local	Senegal	Senegal	2009	Participatory modeling experiment on land use	Literature survey and action-research	
JH19	(Hoekstra 2012)	CB	**ii**	**21**	Biodiversity conservation policy/innovation	Commentary	-	N/A	USA	2012	Biodiversity conservation and modern portfolio theory	Literature survey	1
JL10	(Lejano and Ingram 2007)	CB	**ii**	**21**	Biodiversity conservation policy/innovation	Original	Local	Philippine	USA	2007	Place-based conservation and 'Turtle Islands'	Literature survey	1

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JS6	(Sarkar et al. 2006)	CB	ii	21	Biodiversity conservation policy/innovation	Review	-	N/A	USA	2006	Biodiversity conservation planning tools	Literature review	
JJ1	(Jack et al. 2008)	CB	ii	22	Ecosystem services policy/innovation	Policy analysis	-	N/A	USA	2008	Designing payments for ecosystem services	Policy analysis	
JK35	(Komatsuzaki and Ohta 2007)	CB	ii	22	Ecosystem services policy/innovation	Report	-	N/A	Japan	2006	Soil management practices in agro-ecosystems	Literature survey	1
JT9	(Tomich et al. 2004)	CB	ii	22	Ecosystem services policy/innovation	Original	Regional	Asia	Kenya	2004	Environmental services and land use change in southeast Asia	Literature survey	1
JX1	(Xia and Yan 2012)	CB	ii	22	Ecosystem services policy/innovation	Original	Local	China	China	2011	Ecologically optimal nitrogen rates in rice cropping	Literature survey and modeling	
JL18	(Longhurst et al. 2009)	CB	ii	23	Air quality policy/innovation	Original	-	N/A	UK	2008	Air quality management system	Literature survey	1
JY7	(Yoshida 2007)	CB	ii	24	Environmental restoration policies/innovation	Overview	Local	Japan	Japan	2006	Environmental restoration of Minamata, Japan	Opinion	
JC2	(Carpenter et al. 2009)	CB	iii	6	Natural capital & ecosystem services management/governance	Perspective	-	N/A	USA	2009	Ecosystem services management science	Literature survey	1
JD2	(Daily and Matson 2008)	CB	iii	6	Natural capital & ecosystem services management/governance	Perspective	-	N/A	USA	2008	Ecosystem services implementation	Literature survey	1
JD10	(Depietri et al. 2012)	CB	iii	6	Natural capital & ecosystem services management/governance	Review	-	N/A	Spain	2011	Heat waves and floods in urban areas from policy-perspective	Literature survey	1

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JF5	(Ferraro Jr. and Burztyn 2008)	CB	**iii**	**6**	Natural capital & ecosystem services management/governance	Original	Local	Brazil	USA	2008	Managing other factors in common pool resource management	Literature survey	1
JH4	(Halpin 1997)	CB	**iii**	**6**	Natural capital & ecosystem services management/governance	Overview	-	N/A	USA	1996	Managing global climate change and protecting natural areas	Literature survey	1
JB20	(Bueno and Basurto 2009)	CB	**iii**	**8**	Resilience	Original	Local	Mexico	USA	2009	Resilience and collapse of shellfish fishery in Mexico	Literature survey, modeling and simulation	
JM5	(Mah and Bustami 2012)	CB	**iii**	**8**	Resilience	Report	Local	Malaysia	Malaysia	2011	Resilience of riparian wetlands and river channels	Literature survey	1
JP19	(Potschin and Haines-Young 2006b)	CB	**iii**	**11**	Sustainability challenge	Editorial	-	N/A	UK	2005	Landscapes and sustainability	Literature survey	1
JY6	(York et al. 2003)	CB	**iii**	**11**	Sustainability challenge	Original	-	N/A	USA	2003	Tools for studying driving forces of environmental impacts	Literature survey	1
JF15	(Füssel 2007)	CB	**iii**	**17**	Adaptation	Review	-	N/A	Germany	2007	Adaptation planning for climate change	Literature review	
JD9	(DeFries et al. 2006)	CB	**iii**	**19**	Land cover and land use change science	Original	-	N/A	USA	2006	Landscapes, livelihoods and environment	Literature survey	1
JL1	(Lambin et al. 2003)	CB	**iii**	**19**	Land cover and land use change science	Original	Global	Global	Belgium	2003	Dynamics of land-use and land-cover change	Literature survey	1
JP15	(Pontius Jr and Neeti 2010)	CB	**iii**	**19**	Land cover and land use change science	Original	Local	USA	USA	2009	Maps of future land change scenarios	Literature survey	1

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JF12	(Fung and O'rourke 2000)	CB	iii	24	Environmental regulation	Original	Country	USA	USA	2000	Effectiveness of environmental regulation	Literature survey	1

Table A7.1.10: Observed data on ELA-1 (sphere D, Central organization of sustainability)

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JK20	(Kates and Dasgupta 2007)	**D**	**i**	**10**	African poverty	Synopsis	Continent	Africa	USA	2007	Challenge of African poverty	Summary	
JI6	(IPCC 2007)	**D**	**i**	**11**	Climate change problem/impacts	Communication	Global	Global	Global	2007	IPCC 2007 report 'summary for policymakers'	Synthesis	
JZ7	(Ziv et al. 2012)	**D**	**i**	**19**	River — problems	Original	Regional	Asia	USA	2012	Trading-off fish biodiversity, food security and hydropower	Literature survey	1
JN3	(Nautiyal 2011)	**D**	**ii**	**3**	Interventions and development, and conservation	Original	Local	India	India	2011	Addressing conservation and sustainable livelihood development together in Himalaya	Field survey	
JM18	(Millar et al. 2007)	**D**	**ii**	**9**	Forest management policy/innovation	Original	-	N/A	USA	2007	Managing forest future in uncertainty	Literature survey	1
JA6	(Alcamo et al. 2005)	**D**	**ii**	**12**	Modeling	Original	Global	Global	Germany	2005	Model estimation of future worldwide ecosystem services	Literature survey	1
JG18	(Goodchild 2003)	**D**	**ii**	**12**	Modeling	Review	-	N/A	USA	2003	GIS and environmental management systems	Literature review	

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JM23	(Moser and Ekstrom 2010)	**D**	**ii**	**13**	Adaptation—Natural Disaster—Migration—Benefits	Original	-	N/A	USA	2010	Diagnosing barriers to climate change adaptation	Literature survey	1
JH31	(Han et al. 2012)	**D**	**ii**	**14**	Urban policy/innovation	Overview	Global	Global	Japan	2012	Innovation for future of industrialized cities	Literature survey	1
JS13	(Schmandt 2006)	**D**	**ii**	**17**	Water policy/innovation	Original	Regional	North America	USA	2006	Water basin management	Literature survey	1
JZ8	(Zwane et al. 2009)	**D**	**ii**	**17**	Water policy/innovation	Report	-	N/A	USA	2009	Water and human wellbeing	Summary report on multi-stake executive session	
JS21	(Soberon 2004)	**D**	**ii**	**21**	Biodiversity conservation policy/innovation	Original	-	N/A	Mexico	2004	Communication between scientists and policymakers regarding biodiversity	Literature survey	1
JM1	(Mabogunje and Kates 2004)	**D**	**ii**	**25**	Sustainable Development strategies/innovation	Original	Local	Nigeria	USA	2004	Development in Ijebu-Ode, Nigeria	Literature survey	1
JN8	(Nidumolu et al. 2009)	**D**	**ii**	**25**	Sustainable Development strategies/innovation	Perspective	-	N/A	USA	2009	Sustainability key driver of innovation	Opinion	
JZ1	(van Zeijl-Rozema et al. 2008)	**D**	**ii**	**25**	Sustainable Development strategies/innovation	Original	-	N/A	Netherlands	2008	Framework of governance for sustainable development	Literature survey	1
JZ3	(Zhang et al. 2009)	**D**	**iii**	**4**	Circular economy	Report	Local	China	Japan	2009	Socio-economic and environmental performances of eco-industrial parks in China	Field study	

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JF3	(Fan and Qi 2010)	**D**	**iii**	**5**	Quantitative sustainability	Original	Local	China	USA	2009	Assessing sustainability of cities in China	Literature survey and case study	
JH2	(Haberl et al. 2007)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance	Original	Global	Global	Austria	2007	Quantifying and mapping human appropriation of primary production of terrestrial ecosystems	Literature survey	1
JH8	(Hardin 1968)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance	Original	-	N/A	USA	1968	Tragedy of the commons	Literature survey	1
JH18	(Hoekstra and Mekonnen 2012)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance	Original	Global	Global	Netherlands	2011	Water footprint of humanity	Literature survey	1
JK26	(Kenward et al. 2011)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance	Original	-	N/A	UK	2011	Governance strategies effectively supporting ecosystem services, resource sustainability and biodiversity	Field survey and case studies	
JO6	(Ostrom and Nagendra 2006)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance	Original	-	N/A	USA	2006	Linking forests, trees and people from the air, on the ground and in the laboratory	Literature survey	1
JT3	(Tallis and Kareiva 2006)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance	Review	Global	Global	USA	2006	Millennium ecosystem assessment in shaping environmental decisions	Literature review	

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JW11	(Wilderer 2007)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance	Editorial	-	N/A	Germany	2007	Science behind water resource management	Editorial	
JS19	(Smith and Stirling 2010)	**D**	**iii**	**8**	Resilience	Synthesis	-	N/A	UK	2010	Politics of social-ecological resilience and socio-technical transitions	Literature survey	1
JK11	(Kates 2001)	**D**	**iii**	**11**	Sustainability challenge	Original	Global	Global	USA	2001	Human use of the Earth	Literature survey	1
JM26	(Munasinghe 2010)	**D**	**iii**	**11**	Sustainability challenge	Perspective	Global	Global	Sri Lanka	2010	Global status of millennium development prospects	Opinion	
JR12	(Rockström et al. 2009)	**D**	**iii**	**11**	Sustainability challenge	Original	Global	Global	Sweden	2009	Safe operating space for humanity	Literature survey	1
JS10	(Savage 2006)	**D**	**iii**	**11**	Sustainability challenge	Original	Regional	Asia	Singapore	2006	Development in southeast Asia	Literature survey	1
JS34	(Sumi 2007)	**D**	**iii**	**11**	Sustainability challenge	Overview	-	N/A	Japan	2006	Efforts toward a sustainable society	Opinion	
JW8	(Wilbanks and Kates 1999)	**D**	**iii**	**11**	Sustainability challenge	Original	-	N/A	USA	1999	The matter of scale	Literature survey	1
JP9	(Peet and Peet 2000)	**D**	**iii**	**14**	Poverty—Development	Perspective	-	N/A	New Zealand	2000	Poverties and satisfiers	Opinion	
JM14	(McGranahan and Satterthwaite 2003)	**D**	**iii**	**16**	Urban sustainability and adaptive urban governance	Original	Global	Global	UK	2003	Assessment of sustainability in urban centers	Literature survey	1
JN1-2	(Daigger 2011)	**D**	**iii**	**16**	Urban sustainability and adaptive urban governance	Original	-	N/A	USA	2011	Urban water and resource management	Literature survey	1
JN1-5	(Bai 2011)	**D**	**iii**	**16**	Urban sustainability and adaptive urban governance	Original	Continent	Asia	Australia	2011	Patterns of urban sustainability in Asia	Literature survey	1

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JW10	(Wilbanks and Kates 2010)	**D**	**iii**	**17**	Adaptation	Original	-	N/A	USA	2010	Embedding adaptation for multiple threats and stresses	Literature survey	1
JB19	(Bryant 1998)	**D**	**iii**	**18**	Political ecology	Original	-	N/A	UK	1998	Political ecology in third world	Literature survey	1
JH16	(Hersperger et al. 2010)	**D**	**iii**	**19**	Land cover and land use change science	Original	-	N/A	Switzerland	2010	Driving forces and actors of land change	Literature survey and modeling	
JR9	(Rindfuss et al. 2004)	**D**	**iii**	**19**	Land cover and land use change science	Review	-	N/A	USA	2004	Methodological issues of land change science	Literature survey	1
JS11	(Schaldach and Priess 2008)	**D**	**iii**	**19**	Land cover and land use change science	Review	Global	Global	Germany	2008	Modeling approaches on regional to global scale	Literature review	
JT18	(Turner et al. 2007)	**D**	**iii**	**19**	Land cover and land use change science	Perspective	Global	Global	USA	2007	Land change science	Literature survey	1
JB22	(Burns et al. 2003)	**D**	**iii**	**21**	World System theory	Original	Global	Global	USA	2003	Deforestation in late 20th century	Literature survey	1
JH34	(Hugé et al. 2013)	**D**	**iii**	**26**	Sustainability related discourses	Original	-	N/A	Belgium	2012	Discourse-analytical perspective on sustainability assessment	Literature survey	1
JP12	(Petry et al. 2011)	**D**	**iii**	**29**	Sustainability Science education/curriculum	Original	-	N/A	Canada	2010	Advancing education for sustainable development	Literature survey	1
JB3	(Beck 2010)	**D**	**iii**	**31**	Cosmopolitanism	Original	-	N/A	Germany	2010	Remapping social inequalities and cosmopolitan renewal of social sciences	Literature survey	1

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JR3	(Rapport 2007)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Overview	-	N/A	Canada	2006	Ecohealth perspective of sustainability science	Literature survey	1
JS41	(Shiroyama et al. 2012)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Original	-	N/A	Japan	2011	Knowledge integration and multi-actor governance	Literature survey	1
JC5	(Chapin III et al. 2011)	**D**	**iii**	**36**	Anthropocene and Earth stewardship	Original	-	N/A	USA	2011	Earth stewardship and social-ecological transformation	Literature survey	1
JS26	(Steffen et al. 2011)	**D**	**iii**	**36**	Anthropocene and Earth stewardship	Original	Global	Global	Australia	2011	The anthropocene	Literature survey	1
JS29	(2011)	**D**	**iii**	**36**	Anthropocene and Earth stewardship	Memorandum	-	N/A	Sweden	2011	The Stockholm Memorandum	Opinion	
JT16	(Turner et al. 1994)	**D**	**iii**	**36**	Anthropocene and Earth stewardship	Synopsis	Global	Global	USA	1994	Earth transformation by human action in retrospect	Opinion	
JK38	(Kristjanson et al. 2009)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Original	Regional	Africa and Asia	Kenya	2009	Linking international agricultural research knowledge with action	Literature survey	1
JM28	(Marsden 2013)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Original	-	N/A	UK	2012	Sustainable place-making for sustainability science	Literature survey	1
JD8	(Dearing et al. 2010)	**D**	**iii**	**38**	Complex systems, analysis, and adaptive planning/management	Synthesis	-	N/A	UK	2010	Assessing future of complex land systems	Literature survey	1

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JH24	(Horan et al. 2011)	**D**	iii	**38**	Complex systems, analysis, and adaptive planning/management	Original	-	N/A	USA	2011	Ecological threshold management in coupled environmental-human systems	Literature survey	1
JI3	(Iles 1996)	**D**	iii	**38**	Complex systems, analysis, and adaptive planning/management	Original	-	N/A	USA	1996	Environmental law and policy, and adaptive management	Literature survey	1
JY9	(Young et al. 2006)	**D**	iii	**38**	Complex systems, analysis, and adaptive planning/management	Original	-	N/A	USA	2006	Portfolio to analyzing complex human-environment interactions	Literature survey	1
JD15	(Drechsel and Dongus 2010)	**D**	iii	**40**	Urban agriculture	Original	Local	Tanzania	Sri Lanka	2008	Dynamics of urban agriculture	Literature survey	1
JF10	(Fotopoulos 2007)	**D**	iii	**41**	De-growth	Original	-	N/A	UK	2007	Degrowth and market economy	Literature survey	1
JG26	(Gruen et al. 2008)	**D**	iii	**43**	Sustainable health	Original	-	N/A	Australia	2008	Integrated approach for health-program planning and sustainability science	Literature survey	1

Table A7.2.1: Observed data on ELA-2 (sphere A, Economy)													
Item ID	**Item**	**Sphere**	**Category**	**Theme ID**	**Theme**	**Article type**	**Scale**	**Place**	**Place of authorship (corresponding author)**	**Temporal**	**Q1**	**Q2**	**Archetype (1) / Prototype (2)**
JG11	(Gilbert 2010)	A	i	1	Food security—Agricultural challenges/issues	Report	-	N/A	UK	2010	Agricultural biotechnology	Reporting	

Table A7.2.2: Observed data on ELA-2 (sphere AB, Socio-economy)													
Item ID	**Item**	**Sphere**	**Category**	**Theme ID**	**Theme**	**Article type**	**Scale**	**Place**	**Place of authorship (corresponding author)**	**Temporal**	**Q1**	**Q2**	**Archetype (1) / Prototype (2)**
JF1	(Fabusoro 2009)	AB	ii	4	Community involvement	Original	Local	Nigeria	Japan	2009	Collective action for land accessibility among agro-pastoralists	Field survey	

Table A7.2.3: Observed data on ELA-2 (sphere AC, Environo-economy)													
Item ID	**Item**	**Sphere**	**Category**	**Theme ID**	**Theme**	**Article type**	**Scale**	**Place**	**Place of authorship (corresponding author)**	**Temporal**	**Q1**	**Q2**	**Archetype (1) / Prototype (2)**
JE2	(Ejeta 2010)	AC	i	1	Food security—Agricultural challenges/issues	Perspective	Continent	Africa	USA	2010	African green revolution	Literature survey	1
JF14	(Furuya and Kobayashi 2009)	AC	i	1	Food security—Agricultural challenges/issues	Original	Global	Global	Japan	2008	Global warming affecting global food markets	Literature survey	1
JP11	(Peters et al. 2011)	AC	i	5	Air pollution—GHG Emission—Emission transfers	Original	Global	Global	Norway	2011	Emission transfers via international trade	Literature survey	1
JS35	(Suneetha 2010)	AC	i	6	Biodiversity—Habitat destruction—Trade	Original	-	N/A	Japan	2009	Biodiversity business issues with regard to sustainability	Literature survey	1
JL7	(Lee et al. 2008)	AC	ii	1	Energy policy/innovation	Report	-	N/A	USA	2008	Biofuels with regard to sustainable development	Summary report on multi-stake executive session	
JM21	(Moreira and Goldemberg 1999)	AC	ii	1	Energy policy/innovation	Original	Country	Brazil	Brazil	1999	Biofuel program	Literature survey	1
JT15	(Tsuji et al. 2011)	AC	ii	6	Biodiversity—Agriculture—Poverty	Original	Local	China	Japan	2010	Biodiversity for sustainable pest management	Field survey and simulation	

Table A7.2.4: Observed data on ELA-2 (sphere B, Society)													
Item ID	**Item**	**Sphere**	**Category**	**Theme ID**	**Theme**	**Article type**	**Scale**	**Place**	**Place of authorship (corresponding author)**	**Temporal**	**Q1**	**Q2**	**Archetype (1) / Prototype (2)**

Table A7.2.5: Observed data on ELA-2 (sphere BA, Econo-society)

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JA2	(Struble and Aomari 2003)	BA	i	1	Food security—Agricultural challenges/issues	Report	Global	Global	USA	2003	American Dietetic Association's position on global food insecurity	Literature survey	
JB1	(Barrett 2010)	BA	i	1	Food security—Agricultural challenges/issues	Note	-	N/A	USA	2010	Measuring food insecurity	Literature survey	1
JC6	(Godfray et al. 2010)	BA	i	1	Food security—Agricultural challenges/issues	Review	Global	Global	UK	2010	Food security	Literature survey	1
JC19	(Conway 2000)	BA	i	1	Food security—Agricultural challenges/issues	Original	Global	Global	USA	2000	Food security	Literature survey	1
JF9	(2010)	BA	i	1	Food security—Agricultural challenges/issues	Report	Global	Global	UK	2010	Food security	Literature review	
JF11	(Frongillo 1999)	BA	i	1	Food security—Agricultural challenges/issues	Original	Country	USA	USA	1998	Measuring food insecurity	Literature survey	1
JM10	(Matsumura et al. 2009)	BA	i	1	Food security—Agricultural challenges/issues	Report	Global	Global	Japan	2009	Mapping global demand and supply of rice	Literature survey	1
JW2	(Webb 2010)	BA	i	1	Food security—Agricultural challenges/issues	Original	Global	Global	USA	2010	Implications of high food price for global nutrition	Literature survey	1
JK10	(Kates 2000b)	BA	i	9	Population—Consumption—Environment	Original	-	N/A	USA	2000	Population and consumption	Literature survey	1
JP30	(GF 2009)	BA	ii	3	Interventions and development, and conservation	Report	Global	Global	USA	2009	Progress towards nutrition	Case reporting	

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JL2	(Larson and Ribot 2007)	BA	**ii**	**9**	Forest management policy/innovation	Original	Regional	Honduras-Senegal	USA	2007	Poverty of forestry policy	Literature survey and case study	
JT4	(Tester and Langridge 2010)	BA	**ii**	**10**	Agricultural policy/innovation	Review	-	N/A	Australia	2010	Breeding technologies to increase crop production	Literature review	
JK5	(Kates 1992)	BA	**iii**	**11**	Sustainability challenge	Keynote address	Global	Global	USA	1992	Meeting human needs in changing world	Opinion	

Table A7.2.6: Observed data on ELA-2 (sphere BC, Environo-society)

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JR4	(Rarieya and Fortun 2010)	BC	i	1	Food security—Agricultural challenges/issues	Original	Local	Kenya	USA	2009	Food security in climate-vulnerable area	Literature survey and field survey	
JG13	(Gleick 2003b)	BC	i	9	Population—Consumption—Environment	Review	Global	Global	USA	2003	Water use	Literature survey	1
JS16	(Shahbazbegian and Bagheri 2010)	BC	i	12	Drought	Original	Local	Iran	Iran	2009	Assessment of drought impacts	Systemic assessment	
JS20	(Snapp et al. 2010)	BC	ii	6	Biodiversity—Agriculture—Poverty	Original	Country	Malawi	USA	2010	Biodiversity to support greener revolution in Africa	Empirical field study	
JT7	(Timmer and Juma 2005)	BC	ii	6	Biodiversity—Agriculture—Poverty	Original	-	N/A	Canada	2005	Biodiversity conservation and poverty reduction in Tropics	Literature survey	1
JY10	(Yami et al. 2013)	BC	ii	9	Forest management policy/innovation	Original	Local	Ethiopia	Ethiopia	2012	Village bylaws in management of community managed exclosures	Literature survey and field survey	
JI5	(IAC 2004)	BC	ii	10	Agricultural policy/innovation	Report	Continent	Africa	Netherlands	2006	Realizing the potential of African agriculture	Reporting	
JT13	(Townsend and Porder 2012)	BC	ii	10	Agricultural policy/innovation	Commentary	-	N/A	USA	2012	Agricultural production and environmental consequences	Commentary	
JK41	(Kurian et al. 2013)	BC	iii	3	"Reuse" as theory	Original	Local	India	UK	2011	Wastewater reuse for peri-urban agriculture	Literature survey and empirical field study	

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JL22	(Lynam et al. 2007)	BC	**iii**	**6**	Natural capital & ecosystem services management/governance	Original	-	N/A	Zimbabwe	2007	Decision making in natural resources management	Literature survey	1
JS32	(Su et al. 2012)	BC	**iii**	**6**	Natural capital & ecosystem services management/governance	Original	Local	China	China	2011	Managing ecosystem based on ecosystem services and human activities	Case study	
JR6	(Raudsepp-Hearne et al. 2010)	BC	**iii**	**14**	Poverty—Development	Original	-	N/A	Canada	2010	Untangling the environmentalist's paradox	Literature survey	1
JK9	(Kates 2000a)	BC	**iii**	**17**	Adaptation	Original	Global	Global	USA	2000	Adaptation and the global poor	Literature survey	1
JM20	(Molua 2011)	BC	**iii**	**17**	Adaptation	Original	Country	Cameroon	Cameroon	2010	Typology of male and female adaptation to climate change	Literature survey and field survey	
JW13	(Wu et al. 2010)	BC	**iii**	**19**	Land cover and land use change science	Original	Regional	Asia	Japan	2009	Modeling changes in rice-sown areas in Asia	Modeling, empirical field study and simulation	2
JY4	(Yin and Xiang 2010)	BC	**iii**	**19**	Land cover and land use change science	Original	Local	China	USA	2009	Modeling land use changes	Literature survey and modeling	2

Table A7.2.7: Observed data on ELA-2 (sphere C, Environment)													
Item ID	**Item**	**Sphere**	**Category**	**Theme ID**	**Theme**	**Article type**	**Scale**	**Place**	**Place of authorship (corresponding author)**	**Temporal**	**Q1**	**Q2**	**Archetype (1) / Prototype (2)**
JO8	(Overpeck and Cole 2006)	C	**i**	**11**	Climate change problem/impacts	Review	Global	Global	USA	2006	Abrupt climate change	Literature review	
JK4	(Kasei et al. 2010)	C	**i**	**12**	Drought	Original	Regional	Africa	Germany	2009	Drought frequency in Volta basin	Literature survey	1
JB14	(Boyce et al. 2010)	C	**i**	**14**	Ecological crisis	Original	Global	Global	Canada	2010	Global phytoplankton decline	Literature survey	1
JG22	(Grainger 2008)	C	**i**	**14**	Ecological crisis	Original	Global	Global	UK	2008	Long-term global trend in tropical forest	Literature survey	1
JJ9	(Jin et al. 2008)	C	**ii**	**12**	Modeling	Original	-	N/A	USA	2008	ENSO prediction skill in coupled ocean-atmosphere models	Literature survey	1

Table A7.2.8: Observed data on ELA-2 (sphere CA, Econo-environment)													
Item ID	**Item**	**Sphere**	**Category**	**Theme ID**	**Theme**	**Article type**	**Scale**	**Place**	**Place of authorship (corresponding author)**	**Temporal**	**Q1**	**Q2**	**Archetype (1) / Prototype (2)**
JB8	(Birch et al. 2010)	CA	**ii**	**9**	Forest management policy/innovation	Original	Regional	North and South America	UK	2010	Dryland forest restoration and ecosystem services	Literature survey, scenario study and field survey	
JD11	(Diallo and Brinker 2011)	CA	**ii**	**16**	Technology and nanotechnology	Report	-	N/A	USA	2011	Nanotechnologies for environment, water, food, minerals and climate	Literature survey	1
JC21	(Costanza et al. 1997)	CA	**iii**	**6**	Natural capital & ecosystem services management/governance	Original	Global	Global	USA	1997	Value of ecosystem services and natural capital	Literature survey	1

Table A7.2.9: Observed data on ELA-2 (sphere CB, Socio-environment)

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JM3	(MacDonald et al. 2011)	CB	i	1	Food security—Agricultural challenges/issues	Original	Global	Global	Canada	2011	Global phosphorus imbalance in croplands	Literature survey	1
JM9	(Marty et al. 2010)	CB	i	1	Food security—Agricultural challenges/issues	Original	Local	Canada	USA	2010	Relationship of farm salmon, sea lice and wild salmon population	Literature survey	1
JS1	(Sachs et al. 2010)	CB	i	1	Food security—Agricultural challenges/issues	Report	Global	Global	USA	2010	Monitoring global agriculture	Opinion	
JS8	(Sattari et al. 2012)	CB	i	1	Food security—Agricultural challenges/issues	Original	Global	Global	Netherlands	2012	Residual soil phosphorus and global phosphorus crisis	Literature survey	1
JD13	(Dirzo and Raven 2003)	CB	i	6	Biodiversity—Habitat destruction—Trade	Original	Global	Global	Mexico	2003	State of global biodiversity	Literature survey	1
JG8	(Geist and Lambin 2002)	CB	i	6	Biodiversity—Habitat destruction—Trade	Original	Global	Global	Belgium	2002	Causes and driving forces of tropical deforestation	Literature survey	1
JS4	(Sala and Knowlton 2006)	CB	i	6	Biodiversity—Habitat destruction—Trade	Review	Global	Global	USA	2006	Global marine biodiversity trends	Literature review	
JN2	(NAS 2008)	CB	i	11	Climate change problem/impacts	Review	Global	Global	USA	2008	Understanding on and responding to climate change	Literature review	
JS3	(Sahoo and Schladow 2008)	CB	i	11	Climate change problem/impacts	Original	Local	USA	USA	2008	Climate change impacts on lakes and reservoir dynamics	Literature survey and simulation	
JP18	(Postel 2005)	CB	i	14	Ecological crisis	Original	-	N/A	USA	2005	Protecting freshwater ecosystems	Literature survey	1

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JR14	(Romieu et al. 2010)	CB	i	15	Coastal vulnerability issues & sea level rise	Original	-	N/A	France	2010	Vulnerability assessments between climate change and natural hazards context	Literature survey	1
JS2	(Safriel and Adeel 2008)	CB	ii	2	Alternative livelihood	Original	Global	Global	Canada	2007	Dryland development pathways	Literature survey	1
JA23	(Azadi et al. 2013)	CB	ii	9	Forest management policy/innovation	Original	Local	Iran	Belgium	2012	Forest management in Iran	Literature survey and field survey	
JL4	(Lebel et al. 2004)	CB	ii	9	Forest management policy/innovation	Original	Regional	Asia	Thailand	2003	Forest management and governance in southeast Asia	Literature survey	1
JS24	(Sonwa et al. 2011)	CB	ii	9	Forest management policy/innovation	Review	Regional	Africa	Cameroon	2010	Forestry efforts and climate change mitigation	Literature review	
JY8	(Yoshikawa et al. 2011)	CB	ii	9	Forest management policy/innovation	Original	Global	Global	Japan	2011	Quantitative assessment of global forest biodiversity	Literature survey	1
JC4	(Cassman et al. 2003)	CB	ii	10	Agricultural policy/innovation	Original	-	N/A	USA	2003	Agricultural production with protecting natural resources and improving environmental quality	Literature survey	1
JC7	(Chen et al. 2011)	CB	ii	10	Agricultural policy/innovation	Original	Local	China	China	2011	Integrated soil-crop system management	Literature survey, field survey and empirical field study	
JF4	(Fedoroff et al. 2010)	CB	ii	10	Agricultural policy/innovation	Perspective	Global	Global	USA	2010	Rethinking agriculture	Opinion	

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JG4	(Gebbers and Adamchuk 2010)	CB	**ii**	**10**	Agricultural policy/innovation	Perspective	-	N/A	Germany	2010	Precision agriculture	Literature survey	1
JG9	(Gewin 2010)	CB	**ii**	**10**	Agricultural policy/innovation	Report	-	N/A	USA	2010	Root-based agricultural revolution	Reporting	
JH13	(Herdt 2006)	CB	**ii**	**10**	Agricultural policy/innovation	Original	-	N/A	USA	2006	Biotechnology in agriculture	Literature survey	1
JH15	(Herrero et al. 2010)	CB	**ii**	**10**	Agricultural policy/innovation	Perspective	-	N/A	Kenya	2010	Mixed crop-livestock systems	Literature survey	1
JR11	(Roberts and Brink 2010)	CB	**ii**	**10**	Agricultural policy/innovation	Original	Global	Global	USA	2010	Marine resources management	Literature survey	1
JS43	(Spugnoli and Dainelli 2013)	CB	**ii**	**10**	Agricultural policy/innovation	Original	-	N/A	Italy	2012	Draught animal and tractor power in agriculture	Literature survey	1
JT8	(Tollefson 2010)	CB	**ii**	**10**	Agricultural policy/innovation	Report	Country	Brazil	USA	2010	Giant-scale agriculture	Reporting	
JK22	(Katsuyama et al. 2009)	CB	**ii**	**12**	Modeling	Original	Local	Japan	Japan	2009	Effects of logging in forested watersheds	Literature survey, empirical field study, empirical analysis and simulation	2
JO3	(Ohyama et al. 2008)	CB	**ii**	**14**	Urban policy/innovation	Report	-	N/A	Japan	2008	Urban horticulture and environmental conservation	Literature survey	1
JZ2	(Zhang et al. 2006)	CB	**ii**	**15**	Reuse—Recycling—Pollution control	Original	Local	China	China	2006	Non-point-source pollution control by rural resource recycling	Field survey and modeling	
JG14	(Gleick 2003a)	CB	**ii**	**17**	Water policy/innovation	Original	Global	Global	USA	2003	Soft-path solutions for global freshwater resources	Literature survey	1
JH14	(Hermanowicz 2008)	CB	**ii**	**17**	Water policy/innovation	Original	-	N/A	USA	2008	Perception in water resources management	Literature survey	1

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JB15	(Brack et al. 2006)	CB	ii	19	Emission estimation/control	Overview	Country	Australia	Australia	2006	Integrated GHG emission estimation from land systems	Literature survey and modeling	
JH6	(Hara et al. 2010)	CB	ii	20	Land use system planning/innovation	Original	Local	Thailand	Japan	2010	Mixed land-use planning on large city periphery in Thailand	Case study	
JK33	(Kimura et al. 2010)	CB	ii	20	Land use system planning/innovation	Original	Local	Japan	Japan	2009	Eco-balance analysis of land use combinations	Empirical field study, field survey, modeling	
JK39	(Kumar and Takeuchi 2009)	CB	ii	20	Land use system planning/innovation	Overview	Regional	Asia	India	2009	Sustainable agroforest land use systems in Asia	Literature survey	1
JL5	(Leclerc et al. 2009)	CB	ii	20	Land use system planning/innovation	Report	Local	Senegal	Senegal	2009	Participatory modeling experiment on land use	Literature survey and action-research	
JH19	(Hoekstra 2012)	CB	ii	21	Biodiversity conservation policy/innovation	Commentary	-	N/A	USA	2012	Biodiversity conservation and modern portfolio theory	Literature survey	1
JL10	(Lejano and Ingram 2007)	CB	ii	21	Biodiversity conservation policy/innovation	Original	Local	Philippine	USA	2007	Place-based conservation and 'Turtle Islands'	Literature survey	1
JS6	(Sarkar et al. 2006)	CB	ii	21	Biodiversity conservation policy/innovation	Review	-	N/A	USA	2006	Biodiversity conservation planning tools	Literature review	
JJ1	(Jack et al. 2008)	CB	ii	22	Ecosystem services policy/innovation	Policy analysis	-	N/A	USA	2008	Designing payments for ecosystem services	Policy analysis	
JK35	(Komatsuzaki and Ohta 2007)	CB	ii	22	Ecosystem services policy/innovation	Report	-	N/A	Japan	2006	Soil management practices in agro-ecosystems	Literature survey	1
JT9	(Tomich et al. 2004)	CB	ii	22	Ecosystem services policy/innovation	Original	Regional	Asia	Kenya	2004	Environmental services and land use change in southeast Asia	Literature survey	1

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JX1	(Xia and Yan 2012)	CB	ii	22	Ecosystem services policy/innovation	Original	Local	China	China	2011	Ecologically optimal nitrogen rates in rice cropping	Literature survey and modeling	
JC2	(Carpenter et al. 2009)	CB	iii	6	Natural capital & ecosystem services management/governance	Perspective	-	N/A	USA	2009	Ecosystem services management science	Literature survey	1
JD2	(Daily and Matson 2008)	CB	iii	6	Natural capital & ecosystem services management/governance	Perspective	-	N/A	USA	2008	Ecosystem services implementation	Literature survey	1
JF5	(Ferraro Jr. and Burztyn 2008)	CB	iii	6	Natural capital & ecosystem services management/governance	Original	Local	Brazil	USA	2008	Managing other factors in common pool resource management	Literature survey	1
JG3	(Gardi and Sconosciuto 2007)	CB	iii	6	Natural capital & ecosystem services management/governance	Original	Local	Italy	Italy	2007	Evaluation of soil carbon stock variation	Literature survey	1
JH4	(Halpin 1997)	CB	iii	6	Natural capital & ecosystem services management/governance	Overview	-	N/A	USA	1996	Managing global climate change and protecting natural areas	Literature survey	1
JB20	(Bueno and Basurto 2009)	CB	iii	8	Resilience	Original	Local	Mexico	USA	2009	Resilience and collapse of shellfish fishery in Mexico	Literature survey, modeling and simulation	
JM5	(Mah and Bustami 2012)	CB	iii	8	Resilience	Report	Local	Malaysia	Malaysia	2011	Resilience of riparian wetlands and river channels	Literature survey	1
JD9	(DeFries et al. 2006)	CB	iii	19	Land cover and land use change science	Original	-	N/A	USA	2006	Landscapes, livelihoods and environment	Literature survey	1
JG1	(Gadda and Gasparatos 2009)	CB	iii	19	Land cover and land use change science	Original	Local	Japan	Brazil	2009	Land use and cover change and meat consumption in Tokyo	Literature survey	1
JI4	(Ileva et al. 2009)	CB	iii	19	Land cover and land use change science	Original	Local	Japan	Japan	2008	Nitrogen in river and land use in river watershed	Empirical analysis	

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JL1	(Lambin et al. 2003)	CB	**iii**	**19**	Land cover and land use change science	Original	Global	Global	Belgium	2003	Dynamics of land-use and land-cover change	Literature survey	1
JP15	(Pontius Jr and Neeti 2010)	CB	**iii**	**19**	Land cover and land use change science	Original	Local	USA	USA	2009	Maps of future land change scenarios	Literature survey	1

Table A7.2.10: Observed data on ELA-2 (sphere D, Central organization of sustainability)

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JI6	(IPCC 2007)	**D**	**i**	**11**	Climate change problem/impacts	Communication	Global	Global	Global	2007	IPCC 2007 report 'summary for policymakers'	Synthesis	
JZ7	(Ziv et al. 2012)	**D**	**i**	**19**	River — problems	Original	Regional	Asia	USA	2012	Trading-off fish biodiversity, food security and hydropower	Literature survey	1
JN3	(Nautiyal 2011)	**D**	**ii**	**3**	Interventions and development, and conservation	Original	Local	India	India	2011	Addressing conservation and sustainable livelihood development together in Himalaya	Field survey	
JM18	(Millar et al. 2007)	**D**	**ii**	**9**	Forest management policy/innovation	Original	-	N/A	USA	2007	Managing forest future in uncertainty	Literature survey	1
JA6	(Alcamo et al. 2005)	**D**	**ii**	**12**	Modeling	Original	Global	Global	Germany	2005	Model estimation of future worldwide ecosystem services	Literature survey	1
JZ8	(Zwane et al. 2009)	**D**	**ii**	**17**	Water policy/innovation	Report	-	N/A	USA	2009	Water and human wellbeing	Summary report on multi-stake executive session	
JS21	(Soberon 2004)	**D**	**ii**	**21**	Biodiversity conservation policy/innovation	Original	-	N/A	Mexico	2004	Communication between scientists and policymakers regarding biodiversity	Literature survey	1

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JH2	(Haberl et al. 2007)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance	Original	Global	Global	Austria	2007	Quantifying and mapping human appropriation of primary production of terrestrial ecosystems	Literature survey	1
JK26	(Kenward et al. 2011)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance	Original	-	N/A	UK	2011	Governance strategies effectively supporting ecosystem services, resource sustainability and biodiversity	Field survey and case studies	
JO6	(Ostrom and Nagendra 2006)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance	Original	-	N/A	USA	2006	Linking forests, trees and people from the air, on the ground and in the laboratory	Literature survey	1
JG21	(Graffy 2012)	**D**	**iii**	**11**	Sustainability challenge	Original	-	N/A	USA	2011	Agrarian ideals and sustainability ethics	Literature survey	1
JR9	(Rindfuss et al. 2004)	**D**	**iii**	**19**	Land cover and land use change science	Review	-	N/A	USA	2004	Methodological issues of land change science	Literature survey	1
JS11	(Schaldach and Priess 2008)	**D**	**iii**	**19**	Land cover and land use change science	Review	Global	Global	Germany	2008	Modeling approaches on regional to global scale	Literature review	
JT18	(Turner et al. 2007)	**D**	**iii**	**19**	Land cover and land use change science	Perspective	Global	Global	USA	2007	Land change science	Literature survey	1
JB22	(Burns et al. 2003)	**D**	**iii**	**21**	World System theory	Original	Global	Global	USA	2003	Deforestation in late 20th century	Literature survey	1
JK38	(Kristjanson et al. 2009)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Original	Regional	Africa and Asia	Kenya	2009	Linking international agricultural research knowledge with action	Literature survey	1

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JM28	(Marsden 2013)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Original	-	N/A	UK	2012	Sustainable place-making for sustainability science	Literature survey	1
JD8	(Dearing et al. 2010)	**D**	**iii**	**38**	Complex systems, analysis, and adaptive planning/management	Synthesis	-	N/A	UK	2010	Assessing future of complex land systems	Literature survey	1
JD15	(Drechsel and Dongus 2010)	**D**	**iii**	**40**	Urban agriculture	Original	Local	Tanzania	Sri Lanka	2008	Dynamics of urban agriculture	Literature survey	1

Table A7.3.1: Observed data on ELA-3 (sphere A, Economy)													
Item ID	**Item**	**Sphere**	**Category**	**Theme ID**	**Theme**	**Article type**	**Scale**	**Place**	**Place of authorship (corresponding author)**	**Temporal**	**Q1**	**Q2**	**Archetype (1) / Prototype (2)**
JB26	(Berkhout et al. 2012)	A	ii	1	Energy policy/innovation	Editorial	-	N/A	Netherlands	2012	Energy transitions	Editorial	
JG12	(Gillingham et al. 2006)	A	ii	1	Energy policy/innovation	Review	-	N/A	USA	2006	Energy efficiency policies	Review	

Table A7.3.2: Observed data on ELA-3 (sphere AB, Socio-economy)													
Item ID	**Item**	**Sphere**	**Category**	**Theme ID**	**Theme**	**Article type**	**Scale**	**Place**	**Place of authorship (corresponding author)**	**Temporal**	**Q1**	**Q2**	**Archetype (1) / Prototype (2)**
JB7	(Bettencourt et al. 2007)	AB	i	4	Urbanization—Consumption—Environment	Original	-	N/A	USA	2007	Growth and innovation in life in cities	Literature survey	1
JT2	(Takiguchi and Morita 2009)	AB	ii	5	Low-carbon transitions	Original	Country	Japan	Japan	2008	Sustainability of silicon feedstock	Literature survey	1

Table A7.3.3: Observed data on ELA-3 (sphere AC, Environo-economy)													
Item ID	**Item**	**Sphere**	**Category**	**Theme ID**	**Theme**	**Article type**	**Scale**	**Place**	**Place of authorship (corresponding author)**	**Temporal**	**Q1**	**Q2**	**Archetype (1) / Prototype (2)**
JC8	(Chong and Sunding 2006)	AC	i	2	Water availability/quality	Review	Local	USA	USA	2006	Complications of water supply-demand-markets-trading	Literature survey	1
JK31	(Kim 2006)	AC	i	3	Industrialization—Energy—Environment	Overview	Regional	Asia	R. Korea	2006	Industrialization and environment in East Asia	Literature survey	1
JS17	(Shi et al. 2011)	AC	i	3	Industrialization—Energy—Environment	Original	Country	China	China	2011	Real cost of economic growth in China	Literature survey	1
JS27	(Steinfeld 2006)	AC	ii	1	Energy policy/innovation	Note	-	N/A	USA	2006	Green chemistry and future of energy	Literature survey	1
JM11	(Matsuoka et al. 2008)	AC	ii	5	Low-carbon transitions	Original	Country	Japan	Japan	2007	Implications in Japan for 50% global reduction in GHG emissions	Literature survey	1
JP31	(Patterson and Glavovic 2013)	AC	iii	7	Ecological economics	Original	-	N/A	New Zealand	2012	Ecological economics of oceans and coasts	Literature survey	1

Table A7.3.4: Observed data on ELA-3 (sphere B, Society)													
Item ID	**Item**	**Sphere**	**Category**	**Theme ID**	**Theme**	**Article type**	**Scale**	**Place**	**Place of authorship (corresponding author)**	**Temporal**	**Q1**	**Q2**	**Archetype (1) / Prototype (2)**
JC18	(Colten et al. 2008)	B	iii	8	Resilience	Report	Local	USA	USA	2008	Community resilience lessons after Katrina	Literature survey	1

Table A7.3.5: Observed data on ELA-3 (sphere BA, Econo-society)													
Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JM8	(Marcotullio 2007)	BA	i	2	Water availability/quality	Original	Regional	Asia	USA	2006	Urban water-environmental transitions in southeast Asia	Literature survey	1
JH23	(Homs 2007)	BA	i	4	Urbanization—Consumption—Environment	Original	-	N/A	France	2007	Urban village	Literature survey	1
JD17	(Diffenbaugh 2013)	BA	ii	5	Low-carbon transitions	Note	Global	Global	USA	2012	Global GHG emissions debt and human well-being	Literature survey	1
JT14	(Trieb and Müller-Steinhagen 2007)	BA	ii	11	Regional cooperation	Original	Regional	Eu-ME-NA	Germany	2007	Electricity and water cooperation among Europe-Middle East-North Africa	Literature survey	1
JM13	(McGee 2008)	BA	iii	13	Rural-urban transformation	Overview	Regional	Asia	Canada	2007	Rural-urban transformation in East Asia	Literature survey and case study	
JS5	(Sanya 2012)	BA	iii	15	Sustainable architecture	Original	Country	Uganda	South Africa	2011		Literature survey	1

Table A7.3.6: Observed data on ELA-3 (sphere BC, Environo-society)

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JK25	(Kazama et al. 2012)	BC	i	7	Public health	Original	Country	Cambodia	Japan	2011	Risk assessment of inundation waterborne infectious disease	Risk modeling	
JG13	(Gleick 2003b)	BC	i	9	Population—Consumption—Environment	Review	Global	Global	USA	2003	Water use	Literature survey	1
JO1	(O'Neill et al. 2010)	BC	i	9	Population—Consumption—Environment	Original	Global	Global	USA	2010	Demographic trends and future carbon emissions	Literature survey	1
JS16	(Shahbazbegian and Bagheri 2010)	BC	i	12	Drought	Original	Local	Iran	Iran	2009	Assessment of drought impacts	Systemic assessment	
JS38	(Syvitski 2008)	BC	i	13	Delta — problems	Original	Global	Global	USA	2007	Vulnerability of deltas	Literature survey	1
JH33	(Higgins and Foliente 2013)	BC	ii	3	Interventions and development, and conservation	Original	Local	Australia	Australia	2012	Evaluation of intervention options for environmental benefits in residential sector	Literature survey and case study	
JT11	(Toth and Hizsnyik 2008)	BC	ii	4	Community involvement	Original	-	N/A	Austria	2008	Participatory assessments of extreme climate change impacts and responses	Literature survey	1
JG17	(Gomi et al. 2007)	BC	ii	5	Low-carbon transitions	Report	Local	Japan	Japan	2006	Scenario development for low carbon future	Scenario study	
JN1-4	(Ross and Woo 2011)	BC	ii	11	Regional cooperation	Original	Country	USA	USA	2011	Megaregions and mobility	Literature survey	1
JA22	(Antanasijević et al. 2013)	BC	ii	12	Modeling	Original	Continent	Europe	Serbia	2011	Forecasting of municipal waste generation	Modeling	

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JS36	(Surjan and Shaw 2008)	BC	ii	14	Urban policy/innovation	Report	Local	India	Japan	2008	Eco-city to disaster-resilient eco-community	Literature survey	1
JU3	(UN-Habitat 2012)	BC	ii	14	Urban policy/innovation	Report	Global	Global	Kenya	2012	Urban planning	Literature survey	1
JW9	(Wilbanks et al. 2007)	BC	ii	14	Urban policy/innovation	Original	Local	India	USA	2007	Climate change vulnerabilities and responses	Literature survey	1
JK41	(Kurian et al. 2013)	BC	iii	3	"Reuse" as theory	Original	Local	India	UK	2011	Wastewater reuse for peri-urban agriculture	Literature survey and empirical field study	
JS32	(Su et al. 2012)	BC	iii	6	Natural capital & ecosystem services management/governance	Original	Local	China	China	2011	Managing ecosystem based on ecosystem services and human activities	Case study	
JK37	(Kosamu 2011)	BC	iii	15	Sustainable architecture	Original	Country	Malawi	Malawi	2010	Application of environmental impact assessment in infrastructural projects	Literature survey and field survey	
JN1-3	(Brown 2011)	BC	iii	15	Sustainable architecture	Original	Country	USA	USA	2011	Next-generation infrastructure	Literature survey	1
JB10	(Birkmann et al. 2010)	BC	iii	16	Urban sustainability and adaptive urban governance	Original	-	N/A	Germany	2010	Adaptive urban governance	Literature survey	1
JS9	(Satterthwaite 2007)	BC	iii	16	Urban sustainability and adaptive urban governance	Original	-	N/A	UK	2007	Urban challenge	Literature survey	1
JS23	(Solecki and Leichenko 2006)	BC	iii	16	Urban sustainability and adaptive urban governance	Original	-	N/A	USA	2006	Urbanization and metropolitan environment	Literature survey	
JK9	(Kates 2000a)	BC	iii	17	Adaptation	Original	Global	Global	USA	2000	Adaptation and the global poor	Literature survey	1
JM31	(Mohamad et al. 2012)	BC	iii	20	Sustainability—Culture—Religion	Original	Country	Malaysia	Malaysia	2012	Religious community in solid waste management	Literature survey	1

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JT1	(Tàbara and Ilhan 2008)	BC	**iii**	**20**	Sustainability—Culture—Religion	Original	Country	Spain	Spain	2007	Role of culture in triggering sustainability transition in water domain	Literature survey	1
JW5	(White et al. 2001)	BC	**iii**	**22**	Learning—Knowledge—Ignorance—Condition	Original	-	N/A	USA	2001	Use of knowledge in hazards management	Literature survey	1

Table A7.3.7: Observed data on ELA-3 (sphere C, Environment)													
Item ID	**Item**	**Sphere**	**Category**	**Theme ID**	**Theme**	**Article type**	**Scale**	**Place**	**Place of authorship (corresponding author)**	**Temporal**	**Q1**	**Q2**	**Archetype (1) / Prototype (2)**
JP17	(Pöschl 2005)	C	**i**	**5**	Air pollution—GHG Emission—Emission transfers	Review	-	N/A	Germany	2005	Atmospheric aerosols	Literature review	
JO8	(Overpeck and Cole 2006)	C	**i**	**11**	Climate change problem/impacts	Review	Global	Global	USA	2006	Abrupt climate change	Literature review	
JC9	(Church et al. 2008)	C	**i**	**15**	Coastal vulnerability issues & sea level rise	Original	Global	Global	Australia	2007	Understanding global sea levels	Literature survey	1

Table A7.3.8: Observed data on ELA-3 (sphere CA, Econo-environment)													
Item ID	**Item**	**Sphere**	**Category**	**Theme ID**	**Theme**	**Article type**	**Scale**	**Place**	**Place of authorship (corresponding author)**	**Temporal**	**Q1**	**Q2**	**Archetype (1) / Prototype (2)**
JE5	(Esteban et al. 2009)	CA	**i**	**16**	Global warming—Natural disaster	Original	Country	Taiwan	Japan	2009	Global warming, typhoon intensity and urban productivity	Simulation	
JK24	(Kazama et al. 2010)	CA	**ii**	**12**	Modeling	Original	Country	Japan	Japan	2008	Evaluating cost of flood damage	Modeling and simulation	
JD11	(Diallo and Brinker 2011)	CA	**ii**	**16**	Technology and nanotechnology	Report	-	N/A	USA	2011	Nanotechnologies for environment, water, food, minerals and climate	Literature survey	1
JE4	(Esposto 2009)	CA	**ii**	**17**	Water policy/innovation	Report	Local	Iraq	Switzerland	2008	Water treatment plant design with regard to sustainability in Iraq	Case reporting	

Table A7.3.9: Observed data on ELA-3 (sphere CB, Socio-environment)

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JM19	(Molina and Molina 2004)	CB	i	5	Air pollution—GHG Emission—Emission transfers	Review	Global	Global	USA	2004	Megacities and atmospheric pollution	Literature survey	1
JN2	(NAS 2008)	CB	i	11	Climate change problem/impacts	Review	Global	Global	USA	2008	Understanding on and responding to climate change	Literature review	
JG23	(Gravelle and Mimura 2008)	CB	i	15	Coastal vulnerability issues & sea level rise	Original	Local	Fiji	Japan	2008	Vulnerability assessment of sea level rise	Literature survey	1
JH9	(Harvey and Woodroffe 2008)	CB	i	15	Coastal vulnerability issues & sea level rise	Original	Country	Australia	Australia	2007	Coastal vulnerability assessment	Literature survey	1
JM15	(Mcleod et al. 2010)	CB	i	15	Coastal vulnerability issues & sea level rise	Report	Regional	Asia	USA	2010	Vulnerability assessment of sea level rise	Literature survey	1
JN7	(Nicholls et al. 2008)	CB	i	15	Coastal vulnerability issues & sea level rise	Original	-	N/A	UK	2007	Coastal vulnerability assessment	Literature survey	1
JR14	(Romieu et al. 2010)	CB	i	15	Coastal vulnerability issues & sea level rise	Original	-	N/A	France	2010	Vulnerability assessments between climate change and natural hazards context	Literature survey	1
JT10	(Torresan et al. 2008)	CB	i	15	Coastal vulnerability issues & sea level rise	Original	-	N/A	Italy	2007	Coastal vulnerability assessment	Literature survey	1
JY2	(Yasuhara et al. 2007)	CB	i	15	Coastal vulnerability issues & sea level rise	Original	Regional	Asia	Japan	2006	Coastal infrastructural instability due to global warming	Modeling and case histories	
JY3	(Yasuhara et al. 2011)	CB	i	15	Coastal vulnerability issues & sea level rise	Overview	Country	Japan	Japan	2009	Climate change effects on coastal disasters	Literature survey	1

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JS2	(Safriel and Adeel 2008)	CB	ii	2	Alternative livelihood	Original	Global	Global	Canada	2007	Dryland development pathways	Literature survey	1
JB2	(Barthelmie et al. 2008)	CB	ii	5	Low-carbon transitions	Report	Local	Scotland	UK	2008	Renewable energy options for carbon footprint reduction	Literature survey and modeling	
JB9	(Birkmann and von Teichman 2010)	CB	ii	13	Adaptation—Natural Disaster—Migration—Benefits	Original	-	N/A	Germany	2010	Disaster risk reduction and climate change adaptation	Literature survey	1
JS30	(von Storch and Woth 2008)	CB	ii	13	Adaptation—Natural Disaster—Migration—Benefits	Review	Regional	Europe	Germany	2007	Storm surges	Literature survey	1
JO3	(Ohyama et al. 2008)	CB	ii	14	Urban policy/innovation	Report	-	N/A	Japan	2008	Urban horticulture and environmental conservation	Literature survey	1
JN1-6	(Graedel 2011)	CB	ii	15	Reuse—Recycling—Pollution control	Original	-	N/A	USA	2011	Urban mining	Literature survey	1
JD3	(Daniell et al. 2010)	CB	ii	17	Water policy/innovation	Synthesis	-	N/A	Australia	2010	Participatory water management processes	Literature survey	
JG14	(Gleick 2003a)	CB	ii	17	Water policy/innovation	Original	Global	Global	USA	2003	Soft-path solutions for global freshwater resources	Literature survey	1
JH14	(Hermanowicz 2008)	CB	ii	17	Water policy/innovation	Original	-	N/A	USA	2008	Perception in water resources management	Literature survey	1
JH6	(Hara et al. 2010)	CB	ii	20	Land use system planning/innovation	Original	Local	Thailand	Japan	2010	Mixed land-use planning on large city periphery in Thailand	Case study	
JT9	(Tomich et al. 2004)	CB	ii	22	Ecosystem services policy/innovation	Original	Regional	Asia	Kenya	2004	Environmental services and land use change in southeast Asia	Literature survey	1

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JL18	(Longhurst et al. 2009)	CB	ii	23	Air quality policy/innovation	Original	-	N/A	UK	2008	Air quality management system	Literature survey	1
JD10	(Depietri et al. 2012)	CB	iii	6	Natural capital & ecosystem services management/governance	Review	-	N/A	Spain	2011	Heat waves and floods in urban areas from policy-perspective	Literature survey	1
JP19	(Potschin and Haines-Young 2006b)	CB	iii	11	Sustainability challenge	Editorial	-	N/A	UK	2005	Landscapes and sustainability	Literature survey	1
JS28	(Stocker et al. 2010)	CB	iii	11	Sustainability challenge	Original	Country	Australia	Australia	2010	Coastal zone management in Australia	Literature survey	1
JD9	(DeFries et al. 2006)	CB	iii	19	Land cover and land use change science	Original	-	N/A	USA	2006	Landscapes, livelihoods and environment	Literature survey	1
JP15	(Pontius Jr and Neeti 2010)	CB	iii	19	Land cover and land use change science	Original	Local	USA	USA	2009	Maps of future land change scenarios	Literature survey	1

Table A7.3.10: Observed data on ELA-3 (sphere D, Central organization of sustainability)

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JH31	(Han et al. 2012)	D	ii	14	Urban policy/innovation	Overview	Global	Global	Japan	2012	Innovation for future of industrialized cities	Literature survey	1
JN1-1	(Fink 2011)	D	ii	14	Urban policy/innovation	Overview	-	N/A	USA	2011	Urban genome project	Opinion	
JZ8	(Zwane et al. 2009)	D	ii	17	Water policy/innovation	Report	-	N/A	USA	2009	Water and human wellbeing	Summary report on multi-stake executive session	
JZ3	(Zhang et al. 2009)	D	iii	4	Circular economy	Report	Local	China	Japan	2009	Socio-economic and environmental performances of eco-industrial parks in China	Field study	
JF3	(Fan and Qi 2010)	D	iii	5	Quantitative sustainability	Original	Local	China	USA	2009	Assessing sustainability of cities in China	Literature survey and case study	
JW11	(Wilderer 2007)	D	iii	6	Natural capital & ecosystem services management/governance	Editorial	-	N/A	Germany	2007	Science behind water resource management	Editorial	
JG21	(Graffy 2012)	D	iii	11	Sustainability challenge	Original	-	N/A	USA	2011	Agrarian ideals and sustainability ethics	Literature survey	1
JS10	(Savage 2006)	D	iii	11	Sustainability challenge	Original	Regional	Asia	Singapore	2006	Development in southeast Asia	Literature survey	1
JS34	(Sumi 2007)	D	iii	11	Sustainability challenge	Overview	-	N/A	Japan	2006	Efforts toward a sustainable society	Opinion	
JM14	(McGranahan and Satterthwaite 2003)	D	iii	16	Urban sustainability and adaptive urban governance	Original	Global	Global	UK	2003	Assessment of sustainability in urban centers	Literature survey	1
JN1-2	(Daigger 2011)	D	iii	16	Urban sustainability and adaptive urban governance	Original	-	N/A	USA	2011	Urban water and resource management	Literature survey	1

Item ID	Item	Sphere	Category	Theme ID	Theme	Article type	Scale	Place	Place of authorship (corresponding author)	Temporal	Q1	Q2	Archetype (1) / Prototype (2)
JN1-5	(Bai 2011)	**D**	**iii**	**16**	Urban sustainability and adaptive urban governance	Original	Continent	Asia	Australia	2011	Patterns of urban sustainability in Asia	Literature survey	1
JR9	(Rindfuss et al. 2004)	**D**	**iii**	**19**	Land cover and land use change science	Review	-	N/A	USA	2004	Methodological issues of land change science	Literature survey	1
JS11	(Schaldach and Priess 2008)	**D**	**iii**	**19**	Land cover and land use change science	Review	Global	Global	Germany	2008	Modeling approaches on regional to global scale	Literature review	
JT18	(Turner et al. 2007)	**D**	**iii**	**19**	Land cover and land use change science	Perspective	Global	Global	USA	2007	Land change science	Literature survey	1
JM28	(Marsden 2013)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Original	-	N/A	UK	2012	Sustainable place-making for sustainability science	Literature survey	1
JY9	(Young et al. 2006)	**D**	**iii**	**38**	Complex systems, analysis, and adaptive planning/management	Original	-	N/A	USA	2006	Portfolio to analyzing complex human-environment interactions	Literature survey	1
JD15	(Drechsel and Dongus 2010)	**D**	**iii**	**40**	Urban agriculture	Original	Local	Tanzania	Sri Lanka	2008	Dynamics of urban agriculture	Literature survey	1
JP20	(Potschin and Haines-Young 2006a)	**D**	**iii**	**49**	Landscape ecology	Original	-	N/A	UK	2005	Landscape ecology and sustainability science	Literature survey	1

Appendix 8

Intermediary analyses for the 'empirical literature analyses – 1, 2 and 3'

A structured form is adopted in presenting the analyses. In some parts of the analyses the insights are grouped by the four broad spheres irrespective of further grouping by the three categories, whereas in the remainder parts they are presented in a combined form, grouped by the three categories. The four broad spheres are — the 'broad sphere A' (i.e. 'economic perspectives of sustainability', comprised of **Tables A7.1.1 – A7.1.3**, which present the observed data on the spheres of economy(A), socio-economy(AB) and environo-economy(AC)), the 'broad sphere B' (i.e. 'social perspectives of sustainability', comprised of **Tables A7.1.4 – A7.1.6**, which present the observed data on the spheres of society(B), econo-society(BA) and environo-society(BC)), the 'broad sphere C' (i.e. 'environmental perspectives of sustainability', comprised of **Tables A7.1.7 – A7.1.9**, which present the observed data on the spheres of environment(C), econo-environment(CA) and socio-environment(CB)), and the 'broad sphere D' (i.e. 'central organization of sustainability', comprised of **Table A7.1.10**, presenting the observed data on the sphere D). The three categories are – 'Category – i' i.e. the 'problem/ issue/ challenge/ syndrome-sphere', 'Category – ii' i.e. the 'action/ approach-sphere', and 'Category – iii' i.e. the academic-sphere. See **Section 3.4.3** for details on these three categories and the 10 spheres including the four broad spheres comprising these 10 spheres.

A8.1 Empirical literature analysis (ELA) – 1: Ecologically-benign development pathways in ‘Global South’

The literature map for ‘ELA-1’ contains 270 archive items (appearing in **Appendix 3**). The distribution of these archive items by total count across the three categories exhibit an uneven distribution with only 65 items reflecting on ‘Category – i’ (i.e. the ‘problem/ issue/ challenge/ syndrome-sphere’), whereas 111 items reflect on ‘Category – ii’ (i.e. the ‘action/ approach-sphere’) and the rest of the 94 items reflecting on ‘Category – iii’ (i.e. the academic-sphere). It is important to note that nearly twice the count of studies reflected on actions or approaches for ecologically-benign development pathways for the ‘Global South’ compared to those reflecting on the problems/ issues of sustainability in this regard. This is reflective of a focus given on the efforts towards consciously directing the development activities taking place in the ‘global south’.

The distribution of the archive items across the 10 spheres reveal a balanced presence of the studies across all spheres, which reflect studies being conducted with the sole purpose of singular spheres (such as economy[A], society[B] or environment[C]) as well as at the interface of multiple spheres. This is indicative of both isolated and integrative nature of the sustainability science studies around this issue. An overview on the ELA-1 precedes the presentation of the analysis.

A8.1.1 Overview of ELA-1

The ELA-1 literature map extracts the sustainability science literatures that reflect on the potential pathways of ecologically-benign development in the ‘Global South’. The map extends through the 10 spheres with respect to the three categories in each. It could be followed from **Tables A7.1.1 – A7.1.10** in **Appendix-7**—which present the observed data for the ELA-1—that the respective placements of the archive items across the 10 spheres and the three categories appear well-justified as to the nature of the spheres and the categories as outlined in the research design in **Section 3.4.3**. For example, archive items under the ‘sphere-A[economy]’ discuss the agricultural biotechnological and energy intensity issues in ‘problem/ issue/ challenge/ syndrome-sphere’ i.e. ‘Category–i’, whereas in ‘action/approach sphere’ i.e. ‘Category–ii’ the focus is on energy efficiency and technological innovations with respect to energy transition. In the academic-sphere i.e. ‘Category–iii’ the archive items discuss the technological transitions. It could be noted that all of these subjective items correspond to the ‘sphere-A[economy]’.

Providing an example from the pluralistic spheres could be taken with regard to the ‘sphere-AB[socio-economy]’. Under this sphere, the archive items under the ‘Category–i’ discuss the issue of non-renewable metal resources through developing a metal spectra, whereas the approaches of solar energy upscaling and renewable energy diffusion in societies, adoption of alternative livelihood, development interventions and collective actions, and atmospheric greenhouse gas mitigation in Chinese as well as global society are discussed under the ‘Category–ii’; and dematerialization, reuse, circular economy, quantitating sustainability measures are dealt under the ‘Category–iii’. It is evident from these subjective items that all of these border primarily on the economic perspectives of sustainability while also sharing some degree of social concerns, which justifies the ‘sphere-AB[socio-economy]’, likewise the other spheres, in the research design (**Section 3.4.3**).

The empirical analysis on ELA-1 occurs in a series of six tables containing quantitative insights obtained from analyzing the **Tables A7.1.1 – A7.1.10** in **Appendix-7**.

A8.1.2 The distributive characteristics across the categories and article types

On the whole, the distributive characteristics across the categories and article types (**Table A8.1.1**) reveal — (i) a majority of 60.7% articles being original articles, 71.3% of which are ‘Archetype-I’ articles (see **Section 4.2.1**), (ii) a significant presence of ‘Archetype-I’ articles across all article types, (iii) a striking absence of articles characteristic to ‘Prototype-I theoretical assumption’ (see **Section 4.2.1**), and (iv) the presence of a great variety of article types.

With respect to the article counts for the three categories, 56.9%, 55.8% and 69.1% of the articles are original articles within the ‘Categories – i, ii and iii’, respectively. Such can be rounded to approximately 55% of the articles in the ‘Categories – i and ii’ as being original articles, whereas some 70% in the ‘Category – iii’ for the same. Although both of these levels are significant majority, noticeably a higher proportion in the ‘Category – iii’ compared to the other two is indicative to a higher proportion of original studies being conducted in the academic-sphere (i.e. Category – iii).

In terms of the presence of Archetype-I articles, the trend among the three categories reveal nearly 80% of original articles in the 'Categories – i and iii' correspond to Archetype-I, whereas for 'Category – ii' it is merely 56.4%. This difference could be explained in terms of the 'action/ approach-sphere' (i.e. Category – ii) requiring a mix of various research approaches unlike the other two categories. With regard to the importance of the 'Prototype-I theoretical assumption' as described in **Section 4.2.1**, there are only two articles corresponding to it in the entire literature map, which occur under the original article type.

A total count of 15 different article types have occurred in the ELA-1 literature map, revealing richness in the approaches in addressing the complex sustainability research. Out of these 15 types, the dominant presence of 'original articles' is subsequently followed by the 'report' and 'review' type articles, whereas 'perspective' and 'overview' type articles also reveal their importance by their noticeable presence among the remaining article types.

The bulk majority of 'report' type articles appeared within the 'Categories – i and ii', along with a minor presence under the 'Category – iii'. The distribution of review articles reveals a distributed pattern across all three categories, whereas in the cases of overview and perspective articles it is so, except for a very scarce presence under the 'Category – i'.

Table A8.1.1: The distributive characteristics across the categories and article types in ELA-1

Article types		Number of archive items in ELA-1 literature map							
		Category-i		Category-ii		Category-iii		Total	
Original		**37**		**62**		**65**		**164**	
Archetype-I	*Prototype-I*	*30*	-	*35*	-	*52*	*2*	*117*	*2*
Report		**13**		**24**		**4**		**41**	
Archetype-I	*Prototype-I*	*8*	-	*6*	-	*2*	-	*16*	-
Review		**10**		**7**		**5**		**22**	
Archetype-I	*Prototype-I*	*4*	-	-	-	*2*	-	*6*	-
Perspective		**1**		**5**		**6**		**12**	
Archetype-I	*Prototype-I*	*1*	-	*3*	-	*3*	-	*7*	-
Overview		**1**		**4**		**5**		**10**	
Archetype-I	*Prototype-I*	*1*	-	*1*	-	*3*	-	*5*	-
Synthesis		**-**		**-**		**2**		**2**	
Archetype-I	*Prototype-I*	-	-	-	-	*2*	-	*2*	-
Note		**1**		**3**		**2**		**6**	
Archetype-I	*Prototype-I*	*1*	-	*2*	-	*2*	-	*5*	-
Editorial		**-**		**1**		**2**		**3**	
Archetype-I	*Prototype-I*	-	-	-	-	*1*	-	*1*	-
Synopsis		**1**		**-**		**1**		**2**	
Archetype-I	*Prototype-I*	-	-	-	-	-	-	-	-
Commentary		**-**		**3**		**-**		**3**	
Archetype-I	*Prototype-I*	-	-	*1*	-	-	-	*1*	-
Comment		**-**		**1**		**-**		**1**	
Archetype-I	*Prototype-I*	-	-	-	-	-	-	-	-
Keynote address		**-**		**-**		**1**		**1**	
Archetype-I	*Prototype-I*	-	-	-	-	-	-	-	-
Policy analysis		**-**		**1**		**-**		**1**	
Archetype-I	*Prototype-I*	-	-	-	-	-	-	-	-
Communication		**1**		**-**		**-**		**1**	
Archetype-I	*Prototype-I*	-	-	-	-	-	-	-	-
Memorandum		**-**		**-**		**1**		**1**	
Archetype-I	*Prototype-I*	-	-	-	-	-	-	-	-

A8.1.3 The distributive characteristics across the categories and the broad spheres

There are three characteristic observations exhibited from the distributive characteristics across the categories and the broad spheres (**Table A8.1.2**).

1. Within the broad spheres of A, B and C (i.e. the economic, social and environmental perspectives of sustainability, respectively) the maximum counts of archive items appeared under the 'Category – ii' as compared to the other two categories. It reveals a focus on the actions and approaches in addressing the ecologically-benign development pathways for the 'Global South', compared to fairly significant, although lower, treatment on the other two categories.

2. In the broad sphere D, 75% of the articles occurred under the academic-sphere (i.e. Category – iii), with the rest of the articles distributed across the other two categories. It reveals the importance of the broad sphere D (i.e. central organization of sustainability) within the academic-sphere, in contrast to the focus on 'Category – ii' in the other three broad spheres of A, B and C.

3. In terms of the counts of articles corresponding to the four broad spheres, the broad spheres of B and C corresponded to the two highest counts (34% and 30.7% of the literature map, respectively), followed by somewhat lower cluster size under the broad sphere D (22.2%), however, with significant lower presence in the broad sphere A i.e. the economic perspectives of sustainability (only 12.9%). This reveals a degree of negligence with respect to studying the economic perspectives of sustainability for the ELA-1. Besides, the presence of Archetype-I articles remain equally vital across all broad spheres.

Table A8.1.2: The distributive characteristics across the categories and the broad spheres in ELA-1

Broad spheres		Number of archive items in ELA-1 literature map							
		Category-i		Category-ii		Category-iii		Total	
Broad sphere - A		**9**		**18**		**8**		**35**	
Archetype-I	*Prototype-I*	*8*	*-*	*7*	*-*	*6*	*-*	*21*	*-*
Broad sphere - B		**29**		**38**		**25**		**92**	
Archetype-I	*Prototype-I*	*21*	*-*	*9*	*-*	*14*	*2*	*44*	*2*
Broad sphere - C		**24**		**43**		**16**		**83**	
Archetype-I	*Prototype-I*	*15*	*-*	*24*	*-*	*12*	*-*	*51*	*-*
Broad sphere - D		**3**		**12**		**45**		**60**	
Archetype-I	*Prototype-I*	*1*	*-*	*8*	*-*	*33*	*-*	*42*	*-*
Overall		**65**		**111**		**94**		**270**	
Archetype-I	*Prototype-I*	*45*	*-*	*48*	*-*	*65*	*2*	*158*	*2*

A8.1.4 Cross-comparison between the empirical classification and the broad spheres across the categories

The empirical classifications of the archive items refer to the Q2 aspect of the language of conversation in sustainability research (see **Table 4.1**). The cross-comparison between the empirical classification—having a total count of 19 empirical classes—and the broad spheres across the three categories for ELA-1 are summarized in **Table A8.1.3**. Some 70% of the studies in the literature map (consisting of 270 archive items) either solely or partly consist of 'literature survey' as the overarching method for their conduction, along with a quite distributed pattern over the three categories. In the cases of combined presence of 'literature survey' with other empirical classes, these other classes do not become significant enough—compared to 'literature survey'—to render the studies to correspond to a different empirical class.

In the empirical classes of 'field survey' and 'reporting' the bulk majority of the studies appear under the 'Category – ii', communicating on their importance for studies corresponding to the 'action/ approach-sphere'. In case of 'opinion', expectedly the majority of the articles appeared within the 'Categories – ii and iii', demonstrating its least importance for the 'problem/ issue/ challenge/ syndrome-sphere' (i.e. Category – i). However, in 'empirical field study/analysis', the absence of studies under the 'Category – i'—despite its presence in the other two categories—reveals a weak aspect in sustainability science research in terms of approaching to understand the problems/ issues of the ELA-1 through these manners.

Table A8.1.3: Cross-comparison between the empirical classification and the broad spheres across the categories in ELA-1

Q2	Broad spheres	Number of archive items in ELA-1 literature map				Q2	Broad spheres	Number of archive items in ELA-1 literature map			
		Category-i	Category-ii	Category-iii	Total			Category-i	Category-ii	Category-iii	Total
Literature survey	A	8	11	6	25	Field survey	A	-	3	-	3
	B	24	13	20	57		B	1	5	2	8
	C	17	31	15	63		C	1	5	-	6
	D	1	8	35	44		D	-	1	1	2
	Overall	50	63	76	189		Overall	2	14	3	19
Reporting	A	1	1	-	2	Review	A	-	2	-	2
	B	-	11	-	11		B	3	2	-	5
	C	-	3	-	3		C	4	2	1	7
	D	-	1	-	1		D	-	1	2	3
	Overall	1	16	0	17		Overall	7	7	3	17
Case study	A	-	3	1	4	Modeling	A	-	-	1	1
	B	1	4	2	7		B	1	1	3	5
	C	-	1	-	1		C	1	4	1	6
	D	-	-	1	1		D	-	-	1	1
	Overall	1	8	4	13		Overall	2	5	6	13
Opinion	A	-	-	-	0	Empirical field study/analysis	A	-	1	-	1
	B	-	1	2	3		B	-	2	3	5
	C	1	3	-	4		C	-	1	-	1
	D	-	1	5	6		D	-	-	-	0
	Overall	1	5	7	13		Overall	0	4	3	7
Simulation	A	-	1	-	1	Field study	A	-	-	-	0
	B	-	-	1	1		B	-	1	-	1
	C	2	-	1	3		C	-	-	-	0
	D	-	-	-	0		D	-	-	1	1
	Overall	2	1	2	5		Overall	0	1	1	2

Q2	Broad spheres	Number of archive items in ELA-1 literature map				Q2	Broad spheres	Number of archive items in ELA-1 literature map			
		Category-i	Category-ii	Category-iii	Total			Category-i	Category-ii	Category-iii	Total
Policy analysis	A	-	-	-	0	Editorial	A	-	1	-	1
	B	-	1	-	1		B	-	-	-	0
	C	-	1	-	1		C	-	-	-	0
	D	-	-	-	0		D	-	-	1	1
	Overall	0	2	0	2		Overall	0	1	1	2
Commentary	B	-	1	-	1	Systemic assessment	B	1	-	-	1
	Overall	0	1	0	1		Overall	1	0	0	1
Summary	D	1	-	-	1	Synthesis	D	1	-	-	1
	Overall	1	0	0	1		Overall	1	0	0	1
Scenario study	C	-	1	-	1	Case history	C	1	-	-	1
	Overall	0	1	0	1		Overall	1	0	0	1
Action research	C	-	1	-	1						
	Overall	0	1	0	1						

A8.1.5 Cross-comparison between the empirical classification and the article types across the categories

The cross-comparison between the empirical classifications and the article types (**Table A8.1.4**) reveal a strong correlation between ‘literature survey’ and the original article type (73% of the literature survey type studies being original). Apart from this, almost all other empirical classes overwhelmingly constitute original type articles, except for the classes that are not usually meant for original article-type, such as ‘reporting’, ‘review’, ‘editorial’, ‘opinion’, ‘commentary’, ‘summary’, ‘action research’, and ‘synthesis’. These observations reveal the innovative aspect of sustainability science research with respect to ELA-1.

Table A8.1.4: Cross-comparison between the empirical classification and the article types across the categories in ELA-1

Q2	Article types	Number of archive items in ELA-1 literature map				Q2	Article types	Number of archive items in ELA-1 literature map			
		Category-i	Category-ii	Category-iii	Total			Category-i	Category-ii	Category-iii	Total
	Overall	**50**	**63**	**76**	**189**		**Overall**	**2**	**14**	**3**	**19**
	Original	*33*	*46*	*59*	*138*	**Field survey**	*Original*	*2*	*13*	*3*	*18*
	Report	*10*	*8*	*2*	*20*		*Report*	-	*1*	-	*1*
	Overview	*1*	*3*	*4*	*8*						
Literature survey	*Review*	*4*	-	*3*	*7*		**Overall**	**1**	**16**	**0**	**17**
	Perspective	*1*	*3*	*3*	*7*	**Reporting**	*Report*	*1*	*15*	-	*16*
	Note	*1*	*2*	*2*	*5*		*Note*	-	*1*	-	*1*
	Synthesis	-	-	*2*	*2*						
	Editorial	-	-	*1*	*1*		**Overall**	**7**	**7**	**3**	**17**
	Commentary	-	*1*	-	*1*	**Review**	*Review*	*6*	*7*	*3*	*16*
							Report	*1*	-	-	*1*
	Overall	**1**	**8**	**4**	**13**						
Case study	*Original*	-	*7*	*4*	*11*		**Overall**	**1**	**5**	**7**	**13**
	Overview	-	*1*	-	*1*		*Perspective*	-	*2*	*3*	*5*
	Report	*1*	-	-	*1*		*Overview*	-	*1*	*1*	*2*
							Report	*1*	-	-	*1*
	Overall	**2**	**5**	**6**	**13**	**Opinion**	*Commentary*	-	*1*	-	*1*
Modeling	*Original*	*2*	*3*	*5*	*10*		*Comment*	-	*1*	-	*1*
	Report	-	*1*	*1*	*2*		*Synopsis*	-	-	*1*	*1*
	Overview	-	*1*	-	*1*		*Keynote address*	-	-	*1*	*1*
							Memorandum	-	-	*1*	*1*
Empirical field study/analysis	**Overall**	**0**	**4**	**3**	**7**						
	Original	-	*4*	*3*	*7*	**Simulation**	**Overall**	**2**	**1**	**2**	**5**
							Original	*2*	*1*	*2*	*5*
	Overall	**0**	**2**	**0**	**2**						
Policy analysis	*Original*	-	*1*	-	*1*		**Overall**	**0**	**1**	**1**	**2**
	Policy analysis	-	*1*	-	*1*	**Field study**	*Original*	-	*1*	-	*1*
							Report	-	-	*1*	*1*
Editorial	**Overall**	**0**	**1**	**1**	**2**						
	Editorial	-	*1*	*1*	*2*		**Overall**	**0**	**1**	**0**	**1**
						Commentary	*Commentary*	-	*1*	-	*1*

Q2	Article types	Number of archive items in ELA-1 literature map			
		Category-i	Category-ii	Category-iii	Total
Summary	**Overall**	**1**	**0**	**0**	**1**
	Synopsis	*1*	-	-	*1*
Scenario study	**Overall**	**0**	**1**	**0**	**1**
	Original	-	*1*	-	*1*
Action research	**Overall**	**0**	**1**	**0**	**1**
	Report	-	*1*	-	*1*

Q2	Article types	Number of archive items in ELA-1 literature map			
		Category-i	Category-ii	Category-iii	Total
Systemic assessment	**Overall**	**1**	**0**	**0**	**1**
	Original	*1*	-	-	*1*
Synthesis	**Overall**	**1**	**0**	**0**	**1**
	Communication	*1*	-	-	*1*
Case history	**Overall**	**1**	**0**	**0**	**1**
	Original	*1*	-	-	*1*

A8.1.6 Representative themes in their respective categories based on ELA-1

The appearance of the highly frequent themes (any theme appearing with three or more archive items) for ELA-1 are highlighted in **Table A8.1.5** with greyed shadow. Under the 'Category – i' the mostly recurring theme is found to be '*food security—agricultural challenges/issues*', followed by the three equally frequented themes of '*climate change problem/impacts*', '*human insecurity—conflict*', and '*coastal vulnerability issues & sea level rise*'. These themes reflect some of the most important problems encountered in the 'Global South'. In case of 'action/ approach-sphere' (i.e. Category – ii), '*energy policy/innovation*', '*interventions and development, and conservation*', and '*agricultural policy/innovation*' become the most frequently appeared themes; while in the academic-sphere (category – iii) these are found to be '*sustainability challenge*', '*natural capital & ecosystem services management/governance*', and '*land cover and land use change science*'. Besides these most occurring themes, **Table A8.1.5** also lists all other highly frequent themes across the three categories.

Table A8.1.5: Representative themes in their respective categories based on ELA-1

Themes in 'Category-i' in ELA-1		# of items	Themes in 'Category -ii' in ELA-1		# of items	Themes in 'Category -iii in ELA-1		# of items
ID	Theme		ID	Theme		ID	Theme	
1	Food security—Agricultural challenges/issues	15	**1**	Energy policy/innovation	9	**1**	Transition theory	1
2	Water availability/quality	2	**2**	Alternative livelihood	2	**2**	Dematerialization	1
3	Industrialization—Energy—Environment	2	**3**	Interventions and development, and conservation	15	**3**	"Reuse" as theory	2
4	Urbanization—Consumption—Environment	1	**4**	Community involvement	5	**4**	Circular economy	3
5	Air pollution—GHG Emission—Emission transfers	3	**5**	Low-carbon transitions	7	**5**	Quantitative sustainability	2
6	Biodiversity—Habitat destruction—Trade	4	**6**	Biodiversity—Agriculture—Poverty	3	**6**	Natural capital & ecosystem services management/governance	15
7	Public health	4	**7**	Social learning	1	**7**	Ecological economics	1
8	Human insecurity—Conflict	6	**8**	Population policy	1	**8**	Resilience	3
9	Population—Consumption—Environment	5	**9**	Forest management policy/innovation	8	**10**	Institutional reform	1
10	African poverty	2	**10**	Agricultural policy/innovation	13	**11**	Sustainability challenge	10
11	Climate change problem/impacts	6	**11**	Regional cooperation	1	**13**	Rural-urban transformation	1
12	Drought	2	**12**	Modeling	6	**14**	Poverty—Development	5
13	Delta — problems	1	**13**	Adaptation—Natural Disaster—Migration—Benefits	7	**15**	Sustainable architecture	2
14	Ecological crisis	2	**14**	Urban policy/innovation	5	**16**	Urban sustainability and adaptive urban governance	6
15	Coastal vulnerability issues & sea level rise	6	**15**	Reuse—Recycling—Pollution control	3	**17**	Adaptation	5
16	Global warming—Natural disaster	1	**16**	Technology and nanotechnology	2	**18**	Political ecology	1
17	Estuaries & coastal seas — problems	1	**17**	Water policy/innovation	5	**19**	Land cover and land use change science	10
18	Open water bodies — problems	1	**18**	Treaties—Agreements	1	**20**	Sustainability—Culture—Religion	2
19	River — problems	1	**19**	Emission estimation/control	2	**21**	World System theory	2
Overall		65	**20**	Land use system planning/innovation	2	**22**	Learning—Knowledge—Ignorance—Condition	1
			21	Biodiversity conservation policy/innovation	4	**24**	Environmental regulation	2
			22	Ecosystem services policy/innovation	4	**26**	Sustainability related discourses	1
			23	Air quality policy/innovation	1	**29**	Sustainability Science education/curriculum	1
			24	Environmental restoration policies/innovation	1	**31**	Cosmopolitanism	1
			25	Sustainable Development strategies/innovation	3	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	2
			Overall		111	**36**	Anthropocene and Earth stewardship	4
						37	Ontology and/or epistemology of Sustainability Science	2
						38	Complex systems, analysis, and adaptive planning/management	4
						40	Urban agriculture	1
						41	De-growth	1
						43	Sustainable health	1
						Overall		94

A8.1.7 Frequency distribution of archive items under the themes across the broad spheres

The frequency distribution of archive items under the themes across the broad spheres (**Table A8.1.6**) reveals the least representation for the broad sphere D under the 'Category – i'. Apart from this, the studies have mostly concentrated within the broad spheres of B and C under the 'Category – i'.

On the contrary, in 'action/ approach-sphere' (i.e. Category – ii) the studies are quite distributed across all four broad spheres although major emphasis is observed on the broad spheres of B and C. In the academic-sphere (i.e. Category – iii), this dominance is rather observed on the broad spheres of B, C and D altogether. This continues to communicate the degree of negligence existing in terms of the economic perspectives of sustainability (i.e. the broad sphere A).

Table A8.1.6: Frequency distribution of archive items under the themes across the broad spheres in ELA-1

Themes in 'Category-i' in ELA-1		Number of items				
ID	**Theme**	**Overall**	**Broad sphere A**	**Broad sphere B**	**Broad sphere C**	**Broad sphere D**
1	Food security—Agricultural challenges/issues	**15**	3	9	3	-
8	Human insecurity—Conflict	**6**	-	6	-	-
11	Climate change problem/impacts	**6**	-	1	4	1
15	Coastal vulnerability issues & sea level rise	**6**	-	-	6	-
9	Population—Consumption—Environment	**5**	-	5	-	-
6	Biodiversity—Habitat destruction—Trade	**4**	1	-	3	-
7	Public health	**4**	-	4	-	-
5	Air pollution—GHG Emission—Emission transfers	**3**	1	-	2	-
Total		***49***	***5***	***25***	***18***	***1***
Themes in 'Category-ii' in ELA-1		**Number of items**				
ID	**Theme**	**Overall**	**Broad sphere A**	**Broad sphere B**	**Broad sphere C**	**Broad sphere D**
3	Interventions and development, and conservation	**15**	1	13	-	1
10	Agricultural policy/innovation	**13**	-	3	10	-
1	Energy policy/innovation	**9**	9	-	-	-
9	Forest management policy/innovation	**8**	-	2	5	1
5	Low-carbon transitions	**7**	5	1	1	-
13	Adaptation—Natural Disaster—Migration—Benefits	**7**	-	4	2	1
12	Modeling	**6**	-	2	2	2
4	Community involvement	**5**	1	4	-	-
14	Urban policy/innovation	**5**	-	3	1	1
17	Water policy/innovation	**5**	-	-	3	2
21	Biodiversity conservation policy/innovation	**4**	-	-	3	1
22	Ecosystem services policy/innovation	**4**	-	-	4	-
6	Biodiversity—Agriculture—Poverty	**3**	1	2	-	-
15	Reuse—Recycling—Pollution control	**3**	-	1	2	-
25	Sustainable Development strategies/innovation	**3**	-	-	-	3
Total		***97***	***17***	***35***	***33***	***12***
Themes in 'Category-iii' in ELA-1		**Number of items**				
ID	**Theme**	**Overall**	**Broad sphere A**	**Broad sphere B**	**Broad sphere C**	**Broad sphere D**
6	Natural capital & ecosystem services management/governance	**15**	1	2	5	7
11	Sustainability challenge	**10**	-	2	2	6

19	Land cover and land use change science	**10**	-	3	3	4
16	Urban sustainability and adaptive urban governance	**6**	-	3	-	3
14	Poverty—Development	**5**	-	4	-	1
17	Adaptation	**5**	-	2	2	1
36	Anthropocene and Earth stewardship	**4**	-	-	-	4
38	Complex systems, analysis, and adaptive planning/management	**4**	-	-	-	4
4	Circular economy	**3**	2	-	-	1
8	Resilience	**3**	-	-	2	1
Total		***65***	***3***	***16***	***14***	***32***

A8.2 Empirical literature analysis (ELA) – 2: Hunger and food insecurity in human societies and the agricultural production issues

The literature map for ELA-2 contains 120 archive items (appearing in **Appendix 3**). The distribution of these archive items by total count across the three categories exhibit a somewhat distributed pattern, with a count of 52 items reflecting on 'Category – ii' (i.e. the 'action/ approach-sphere'), and 34 items reflecting each on the 'Categories – i and ii' (i.e. the 'problem/ issue/ challenge/ syndrome-sphere' and the academic-sphere, respectively). This pattern communicates a balanced focus on adopting actions and approaches towards addressing the issues of hunger and food insecurity. Consistent to the observation in ELA-1, the 'Category – ii' also corresponds to the highest count of articles in ELA-2. The distribution of archive items across the 10 spheres and the three categories appear also well-justified (similar to ELA-1) as to the nature of these spheres and categories as outlined in the research design. These justifications can be followed in **Tables A7.2.1 – A7.2.10** in **Appendix-7**, containing the observed data for ELA-2.

A8.2.1 The distributive characteristics across the categories and article types

The distributive characteristics across the categories and article types in ELA-2 (**Table A8.2.1**) coincide precisely with all corresponding observations in ELA-1, including the four overall observations on ELA-1. Articulating these four overall observations in terms of ELA-2 would be — (i) a majority of 64.1% articles being original articles, 67.5% of which are 'Archetype-I' articles (see **Section 4.2.1**), (ii) significant presence of 'Archetype-I' articles across all article types, (iii) a striking absence of articles characteristic to 'Prototype-I theoretical assumption' (see **Section 4.2.1**), and (iv) the presence of a great variety of article types.

With respect to the article counts for the three categories, 61.7%, 59.6% and 73.5% of the articles are original articles within the 'Categories – i, ii and iii', respectively. Such can be rounded to approximately 60% of the articles in the 'Categories – i and ii' as being original articles, whereas some 75% in the 'Category – iii' for the same. Although both of these levels are significant majority, noticeably a higher proportion in the 'Category – iii' compared to the other two—consistent to the respective observation in ELA-1—is indicative to a higher proportion of original studies taking place under the academic-sphere (i.e. Category – iii).

In terms of the presence of Archetype-I articles, the trend among the three categories reveal 85.7% and 68% of the original articles in ‘Categories – i and iii’, respectively, to correspond to Archetype-I, whereas for ‘Category – ii’ it is merely 54.8%. Consistent to similar observation in ELA-1, this difference could be explained in terms of the ‘action/ approach-sphere’ (i.e. Category – ii) requiring a mix of various research approaches unlike the other two categories. Similar to the observations in ELA-1, with regard to the importance of ‘Prototype-I theoretical assumption’ described in **Section 4.2.1**, there are only three articles corresponding to it in the entire literature map, which are also original type articles.

A total count of 11 different article types have occurred in the ELA-2 literature map, revealing richness in the approaches in addressing the complex sustainability research. Out of these 11 types, the dominant presence of ‘original articles’ is subsequently followed by the ‘report’ and ‘review’ articles types, whereas ‘perspective’ and ‘overview’ type articles also reveal their importance by their noticeable presence among the remaining article types.

The bulk majority of ‘report’ type articles appeared within the ‘Categories – i and ii’, along with only one article under ‘Category – iii’. The distribution of review articles reveals a distributed pattern across all three categories, whereas in the cases of overview and perspective articles it is so, except for a very scarce presence of perspective articles and an absence of overview articles under the ‘Category – i’.

Table A8.2.1: The distributive characteristics across the categories and article types in ELA-2

Article types		Number of archive items in ELA-2 literature map							
		Category-i		Category-ii		Category-iii		Total	
Original		**21**		**31**		**25**		**77**	
Archetype-I	*Prototype-I*	*18*	-	*17*	*1*	*17*	*2*	*52*	*3*
Report		**5**		**10**		**1**		**16**	
Archetype-I	*Prototype-I*	*1*	-	*3*	-	*1*	-	*5*	-
Review		**5**		**3**		**2**		**10**	
Archetype-I	*Prototype-I*	*2*	-	-	-	*1*	-	*3*	-
Perspective		**1**		**3**		**3**		**7**	
Archetype-I	*Prototype-I*	*1*	-	*2*	-	*3*	-	*6*	-
Overview		**-**		**2**		**1**		**3**	
Archetype-I	*Prototype-I*	-	-	*1*	-	*1*	-	*2*	-
Commentary		**-**		**2**		**-**		**2**	
Archetype-I	*Prototype-I*	-	-	*1*	-	-		*1*	-
Synthesis		**-**		**-**		**1**		**1**	
Archetype-I	*Prototype-I*	-	-	-	-	*1*	-	*1*	-
Note		**1**		**-**		**-**		**1**	
Archetype-I	*Prototype-I*	*1*	-	-	-	-	-	*1*	-
Keynote address		**-**		**-**		**1**		**1**	
Archetype-I	*Prototype-I*	-	-	-	-	-	-	-	-
Policy analysis		**-**		**1**		**-**		**1**	
Archetype-I	*Prototype-I*	-	-	-	-	-	-	-	-
Communication		**1**		**-**		**-**		**1**	
Archetype-I	*Prototype-I*	-	-	-	-	-	-	-	-

A8.2.2 The distributive characteristics across the categories and the broad spheres

Three characteristic observations are exhibited from the distributive characteristics across the categories and the broad spheres (**Table A8.2.2**).

1. Unlike in ELA-1, the ELA-2 demonstrates quite distributed pattern among the three categories within the broad spheres of A, B and C (i.e. the economic, social and environmental perspectives of sustainability, respectively).

2. Similar to ELA-1, in the broad sphere D, 63.1% of the articles occurred under the academic-sphere (i.e. Category **–** iii), with the rest of the articles distributed across the other two categories. It reveals the importance of the broad sphere D (i.e. central organization of sustainability) within the academic-sphere, in contrast to the distributed pattern across the three categories in the other three broad spheres of A, B and C.

3. In terms of the counts of articles corresponding to the four broad spheres, the broad sphere C corresponded to the highest count (52.5%), followed by somewhat lower cluster sizes in the broad spheres of B and D (24.1% and 15.8%, respectively), however, with significant lower presence in the broad sphere A i.e. economic perspectives of sustainability (only 7.5%). This continues to a degree of negligence with respect to studying the economic perspectives of sustainability, also evidenced from the ELA-1. Consistent to the ELA-1, the presence of Archetype-I articles also remain equally vital across all broad spheres.

Table A8.2.2: The distributive characteristics across the categories and the broad spheres in ELA-2

Broad spheres		**Number of archive items in ELA-2 literature map**							
		Category-i		**Category-ii**		**Category-iii**		**Total**	
Broad sphere - A		**5**		**4**		**-**		**9**	
Archetype-I	*Prototype-I*	*4*	*-*	*1*	*-*	*-*	*-*	*5*	*-*
Broad sphere - B		**12**		**8**		**9**		**29**	
Archetype-I	*Prototype-I*	*8*	*-*	*1*	*-*	*3*	*2*	*12*	*2*
Broad sphere - C		**15**		**35**		**13**		**63**	
Archetype-I	*Prototype-I*	*10*	*-*	*19*	*1*	*11*	*-*	*40*	*1*
Broad sphere - D		**2**		**5**		**12**		**19**	
Archetype-I	*Prototype-I*	*1*	*-*	*3*	*-*	*10*	*-*	*14*	*-*
Overall		**34**		**52**		**34**		**120**	
Archetype-I	*Prototype-I*	*23*	*-*	*24*	*1*	*24*	*2*	*71*	*3*

A8.2.3 Cross-comparison between the empirical classification and the broad spheres across the categories

The cross-comparison between the empirical classification—having a total count of 15 empirical classes—and the broad spheres across the three categories for ELA-2 are summarized in **Table A8.2.3**. Similar to the observation in ELA-1, ‘literature survey’ continues to reveal enormous importance, with 72.5% of the studies in the literature map solely or partly consisting of ‘literature survey’ as the overarching method for their conduction, along with a distributed pattern over the three categories.

In conformity to the observations in ELA-1, the bulk majority of the studies under the empirical classes of ‘field survey’ and ‘reporting’ appear under the ‘Category – ii’, thus, continuing to communicate on their importance for studies corresponding to the ‘action/ approach-sphere’. Similar to ELA-1, in ‘empirical field study/analysis’, the absence of studies under the ‘Category – i’—despite its presence in the other two categories—reveals a weak aspect in sustainability science research in terms of approaching to understand the problems/ issues of the ELA-2 through these manners.

Table A8.2.3: Cross-comparison between the empirical classification and the broad spheres across the categories in ELA-2

Q2	Broad spheres	Number of archive items in ELA-2 literature map			
		Category-i	Category-ii	Category-iii	Total
Literature survey	A	4	1	-	5
	B	10	3	6	19
	C	11	26	12	49
	D	1	3	10	14
	Overall	26	33	28	87
Review	B	1	1	-	2
	C	3	2	-	5
	D	-	-	1	1
	Overall	4	3	1	8
Modeling	B	-	-	2	2
	C	-	4	1	5
	Overall	0	4	3	7
Empirical field study/analysis	B	-	1	2	3
	C	-	3	1	4
	Overall	0	4	3	7
Opinion	B	-	-	1	1
	C	1	1	-	2
	Overall	1	1	1	3
Policy analysis	C	-	1	-	1
	Overall	0	1	0	1
Commentary	B	-	1	-	1
	Overall	0	1	0	1
Action research	C	-	1	-	1
	Overall	0	1	0	1

Q2	Broad spheres	Number of archive items in ELA-2 literature map			
		Category-i	Category-ii	Category-iii	Total
Field survey	A	-	2	-	2
	B	1	1	1	3
	C	-	5	-	5
	D	-	1	1	2
	Overall	1	9	2	12
Reporting	A	1	1	-	2
	B	-	2	-	2
	C	-	2	-	2
	D	-	1	-	1
	Overall	1	6	0	7
Simulation	A	-	1	-	1
	B	-	-	1	1
	C	1	1	1	3
	Overall	1	2	2	5
Case study	B	-	1	1	2
	C		1	-	1
	D	-	-	1	1
	Overall	0	2	2	4
Systemic assessment	B	1	-	-	1
	Overall	1	0	0	1
Synthesis	D	1	-	-	1
	Overall	1	0	0	1
Scenario study	C	-	1	-	1
	Overall	0	1	0	1

A8.2.4 Cross-comparison between the empirical classification and the article types across the categories

Similar to the ELA-1, the cross-comparison between the empirical classifications and the article types in ELA-2 (**Table A8.2.4**) also reveal a strong correlation between 'literature survey' and the original article type (74.7% of the literature survey type studies being original). Apart from this, almost all other empirical classes overwhelmingly constitute original type articles, except for the classes that are not usually meant for original article-type, such as 'reporting', 'review', 'opinion', 'commentary', 'action research', and 'synthesis'. Similar to the ELA-1, these observations for ELA-2 continue to reveal the innovative aspect of sustainability science research.

Table A8.2.4: Cross-comparison between the empirical classification and the article types across the categories in ELA-2

Q2	Article types	Number of archive items in ELA-2 literature map				Q2	Article types	Number of archive items in ELA-2 literature map			
		Category-i	Category-ii	Category-iii	Total			Category-i	Category-ii	Category-iii	Total
Literature survey	**Overall**	**26**	**33**	**28**	**87**	**Field survey**	**Overall**	**1**	**9**	**2**	**12**
	Original	*20*	*24*	*21*	*65*		*Original*	*1*	*9*	*2*	*12*
	Report	*2*	*4*	*1*	*7*						
	Perspective	*1*	*2*	*3*	*6*	**Review**	**Overall**	**4**	**3**	**1**	**8**
	Review	*2*	*-*	*1*	*3*		*Review*	*3*	*3*	*1*	*7*
	Overview	*-*	*2*	*1*	*3*		*Report*	*1*	*-*	*-*	*1*
	Note	*1*	*-*	*-*	*1*						
	Synthesis	*-*	*-*	*1*	*1*	**Modeling**	**Overall**	**0**	**4**	**3**	**7**
	Commentary	*-*	*1*	*-*	*1*		*Original*	*-*	*3*	*3*	*6*
							Overview	*-*	*1*	*-*	*1*
Reporting	**Overall**	**1**	**6**	**0**	**7**						
	Report	*1*	*6*	*-*	*7*	**Empirical field study/analysis**	**Overall**	**0**	**4**	**3**	**7**
							Original	*-*	*4*	*3*	*7*
Simulation	**Overall**	**1**	**2**	**2**	**5**						
	Original	*1*	*2*	*2*	*5*	**Case study**	**Overall**	**0**	**2**	**2**	**4**
							Original	*-*	*2*	*2*	*4*
Opinion	**Overall**	**1**	**1**	**1**	**3**						
	Report	*1*	*-*	*-*	*1*	**Policy analysis**	**Overall**	**0**	**1**	**0**	**1**
	Perspective	*-*	*1*	*-*	*1*		*Policy analysis*	*-*	*1*	*-*	*1*
	Keynote address	*-*	*-*	*1*	*1*						
						Commentary	**Overall**	**0**	**1**	**0**	**1**
Action research	**Overall**	**0**	**1**	**0**	**1**		*Commentary*	*-*	*1*	*-*	*1*
	Report	*-*	*1*	*-*	*1*						
						Systemic assessment	**Overall**	**1**	**0**	**0**	**1**
Synthesis	**Overall**	**1**	**0**	**0**	**1**		*Original*	*1*	*-*	*-*	*1*
	Communication	*1*	*-*	*-*	*1*						
						Scenario study	**Overall**	**0**	**1**	**0**	**1**
							Original	*-*	*1*	*-*	*1*

A8.2.5 Representative themes in their respective categories based on ELA-2

The appearance of the highly frequent themes (any theme appearing with three or more archive items) for ELA-2 are highlighted in **Table A8.2.5** with greyed shadow. Under the 'Category – i', two of the three mostly recurring themes are found to be the same as in ELA-1, these being '*food security—agricultural challenges/issues*' and '*climate change problem/impacts*'. These two themes, thus, become the intersecting issues between the ELA-1 and ELA-2. The third most frequented theme under this category is found to be '*biodiversity—habitat destruction—trade*'.

In case of 'action/ approach-sphere' (i.e. Category – ii), '*agricultural policy/innovation*', '*forest management policy/innovation*', and the three equally frequented themes of '*land use system planning/innovation*', '*biodiversity conservation policy/innovation*', and '*ecosystem services policy/innovation*' become the most frequently appeared themes, while in the academic-sphere (category – iii) these are found to be '*natural capital & ecosystem services management/governance*', and '*land cover and land use change science*', which are also in common with ELA-1.

Table A8.2.5: Representative themes in their respective categories based on ELA-2

Themes in 'Category-i' in ELA-2		# of items	Themes in 'Category -ii' in ELA-2		# of items	Themes in 'Category -iii in ELA-2		# of items
ID	Theme		ID	Theme		ID	Theme	
1	Food security—Agricultural challenges/issues	16	**1**	Energy policy/innovation	2	**3**	"Reuse" as theory	1
5	Air pollution—GHG Emission—Emission transfers	1	**2**	Alternative livelihood	1	**6**	Natural capital & ecosystem services management/governance	11
6	Biodiversity—Habitat destruction—Trade	4	**3**	Interventions and development, and conservation	2	**8**	Resilience	2
9	Population—Consumption—Environment	2	**4**	Community involvement	1	**11**	Sustainability challenge	2
11	Climate change problem/impacts	4	**6**	Biodiversity—Agriculture—Poverty	3	**14**	Poverty—Development	1
12	Drought	2	**9**	Forest management policy/innovation	8	**17**	Adaptation	2
14	Ecological crisis	3	**10**	Agricultural policy/innovation	13	**19**	Land cover and land use change science	10
15	Coastal vulnerability issues & sea level rise	1	**12**	Modeling	3	**21**	World System theory	1
19	River — problems	1	**14**	Urban policy/innovation	1	**37**	Ontology and/or epistemology of Sustainability Science	2
Overall		34	**15**	Reuse—Recycling—Pollution control	1	**38**	Complex systems, analysis, and adaptive planning/management	1
			16	Technology and nanotechnology	1	**40**	Urban agriculture	1
			17	Water policy/innovation	3	Overall		34
			19	Emission estimation/control	1			
			20	Land use system planning/innovation	4			
			21	Biodiversity conservation policy/innovation	4			
			22	Ecosystem services policy/innovation	4			
			Overall		52			

A8.2.6 Frequency distribution of archive items under the themes across the broad spheres

Similar observations as of ELA-1 occur in the ELA-2 in terms of the frequency distribution of archive items under the themes across the broad spheres (**Table A8.2.6**). Same as observed in ELA-1, the broad sphere D under the 'Category – i' exhibits the least representation in ELA-2. In conformity to the ELA-1, the studies in ELA-2 also have mostly concentrated within the broad spheres of B and C under the 'Category – i'.

In the 'action/ approach-sphere' (i.e. Category – ii), the studies have mostly concentrated within the broad spheres of B and C, which is in agreement with the ELA-1 observations in terms of the major emphasis observed within the broad spheres of B and C despite the quite distributed presence across the broad spheres. Finally, same as in ELA-1, under the academic-sphere (i.e. Category – iii) the dominance is also observed on the broad spheres of B, C and D altogether. This further communicates the degree of negligence existing in terms of the economic perspectives of sustainability (i.e. the broad sphere A).

Table A8.2.6: Frequency distribution of archive items under the themes across the broad spheres in ELA-2

Themes in 'Category-i' in ELA-2		Number of items				
ID	Theme	Overall	Broad sphere A	Broad sphere B	Broad sphere C	Broad sphere D
1	Food security—Agricultural challenges/issues	16	3	9	4	-
6	Biodiversity—Habitat destruction—Trade	4	1	-	3	-
11	Climate change problem/impacts	4	-	-	3	1
14	Ecological crisis	3	-	-	3	-
Total		***27***	***4***	***9***	***13***	***1***
Themes in 'Category-ii' in ELA-2		**Number of items**				
ID	**Theme**	**Overall**	**Broad sphere A**	**Broad sphere B**	**Broad sphere C**	**Broad sphere D**
10	Agricultural policy/innovation	13	-	3	10	-
9	Forest management policy/innovation	8	-	2	5	1
20	Land use system planning/innovation	4	-	-	4	-
21	Biodiversity conservation policy/innovation	4	-	-	3	1
22	Ecosystem services policy/innovation	4	-	-	4	-
6	Biodiversity—Agriculture—Poverty	3	1	2	-	-
12	Modeling	3	-	-	2	1
17	Water policy/innovation	3	-	-	2	1
Total		***42***	***1***	***7***	***30***	***4***
Themes in 'Category-iii' in ELA-2		**Number of items**				
ID	**Theme**	**Overall**	**Broad sphere A**	**Broad sphere B**	**Broad sphere C**	**Broad sphere D**
6	Natural capital & ecosystem services management/governance	11	-	2	6	3
19	Land cover and land use change science	10	-	2	5	3
Total		***21***	***0***	***4***	***11***	***6***

A8.3 Empirical literature analysis (ELA) – 3: Sustainability science issues in urban planning

The literature map for ELA-3 contains 94 archive items (appearing in **Appendix 3**). The distribution of these archive items by total count across the three categories reveals a fairly distributed pattern. Similar to the observations in ELAs – 1 and 2, the distribution of archive items across the 10 spheres and the three categories adequately justify the purpose of these spheres and the categories as outlined in the research design. These justifications can be followed in **Tables A7.3.1 – A7.3.10** in **Appendix–7**, which contain the observed data for ELA-3.

A8.3.1 The distributive characteristics across the categories and article types

The distributive characteristics across the categories and article types in ELA-3 (**Table A8.3.1**) exhibit four main characteristics in conformity to similar observations in ELAs – 1 and 2. These are — (i) a majority of 62.7% articles being original articles, 77.9% of which are 'Archetype-I' articles (see **Section 4.2.1**), (ii) significant presence of 'Archetype-I' articles across all article types, (iii) the entire absence of articles characteristic to 'Prototype-I theoretical assumption' (see **Section 4.2.1**), and (iv) the presence of a diverse range of article types.

With respect to article counts for the three categories, 64%, 51.5% and 72.2% of the articles are original articles within the 'Categories – i, ii and iii', respectively. The highest proportion of original articles in the 'Category – iii' compared to the other two—consistent to the respective observations in the ELAs – 1 and 2—continues to be indicative of a higher proportion of original studies taking place under the academic-sphere (i.e. Category – iii).

In terms of the presence of Archetype-I articles, the trend among the three categories reveal 75%, 76.4% and 80.7% of the original articles in 'Categories – i, ii and iii', respectively, to correspond to Archetype-I. This reveals a fairly similar distribution of Archetype-I articles across the three spheres, unlike a comparative lesser presence under the 'Category – ii' in the ELAs – 1 and 2. With regard to the importance of 'Prototype-I theoretical assumption' described in **Section 4.2.1**, none of the articles in the literature map corresponding to it continues to agree with similar observations in the ELAs – 1 and 2.

A total count of eight different article types have occurred in the ELA-3 literature map, revealing considerable degree of richness in addressing the complex sustainability research. Out of these eight types, the dominance presence of ‘original articles’ continues to subsequently be followed by the ‘report’ and ‘review’ type articles, whereas ‘overview’ type articles also reveal its importance with its noticeable presence amid the remaining article types.

The bulk majority of ‘report’ type articles appeared within the ‘Category – ii’, unlike in ELAs – 1 and 2, where these articles were distributed across the ‘Categories – i and ii’. In terms of the scarce presence of ‘report’ type articles under the ‘Category – iii’, the observation in ELA-3, thus, also conforms to the observations in ELAs – 1 and 2. The distribution of review articles reveals a distributed pattern across all three categories, which is consistent to the observations in ELAs – 1 and 2. While the lack in overview type articles corresponding to ‘Category – i’ remained questioned in the ELAs – 1 and 2, in ELA-3 such is observed with the expected equal emphasis placed on this category i.e. the ‘problem/ issue/ challenge/ syndrome-sphere’.

Table A8.3.1: The distributive characteristics across the categories and article types in ELA-3

Article types		**Number of archive items in ELA-3 literature map**							
		Category-i		**Category-ii**		**Category-iii**		**Total**	
Original		**16**		**17**		**26**		**59**	
Archetype-I	*Prototype-I*	*12*	-	*13*	-	*21*	-	*46*	-
Report		**1**		**8**		**2**		**11**	
Archetype-I	*Prototype-I*	*1*	-	*4*	-	*1*	-	*6*	-
Review		**6**		**2**		**3**		**11**	
Archetype-I	*Prototype-I*	*3*	-	*1*	-	*2*	-	*6*	-
Overview		**2**		**2**		**2**		**6**	
Archetype-I	*Prototype-I*	*2*	-	*1*	-	-	-	*3*	-
Perspective		**-**		**-**		**1**		**1**	
Archetype-I	*Prototype-I*	-	-	-	-	*1*	-	*1*	-
Synthesis		**-**		**1**		**-**		**1**	
Archetype-I	*Prototype-I*	-	-	-	-	-	-	-	-
Editorial		**-**		**1**		**2**		**3**	
Archetype-I	*Prototype-I*	-	-	-	-	*1*	-	*1*	-
Note		**-**		**2**		**-**		**2**	
Archetype-I	*Prototype-I*	-	-	*2*	-	-	-	*2*	-

A8.3.2 The distributive characteristics across the categories and the broad spheres

Three characteristic observations are exhibited from the distributive characteristics across the categories and the broad spheres (**Table A8.3.2**).

1. Similar to the ELA-2, the ELA-3 demonstrates a quite distributed pattern among the three categories within the broad spheres of A, B and C (i.e. the economic, social and environmental perspectives of sustainability, respectively). This is unlike the observation in ELA-1.

2. In the broad sphere D, 84.2% of the articles occurred under the academic-sphere (i.e. Category – iii), with the rest of the articles appearing in the 'Category – ii'. It continues to reveal the importance of the broad sphere D (i.e. central organization of sustainability) in the academic-sphere, in contrast to the distributed pattern across the three categories in the other three broad spheres of A, B and C. This observation conforms to the observations in the ELAs – 1 and 2.

3. In terms of the counts of articles corresponding to the four broad spheres, while the broad spheres of B and C in the ELA-1 and the broad sphere C in the ELA-2 correspond to the highest counts, the ELA-3 coincides with the observation on ELA-1, with 32.9% and 36.1% items from the literature map appearing under the broad spheres of B and C, respectively. However, the trend of significant lower presence of the archive items under the broad sphere A (i.e. economic perspectives of sustainability) remains constant across the three ELAs, which counts only 10.6% in the ELA-3. The cluster size of the broad sphere D (with 20.2% archive items from the literature map) in the ELA-3 maintains a somewhat intermediate position similar to ELA-1. Similar to the ELAs – 1 and 2, the presence of Archetype-I articles also remain equally vital across all broad spheres.

Table A8.3.2: The distributive characteristics across the categories and the broad spheres in ELA-3

Broad spheres		Number of archive items in ELA-3 literature map							
		Category-i		Category-ii		Category-iii		Total	
Broad sphere - A		**4**		**5**		**1**		**10**	
Archetype-I	*Prototype-I*	*4*	-	*3*	-	*1*	-	*8*	-
Broad sphere - B		**7**		**10**		**14**		**31**	
Archetype-I	*Prototype-I*	*5*	-	*7*	-	*9*	-	*21*	-
Broad sphere - C		**14**		**15**		**5**		**34**	
Archetype-I	*Prototype-I*	*9*	-	*10*	-	*5*	-	*24*	-
Broad sphere - D		**-**		**3**		**16**		**19**	
Archetype-I	*Prototype-I*	-	-	*1*	-	*11*	-	*12*	-
Overall		**25**		**33**		**36**		**94**	
Archetype-I	*Prototype-I*	*18*	-	*21*	-	*26*	-	*65*	-

A8.3.3 Cross-comparison between the empirical classification and the broad spheres across the categories

The cross-comparison between the empirical classification—having a total count of 14 empirical classes—and the broad spheres across the three categories for ELA-3 are summarized in **Table A8.3.3**. Similar to the observations in the ELAs – 1 and 2, ‘literature survey’ continues to reveal enormous importance, with 77.6% of the studies in the literature map solely or partly consisting of ‘literature survey’ as the overarching method for their conduction, along with a distributed pattern over the three categories.

All of the studies under the empirical class ‘reporting’ appear under the ‘Category – ii’, which communicates on its predominant utilization for studies corresponding to the ‘action/ approach-sphere’. This observation is in conformity to the ELAs – 1 and 2, where the bulk majority of the studies—instead of the entirety of it—appearing under the ‘Category – ii’. In ‘empirical field study/analysis’, the absence of studies under the ‘Categories – i and ii’—despite its presence in the remaining ‘Category – iii’—reveals a weak aspect in sustainability science research, which is in conformity to the ‘ELAs – 1 and 2’ in terms of a continued absence under the ‘Category – i’ in these ELAs.

Table A8.3.3: Cross-comparison between the empirical classification and the broad spheres across the categories in ELA-3

Q2	Broad spheres	Number of archive items in ELA-3 literature map			
		Category-i	Category-ii	Category-iii	Total
Literature survey	A	4	3	1	8
	B	5	8	13	26
	C	9	12	5	26
	D	-	1	12	13
	Overall	18	24	31	73
Modeling	B	1	1	-	2
	C	1	2	-	3
	Overall	2	3	0	5
Reporting	C	-	1	-	1
	D	-	1	-	1
	Overall	0	2	0	2
Editorial	A	-	1	-	1
	D	-	-	1	1
	Overall	0	1	1	2
Empirical field study/analysis	B	-	-	1	1
	Overall	0	0	1	1
Field study	D	-	-	1	1
	Overall	0	0	1	1
Case history	C	1	-	-	1
	Overall	1	0	0	1

Q2	Broad spheres	Number of archive items in ELA-3 literature map			
		Category-i	Category-ii	Category-iii	Total
Case study	B	-	1	2	3
	C	-	1	-	1
	D	-	-	1	1
	Overall	0	2	3	5
Review	A	-	1	-	1
	C	3	-	-	3
	D	-	-	1	1
	Overall	3	1	1	5
Opinion	D	-	1	1	2
	Overall	0	1	1	2
Simulation	C	1	1	-	2
	Overall	1	1	0	2
Scenario study	B	-	1	-	1
	Overall	0	1	0	1
Field survey	B	-	-	1	1
	Overall	0	0	1	1
Systemic assessment	B	1	-	-	1
	Overall	1	0	0	1

A8.3.4 Cross-comparison between the empirical classification and the article types across the categories

Similar to ELAs – 1 and 2, the cross-comparison between the empirical classifications and the article types in ELA-2 (**Table A8.3.4**) continue to reveal a strong correlation between 'literature survey' and the original article type (approximately 70% of the literature survey type studies being original). Apart from this, almost all other empirical classes overwhelmingly constitute original type articles, except for the classes that are not usually meant for original article-type, such as 'reporting', 'review', 'editorial', and 'opinion'. Therefore, consistent with the observation in ELAs – 1 and 2, the observations from ELA-3 also reveal the innovative aspect of sustainability science research.

Table A8.3.4: Cross-comparison between the empirical classification and the article types across the categories in ELA-3

Q2	Article types	Number of archive items in ELA-3 literature map			
		Category-i	Category-ii	Category-iii	Total
Literature survey	**Overall**	**18**	**24**	**31**	**73**
	Original	*12*	*14*	*25*	*51*
	Report	*1*	*5*	*1*	*7*
	Review	*3*	*1*	*2*	*6*
	Overview	*2*	*1*	*1*	*4*
	Note	-	*2*	-	*2*
	Perspective	-	-	*1*	*1*
	Synthesis	-	*1*	-	*1*
	Editorial	-	-	*1*	*1*
Reporting	**Overall**	**0**	**2**	**0**	**2**
	Report	-	*2*	-	*2*
Editorial	**Overall**	**0**	**1**	**1**	**2**
	Editorial	-	*1*	*1*	*2*
Empirical field study/analysis	**Overall**	**0**	**0**	**1**	**1**
	Original	-	-	*1*	*1*
Field study	**Overall**	**0**	**0**	**1**	**1**
	Report	-	-	*1*	*1*
Field survey	**Overall**	**0**	**0**	**1**	**1**
	Original	-	-	*1*	*1*

Q2	Article types	Number of archive items in ELA-3 literature map			
		Category-i	Category-ii	Category-iii	Total
Case study	**Overall**	**0**	**2**	**3**	**5**
	Original	-	*2*	*2*	*4*
	Overview	-	-	*1*	*1*
Review	**Overall**	**3**	**1**	**1**	**5**
	Review	*3*	*1*	*1*	*5*
Modeling	**Overall**	**2**	**3**	**0**	**5**
	Original	*2*	*2*	-	*4*
	Report	-	*1*	-	*1*
Opinion	**Overall**	**0**	**1**	**1**	**2**
	Overview	-	*1*	*1*	*2*
Simulation	**Overall**	**1**	**1**	**0**	**2**
	Original	*1*	*1*	-	*2*
Case history	**Overall**	**1**	**0**	**0**	**1**
	Original	*1*	-	-	*1*
Scenario study	**Overall**	**0**	**1**	**0**	**1**
	Report	-	*1*	-	*1*
Systemic assessment	**Overall**	**1**	**0**	**0**	**1**
	Original	*1*	-	-	*1*

A8.3.5 Representative themes in their respective categories based on ELA-3

The appearance of the highly frequent themes (any theme appearing with three or more archive items) for ELA-2 are highlighted in **Table A8.3.5** with greyed shadow. Under the 'Category – i', there is only one highly frequent theme — '*coastal vulnerability issues & sea level rise*', which is also in common with the ELA-1. With regard to the ELA-3 topic, the vulnerability of a number of global cities situated along the coastal areas is reflected in this theme.

In case of 'action/ approach-sphere' (i.e. Category – ii), '*low-carbon transitions*', '*urban policy/innovation*', and '*water policy/innovation*' become the most frequently appeared themes, while in the academic-sphere (category – iii) these are found to be '*sustainability challenge*', '*land cover and land use change science*', and '*urban sustainability and adaptive urban governance*', the first two of which are in common with the ELA-1 while 'land cover and land use change science' has been among the three most highlighted themes across all three ELAs.

Table A8.3.5: Representative themes in their respective categories based on ELA-3

Themes in 'Category-i' in ELA-3		# of items	Themes in 'Category -ii' in ELA-3		# of items	Themes in 'Category -iii in ELA-3		# of items
ID	Theme		ID	Theme		ID	Theme	
2	Water availability/quality	2	**1**	Energy policy/innovation	3	**3**	"Reuse" as theory	1
3	Industrialization—Energy—Environment	2	**2**	Alternative livelihood	1	**4**	Circular economy	1
4	Urbanization—Consumption—Environment	2	**3**	Interventions and development, and conservation	1	**5**	Quantitative sustainability	1
5	Air pollution—GHG Emission—Emission transfers	2	**4**	Community involvement	1	**6**	Natural capital & ecosystem services management/governance	3
7	Public health	1	**5**	Low-carbon transitions	5	**7**	Ecological economics	1
9	Population—Consumption—Environment	2	**11**	Regional cooperation	2	**8**	Resilience	1
11	Climate change problem/impacts	2	**12**	Modeling	2	**11**	Sustainability challenge	5
12	Drought	1	**13**	Adaptation—Natural Disaster—Migration—Benefits	2	**13**	Rural-urban transformation	1
13	Delta — problems	1	**14**	Urban policy/innovation	6	**15**	Sustainable architecture	3
15	Coastal vulnerability issues & sea level rise	9	**15**	Reuse—Recycling—Pollution control	1	**16**	Urban sustainability and adaptive urban governance	6
16	Global warming—Natural disaster	1	**16**	Technology and nanotechnology	1	**17**	Adaptation	1
Overall		25	**17**	Water policy/innovation	5	**19**	Land cover and land use change science	5
			20	Land use system planning/innovation	1	**20**	Sustainability—Culture—Religion	2
			22	Ecosystem services policy/innovation	1	**22**	Learning—Knowledge—Ignorance—Condition	1
			23	Air quality policy/innovation	1	**37**	Ontology and/or epistemology of Sustainability Science	1
			Overall		33	**38**	Complex systems, analysis, and adaptive planning/management	1
						40	Urban agriculture	1
						49	Landscape ecology	1
						Overall		36

A8.3.6 Frequency distribution of archive items under the themes across the broad spheres

Consistent with the observations in the ELAs – 1 and 2, the frequency distribution of archive items under the themes across the broad spheres for ELA-3 (**Table A8.3.6**) continues to reveal the least representation in the broad sphere D under 'Category – i'. This consistent observation across all three ELAs communicate a lack in sustainability science research in attempting to understand the problems/ issues from a conjoint perspective of the economic, social and environmental aspects (i.e. reflecting the sphere D). While in the 'ELAs – 1 and 2' the studies have mostly concentrated within the broad spheres of B and C under the 'Category – i', in case of ELA-3 it instead occurs merely with the broad sphere C.

In the 'action/ approach-sphere' (i.e. Category – ii), the observations follow the trend as observed in ELA-1, with a distributed presence of the studies across all four broad spheres along with major emphasis observed within the broad spheres of B and C. In case of ELA-2 the studies were also found as mostly concentrating within the broad spheres of B and C, however, without a distributed presence across the other two broad spheres. Under the academic-sphere (i.e. Category – iii), identical as in the ELAs – 1 and 2, the dominance continues to be observed on the broad spheres of B, C and D altogether, thereby, communicating a degree of negligence existing in terms of the economic perspectives of sustainability (i.e. the broad sphere A).

Table A8.3.6: Frequency distribution of archive items under the themes across the broad spheres in ELA-3

Themes in 'Category-i' in ELA-3		Number of items				
ID	Theme	Overall	Broad sphere A	Broad sphere B	Broad sphere C	Broad sphere D
15	Coastal vulnerability issues & sea level rise	*9*	-	-	9	-
Themes in 'Category-ii' in ELA-3		**Number of items**				
ID	**Theme**	**Overall**	**Broad sphere A**	**Broad sphere B**	**Broad sphere C**	**Broad sphere D**
14	Urban policy/innovation	6	-	3	1	2
5	Low-carbon transitions	5	2	2	1	-
17	Water policy/innovation	5	-	-	4	1
1	Energy policy/innovation	3	3	-	-	-
Total		*19*	*5*	*5*	*6*	*3*
Themes in 'Category-iii' in ELA-3		**Number of items**				
ID	**Theme**	**Overall**	**Broad sphere A**	**Broad sphere B**	**Broad sphere C**	**Broad sphere D**
16	Urban sustainability and adaptive urban governance	6	-	3	-	3
11	Sustainability challenge	5	-	-	2	3
19	Land cover and land use change science	5	-	-	2	3
6	Natural capital & ecosystem services management/governance	3	-	1	1	1
15	Sustainable architecture	3	-	3	-	-
Total		*22*	*0*	*7*	*5*	*10*

Appendix 9

Observed data on the focus analyses (FA – I, II, III and IV)

See **Section 4.3** of the thesis for detail explanation on the column headings ‘Item ID’, ‘Item’, ‘Sphere’, ‘Category’, ‘Theme ID’ and ‘Theme’ in the table. The tables are designed as per the 10 spheres (sphere A[Economy], AB[Socio-economy], AC[Environo-economy], B[Society], BA[Econo-society], BC[Environo-society], C[Environment], CA[Econo-environment], CB[Socio-environment], and D[Central organization of sustainability]). These 10 spheres construct the second layer of organization within the ‘Group-A’ literature archive, the details of which are provided in the thesis in **Section 3.4.3**.

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	[Hum-Env] / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JG11	(Gilbert 2010)	A	i	1	Food security—Agricultural challenges/issues				
JH7	(Hara et al. 2011)	A	i	3	Industrialization—Energy—Environment				
JB26	(Berkhout et al. 2012)	A	ii	1	Energy policy/innovation				
JG2	(Gallagher et al. 2006)	A	ii	1	Energy policy/innovation				
JG12	(Gillingham et al. 2006)	A	ii	1	Energy policy/innovation				
JG5	(Geels 2002)	A	iii	1	Transition theory				

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	[Hum-Env] / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JB7	(Bettencourt et al. 2007)	AB	i	4	Urbanization—Consumption—Environment				
JG20	(Graedel and Cao 2010)	AB	i	4	Urbanization—Consumption—Environment				
JJ12	(Jolly et al. 2012)	AB	ii	1	Energy policy/innovation				
JM29	(McCauley and Stephens 2012)	AB	ii	1	Energy policy/innovation				
JN9	(Nakamura et al. 2013)	AB	ii	1	Energy policy/innovation				
JS44	(Suwa and Jupesta 2012)	AB	ii	1	Energy policy/innovation				

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	[Hum-Env] / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JA3	(Adeel and Safriel 2008)	AB	ii	2	Alternative livelihood				
JA13	(Arnold et al. 2010)	AB	ii	3	Interventions and development, and conservation				
JF1	(Fabusoro 2009)	AB	ii	4	Community involvement				
JH32	(Hanaoka and Kainuma 2012)	AB	ii	5	Low-carbon transitions				
JT2	(Takiguchi and Morita 2009)	AB	ii	5	Low-carbon transitions				
JZ5	(Zhou 2006)	AB	ii	5	Low-carbon transitions				
JA18	(Ausubel and Waggoner 2008)	AB	iii	2	Dematerialization				
JY5	(Yokoo 2010)	AB	iii	3	"Reuse" as theory				
JZ4	(Zhijun and Nailing 2007)	AB	iii	4	Circular economy				
JZ9	(Zik and Kulatilaka 2013)	AB	iii	5	Quantitative sustainability				

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JE2	(Ejeta 2010)	AC	i	1	Food security—Agricultural challenges/issues				
JF14	(Furuya and Kobayashi 2009)	AC	i	1	Food security—Agricultural challenges/issues		Agricultural product market - Global warming		
JC8	(Chong and Sunding 2006)	AC	i	2	Water availability/quality		Market - Water		
JK31	(Kim 2006)	AC	i	3	Industrialization—Energy—Environment		Human manipulation - Natural setting		
JS17	(Shi et al. 2011)	AC	i	3	Industrialization—Energy—Environment				
JP11	(Peters et al. 2011)	AC	i	5	Air pollution—GHG Emission—Emission transfers				
JS35	(Suneetha 2010)	AC	i	6	Biodiversity—Habitat destruction—Trade		Market - Biodiversity		
JL7	(Lee et al. 2008)	AC	ii	1	Energy policy/innovation		Biofuels - Agricultural land		
JM21	(Moreira and Goldemberg 1999)	AC	ii	1	Energy policy/innovation		Biofuels - Agricultural land		
JS27	(Steinfeld 2006)	AC	ii	1	Energy policy/innovation				
JS42	(Sovacool and Bulan 2013)	AC	ii	1	Energy policy/innovation		Renewable energy - Fluvial water		
JA20	(Akashi and Hanaoka 2012)	AC	ii	5	Low-carbon transitions				

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JA21	(Akimoto et al. 2012)	AC	ii	5	Low-carbon transitions				
JI2	(Ikkatai et al. 2008)	AC	ii	5	Low-carbon transitions				
JM11	(Matsuoka et al. 2008)	AC	ii	5	Low-carbon transitions				
JW15	(Wagner et al. 2012)	AC	ii	5	Low-carbon transitions				
JT15	(Tsuji et al. 2011)	AC	ii	6	Biodiversity—Agriculture—Poverty				
JA9	(Andersen 2007)	AC	iii	4	Circular economy		Economy - Environment		
JD6	(Dasgupta 2008)	AC	iii	6	Natural capital & ecosystem services management/governance		Economy - Natural capital		
JP31	(Patterson and Glavovic 2013)	AC	iii	7	Ecological economics		Ecological economy of oceans and coasts		

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	[Hum-Env] / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JA1	(Acuin et al. 2011)	B	i	7	Public health				
JC16	(Coker et al. 2011)	B	i	7	Public health				
JW6	(WHO 2009)	B	i	7	Public health				
JA16	(Aspinall 2005)	B	i	8	Human insecurity—Conflict				
JH28	(HSC 2005)	B	i	8	Human insecurity—Conflict				
JH29	(HSC 2011, Part I)	B	i	8	Human insecurity—Conflict				

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JH30	(HSC 2011, Part III)	B	**i**	**8**	Human insecurity—Conflict				
JU1	(UN-ESC 2009)	B	**i**	**9**	Population—Consumption—Environment				
JP13	(Phillips et al. 2005)	B	**ii**	**3**	Interventions and development, and conservation				
JP23	(GF 2009)	B	**ii**	**3**	Interventions and development, and conservation				
JP24	(GF 2009)	B	**ii**	**3**	Interventions and development, and conservation				
JP26	(GF 2009)	B	**ii**	**3**	Interventions and development, and conservation				
JP27	(GF 2009)	B	**ii**	**3**	Interventions and development, and conservation				
JP28	(GF 2009)	B	**ii**	**3**	Interventions and development, and conservation				
JP29	(GF 2009)	B	**ii**	**3**	Interventions and development, and conservation				
JS33	(GF 2009)	B	**ii**	**3**	Interventions and development, and conservation				
JJ6	(Jarchow et al. 2011)	B	**ii**	**4**	Community involvement				
JK34	(Kisinza et al. 2008)	B	**ii**	**4**	Community involvement				
JR1	(Raloff 1998)	B	**ii**	**4**	Community involvement				

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JA10	(Andersson 2008)	B	**ii**	**7**	Social learning				
JB12	(Bongaarts 1994)	B	**ii**	**8**	Population policy				
JC18	(Colten et al. 2008)	B	**iii**	**8**	Resilience				
JL8	(Leiserowitz et al. 2005)	B	**iii**	**9**	Value—Attitude—Behavior				
JL9	(Leiserowitz et al. 2006)	B	**iii**	**9**	Value—Attitude—Behavior				

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	[Hum-Env] / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JA2	(Struble and Aomari 2003)	BA	**i**	**1**	Food security—Agricultural challenges/issues				
JB1	(Barrett 2010)	BA	**i**	**1**	Food security—Agricultural challenges/issues				
JC6	(Godfray et al. 2010)	BA	**i**	**1**	Food security—Agricultural challenges/issues				
JC19	(Conway 2000)	BA	**i**	**1**	Food security—Agricultural challenges/issues				
JF9	(2010)	BA	**i**	**1**	Food security—Agricultural challenges/issues				
JF11	(Frongillo 1999)	BA	**i**	**1**	Food security—Agricultural challenges/issues				
JM10	(Matsumura et al. 2009)	BA	**i**	**1**	Food security—Agricultural challenges/issues				

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JW2	(Webb 2010)	BA	**i**	**1**	Food security—Agricultural challenges/issues				
JM8	(Marcotullio 2007)	BA	**i**	**2**	Water availability/quality				
JH23	(Homs 2007)	BA	**i**	**4**	Urbanization—Consumption—Environment				
JK10	(Kates 2000b)	BA	**i**	**9**	Population—Consumption—Environment				
JC17	(Collier 2007)	BA	**i**	**10**	African poverty				
JP30	(GF 2009)	BA	**ii**	**3**	Interventions and development, and conservation				
JM2	(Mabogunje 2007)	BA	**ii**	**4**	Community involvement				
JD17	(Diffenbaugh 2013)	BA	**ii**	**5**	Low-carbon transitions				
JL2	(Larson and Ribot 2007)	BA	**ii**	**9**	Forest management policy/innovation				
JT4	(Tester and Langridge 2010)	BA	**ii**	**10**	Agricultural policy/innovation				
JT14	(Trieb and Müller-Steinhagen 2007)	BA	**ii**	**11**	Regional cooperation				
JA17	(Auer 2007)	BA	**iii**	**10**	Institutional reform				
JK5	(Kates 1992)	BA	**iii**	**11**	Sustainability challenge				

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JL13	(Levi-Faur 2005)	BA	**iii**	**12**	Regulatory capitalism				
JL14	(Levi-Faur and Jordana 2005)	BA	**iii**	**12**	Regulatory capitalism				
JM13	(McGee 2008)	BA	**iii**	**13**	Rural-urban transformation				
JR15	(Rosenfeld 2010)	BA	**iii**	**14**	Poverty—Development				
JT12	(Townsend 2010)	BA	**iii**	**14**	Poverty—Development				
JS5	(Sanya 2012)	BA	**iii**	**15**	Sustainable architecture				

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JR4	(Rarieya and Fortun 2010)	BC	**i**	**1**	Food security—Agricultural challenges/issues				
JF13	(Funke et al. 2007)	BC	**i**	**2**	Water availability/quality		Human consumption - Water resources		
JK25	(Kazama et al. 2012)	BC	**i**	**7**	Public health		Infectious disease - Tropical monsoon inundation		
JI7	(Iwasaki and Shaw 2009)	BC	**i**	**8**	Human insecurity—Conflict		Human security - Natural resources		
JK29	(Khagram and Ali 2006)	BC	**i**	**8**	Human insecurity—Conflict		Human security - Natural resources		
JD12	(Dietz et al. 2003)	BC	**i**	**9**	Population—Consumption—Environment		Human consumption - Natural resource		
JG13	(Gleick 2003b)	BC	**i**	**9**	Population—Consumption—Environment		Human consumption - Water resources		

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JO1	(O'Neill et al. 2010)	BC	**i**	**9**	Population—Consumption—Environment				
JP16	(Popovski and Mundy 2012)	BC	**i**	**11**	Climate change problem/impacts				
JS16	(Shahbazbegian and Bagheri 2010)	BC	**i**	**12**	Drought		Human water consumption - Drought vulnerability		
JS38	(Syvitski 2008)	BC	**i**	**13**	Delta — problems		Human manipulation - Vulnerable deltas		
JH33	(Higgins and Foliente 2013)	BC	**ii**	**3**	Interventions and development, and conservation		Conservation intervention - Environmental benefits		
JP1	(de Palencia and Pérez-Foguet 2011)	BC	**ii**	**3**	Interventions and development, and conservation				
JP25	(GF 2009)	BC	**ii**	**3**	Interventions and development, and conservation				
JR17	(Rehman et al. 2012)	BC	**ii**	**3**	Interventions and development, and conservation				
JT11	(Toth and Hizsnyik 2008)	BC	**ii**	**4**	Community involvement				
JG17	(Gomi et al. 2007)	BC	**ii**	**5**	Low-carbon transitions		Low-carbon society		
JS20	(Snapp et al. 2010)	BC	**ii**	**6**	Biodiversity—Agriculture—Poverty				

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JT7	(Timmer and Juma 2005)	BC	ii	6	Biodiversity—Agriculture—Poverty		Poverty reduction - Biodiversity conservation		
JY10	(Yami et al. 2013)	BC	ii	9	Forest management policy/innovation		Rural community institutions - Exclosure management		
JI5	(IAC 2004)	BC	ii	10	Agricultural policy/innovation				
JT13	(Townsend and Porder 2012)	BC	ii	10	Agricultural policy/innovation		Agriculture - Environment		
JN1-4	(Ross and Woo 2011)	BC	ii	11	Regional cooperation				
JA22	(Antanasijević et al. 2013)	BC	ii	12	Modeling				
JP22	(Preston et al. 2011)	BC	ii	12	Modeling				
JB11	(Black et al. 2011)	BC	ii	13	Adaptation—Natural Disaster—Migration—Benefits		Adaptive migration - Natural disaster		
JG24	(Gray and Mueller 2012)	BC	ii	13	Adaptation—Natural Disaster—Migration—Benefits		Adaptive migration - Natural disaster		
JP2	(Parker et al. 2007)	BC	ii	13	Adaptation—Natural Disaster—Migration—Benefits				
JR16	(Reckien et al. 2013)	BC	ii	13	Adaptation—Natural Disaster—Migration—Benefits				
JS36	(Surjan and Shaw 2008)	BC	ii	14	Urban policy/innovation		Disaster-resilient eco-community		

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JU3	(UN-Habitat 2012)	BC	**ii**	**14**	Urban policy/innovation				
JW9	(Wilbanks et al. 2007)	BC	**ii**	**14**	Urban policy/innovation		City response - Climate change vulnerability		
JT5	(Thomas 2011)	BC	**ii**	**15**	Reuse—Recycling—Pollution control				
JK41	(Kurian et al. 2013)	BC	**iii**	**3**	"Reuse" as theory		Agricultural re-use of wastewater - Peri-urban areas		
JL11	(Lemos and Agrawal 2006)	BC	**iii**	**6**	Natural capital & ecosystem services management/governance				
JL22	(Lynam et al. 2007)	BC	**iii**	**6**	Natural capital & ecosystem services management/governance		Co-management community decision making - Natural resources		
JS32	(Su et al. 2012)	BC	**iii**	**6**	Natural capital & ecosystem services management/governance		Human activities - Ecosystem services		
JW4	(White 1967)	BC	**iii**	**11**	Sustainability challenge		Historical root - Ecological crisis		
JK6	(Kates and Haarmann 1992)	BC	**iii**	**14**	Poverty—Development		Poor community - Place		
JR6	(Raudsepp-Hearne et al. 2010)	BC	**iii**	**14**	Poverty—Development		More human well-being - Less ecosystem services		
JK37	(Kosamu 2011)	BC	**iii**	**15**	Sustainable architecture		Infrastructural projects - Environmental impacts		

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JN1-3	(Brown 2011)	BC	**iii**	**15**	Sustainable architecture				
JB10	(Birkmann et al. 2010)	BC	**iii**	**16**	Urban sustainability and adaptive urban governance		Adaptive urban governance		
JS9	(Satterthwaite 2007)	BC	**iii**	**16**	Urban sustainability and adaptive urban governance		Concentrated consumption - Urban areas		
JS23	(Solecki and Leichenko 2006)	BC	**iii**	**16**	Urban sustainability and adaptive urban governance		Urbanization - Metropolitan environment		
JK9	(Kates 2000a)	BC	**iii**	**17**	Adaptation		Adaptation - Climate change		
JM20	(Molua 2011)	BC	**iii**	**17**	Adaptation		Adaptation - Climate change		
JL15	(Lie 2007)	BC	**iii**	**18**	Political ecology				
JL17	(Liverman and Vilas 2006)	BC	**iii**	**18**	Political ecology		Politics - Environment		
JM7	(Manson 2006)	BC	**iii**	**19**	Land cover and land use change science		Population and institution - Land-use and land-cover		
JW13	(Wu et al. 2010)	BC	**iii**	**19**	Land cover and land use change science		Agriculture - Land		
JY4	(Yin and Xiang 2010)	BC	**iii**	**19**	Land cover and land use change science		Agriculture - Land use		
JM31	(Mohamad et al. 2012)	BC	**iii**	**20**	Sustainability—Culture—Religion				
JT1	(Tàbara and Ilhan 2008)	BC	**iii**	**20**	Sustainability—Culture—Religion		Culture - Water domain sustainability		
JR10	(Roberts et al. 2003)	BC	**iii**	**21**	World System theory				

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JW5	(White et al. 2001)	BC	iii	22	Learning—Knowledge—Ignorance—Condition				

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	[Hum-Env] / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JP17	(Pöschl 2005)	C	i	5	Air pollution—GHG Emission—Emission transfers				
JO8	(Overpeck and Cole 2006)	C	i	11	Climate change problem/impacts				
JP3	(Parkinson 2006)	C	i	11	Climate change problem/impacts				
JK4	(Kasei et al. 2010)	C	i	12	Drought				
JB14	(Boyce et al. 2010)	C	i	14	Ecological crisis				
JG22	(Grainger 2008)	C	i	14	Ecological crisis				
JC9	(Church et al. 2008)	C	i	15	Coastal vulnerability issues & sea level rise				
JJ9	(Jin et al. 2008)	C	ii	12	Modeling				
JL12	(Lenton et al. 2008)	C	iii	23	Earth System analysis and tipping elements/points				
JL20	(Lovelock 1986)	C	iii	23	Earth System analysis and tipping elements/points				

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JE5	(Esteban et al. 2009)	CA	i	16	Global warming—Natural disaster		Urban productivity - Global warming-induced typhoon intensity		
JB8	(Birch et al. 2010)	CA	ii	9	Forest management policy/innovation				
JH27	(Hosoda and Hayashi 2010)	CA	ii	11	Regional cooperation				
JK24	(Kazama et al. 2010)	CA	ii	12	Modeling		Flood damage - extreme rainfall		
JD11	(Diallo and Brinker 2011)	CA	ii	16	Technology and nanotechnology				
JS22	(Socolow et al. 2004)	CA	ii	16	Technology and nanotechnology				
JE4	(Esposto 2009)	CA	ii	17	Water policy/innovation				
JE6	(Eyckmans and Finus 2007)	CA	ii	18	Treaties—Agreements				
JC21	(Costanza et al. 1997)	CA	iii	6	Natural capital & ecosystem services management/governance		Economic value - Ecosystem services and natural capital		
JD1	(Daily et al. 2000)	CA	iii	6	Natural capital & ecosystem services management/governance		Economic value - Ecosystem services and natural capital		
JA12	(Arndt et al. 2011)	CA	iii	17	Adaptation		Adaptation - Climate change		
JD4	(Dasgupta et al. 1995)	CA	iii	24	Environmental regulation				

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JM3	(MacDonald et al. 2011)	CB	i	1	Food security—Agricultural challenges/issues				
JM9	(Marty et al. 2010)	CB	i	1	Food security—Agricultural challenges/issues				
JS1	(Sachs et al. 2010)	CB	i	1	Food security—Agricultural challenges/issues		Farming practices - Land impacts		
JS8	(Sattari et al. 2012)	CB	i	1	Food security—Agricultural challenges/issues				
JM19	(Molina and Molina 2004)	CB	i	5	Air pollution—GHG Emission—Emission transfers		Megacity atmospheric pollution		
JD13	(Dirzo and Raven 2003)	CB	i	6	Biodiversity—Habitat destruction—Trade				
JG8	(Geist and Lambin 2002)	CB	i	6	Biodiversity—Habitat destruction—Trade		Human manipulation - Tropical deforestation		
JS4	(Sala and Knowlton 2006)	CB	i	6	Biodiversity—Habitat destruction—Trade		Human manipulation - Marine biodiversity		
JK14	(Kates and Wilbanks 2003)	CB	i	11	Climate change problem/impacts				
JN2	(NAS 2008)	CB	i	11	Climate change problem/impacts				
JS3	(Sahoo and Schladow 2008)	CB	i	11	Climate change problem/impacts				
JP18	(Postel 2005)	CB	i	14	Ecological crisis				

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JG23	(Gravelle and Mimura 2008)	CB	**i**	**15**	Coastal vulnerability issues & sea level rise				
JH9	(Harvey and Woodroffe 2008)	CB	**i**	**15**	Coastal vulnerability issues & sea level rise				
JM15	(Mcleod et al. 2010)	CB	**i**	**15**	Coastal vulnerability issues & sea level rise				
JN7	(Nicholls et al. 2008)	CB	**i**	**15**	Coastal vulnerability issues & sea level rise				
JR14	(Romieu et al. 2010)	CB	**i**	**15**	Coastal vulnerability issues & sea level rise				
JT10	(Torresan et al. 2008)	CB	**i**	**15**	Coastal vulnerability issues & sea level rise				
JY2	(Yasuhara et al. 2007)	CB	**i**	**15**	Coastal vulnerability issues & sea level rise				
JY3	(Yasuhara et al. 2011)	CB	**i**	**15**	Coastal vulnerability issues & sea level rise				
JL19	(Lotze et al. 2006)	CB	**i**	**17**	Estuaries & coastal seas — problems				
JS18	(Sidle et al. 2007)	CB	**i**	**18**	Open water bodies — problems		Floating garden agriculture - Open water surface		
JS2	(Safriel and Adeel 2008)	CB	**ii**	**2**	Alternative livelihood		Alternative livelihood - Dryland development		
JB2	(Barthelmie et al. 2008)	CB	**ii**	**5**	Low-carbon transitions				

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JA23	(Azadi et al. 2013)	CB	**ii**	**9**	Forest management policy/innovation				
JL4	(Lebel et al. 2004)	CB	**ii**	**9**	Forest management policy/innovation				
JS24	(Sonwa et al. 2011)	CB	**ii**	**9**	Forest management policy/innovation				
JY8	(Yoshikawa et al. 2011)	CB	**ii**	**9**	Forest management policy/innovation		Forest land use and biodiversity		
JC4	(Cassman et al. 2003)	CB	**ii**	**10**	Agricultural policy/innovation		Sustainable agriculture - Natural resources and environmental quality		
JC7	(Chen et al. 2011)	CB	**ii**	**10**	Agricultural policy/innovation				
JF4	(Fedoroff et al. 2010)	CB	**ii**	**10**	Agricultural policy/innovation				
JG4	(Gebbers and Adamchuk 2010)	CB	**ii**	**10**	Agricultural policy/innovation				
JG9	(Gewin 2010)	CB	**ii**	**10**	Agricultural policy/innovation				
JH13	(Herdt 2006)	CB	**ii**	**10**	Agricultural policy/innovation				
JH15	(Herrero et al. 2010)	CB	**ii**	**10**	Agricultural policy/innovation				
JR11	(Roberts and Brink 2010)	CB	**ii**	**10**	Agricultural policy/innovation		Conservation - Marine resources		
JS43	(Spugnoli and Dainelli 2013)	CB	**ii**	**10**	Agricultural policy/innovation		Agriculture - Environment		

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JT8	(Tollefson 2010)	CB	**ii**	**10**	Agricultural policy/innovation		Agriculture - Natural areas		
JK22	(Katsuyama et al. 2009)	CB	**ii**	**12**	Modeling		Logging - Forested watershed		
JP21	(Poumadère et al. 2008)	CB	**ii**	**12**	Modeling				
JB9	(Birkmann and von Teichman 2010)	CB	**ii**	**13**	Adaptation—Natural Disaster—Migration—Benefits				
JH11	(Hay and Mimura 2006)	CB	**ii**	**13**	Adaptation—Natural Disaster—Migration—Benefits				
JS30	(von Storch and Woth 2008)	CB	**ii**	**13**	Adaptation—Natural Disaster—Migration—Benefits				
JO3	(Ohyama et al. 2008)	CB	**ii**	**14**	Urban policy/innovation		Urban horticulture - Environmental conservation		
JN1-6	(Graedel 2011)	CB	**ii**	**15**	Reuse—Recycling—Pollution control				
JZ2	(Zhang et al. 2006)	CB	**ii**	**15**	Reuse—Recycling—Pollution control		Rural resource recycling - Environmental pollution management		
JD3	(Daniell et al. 2010)	CB	**ii**	**17**	Water policy/innovation				
JG14	(Gleick 2003a)	CB	**ii**	**17**	Water policy/innovation				
JH14	(Hermanowicz 2008)	CB	**ii**	**17**	Water policy/innovation				
JR2	(Ramanathan and Xu 2010)	CB	**ii**	**18**	Treaties—Agreements				

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JB15	(Brack et al. 2006)	CB	**ii**	**19**	Emission estimation/control		Greenhouse gas emissions - Land systems		
JC1	(Caldeira and Davis 2011)	CB	**ii**	**19**	Emission estimation/control				
JH6	(Hara et al. 2010)	CB	**ii**	**20**	Land use system planning/innovation		Mixed land-use planning - City periphery		
JK33	(Kimura et al. 2010)	CB	**ii**	**20**	Land use system planning/innovation		Land use combinations - Low environmental impact		
JK39	(Kumar and Takeuchi 2009)	CB	**ii**	**20**	Land use system planning/innovation		Sustainable land use systems		
JL5	(Leclerc et al. 2009)	CB	**ii**	**20**	Land use system planning/innovation				
JH19	(Hoekstra 2012)	CB	**ii**	**21**	Biodiversity conservation policy/innovation				
JL10	(Lejano and Ingram 2007)	CB	**ii**	**21**	Biodiversity conservation policy/innovation		Species conservation - Local place		
JS6	(Sarkar et al. 2006)	CB	**ii**	**21**	Biodiversity conservation policy/innovation				
JJ1	(Jack et al. 2008)	CB	**ii**	**22**	Ecosystem services policy/innovation				
JK35	(Komatsuzaki and Ohta 2007)	CB	**ii**	**22**	Ecosystem services policy/innovation				
JT9	(Tomich et al. 2004)	CB	**ii**	**22**	Ecosystem services policy/innovation		Land use change - Environmental services		

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JX1	(Xia and Yan 2012)	CB	ii	22	Ecosystem services policy/innovation		Agricultural nitrogen application - Ecology		
JL18	(Longhurst et al. 2009)	CB	ii	23	Air quality policy/innovation				
JY7	(Yoshida 2007)	CB	ii	24	Environmental restoration policies/innovation				
JC2	(Carpenter et al. 2009)	CB	iii	6	Natural capital & ecosystem services management/governance				
JD2	(Daily and Matson 2008)	CB	iii	6	Natural capital & ecosystem services management/governance		Human - Environment interactions system		
JD10	(Depietri et al. 2012)	CB	iii	6	Natural capital & ecosystem services management/governance		Urbanization - Environmental hazards		
JF5	(Ferraro Jr. and Burztyn 2008)	CB	iii	6	Natural capital & ecosystem services management/governance		Human manipulation - Natural areas		
JG3	(Gardi and Sconosciuto 2007)	CB	iii	6	Natural capital & ecosystem services management/governance				
JH4	(Halpin 1997)	CB	iii	6	Natural capital & ecosystem services management/governance				
JB20	(Bueno and Basurto 2009)	CB	iii	8	Resilience				

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JM5	(Mah and Bustami 2012)	CB	**iii**	**8**	Resilience				
JP19	(Potschin and Haines-Young 2006b)	CB	**iii**	**11**	Sustainability challenge				
JS28	(Stocker et al. 2010)	CB	**iii**	**11**	Sustainability challenge				
JY6	(York et al. 2003)	CB	**iii**	**11**	Sustainability challenge		Human manipulation - Environmental impacts		
JF15	(Füssel 2007)	CB	**iii**	**17**	Adaptation				
JD9	(DeFries et al. 2006)	CB	**iii**	**19**	Land cover and land use change science		Human - Environment interactions system		
JG1	(Gadda and Gasparatos 2009)	CB	**iii**	**19**	Land cover and land use change science		Urban consumption - Land use and cover change		
JI4	(Ileva et al. 2009)	CB	**iii**	**19**	Land cover and land use change science		Land use - River ecosystem health		
JL1	(Lambin et al. 2003)	CB	**iii**	**19**	Land cover and land use change science		Land-use and land-cover change in tropical regions		
JP15	(Pontius Jr and Neeti 2010)	CB	**iii**	**19**	Land cover and land use change science				
JF12	(Fung and O'rourke 2000)	CB	**iii**	**24**	Environmental regulation				
JC14	(Clark et al. 2006)	CB	**iii**	**25**	Environmental assessment				

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JM24	(Mühlhäusler and Peace 2006)	CB	**iii**	**26**	Sustainability related discourses				
JK20	(Kates and Dasgupta 2007)	**D**	**i**	**10**	African poverty	Theoretical position of place in sustainability science		Theoretical position of place in sustainability science	
JI6	(IPCC 2007)	**D**	**i**	**11**	Climate change problem/impacts	Methodological practice of informing policy-makers/stake-holders	Global 'environmental-social' system	Methodology of complexity in simpler form of communication	
JZ7	(Ziv et al. 2012)	**D**	**i**	**19**	River — problems	Measuring trade-off between human appropriation and natural health	Human manipulation - Natural setting	Trading-off human interest from/with natural setting	
JN3	(Nautiyal 2011)	**D**	**ii**	**3**	Interventions and development, and conservation	Measuring trade-off between development intervention and conservation intervention	Development intervention - Conservation intervention	Trading-off between development intervention and conservation intervention	
JM18	(Millar et al. 2007)	**D**	**ii**	**9**	Forest management policy/innovation	Framework management of natural resources in uncertainty		Management of uncertainty (natural resource management)	
JA6	(Alcamo et al. 2005)	**D**	**ii**	**12**	Modeling				Future estimates on global ecosystem services
JG18	(Goodchild 2003)	**D**	**ii**	**12**	Modeling	GIS in environmental management systems			Applying GIS in environmental management systems
JJ5	(Janssen and Ostrom 2006)	**D**	**ii**	**12**	Modeling	Empirical- and agent-based modeling in social sciences		Complexity of empirical- and agent-based modeling in social sciences	
JM23	(Moser and Ekstrom 2010)	**D**	**ii**	**13**	Adaptation—Natural Disaster—Migration—Benefits	Framework for diagnosis of barriers to climate change adaptation		Complexity of framework for diagnosis of barriers to climate change adaptation	

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JH31	(Han et al. 2012)	**D**	**ii**	**14**	Urban policy/innovation	Innovations for industrialized urban sustainability	Industrialized urban system	Innovation system for industrialized urban sustainability	
JN1-1	(Fink 2011)	**D**	**ii**	**14**	Urban policy/innovation	Closer human networking for global sustainability			Urban genome mapping for global sustainability
JS13	(Schmandt 2006)	**D**	**ii**	**17**	Water policy/innovation	Scientific underpinnings of integrated analysis and management	Human settlement - Local natural geography	Scientific soundness of complexity in integrated analysis	
JZ8	(Zwane et al. 2009)	**D**	**ii**	**17**	Water policy/innovation	Place of multi-stake discussion in scientific activities	Human health and well-being - Water	Methodology of complexity in multi-stake discussion for scientific activity	
JS21	(Soberon 2004)	**D**	**ii**	**21**	Biodiversity conservation policy/innovation	Place of multi-stake discussion in scientific activities		Methodology of complexity in multi-stake discussion for scientific activity	
JG15	(2007)	**D**	**ii**	**24**	Environmental restoration policies/innovation	Global cooling through rainwater harvesting			
JA14	(Ascher 2006)	**D**	**ii**	**25**	Sustainable Development strategies/innovation	Place of strategic thinking in sustainability science		Methodology of complexity in strategic thinking in sustainability science	
JM1	(Mabogunje and Kates 2004)	**D**	**ii**	**25**	Sustainable Development strategies/innovation	Place of balance in the scientific making of sustainable development case study		Place of complexity in the scientific balance of sustainable development case study	
JN8	(Nidumolu et al. 2009)	**D**	**ii**	**25**	Sustainable Development strategies/innovation	Sustainability as driver of innovation		Complexity of innovation system in sustainability	
JZ1	(van Zeijl-Rozema et al. 2008)	**D**	**ii**	**25**	Sustainable Development strategies/innovation	Framework for governance in sustainability		Complexity of governance in sustainability	

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JG6	(Geels and Schot 2007)	**D**	**iii**	**1**	Transition theory	Place of sociotechnical transition paths in sustainability science			
JG7	(Geels 2011)	**D**	**iii**	**1**	Transition theory	Place of multi-level perspective in transition paths, in sustainability science		Complexity of framework for socio-technical transition paths in sustainability science	
JZ3	(Zhang et al. 2009)	**D**	**iii**	**4**	Circular economy	Analyzing multi-perspective performances of localized systems	Human manipulation - Natural setting	Complexity of multi-perspective performance analysis	
JB13	(Boulanger 2008)	**D**	**iii**	**5**	Quantitative sustainability	Place of sustainability indicator in sustainability science		Scientific complexity of developing sustainability indicator	
JF3	(Fan and Qi 2010)	**D**	**iii**	**5**	Quantitative sustainability	Sustainability assessment system			
JH5	(Hara et al. 2009)	**D**	**iii**	**5**	Quantitative sustainability	Sustainability assessment system		Complexity of sustainability assessment system	
JK18	(Kates et al. 2005)	**D**	**iii**	**5**	Quantitative sustainability	Scientific underpinnings of sustainable development		Scientific complexity of sustainable development	
JM27	(MacDonald 2005)	**D**	**iii**	**5**	Quantitative sustainability	Place of strategic thinking in sustainability science		Methodology of complexity in strategic thinking in sustainability science	
JN5	(Ness et al. 2007)	**D**	**iii**	**5**	Quantitative sustainability	Sustainability assessment system		Complexity of sustainability assessment system	
JO5	(Orecchini 2007)	**D**	**iii**	**5**	Quantitative sustainability	Scientific underpinnings of sustainable development		Scientific complexity of sustainable development	
JP4	(Parris and Kates 2003b)	**D**	**iii**	**5**	Quantitative sustainability	Scientific underpinnings of sustainable development		Scientific complexity of sustainable development	
JP5	(Parris and Kates 2003a)	**D**	**iii**	**5**	Quantitative sustainability	Scientific characteristics of sustainability transition		Scientific complexity of sustainability transition	
JP14	(Phillips 2010)	**D**	**iii**	**5**	Quantitative sustainability	Scientific underpinnings of sustainable development		Scientific complexity of sustainable development	

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JH2	(Haberl et al. 2007)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance		Human manipulation - Natural setting		Global depiction of human ecosystem primary production appropriation
JH8	(Hardin 1968)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance	Governance system in sustainability science	Human manipulation - Natural setting		
JH18	(Hoekstra and Mekonnen 2012)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance		Human consumption - Natural resource		Global depiction of water use by humans
JK26	(Kenward et al. 2011)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance	Place of governance strategies in sustainability science		Methodology of complexity in governance strategies in sustainability science	
JO6	(Ostrom and Nagendra 2006)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance	Natural resource governance in sustainability science	Land tenure system - Forests	Complexity of natural resource governance in sustainability science	
JO7	(Ostrom et al. 2007)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance	Natural resource governance in sustainability science	Human - Environment interactions system	Complexity of natural resource governance in sustainability science	
JT3	(Tallis and Kareiva 2006)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance	Natural resource management in sustainability science	Human - Environment interactions system	Complexity of natural resource management in sustainability science	Global ecosystem assessment models
JW11	(Wilderer 2007)	**D**	**iii**	**6**	Natural capital & ecosystem services management/governance	Natural resource management in sustainability science		Complexity of natural resource management in sustainability science	
JA4	(Adger 2000)	**D**	**iii**	**8**	Resilience	Place of resilience in sustainability science	Human - Ecological resilience		
JB16	(Brand and Jax 2007)	**D**	**iii**	**8**	Resilience	Place of resilience in sustainability science	Human - Ecological resilience		

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JF7	(Folke et al. 2010)	**D**	**iii**	**8**	Resilience	Place of resilience in sustainability science	Human - Environment interactions system	Complexity of resilience in sustainability science	
JH21	(Holling 1973)	**D**	**iii**	**8**	Resilience	Place of resilience in sustainability science	Human - Environment interactions system		
JS19	(Smith and Stirling 2010)	**D**	**iii**	**8**	Resilience	Resilience versus socio-technical transitions in sustainability science		Complexity of politics of resilience and socio-technical transitions	
JK19	(Kates et al. 2006)	**D**	**iii**	**9**	Value—Attitude—Behavior	Place of sustainability transition in sustainability science			
JA19	(Ayres 2000)	**D**	**iii**	**11**	Sustainability challenge	Dimensions of sustainability challenge			Understanding global trends in sustainability challenge
JB17	(Brewer 2007)	**D**	**iii**	**11**	Sustainability challenge	Dimensions of sustainability challenge		Complexity of dimensions of sustainability challenge	
JB18	(WCED 1987)	**D**	**iii**	**11**	Sustainability challenge	Dimensions of sustainability challenge			
JC11	(Clark 2003b)	**D**	**iii**	**11**	Sustainability challenge	Dimensions of sustainability challenge		Complexity of dimensions of sustainability challenge	
JC13	(Clark et al. 2004)	**D**	**iii**	**11**	Sustainability challenge	Nature of sustainability science		Complexity into the nature of sustainability science	Sustainability science for global sustainability
JD5	(Dasgupta 2007)	**D**	**iii**	**11**	Sustainability challenge	Scientific underpinnings of sustainable development		Scientific complexity of sustainable development	
JF8	(Folke et al. 2011)	**D**	**iii**	**11**	Sustainability challenge	Dimensions of sustainability challenge	Human - Environment interactions system	Complexity of dimensions of sustainability challenge	
JG21	(Graffy 2012)	**D**	**iii**	**11**	Sustainability challenge	Dimensions of sustainability challenge			
JH20	(Holdren 2008)	**D**	**iii**	**11**	Sustainability challenge	Dimensions of sustainability challenge		Complexity of dimensions of sustainability challenge	
JI1	(ICSU 2002)	**D**	**iii**	**11**	Sustainability challenge	Dimensions of sustainability challenge		Complexity of dimensions of sustainability challenge	
JK7	(Kates 1996)	**D**	**iii**	**11**	Sustainability challenge	Dimensions of sustainability challenge	Human - Environment interactions system	Complexity of dimensions of sustainability challenge	
JK8	(Kates and Torrie 1998)	**D**	**iii**	**11**	Sustainability challenge				Local places to carry out global actions

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JK11	(Kates 2001a)	**D**	**iii**	**11**	Sustainability challenge	Dimensions of sustainability challenge	Human - Environment interactions system	Complexity of dimensions of sustainability challenge	
JK13	(Kates et al. 2001)	**D**	**iii**	**11**	Sustainability challenge	Nature of sustainability science		Complexity into the nature of sustainability science	
JK16	(Kates 2003b)	**D**	**iii**	**11**	Sustainability challenge	Nature of sustainability science		Complexity into the nature of sustainability science	
JK17	(Kates and Parris 2003)	**D**	**iii**	**11**	Sustainability challenge	Place of sustainability transition in sustainability science			Long-term global trends and sustainability transition
JM26	(Munasingh e 2010)	**D**	**iii**	**11**	Sustainability challenge	Dimensions of sustainability challenge		Complexity of dimensions of sustainability challenge	
JP10	(Perrings 2007)	**D**	**iii**	**11**	Sustainability challenge	Dimensions of sustainability challenge		Complexity of dimensions of sustainability challenge	
JR5	(Raskin et al. 2010)	**D**	**iii**	**11**	Sustainability challenge	Dimensions of sustainability science	Human - Environment interactions system	Complexity of dimensions of sustainability science	Global future studies for sustainability science
JR7	(Raven 2002)	**D**	**iii**	**11**	Sustainability challenge	Dimensions of sustainability challenge		Complexity of dimensions of sustainability challenge	Global dimensions of sustainability challenge
JR12	(Rockström et al. 2009)	**D**	**iii**	**11**	Sustainability challenge	Place of planetary boundary studies in sustainability science			
JS10	(Savage 2006)	**D**	**iii**	**11**	Sustainability challenge	Scientific underpinnings of sustainable development	Human - Environment interactions system		
JS34	(Suneetha 2010)	**D**	**iii**	**11**	Sustainability challenge	Dimensions of sustainability science		Complexity of dimensions of sustainability science	
JS39	(Doran et al. 2012)	**D**	**iii**	**11**	Sustainability challenge	Scientific underpinnings of sustainable development		Scientific complexity of sustainable development	Global sustainable development deliberation
JW8	(Wilbanks and Kates 1999)	**D**	**iii**	**11**	Sustainability challenge	Theoretical position of scale in sustainability science	Human - Environment interactions system	Theoretical position of scale	Local places to carry out global actions
JP9	(Peet and Peet 2000)	**D**	**iii**	**14**	Poverty—Development	Poverty and human needs in sustainability science		Complex systems of human needs in sustainability science	

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JM14	(McGranahan and Satterthwaite 2003)	**D**	**iii**	**16**	Urban sustainability and adaptive urban governance	Urban sustainability assessment system		Complexity of urban sustainability assessment system	
JN1-2	(Daigger 2011)	**D**	**iii**	**16**	Urban sustainability and adaptive urban governance	Natural resource management in sustainability science			
JN1-5	(Bai 2011)	**D**	**iii**	**16**	Urban sustainability and adaptive urban governance	Urban sustainability assessment system		Complexity of urban sustainability assessment system	
JW10	(Wilbanks and Kates 2010)	**D**	**iii**	**17**	Adaptation	Adaptation in sustainability science	Human - Environment interactions system	Complexity of adaptation in sustainability science	
JB19	(Bryant 1998)	**D**	**iii**	**18**	Political ecology	Political ecology in sustainability science		Political ecological complexity of sustainability science	
JC20	(Cox 1981)	**D**	**iii**	**18**	Political ecology	Political ecology in sustainability science		Political ecological complexity of sustainability science	
JH16	(Hersperger et al. 2010)	**D**	**iii**	**19**	Land cover and land use change science	Land cover and land use change modeling, and sustainability science	Human manipulation - Natural setting		
JR9	(Rindfuss et al. 2004)	**D**	**iii**	**19**	Land cover and land use change science	Science of land change in sustainability science	Human manipulation - Natural setting	Complexity of science of land change in sustainability science	
JS11	(Schaldach and Priess 2008)	**D**	**iii**	**19**	Land cover and land use change science	Land cover and land use change modeling, and sustainability science	Human manipulation - Natural setting	Complexity of land system modeling in sustainability science	Land system modeling at global scale
JT18	(Turner et al. 2007)	**D**	**iii**	**19**	Land cover and land use change science	Science of land change in sustainability science	Human manipulation - Natural setting	Complexity of science of land change in sustainability science	Global utility of land change science
JB22	(Burns et al. 2003)	**D**	**iii**	**21**	World System theory	World system theory in sustainability science			
JH25	(Hornborg 1998)	**D**	**iii**	**21**	World System theory	World system theory and ecological economics in sustainability science	Human - Environment interactions system		

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JM6	(Mann 2010)	**D**	**iii**	**21**	World System theory	World system theory in sustainability science	Human - Environment interactions system	Complexity of world system in sustainability science	
JH12	(Henry 2009)	**D**	**iii**	**22**	Learning—Knowledge—Ignorance—Condition	Challenge of learning for sustainability		Complexity of learning for sustainability	
JS12	(Schellnhuber 2009)	**D**	**iii**	**23**	Earth System analysis and tipping elements/points	Tipping elements analysis in sustainability science	Human - Environment interactions system	Complexity of analyzing tipping elements in sustainability science	Tipping elements in Earth system
JK3	(Kajikawa et al. 2011)	**D**	**iii**	**25**	Environmental assessment	Place of environmental assessment framework and sustainability indicator in sustainability science		Scientific complexity of developing environmental assessment frameworks and sustainability indicators	
JP6	(Parson 1997)	**D**	**iii**	**25**	Environmental assessment	Environmental change assessment for sustainability science		Environmental assessment system for sustainability science	
JA5	(Adger et al. 2001)	**D**	**iii**	**26**	Sustainability related discourses	Global environmental discourses in sustainability science			
JH34	(Hugé et al. 2013)	**D**	**iii**	**26**	Sustainability related discourses	Discourse of sustainability assessment	Human - Environment interactions system	Analysis of sustainability assessment discourse	
JA7	(Allenby 2006)	**D**	**iii**	**27**	Ethics	Ethics in the making of sustainability science			
JD16	(Dwyer 2008)	**D**	**iii**	**27**	Ethics	Ethical dilemmas of future in sustainability science			
JA8	(Allenby et al. 2009)	**D**	**iii**	**28**	Sustainable engineering education	Engineering education in sustainability science		Engineering curricula in sustainability science	
JS15	(Segalas et al. 2009)	**D**	**iii**	**28**	Sustainable engineering education	Engineering education in sustainability science		Engineering curricula in sustainability science	

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JA11	(Andersson et al. 2008)	**D**	**iii**	**29**	Sustainability Science education/curriculum	Education in sustainability science		Curriculum for sustainability science	
JB24	(Barth and Michelsen 2013)	**D**	**iii**	**29**	Sustainability Science education/curriculum	Education in sustainability science		Curriculum for sustainability science	
JE3	(Epstein et al. 2009)	**D**	**iii**	**29**	Sustainability Science education/curriculum	Education in sustainability science		Curriculum for sustainability science	
JF2	(Fadeeva and Mochizuki 2010)	**D**	**iii**	**29**	Sustainability Science education/curriculum	Education and university in sustainability science		Institutional complexity of education in sustainability science	
JO4	(Onuki and Mino 2009)	**D**	**iii**	**29**	Sustainability Science education/curriculum	Education in sustainability science		Curriculum for sustainability science	
JP12	(Petry et al. 2011)	**D**	**iii**	**29**	Sustainability Science education/curriculum	Education and multi-stakeholder networks in sustainability science		Institutional complexity of education in sustainability science	
JT21	(Tamura and Uegaki 2012)	**D**	**iii**	**29**	Sustainability Science education/curriculum	Education in sustainability science		Curriculum for sustainability science	
JU2	(Uwasu et al. 2009)	**D**	**iii**	**29**	Sustainability Science education/curriculum	Education in sustainability science		Curriculum for sustainability science	
JW7	(Wiek et al. 2011)	**D**	**iii**	**29**	Sustainability Science education/curriculum	Education in sustainability science		Curriculum for sustainability science	

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JW12	(Wright et al. 2009)	**D**	**iii**	**29**	Sustainability Science education/curriculum	Education in sustainability science		Curriculum for sustainability science	
JY11	(Yarime et al. 2012)	**D**	**iii**	**29**	Sustainability Science education/curriculum	Institutions, stakeholders, and education in sustainability science		Institutional complexity of education in sustainability science	
JA15	(Ascher 2007)	**D**	**iii**	**30**	Policy science	Policy science in sustainability science		Policy science analysis for sustainability	
JR13	(Rodriguez and Montalvo 2007)	**D**	**iii**	**30**	Policy science			Study of innovation policies for sustainability	
JB3	(Beck 2010b)	**D**	**iii**	**31**	Cosmopolitanism	Cosmopolitanism and sustainability science			
JB4	(Beck 2010a)	**D**	**iii**	**31**	Cosmopolitanism	Cosmopolitanism and sustainability science			
JB5	(Beratan 2007)	**D**	**iii**	**32**	Decision making	Decision processes and sustainability science	Human - Environment interactions system	Decision process in complex Human - Environment interactions system	
JB6	(Berger et al. 2001)	**D**	**iii**	**33**	Ecological modernization	Ecological modernization and sustainability science			
JJ4	(Jänicke 2008)	**D**	**iii**	**33**	Ecological modernization	Ecological modernization and sustainability science	Human - Environment interactions system		
JB21	(Burian 2001)	**D**	**iii**	**34**	Case studies for sustainability science				
JB23	(Bursztyn 2008)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Pluralistic modes of disciplinarity in sustainability science		Complexity of pluralistic disciplinarity in sustainability science	

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JB25	(Benessia et al. 2012)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Pluralistic modes of disciplinarity in sustainability science		Complexity of pluralistic disciplinarity in sustainability science	
JB27	(Buter and Van Raan 2013)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Interlinked knowledge base for sustainability science		Linkages in knowledge base, and sustainability science	
JC3	(Cash et al. 2003)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Knowledge systems for sustainability science		Complexity of knowledge system for sustainability science	
JC10	(Clark 2003a)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Research systems for sustainability science		Complexity of research system for sustainability science	
JC12	(Clark and Dickson 2003)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Nature of sustainability science		Complexity into the nature of sustainability science	
JC22	(Costa and Kropp 2013)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Interdisciplinary concept of vulnerability in sustainability science	Human - Environment interactions system	Complexity of use of vulnerability in sustainability science	
JE1	(Eakin and Luers 2006)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Vulnerability of social-environmental systems and sustainability science	Human - Environment interactions system		
JG10	(Gieryn 1983)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Demarcating science from non-science		Clearing the complexity of mixing of science and non-science	
JG16	(Goldman and Schurman 2000)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Society - Nature divide with respect to sustainability science	Society - Nature intellectual divide		

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JG19	(Gotts 2007)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Panarchy versus 'world system' approaches with respect to sustainability science	Human - Environment interactions system	Complexity of sustainability science with regard to conceptual structures	World-systems analysis versus panarchy
JG27	(Gardner 2013)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Pluralistic modes of research in sustainability science		Complexity of pluralistic research in sustainability science	
JH1	(Haapasaari et al. 2012)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Pluralistic modes of research in sustainability science		Complexity of pluralistic research in sustainability science	
JH3	(Hadorn 2004)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Pluralistic modes of research in sustainability science		Complexity of pluralistic research in sustainability science	
JH17	(Hiramatsu et al. 2008)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Pluralistic modes of research in sustainability science		Complexity of pluralistic research in sustainability science	
JJ2	(Jäger 2006)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Nature of sustainability science		Complexity into the nature of sustainability science	
JJ3	(Jäger 2011)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Sustainability science and Europe			
JK1	(Kajikawa et al. 2007)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Pluralistic modes of disciplinarity in sustainability science		Complexity of pluralistic disciplinarity in sustainability science	
JK23	(Kauffman 2009)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Nature of sustainability science		Complexity into the nature of sustainability science	

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JK36	(Komiyama and Takeuchi 2006)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Nature of sustainability science		Complexity into the nature of sustainability science	
JL23	(Lang et al. 2012)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Pluralistic modes of research in sustainability science		Complexity of pluralistic research in sustainability science	
JL24	(van der Leeuw et al. 2012)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Urgency and nature of sustainability science		Complexity imparted by urgency in sustainability science	
JM4	(MacMynowski 2007)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Pluralistic modes of disciplinarity in sustainability science	Social-biophysical systems	Complexity of pluralistic disciplinarity in sustainability science	
JM17	(Mihelcic et al. 2003)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Pluralistic modes of disciplinarity in sustainability science		Complexity of pluralistic disciplinarity in sustainability science	
JM22	(Morioka et al. 2006)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Pluralistic modes of research in sustainability science		Complexity of pluralistic research in sustainability science	
JM25	(Mulder 2007)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Nature of innovation in sustainability science		Complex nature of innovation in sustainability science	
JN4	(Nelson 2006)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Pluralistic modes of research in sustainability science		Complexity of pluralistic research in sustainability science	
JO9	(Orecchini et al. 2012)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	University-industry collaborations for sustainability science		Complexity of university-industry collaboration in sustainability science	

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JP8	(Pauwels 2011)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Pluralistic modes of research in sustainability science		Complexity of pluralistic research in sustainability science	
JR3	(Rapport 2007)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Pluralistic modes of disciplinarity in sustainability science	Human activity - Ecosystem health	Complexity of pluralistic disciplinarity in sustainability science	
JR8	(Reitan 2005)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Question of non-science in sustainability science		Complexity of the question of non-science in sustainability science	
JS14	(Schoolman et al. 2012)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Pluralistic modes of research in sustainability science		Complexity of pluralistic research in sustainability science	
JS41	(Shiroyama et al. 2012)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Framework for governance in sustainability		Complexity of governance in sustainability	
JW1	(Wallerstein 2010)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Social science perspectives in sustainability science	Human - Environment interactions system	Complexity of social science integration in sustainability science	World-system perspective on social sciences
JW3	(Westley et al. 2011)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Agency, institutions and innovation in sustainability science	Human - Environment interactions system	Complex linkages among agency, institutions and innovation in sustainability science	
JW14	(Wuelser et al. 2012)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Pluralistic modes of research in sustainability science		Complexity of pluralistic research in sustainability science	
JW17	(Wiek et al. 2012b)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Pluralistic modes of research in sustainability science		Complexity of pluralistic research in sustainability science	

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JY1	(Yarime et al. 2010)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Institution and research in sustainability science		Institutional complexity of research in sustainability science	
JC5	(Chapin III et al. 2011)	**D**	**iii**	**36**	Anthropocene and Earth stewardship	Earth stewardship and sustainability science	Human - Environment interactions system		
JS26	(Steffen et al. 2011)	**D**	**iii**	**36**	Anthropocene and Earth stewardship	Anthropocene and Earth stewardship, and sustainability science	Human - Environment interactions system	Complexity of anthropocene and Earth stewardship with respect to sustainability science	Global change and planetary stewardship
JS29	(2011)	**D**	**iii**	**36**	Anthropocene and Earth stewardship	Anthropocene and Earth stewardship, and sustainability science		Complexity of anthropocene and Earth stewardship with respect to sustainability science	Global change and planetary stewardship
JT16	(Turner et al. 1994)	**D**	**iii**	**36**	Anthropocene and Earth stewardship	Anthropocene and Earth stewardship, and sustainability science	Human activity - Global system	Complexity of anthropocene and Earth stewardship with respect to sustainability science	Global change and planetary stewardship
JC15	(Clark 2007)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Nature of sustainability science		Complexity into the nature of sustainability science	
JF16	(Forsyth 2001)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Critical realism and political ecology with respect to sustainability science			
JH26	(Hornborg 2003)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Epistemology of sustainability science			
JJ8	(Jerneck et al. 2011)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Nature of sustainability science		Complexity into the nature of sustainability science	Global sustainability issues in structuring sustainability science

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JK2	(Kajikawa 2008)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Nature of sustainability science		Complexity into the nature of sustainability science	
JK12	(Kates 2001b)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Scientific characteristics of sustainability transition	Human - Environment interactions system	Scientific complexity of sustainability transition	
JK21	(Kates 2011)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Nature of sustainability science	Human - Environment interactions system	Complexity into the nature of sustainability science	Unity of nature and sustainability science
JK27	(Kerkhoff and Lebel 2006)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Knowledge and action in sustainability science		Complex linkages of knowledge and action in sustainability science	
JK30	(Khagram et al. 2010)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Pluralistic modes of research in sustainability science		Complexity of pluralistic research in sustainability science	
JK38	(Kristjanson et al. 2009)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Knowledge and action in sustainability science			Linking knowledge and action in agricultural research
JK40	(Kumazawa et al. 2009)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Knowledge structuring in sustainability science		Complex structuring of knowledge in sustainability science	
JM12	(Max-Neef 2005)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Pluralistic modes of research in sustainability science		Complexity of pluralistic research in sustainability science	
JM28	(Marsden 2013)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Theoretical position of place in sustainability science	Community - Place	Theoretical position of place	

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JM30	(Miller 2013)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Nature of sustainability science		Complexity into the nature of sustainability science	
JN6	(Ness et al. 2010)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Problem structuring in sustainability science		Complex structuring of problems in sustainability science	
JS7	(Sato 2007)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Knowledge integration in sustainability science		Complexity of knowledge integration	
JS25	(Steffen 2006)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Pluralistic modes of research in sustainability science		Complexity of pluralistic research in sustainability science	
JS31	(Strunz 2012)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Nature of sustainability science	Human - Environment interactions system	Complexity into the nature of sustainability science	
JS40	(Salas-Zapata et al. 2013)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Pluralistic modes of research in sustainability science		Complexity of pluralistic research in sustainability science	
JT19	(Turner and Robbins 2008)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Land-change science and political ecology with respect to sustainability science	Human - Environment interactions system	Complexity of sustainability science with regard to conceptual structures	
JT20	(Tushman and O'Reilly 2007)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Doctoral program and sustainability science	Human - Environment interactions system	Curriculum for sustainability science	
JW16	(Wiek et al. 2012a)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Nature of sustainability science		Complexity into the nature of sustainability science	

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JZ6	(Ziegler and Ott 2011)	**D**	**iii**	**37**	Ontology and/or epistemology of Sustainability Science	Philosophical nature of sustainability science		Complexity into the philosophical nature of sustainability science	
JD7	(Davis 2006)	**D**	**iii**	**38**	Complex systems, analysis, and adaptive planning/management			Planning in uncertainty in complex adaptive systems	
JD8	(Dearing et al. 2010)	**D**	**iii**	**38**	Complex systems, analysis, and adaptive planning/management	Complex land systems in sustainability science	Complex land system	Complexity of land systems	
JF6	(Folke et al. 2007)	**D**	**iii**	**38**	Complex systems, analysis, and adaptive planning/management	Ecosystems and institutions in sustainability science	Institutions - Ecosystems		
JH22	(Holling 2001)	**D**	**iii**	**38**	Complex systems, analysis, and adaptive planning/management	Economic, ecological and social systems in sustainability science	Human - Environment interactions system	Complexity of economic, ecological and social systems	
JH24	(Horan et al. 2011)	**D**	**iii**	**38**	Complex systems, analysis, and adaptive planning/management	Ecological thresholds management in sustainability science	Human - Environment interactions system		
JI3	(Iles 1996)	**D**	**iii**	**38**	Complex systems, analysis, and adaptive planning/management	Adaptive management and sustainability science	Human - Environment interactions system	Complexity of adaptive management	

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JJ10	(Johnson 1999)	**D**	iii	**38**	Complex systems, analysis, and adaptive planning/management	Adaptive management and sustainability science	Human - Environment interactions system	Complexity of adaptive management	
JL6	(Lee 1999)	**D**	iii	**38**	Complex systems, analysis, and adaptive planning/management	Adaptive management and sustainability science	Human - Environment interactions system	Complexity of adaptive management	
JL16	(Liu et al. 2007)	**D**	iii	**38**	Complex systems, analysis, and adaptive planning/management	Human - Environment interactions system in sustainability science	Human - Environment interactions system	Complexity of Human - Environment interactions system	
JM16	(Meadows 1999)	**D**	iii	**38**	Complex systems, analysis, and adaptive planning/management	Intervention in complex systems in sustainability science		Intervening into a complex system	
JP7	(Parsons 2007)	**D**	iii	**38**	Complex systems, analysis, and adaptive planning/management	Complex adaptive social systems in sustainability science		Complexity of adaptive social systems	
JT17	(Turner et al. 2003)	**D**	iii	**38**	Complex systems, analysis, and adaptive planning/management	Vulnerability of social-environmental systems and sustainability science	Human - Environment interactions system	Complexity of vulnerability analysis	
JY9	(Young et al. 2006)	**D**	iii	**38**	Complex systems, analysis, and adaptive planning/management	Institutional dimensions of environmental and land change in sustainability science	Institutions - Land change	Institutional dimensions of environmental and land change	Institutional dimensions of global environmental change

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JD14	(Douglas 2007)	**D**	**iii**	**39**	Cultural theory	Cultural theory and sustainability science			
JO2	(O'Riordan and Jordan 1999)	**D**	**iii**	**39**	Cultural theory	Institutional failure and sustainability science		Complexity of institutional failure	
JT6	(Thompson 1997)	**D**	**iii**	**39**	Cultural theory	Cultural theory and integrated assessment in sustainability science		Treating bias in integrated assessment	
JD15	(Drechsel and Dongus 2010)	**D**	**iii**	**40**	Urban agriculture	Urban agricultural innovations in sustainability science	Agriculture - Urban area	Dynamics of urban agriculture	
JF10	(Fotopoulos 2007)	**D**	**iii**	**41**	De-growth	Degrowth and sustainability science			
JK28	(Kerschner 2010)	**D**	**iii**	**41**	De-growth	Degrowth and sustainability science			
JL3	(Latouche 2007)	**D**	**iii**	**41**	De-growth	Degrowth and sustainability science			
JG25	(Grey 1993)	**D**	**iii**	**42**	Anthropocentrism vs. deep ecology	Anthropocentrism and deep ecology with respect to sustainability science	Human - Environment interactions system		
JG26	(Gruen et al. 2008)	**D**	**iii**	**43**	Sustainable health	Health program planning in sustainability science		Complexity of health program planning	
JH10	(von Hauff and Wilderer 2008)	**D**	**iii**	**44**	Industrial ecology	Industrial ecology and sustainability science			
JJ7	(Jerneck and Olsson 2011)	**D**	**iii**	**45**	Reframing	Pluralistic modes of research in sustainability science			Pluralistic mode of research for global health challenges
JJ11	(Jorgenson and Kick 2003)	**D**	**iii**	**46**	Globalization				Environment in globalization
JK15	(Kates 2003a)	**D**	**iii**	**46**	Globalization	Globalization and North-South divide in sustainability science			North-South divide and global sustainability transition

Item ID	Item	Sphere	Category	Theme ID	Theme	SusSD / FA-I (observation)	Hum-Env / FA-II (observation)	Cmplx / FA-III (observation)	Global / FA-IV (observation)
JK32	(Kim and Oki 2011)	**D**	**iii**	**47**	Scenario analysis—Visioneering	Visioneering and sustainability science		Visioneering and system's thinking	
JS37	(Kosamu 2011)	**D**	**iii**	**47**	Scenario analysis—Visioneering	Scenario analysis and sustainability science		Analysis of future scenario	Future scenarios of combined social and environmental systems
JL21	(Lüdeke et al. 2004)	**D**	**iii**	**48**	Syndromes	Syndromes in sustainability science		Complexity of syndromes	Syndromes of global change
JP20	(Potschin and Haines-Young 2006a)	**D**	**iii**	**49**	Landscape ecology	Landscape ecology and sustainability science	Community - Landscape	Theoretical position of landscape in sustainability science	

Appendix 10

Observations on the entire literature map for 'place/ scale-based' analysis

See **Section 4.3** of the thesis for detail explanation on the column headings 'Item ID', 'Item', 'Sphere', 'Category', 'Theme ID' and 'Theme' in the table. The tables are designed as per the 10 spheres (sphere A[Economy], AB[Socio-economy], AC[Environo-economy], B[Society], BA[Econo-society], BC[Environo-society], C[Environment], CA[Econo-environment], CB[Socio-environment], and D[Central organization of sustainability]). These 10 spheres construct the second layer of organization within the 'Group-A' literature archive, the details of which are provided in the thesis in **Section 3.4.3**.

Item ID	Item	Sphere	Category	Theme ID	Theme	Scale	Place	Place of authorship (corresponding author)	Temporal
JG11	(Gilbert 2010)	A	i	1	Food security—Agricultural challenges/issues	-	N/A	UK	2010
JH7	(Hara et al. 2011)	A	i	3	Industrialization—Energy—Environment	Local	China	Japan	2010
JB26	(Berkhout et al. 2012)	A	ii	1	Energy policy/innovation	-	N/A	Netherlands	2012
JG2	(Gallagher et al. 2006)	A	ii	1	Energy policy/innovation	-	N/A	USA	2006
JG12	(Gillingham et al. 2006)	A	ii	1	Energy policy/innovation	-	N/A	USA	2006
JG5	(Geels 2002)	A	iii	1	Transition theory	-	N/A	Netherlands	2001

Item ID	Item	Sphere	Category	Theme ID	Theme	Scale	Place	Place of authorship (corresponding author)	Temporal
JB7	(Bettencourt et al. 2007)	AB	i	4	Urbanization—Consumption—Environment	-	N/A	USA	2007
JG20	(Graedel and Cao 2010)	AB	i	4	Urbanization—Consumption—Environment	Global	Global	USA	2010
JJ12	(Jolly et al. 2012)	AB	ii	1	Energy policy/innovation	Country	India	Netherlands	2012
JM29	(McCauley and Stephens 2012)	AB	ii	1	Energy policy/innovation	Local	USA	USA	2012
JN9	(Nakamura et al. 2013)	AB	ii	1	Energy policy/innovation	-	N/A	Japan	2012
JS44	(Suwa and Jupesta 2012)	AB	ii	1	Energy policy/innovation	Country	Japan	Japan	2012
JA3	(Adeel and Safriel 2008)	AB	ii	2	Alternative livelihood	Regional	Asia	Canada	2007
JA13	(Arnold et al. 2010)	AB	ii	3	Interventions and development, and conservation	Local	India	USA	2010
JF1	(Fabusoro 2009)	AB	ii	4	Community involvement	Local	Nigeria	Japan	2009
JH32	(Hanaoka and Kainuma 2012)	AB	ii	5	Low-carbon transitions	Global	Global	Japan	2012
JT2	(Takiguchi and Morita 2009)	AB	ii	5	Low-carbon transitions	Country	Japan	Japan	2008
JZ5	(Zhou 2006)	AB	ii	5	Low-carbon transitions	Country	China	Japan	2006
JA18	(Ausubel and Waggoner 2008)	AB	iii	2	Dematerialization	-	N/A	USA	2008
JY5	(Yokoo 2010)	AB	iii	3	"Reuse" as theory	-	N/A	Japan	2009
JZ4	(Zhijun and Nailing 2007)	AB	iii	4	Circular economy	Country	China	China	2006
JZ9	(Zik and Kulatilaka 2013)	AB	iii	5	Quantitative sustainability	-	N/A	USA	2012

Item ID	Item	Sphere	Category	Theme ID	Theme	Scale	Place	Place of authorship (corresponding author)	Temporal
JE2	(Ejeta 2010)	AC	**i**	**1**	Food security—Agricultural challenges/issues	Continent	Africa	USA	2010
JF14	(Furuya and Kobayashi 2009)	AC	**i**	**1**	Food security—Agricultural challenges/issues	Global	Global	Japan	2008
JC8	(Chong and Sunding 2006)	AC	**i**	**2**	Water availability/quality	Local	USA	USA	2006
JK31	(Kim 2006)	AC	**i**	**3**	Industrialization—Energy—Environment	Regional	Asia	R. Korea	2006
JS17	(Shi et al. 2011)	AC	**i**	**3**	Industrialization—Energy—Environment	Country	China	China	2011
JP11	(Peters et al. 2011)	AC	**i**	**5**	Air pollution—GHG Emission—Emission transfers	Global	Global	Norway	2011
JS35	(Suneetha 2010)	AC	**i**	**6**	Biodiversity—Habitat destruction—Trade	-	N/A	Japan	2009
JL7	(Lee et al. 2008)	AC	**ii**	**1**	Energy policy/innovation	-	N/A	USA	2008
JM21	(Moreira and Goldemberg 1999)	AC	**ii**	**1**	Energy policy/innovation	Country	Brazil	Brazil	1999
JS27	(Steinfeld 2006)	AC	**ii**	**1**	Energy policy/innovation	-	N/A	USA	2006
JS42	(Sovacool and Bulan 2013)	AC	**ii**	**1**	Energy policy/innovation	Local	Malaysia	USA	2012
JA20	(Akashi and Hanaoka 2012)	AC	**ii**	**5**	Low-carbon transitions	Global	Global	Japan	2012
JA21	(Akimoto et al. 2012)	AC	**ii**	**5**	Low-carbon transitions	Global	Global	Japan	2012
JI2	(Ikkatai et al. 2008)	AC	**ii**	**5**	Low-carbon transitions	Local	Japan	Japan	2008
JM11	(Matsuoka et al. 2008)	AC	**ii**	**5**	Low-carbon transitions	Country	Japan	Japan	2007
JW15	(Wagner et al. 2012)	AC	**ii**	**5**	Low-carbon transitions	-	N/A	Austria	2012
JT15	(Tsuji et al. 2011)	AC	**ii**	**6**	Biodiversity—Agriculture—Poverty	Local	China	Japan	2010
JA9	(Andersen 2007)	AC	**iii**	**4**	Circular economy	-	N/A	Denmark	2006
JD6	(Dasgupta 2008)	AC	**iii**	**6**	Natural capital & ecosystem services management/governance	-	N/A	UK	2008
JP31	(Patterson and Glavovic 2013)	AC	**iii**	**7**	Ecological economics	-	N/A	New Zealand	2012

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JA1	(Acuin et al. 2011)	B	**i**	**7**	Public health	Regional	Asia	Philippines	2011
JC16	(Coker et al. 2011)	B	**i**	**7**	Public health	Regional	Asia	Thailand	2011
JW6	(WHO 2009)	B	**i**	**7**	Public health	Global	Global	Switzerland	2009

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JA16	(Aspinall 2005)	B	**i**	**8**	Human insecurity—Conflict	Local	Indonesia	Australia	2005
JH28	(HSC 2005)	B	**i**	**8**	Human insecurity—Conflict	Global	Global	Canada	2005
JH29	(HSC 2011, Part I)	B	**i**	**8**	Human insecurity—Conflict	Global	Global	Canada	2011
JH30	(HSC 2011, Part III)	B	**i**	**8**	Human insecurity—Conflict	Global	Global	Canada	2011
JU1	(UN-ESC 2009)	B	**i**	**9**	Population—Consumption—Environment	Global	Global	USA	2009
JP13	(Phillips et al. 2005)	B	**ii**	**3**	Interventions and development, and conservation	Country	Ghana	USA	2005
JP23	(GF 2009)	B	**ii**	**3**	Interventions and development, and conservation	Global	Global	USA	2009
JP24	(GF 2009)	B	**ii**	**3**	Interventions and development, and conservation	Global	Global	USA	2009
JP26	(GF 2009)	B	**ii**	**3**	Interventions and development, and conservation	Global	Global	USA	2009
JP27	(GF 2009)	B	**ii**	**3**	Interventions and development, and conservation	Global	Global	USA	2009
JP28	(GF 2009)	B	**ii**	**3**	Interventions and development, and conservation	Global	Global	USA	2009
JP29	(GF 2009)	B	**ii**	**3**	Interventions and development, and conservation	Global	Global	USA	2009
JS33	(GF 2009)	B	**ii**	**3**	Interventions and development, and conservation	Global	Global	USA	2009
JJ6	(Jarchow et al. 2011)	B	**ii**	**4**	Community involvement	-	N/A	USA	2011
JK34	(Kisinza et al. 2008)	B	**ii**	**4**	Community involvement	Local	Tanzania	Tanzania	2008
JR1	(Raloff 1998)	B	**ii**	**4**	Community involvement	Local	USA	USA	1998
JA10	(Andersson 2008)	B	**ii**	**7**	Social learning	Local	Sweden	USA	2008
JB12	(Bongaarts 1994)	B	**ii**	**8**	Population policy	Global	Global	USA	1994
JC18	(Colten et al. 2008)	B	**iii**	**8**	Resilience	Local	USA	USA	2008
JL8	(Leiserowitz et al. 2005)	B	**iii**	**9**	Value—Attitude—Behavior	Global	Global	USA	2005
JL9	(Leiserowitz et al. 2006)	B	**iii**	**9**	Value—Attitude—Behavior	Global	Global	USA	2006

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JA2	(Struble and Aomari 2003)	BA	**i**	**1**	Food security—Agricultural challenges/issues	Global	Global	USA	2003
JB1	(Barrett 2010)	BA	**i**	**1**	Food security—Agricultural challenges/issues	-	N/A	USA	2010
JC6	(Godfray et al. 2010)	BA	**i**	**1**	Food security—Agricultural challenges/issues	Global	Global	UK	2010
JC19	(Conway 2000)	BA	**i**	**1**	Food security—Agricultural challenges/issues	Global	Global	USA	2000
JF9	(2010)	BA	**i**	**1**	Food security—Agricultural challenges/issues	Global	Global	UK	2010
JF11	(Frongillo 1999)	BA	**i**	**1**	Food security—Agricultural challenges/issues	Country	USA	USA	1998
JM10	(Matsumura et al. 2009)	BA	**i**	**1**	Food security—Agricultural challenges/issues	Global	Global	Japan	2009
JW2	(Webb 2010)	BA	**i**	**1**	Food security—Agricultural challenges/issues	Global	Global	USA	2010
JM8	(Marcotullio 2007)	BA	**i**	**2**	Water availability/quality	Regional	Asia	USA	2006
JH23	(Homs 2007)	BA	**i**	**4**	Urbanization—Consumption—Environment	-	N/A	France	2007
JK10	(Kates 2000b)	BA	**i**	**9**	Population—Consumption—Environment	-	N/A	USA	2000
JC17	(Collier 2007)	BA	**i**	**10**	African poverty	Continent	Africa	UK	2007
JP30	(GF 2009)	BA	**ii**	**3**	Interventions and development, and conservation	Global	Global	USA	2009
JM2	(Mabogunje 2007)	BA	**ii**	**4**	Community involvement	Local	Nigeria	Nigeria	2007
JD17	(Diffenbaugh 2013)	BA	**ii**	**5**	Low-carbon transitions	Global	Global	USA	2012
JL2	(Larson and Ribot 2007)	BA	**ii**	**9**	Forest management policy/innovation	Regional	Honduras-Senegal	USA	2007
JT4	(Tester and Langridge 2010)	BA	**ii**	**10**	Agricultural policy/innovation	-	N/A	Australia	2010
JT14	(Trieb and Müller-Steinhagen 2007)	BA	**ii**	**11**	Regional cooperation	Regional	Eu-ME-NA	Germany	2007
JA17	(Auer 2007)	BA	**iii**	**10**	Institutional reform	-	N/A	USA	2007
JK5	(Kates 1992)	BA	**iii**	**11**	Sustainability challenge	Global	Global	USA	1992
JL13	(Levi-Faur 2005)	BA	**iii**	**12**	Regulatory capitalism	Global	Global	Australia	2005
JL14	(Levi-Faur and Jordana 2005)	BA	**iii**	**12**	Regulatory capitalism	Global	Global	Australia	2005
JM13	(McGee 2008)	BA	**iii**	**13**	Rural-urban transformation	Regional	Asia	Canada	2007
JR15	(Rosenfeld 2010)	BA	**iii**	**14**	Poverty—Development	-	N/A	USA	2009
JT12	(Townsend 2010)	BA	**iii**	**14**	Poverty—Development	-	N/A	UK	2010
JS5	(Sanya 2012)	BA	**iii**	**15**	Sustainable architecture	Country	Uganda	South Africa	2011

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JR4	(Rarieya and Fortun 2010)	BC	i	1	Food security—Agricultural challenges/issues	Local	Kenya	USA	2009
JF13	(Funke et al. 2007)	BC	i	2	Water availability/quality	Country	South Africa	South Africa	2007
JK25	(Kazama et al. 2012)	BC	i	7	Public health	Country	Cambodia	Japan	2011
JI7	(Iwasaki and Shaw 2009)	BC	i	8	Human insecurity—Conflict	Local	India	Japan	2009
JK29	(Khagram and Ali 2006)	BC	i	8	Human insecurity—Conflict	-	N/A	USA	2006
JD12	(Dietz et al. 2003)	BC	i	9	Population—Consumption—Environment	-	N/A	USA	2003
JG13	(Gleick 2003b)	BC	i	9	Population—Consumption—Environment	Global	Global	USA	2003
JO1	(O'Neill et al. 2010)	BC	i	9	Population—Consumption—Environment	Global	Global	USA	2010
JP16	(Popovski and Mundy 2012)	BC	i	11	Climate change problem/impacts	-	N/A	Japan	2011
JS16	(Shahbazbegian and Bagheri 2010)	BC	i	12	Drought	Local	Iran	Iran	2009
JS38	(Syvitski 2008)	BC	i	13	Delta — problems	Global	Global	USA	2007
JH33	(Higgins and Foliente 2013)	BC	ii	3	Interventions and development, and conservation	Local	Australia	Australia	2012
JP1	(de Palencia and Pérez-Foguet 2011)	BC	ii	3	Interventions and development, and conservation	Local	Tanzania	Spain	2010
JP25	(GF 2009)	BC	ii	3	Interventions and development, and conservation	Global	Global	USA	2009
JR17	(Rehman et al. 2012)	BC	ii	3	Interventions and development, and conservation	Local	India	India	2012
JT11	(Toth and Hizsnyik 2008)	BC	ii	4	Community involvement	-	N/A	Austria	2008
JG17	(Gomi et al. 2007)	BC	ii	5	Low-carbon transitions	Local	Japan	Japan	2006
JS20	(Snapp et al. 2010)	BC	ii	6	Biodiversity—Agriculture—Poverty	Country	Malawi	USA	2010
JT7	(Timmer and Juma 2005)	BC	ii	6	Biodiversity—Agriculture—Poverty	-	N/A	Canada	2005
JY10	(Yami et al. 2013)	BC	ii	9	Forest management policy/innovation	Local	Ethiopia	Ethiopia	2012
JI5	(IAC 2004)	BC	ii	10	Agricultural policy/innovation	Continent	Africa	Netherlands	2006
JT13	(Townsend and Porder 2012)	BC	ii	10	Agricultural policy/innovation	-	N/A	USA	2012
JN1-4	(Ross and Woo 2011)	BC	ii	11	Regional cooperation	Country	USA	USA	2011
JA22	(Antanasijević et al. 2013)	BC	ii	12	Modeling	Continent	Europe	Serbia	2011
JP22	(Preston et al. 2011)	BC	ii	12	Modeling	-	N/A	USA	2011
JB11	(Black et al. 2011)	BC	ii	13	Adaptation—Natural Disaster—Migration—Benefits	Country	Bangladesh	UK	2011

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JG24	(Gray and Mueller 2012)	BC	**ii**	**13**	Adaptation—Natural Disaster—Migration—Benefits	Local	Bangladesh	USA	2012
JP2	(Parker et al. 2007)	BC	**ii**	**13**	Adaptation—Natural Disaster—Migration—Benefits	Country	UK	UK	2007
JR16	(Reckien et al. 2013)	BC	**ii**	**13**	Adaptation—Natural Disaster—Migration—Benefits	Local	India	USA	2012
JS36	(Surjan and Shaw 2008)	BC	**ii**	**14**	Urban policy/innovation	Local	India	Japan	2008
JU3	(UN-Habitat 2012)	BC	**ii**	**14**	Urban policy/innovation	Global	Global	Kenya	2012
JW9	(Wilbanks et al. 2007)	BC	**ii**	**14**	Urban policy/innovation	Local	India	USA	2007
JT5	(Thomas 2011)	BC	**ii**	**15**	Reuse—Recycling—Pollution control	Country	USA	USA	2010
JK41	(Kurian et al. 2013)	BC	**iii**	**3**	"Reuse" as theory	Local	India	UK	2011
JL11	(Lemos and Agrawal 2006)	BC	**iii**	**6**	Natural capital & ecosystem services management/governance	-	N/A	USA	2006
JL22	(Lynam et al. 2007)	BC	**iii**	**6**	Natural capital & ecosystem services management/governance	-	N/A	Zimbabwe	2007
JS32	(Su et al. 2012)	BC	**iii**	**6**	Natural capital & ecosystem services management/governance	Local	China	China	2011
JW4	(White 1967)	BC	**iii**	**11**	Sustainability challenge	-	N/A	USA	1967
JK6	(Kates and Haarmann 1992)	BC	**iii**	**14**	Poverty—Development	-	N/A	USA	1992
JR6	(Raudsepp-Hearne et al. 2010)	BC	**iii**	**14**	Poverty—Development	-	N/A	Canada	2010
JK37	(Kosamu 2011)	BC	**iii**	**15**	Sustainable architecture	Country	Malawi	Malawi	2010
JN1-3	(Brown 2011)	BC	**iii**	**15**	Sustainable architecture	Country	USA	USA	2011
JB10	(Birkmann et al. 2010)	BC	**iii**	**16**	Urban sustainability and adaptive urban governance	-	N/A	Germany	2010
JS9	(Satterthwaite 2007)	BC	**iii**	**16**	Urban sustainability and adaptive urban governance	-	N/A	UK	2007
JS23	(Solecki and Leichenko 2006)	BC	**iii**	**16**	Urban sustainability and adaptive urban governance	-	N/A	USA	2006
JK9	(Kates 2000a)	BC	**iii**	**17**	Adaptation	Global	Global	USA	2000
JM20	(Molua 2011)	BC	**iii**	**17**	Adaptation	Country	Cameroon	Cameroon	2010
JL15	(Lie 2007)	BC	**iii**	**18**	Political ecology	Global	Global	USA	2007

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JL17	(Liverman and Vilas 2006)	BC	**iii**	**18**	Political ecology	Regional	North and South America	UK	2006
JM7	(Manson 2006)	BC	**iii**	**19**	Land cover and land use change science	Local	Mexico	USA	2005
JW13	(Wu et al. 2010)	BC	**iii**	**19**	Land cover and land use change science	Regional	Asia	Japan	2009
JY4	(Yin and Xiang 2010)	BC	**iii**	**19**	Land cover and land use change science	Local	China	USA	2009
JM31	(Mohamad et al. 2012)	BC	**iii**	**20**	Sustainability—Culture—Religion	Country	Malaysia	Malaysia	2012
JT1	(Tàbara and Ilhan 2008)	BC	**iii**	**20**	Sustainability—Culture—Religion	Country	Spain	Spain	2007
JR10	(Roberts et al. 2003)	BC	**iii**	**21**	World System theory	Global	Global	USA	2003
JW5	(White et al. 2001)	BC	**iii**	**22**	Learning—Knowledge—Ignorance—Condition	-	N/A	USA	2001
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JP17	(Pöschl 2005)	C	**i**	**5**	Air pollution—GHG Emission—Emission transfers	-	N/A	Germany	2005
JO8	(Overpeck and Cole 2006)	C	**i**	**11**	Climate change problem/impacts	Global	Global	USA	2006
JP3	(Parkinson 2006)	C	**i**	**11**	Climate change problem/impacts	Global	Global	USA	2006
JK4	(Kasei et al. 2010)	C	**i**	**12**	Drought	Regional	Africa	Germany	2009
JB14	(Boyce et al. 2010)	C	**i**	**14**	Ecological crisis	Global	Global	Canada	2010
JG22	(Grainger 2008)	C	**i**	**14**	Ecological crisis	Global	Global	UK	2008
JC9	(Church et al. 2008)	C	**i**	**15**	Coastal vulnerability issues & sea level rise	Global	Global	Australia	2007
JJ9	(Jin et al. 2008)	C	**ii**	**12**	Modeling	-	N/A	USA	2008
JL12	(Lenton et al. 2008)	C	**iii**	**23**	Earth System analysis and tipping elements/points	Global	Global	UK	2008
JL20	(Lovelock 1986)	C	**iii**	**23**	Earth System analysis and tipping elements/points	Global	Global	UK	1986
Item ID	**Item**	**Sphere**	**Category**	**Theme ID**	**Theme**	**Scale**	**Place**	**Place of authorship (corresponding author)**	**Temporal**
JE5	(Esteban et al. 2009)	CA	**i**	**16**	Global warming—Natural disaster	Country	Taiwan	Japan	2009

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JB8	(Birch et al. 2010)	CA	ii	9	Forest management policy/innovation	Regional	North and South America	UK	2010
JH27	(Hosoda and Hayashi 2010)	CA	ii	11	Regional cooperation	Regional	Asia	Japan	2009
JK24	(Kazama et al. 2010)	CA	ii	12	Modeling	Country	Japan	Japan	2008
JD11	(Diallo and Brinker 2011)	CA	ii	16	Technology and nanotechnology	-	N/A	USA	2011
JS22	(Socolow et al. 2004)	CA	ii	16	Technology and nanotechnology	-	N/A	USA	2004
JE4	(Esposto 2009)	CA	ii	17	Water policy/innovation	Local	Iraq	Switzerland	2008
JE6	(Eyckmans and Finus 2007)	CA	ii	18	Treaties—Agreements	Global	Global	Germany	2006
JC21	(Costanza et al. 1997)	CA	iii	6	Natural capital & ecosystem services management/governance	Global	Global	USA	1997
JD1	(Daily et al. 2000)	CA	iii	6	Natural capital & ecosystem services management/governance	Global	Global	Sweden	2000
JA12	(Arndt et al. 2011)	CA	iii	17	Adaptation	Country	Mozambique	Finland	2010
JD4	(Dasgupta et al. 1995)	CA	iii	24	Environmental regulation	-	N/A	USA	1995

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JM3	(MacDonald et al. 2011)	CB	i	1	Food security—Agricultural challenges/issues	Global	Global	Canada	2011
JM9	(Marty et al. 2010)	CB	i	1	Food security—Agricultural challenges/issues	Local	Canada	USA	2010
JS1	(Sachs et al. 2010)	CB	i	1	Food security—Agricultural challenges/issues	Global	Global	USA	2010
JS8	(Sattari et al. 2012)	CB	i	1	Food security—Agricultural challenges/issues	Global	Global	Netherlands	2012
JM19	(Molina and Molina 2004)	CB	i	5	Air pollution—GHG Emission—Emission transfers	Global	Global	USA	2004
JD13	(Dirzo and Raven 2003)	CB	i	6	Biodiversity—Habitat destruction—Trade	Global	Global	Mexico	2003
JG8	(Geist and Lambin 2002)	CB	i	6	Biodiversity—Habitat destruction—Trade	Global	Global	Belgium	2002
JS4	(Sala and Knowlton 2006)	CB	i	6	Biodiversity—Habitat destruction—Trade	Global	Global	USA	2006
JK14	(Kates and Wilbanks 2003)	CB	i	11	Climate change problem/impacts	Local	USA	USA	2003
JN2	(NAS 2008)	CB	i	11	Climate change problem/impacts	Global	Global	USA	2008
JS3	(Sahoo and Schladow 2008)	CB	i	11	Climate change problem/impacts	Local	USA	USA	2008

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JP18	(Postel 2005)	CB	i	14	Ecological crisis	-	N/A	USA	2005
JG23	(Gravelle and Mimura 2008)	CB	i	15	Coastal vulnerability issues & sea level rise	Local	Fiji	Japan	2008
JH9	(Harvey and Woodroffe 2008)	CB	i	15	Coastal vulnerability issues & sea level rise	Country	Australia	Australia	2007
JM15	(Mcleod et al. 2010)	CB	i	15	Coastal vulnerability issues & sea level rise	Regional	Asia	USA	2010
JN7	(Nicholls et al. 2008)	CB	i	15	Coastal vulnerability issues & sea level rise	-	N/A	UK	2007
JR14	(Romieu et al. 2010)	CB	i	15	Coastal vulnerability issues & sea level rise	-	N/A	France	2010
JT10	(Torresan et al. 2008)	CB	i	15	Coastal vulnerability issues & sea level rise	-	N/A	Italy	2007
JY2	(Yasuhara et al. 2007)	CB	i	15	Coastal vulnerability issues & sea level rise	Regional	Asia	Japan	2006
JY3	(Yasuhara et al. 2011)	CB	i	15	Coastal vulnerability issues & sea level rise	Country	Japan	Japan	2009
JL19	(Lotze et al. 2006)	CB	i	17	Estuaries & coastal seas — problems	Global	Global	Canada	2006
JS18	(Sidle et al. 2007)	CB	i	18	Open water bodies — problems	Local	Myanmar	Japan	2006
JS2	(Safriel and Adeel 2008)	CB	ii	2	Alternative livelihood	Global	Global	Canada	2007
JB2	(Barthelmie et al. 2008)	CB	ii	5	Low-carbon transitions	Local	Scotland	UK	2008
JA23	(Azadi et al. 2013)	CB	ii	9	Forest management policy/innovation	Local	Iran	Belgium	2012
JL4	(Lebel et al. 2004)	CB	ii	9	Forest management policy/innovation	Regional	Asia	Thailand	2003
JS24	(Sonwa et al. 2011)	CB	ii	9	Forest management policy/innovation	Regional	Africa	Cameroon	2010
JY8	(Yoshikawa et al. 2011)	CB	ii	9	Forest management policy/innovation	Global	Global	Japan	2011
JC4	(Cassman et al. 2003)	CB	ii	10	Agricultural policy/innovation	-	N/A	USA	2003
JC7	(Chen et al. 2011)	CB	ii	10	Agricultural policy/innovation	Local	China	China	2011
JF4	(Fedoroff et al. 2010)	CB	ii	10	Agricultural policy/innovation	Global	Global	USA	2010
JG4	(Gebbers and Adamchuk 2010)	CB	ii	10	Agricultural policy/innovation	-	N/A	Germany	2010
JG9	(Gewin 2010)	CB	ii	10	Agricultural policy/innovation	-	N/A	USA	2010
JH13	(Herdt 2006)	CB	ii	10	Agricultural policy/innovation	-	N/A	USA	2006
JH15	(Herrero et al. 2010)	CB	ii	10	Agricultural policy/innovation	-	N/A	Kenya	2010
JR11	(Roberts and Brink 2010)	CB	ii	10	Agricultural policy/innovation	Global	Global	USA	2010
JS43	(Spugnoli and Dainelli 2013)	CB	ii	10	Agricultural policy/innovation	-	N/A	Italy	2012
JT8	(Tollefson 2010)	CB	ii	10	Agricultural policy/innovation	Country	Brazil	USA	2010
JK22	(Katsuyama et al. 2009)	CB	ii	12	Modeling	Local	Japan	Japan	2009
JP21	(Poumadère et al. 2008)	CB	ii	12	Modeling	Local	France	France	2008

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JB9	(Birkmann and von Teichman 2010)	CB	**ii**	**13**	Adaptation—Natural Disaster—Migration—Benefits	-	N/A	Germany	2010
JH11	(Hay and Mimura 2006)	CB	**ii**	**13**	Adaptation—Natural Disaster—Migration—Benefits	Regional	Asia	Japan	2006
JS30	(von Storch and Woth 2008)	CB	**ii**	**13**	Adaptation—Natural Disaster—Migration—Benefits	Regional	Europe	Germany	2007
JO3	(Ohyama et al. 2008)	CB	**ii**	**14**	Urban policy/innovation	-	N/A	Japan	2008
JN1-6	(Graedel 2011)	CB	**ii**	**15**	Reuse—Recycling—Pollution control	-	N/A	USA	2011
JZ2	(Zhang et al. 2006)	CB	**ii**	**15**	Reuse—Recycling—Pollution control	Local	China	China	2006
JD3	(Daniell et al. 2010)	CB	**ii**	**17**	Water policy/innovation	-	N/A	Australia	2010
JG14	(Gleick 2003a)	CB	**ii**	**17**	Water policy/innovation	Global	Global	USA	2003
JH14	(Hermanowicz 2008)	CB	**ii**	**17**	Water policy/innovation	-	N/A	USA	2008
JR2	(Ramanathan and Xu 2010)	CB	**ii**	**18**	Treaties—Agreements	Global	Global	USA	2010
JB15	(Brack et al. 2006)	CB	**ii**	**19**	Emission estimation/control	Country	Australia	Australia	2006
JC1	(Caldeira and Davis 2011)	CB	**ii**	**19**	Emission estimation/control	-	N/A	USA	2011
JH6	(Hara et al. 2010)	CB	**ii**	**20**	Land use system planning/innovation	Local	Thailand	Japan	2010
JK33	(Kimura et al. 2010)	CB	**ii**	**20**	Land use system planning/innovation	Local	Japan	Japan	2009
JK39	(Kumar and Takeuchi 2009)	CB	**ii**	**20**	Land use system planning/innovation	Regional	Asia	India	2009
JL5	(Leclerc et al. 2009)	CB	**ii**	**20**	Land use system planning/innovation	Local	Senegal	Senegal	2009
JH19	(Hoekstra 2012)	CB	**ii**	**21**	Biodiversity conservation policy/innovation	-	N/A	USA	2012
JL10	(Lejano and Ingram 2007)	CB	**ii**	**21**	Biodiversity conservation policy/innovation	Local	Philippine	USA	2007
JS6	(Sarkar et al. 2006)	CB	**ii**	**21**	Biodiversity conservation policy/innovation	-	N/A	USA	2006
JJ1	(Jack et al. 2008)	CB	**ii**	**22**	Ecosystem services policy/innovation	-	N/A	USA	2008
JK35	(Komatsuzaki and Ohta 2007)	CB	**ii**	**22**	Ecosystem services policy/innovation	-	N/A	Japan	2006
JT9	(Tomich et al. 2004)	CB	**ii**	**22**	Ecosystem services policy/innovation	Regional	Asia	Kenya	2004
JX1	(Xia and Yan 2012)	CB	**ii**	**22**	Ecosystem services policy/innovation	Local	China	China	2011
JL18	(Longhurst et al. 2009)	CB	**ii**	**23**	Air quality policy/innovation	-	N/A	UK	2008
JY7	(Yoshida 2007)	CB	**ii**	**24**	Environmental restoration policies/innovation	Local	Japan	Japan	2006
JC2	(Carpenter et al. 2009)	CB	**iii**	**6**	Natural capital & ecosystem services management/governance	-	N/A	USA	2009

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JD2	(Daily and Matson 2008)	CB	**iii**	**6**	Natural capital & ecosystem services management/governance	-	N/A	USA	2008
JD10	(Depietri et al. 2012)	CB	**iii**	**6**	Natural capital & ecosystem services management/governance	-	N/A	Spain	2011
JF5	(Ferraro Jr. and Burztyn 2008)	CB	**iii**	**6**	Natural capital & ecosystem services management/governance	Local	Brazil	USA	2008
JG3	(Gardi and Sconosciuto 2007)	CB	**iii**	**6**	Natural capital & ecosystem services management/governance	Local	Italy	Italy	2007
JH4	(Halpin 1997)	CB	**iii**	**6**	Natural capital & ecosystem services management/governance	-	N/A	USA	1996
JB20	(Bueno and Basurto 2009)	CB	**iii**	**8**	Resilience	Local	Mexico	USA	2009
JM5	(Mah and Bustami 2012)	CB	**iii**	**8**	Resilience	Local	Malaysia	Malaysia	2011
JP19	(Potschin and Haines-Young 2006b)	CB	**iii**	**11**	Sustainability challenge	-	N/A	UK	2005
JS28	(Stocker et al. 2010)	CB	**iii**	**11**	Sustainability challenge	Country	Australia	Australia	2010
JY6	(York et al. 2003)	CB	**iii**	**11**	Sustainability challenge	-	N/A	USA	2003
JF15	(Füssel 2007)	CB	**iii**	**17**	Adaptation	-	N/A	Germany	2007
JD9	(DeFries et al. 2006)	CB	**iii**	**19**	Land cover and land use change science	-	N/A	USA	2006
JG1	(Gadda and Gasparatos 2009)	CB	**iii**	**19**	Land cover and land use change science	Local	Japan	Brazil	2009
JI4	(Ileva et al. 2009)	CB	**iii**	**19**	Land cover and land use change science	Local	Japan	Japan	2008
JL1	(Lambin et al. 2003)	CB	**iii**	**19**	Land cover and land use change science	Global	Global	Belgium	2003
JP15	(Pontius Jr and Neeti 2010)	CB	**iii**	**19**	Land cover and land use change science	Local	USA	USA	2009
JF12	(Fung and O'rourke 2000)	CB	**iii**	**24**	Environmental regulation	Country	USA	USA	2000
JC14	(Clark et al. 2006)	CB	**iii**	**25**	Environmental assessment	Global	Global	USA	2006
JM24	(Mühlhäusler and Peace 2006)	CB	**iii**	**26**	Sustainability related discourses	-	N/A	Australia	2006

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JK20	(Kates and Dasgupta 2007)	**D**	**i**	**10**	African poverty	Continent	Africa	USA	2007
JI6	(IPCC 2007)	**D**	**i**	**11**	Climate change problem/impacts	Global	Global	Global	2007

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JZ7	(Ziv et al. 2012)	D	i	19	River — problems	Regional	Asia	USA	2012
JN3	(Nautiyal 2011)	D	ii	3	Interventions and development, and conservation	Local	India	India	2011
JM18	(Millar et al. 2007)	D	ii	9	Forest management policy/innovation	-	N/A	USA	2007
JA6	(Alcamo et al. 2005)	D	ii	12	Modeling	Global	Global	Germany	2005
JG18	(Goodchild 2003)	D	ii	12	Modeling	-	N/A	USA	2003
JJ5	(Janssen and Ostrom 2006)	D	ii	12	Modeling	-	N/A	USA	2006
JM23	(Moser and Ekstrom 2010)	D	ii	13	Adaptation—Natural Disaster—Migration—Benefits	-	N/A	USA	2010
JH31	(Han et al. 2012)	D	ii	14	Urban policy/innovation	Global	Global	Japan	2012
JN1-1	(Fink 2011)	D	ii	14	Urban policy/innovation	-	N/A	USA	2011
JS13	(Schmandt 2006)	D	ii	17	Water policy/innovation	Regional	North America	USA	2006
JZ8	(Zwane et al. 2009)	D	ii	17	Water policy/innovation	-	N/A	USA	2009
JS21	(Soberon 2004)	D	ii	21	Biodiversity conservation policy/innovation	-	N/A	Mexico	2004
JG15	(2007)	D	ii	24	Environmental restoration policies/innovation	Global	Global	UK	2007
JA14	(Ascher 2006)	D	ii	25	Sustainable Development strategies/innovation	-	N/A	USA	2006
JM1	(Mabogunje and Kates 2004)	D	ii	25	Sustainable Development strategies/innovation	Local	Nigeria	USA	2004
JN8	(Nidumolu et al. 2009)	D	ii	25	Sustainable Development strategies/innovation	-	N/A	USA	2009
JZ1	(van Zeijl-Rozema et al. 2008)	D	ii	25	Sustainable Development strategies/innovation	-	N/A	Netherlands	2008
JG6	(Geels and Schot 2007)	D	iii	1	Transition theory	-	N/A	Netherlands	2007
JG7	(Geels 2011)	D	iii	1	Transition theory	-	N/A	UK	2011
JZ3	(Zhang et al. 2009)	D	iii	4	Circular economy	Local	China	Japan	2009
JB13	(Boulanger 2008)	D	iii	5	Quantitative sustainability	-	N/A	Belgium	2008
JF3	(Fan and Qi 2010)	D	iii	5	Quantitative sustainability	Local	China	USA	2009
JH5	(Hara et al. 2009)	D	iii	5	Quantitative sustainability	Country	China	Japan	2008
JK18	(Kates et al. 2005)	D	iii	5	Quantitative sustainability	-	N/A	USA	2005
JM27	(MacDonald 2005)	D	iii	5	Quantitative sustainability	-	N/A	Canada	2004

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JN5	(Ness et al. 2007)	D	iii	5	Quantitative sustainability	-	N/A	Sweden	2006
JO5	(Orecchini 2007)	D	iii	5	Quantitative sustainability	-	N/A	Italy	2007
JP4	(Parris and Kates 2003b)	D	iii	5	Quantitative sustainability	-	N/A	USA	2003
JP5	(Parris and Kates 2003a)	D	iii	5	Quantitative sustainability	-	N/A	USA	2003
JP14	(Phillips 2010)	D	iii	5	Quantitative sustainability	-	N/A	UK	2009
JH2	(Haberl et al. 2007)	D	iii	6	Natural capital & ecosystem services management/governance	Global	Global	Austria	2007
JH8	(Hardin 1968)	D	iii	6	Natural capital & ecosystem services management/governance	-	N/A	USA	1968
JH18	(Hoekstra and Mekonnen 2012)	D	iii	6	Natural capital & ecosystem services management/governance	Global	Global	Netherlands	2011
JK26	(Kenward et al. 2011)	D	iii	6	Natural capital & ecosystem services management/governance	-	N/A	UK	2011
JO6	(Ostrom and Nagendra 2006)	D	iii	6	Natural capital & ecosystem services management/governance	-	N/A	USA	2006
JO7	(Ostrom et al. 2007)	D	iii	6	Natural capital & ecosystem services management/governance	-	N/A	USA	2007
JT3	(Tallis and Kareiva 2006)	D	iii	6	Natural capital & ecosystem services management/governance	Global	Global	USA	2006
JW11	(Wilderer 2007)	D	iii	6	Natural capital & ecosystem services management/governance	-	N/A	Germany	2007
JA4	(Adger 2000)	D	iii	8	Resilience	-	N/A	UK	2000
JB16	(Brand and Jax 2007)	D	iii	8	Resilience	-	N/A	Germany	2007
JF7	(Folke et al. 2010)	D	iii	8	Resilience	-	N/A	Sweden	2010
JH21	(Holling 1973)	D	iii	8	Resilience	-	N/A	Canada	1973
JS19	(Smith and Stirling 2010)	D	iii	8	Resilience	-	N/A	UK	2010
JK19	(Kates et al. 2006)	D	iii	9	Value—Attitude—Behavior	-	N/A	USA	2006
JA19	(Ayres 2000)	D	iii	11	Sustainability challenge	-	N/A	USA	2000
JB17	(Brewer 2007)	D	iii	11	Sustainability challenge	-	N/A	USA	2007
JB18	(WCED 1987)	D	iii	11	Sustainability challenge	-	N/A	Norway	1987
JC11	(Clark 2003b)	D	iii	11	Sustainability challenge	-	N/A	USA	2003
JC13	(Clark et al. 2004)	D	iii	11	Sustainability challenge	-	N/A	USA	2004
JD5	(Dasgupta 2007)	D	iii	11	Sustainability challenge	-	N/A	UK	2007
JF8	(Folke et al. 2011)	D	iii	11	Sustainability challenge	-	N/A	Sweden	2011
JG21	(Graffy 2012)	D	iii	11	Sustainability challenge	-	N/A	USA	2011

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JH20	(Holdren 2008)	**D**	**iii**	**11**	Sustainability challenge	-	N/A	USA	2008
JI1	(ICSU 2002)	**D**	**iii**	**11**	Sustainability challenge	-	N/A	France	2002
JK7	(Kates 1996)	**D**	**iii**	**11**	Sustainability challenge	-	N/A	USA	1996
JK8	(Kates and Torrie 1998)	**D**	**iii**	**11**	Sustainability challenge	-	N/A	USA	1998
JK11	(Kates 2001a)	**D**	**iii**	**11**	Sustainability challenge	Global	Global	USA	2001
JK13	(Kates et al. 2001)	**D**	**iii**	**11**	Sustainability challenge	-	N/A	USA	2001
JK16	(Kates 2003b)	**D**	**iii**	**11**	Sustainability challenge	-	N/A	USA	2003
JK17	(Kates and Parris 2003)	**D**	**iii**	**11**	Sustainability challenge	-	N/A	USA	2003
JM26	(Munasinghe 2010)	**D**	**iii**	**11**	Sustainability challenge	Global	Global	Sri Lanka	2010
JP10	(Perrings 2007)	**D**	**iii**	**11**	Sustainability challenge	-	N/A	USA	2007
JR5	(Raskin et al. 2010)	**D**	**iii**	**11**	Sustainability challenge	-	N/A	USA	2010
JR7	(Raven 2002)	**D**	**iii**	**11**	Sustainability challenge	-	N/A	USA	2002
JR12	(Rockström et al. 2009)	**D**	**iii**	**11**	Sustainability challenge	Global	Global	Sweden	2009
JS10	(Savage 2006)	**D**	**iii**	**11**	Sustainability challenge	Regional	Asia	Singapore	2006
JS34	(Suneetha 2010)	**D**	**iii**	**11**	Sustainability challenge	-	N/A	Japan	2006
JS39	(Doran et al. 2012)	**D**	**iii**	**11**	Sustainability challenge	-	N/A	Canada	2012
JW8	(Wilbanks and Kates 1999)	**D**	**iii**	**11**	Sustainability challenge	-	N/A	USA	1999
JP9	(Peet and Peet 2000)	**D**	**iii**	**14**	Poverty—Development	-	N/A	New Zealand	2000
JM14	(McGranahan and Satterthwaite 2003)	**D**	**iii**	**16**	Urban sustainability and adaptive urban governance	Global	Global	UK	2003
JN1-2	(Daigger 2011)	**D**	**iii**	**16**	Urban sustainability and adaptive urban governance	-	N/A	USA	2011
JN1-5	(Bai 2011)	**D**	**iii**	**16**	Urban sustainability and adaptive urban governance	Continent	Asia	Australia	2011
JW10	(Wilbanks and Kates 2010)	**D**	**iii**	**17**	Adaptation	-	N/A	USA	2010
JB19	(Bryant 1998)	**D**	**iii**	**18**	Political ecology	-	N/A	UK	1998
JC20	(Cox 1981)	**D**	**iii**	**18**	Political ecology	-	N/A	Canada	1981
JH16	(Hersperger et al. 2010)	**D**	**iii**	**19**	Land cover and land use change science	-	N/A	Switzerland	2010
JR9	(Rindfuss et al. 2004)	**D**	**iii**	**19**	Land cover and land use change science	-	N/A	USA	2004
JS11	(Schaldach and Priess 2008)	**D**	**iii**	**19**	Land cover and land use change science	Global	Global	Germany	2008
JT18	(Turner et al. 2007)	**D**	**iii**	**19**	Land cover and land use change science	Global	Global	USA	2007
JB22	(Burns et al. 2003)	**D**	**iii**	**21**	World System theory	Global	Global	USA	2003
JH25	(Hornborg 1998)	**D**	**iii**	**21**	World System theory	-	N/A	Sweden	1997

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JM6	(Mann 2010)	D	iii	21	World System theory	-	N/A	USA	2010
JH12	(Henry 2009)	D	iii	22	Learning—Knowledge—Ignorance—Condition	-	N/A	USA	2009
JS12	(Schellnhuber 2009)	D	iii	23	Earth System analysis and tipping elements/points	Global	Global	Germany	2009
JK3	(Kajikawa et al. 2011)	D	iii	25	Environmental assessment	-	N/A	Japan	2011
JP6	(Parson 1997)	D	iii	25	Environmental assessment	-	N/A	USA	1997
JA5	(Adger et al. 2001)	D	iii	26	Sustainability related discourses	-	N/A	UK	2001
JH34	(Hugé et al. 2013)	D	iii	26	Sustainability related discourses	-	N/A	Belgium	2012
JA7	(Allenby 2006)	D	iii	27	Ethics	-	N/A	USA	2006
JD16	(Dwyer 2008)	D	iii	27	Ethics	-	N/A	USA	2008
JA8	(Allenby et al. 2009)	D	iii	28	Sustainable engineering education	Country	USA	USA	2008
JS15	(Segalas et al. 2009)	D	iii	28	Sustainable engineering education	Regional	Europe	Spain	2008
JA11	(Andersson et al. 2008)	D	iii	29	Sustainability Science education/curriculum	-	N/A	USA	2008
JB24	(Barth and Michelsen 2013)	D	iii	29	Sustainability Science education/curriculum	-	N/A	Australia	2012
JE3	(Epstein et al. 2009)	D	iii	29	Sustainability Science education/curriculum	-	N/A	USA	2009
JF2	(Fadeeva and Mochizuki 2010)	D	iii	29	Sustainability Science education/curriculum	-	N/A	Japan	2010
JO4	(Onuki and Mino 2009)	D	iii	29	Sustainability Science education/curriculum	-	N/A	Japan	2009
JP12	(Petry et al. 2011)	D	iii	29	Sustainability Science education/curriculum	-	N/A	Canada	2010
JT21	(Tamura and Uegaki 2012)	D	iii	29	Sustainability Science education/curriculum	-	N/A	Japan	2011
JU2	(Uwasu et al. 2009)	D	iii	29	Sustainability Science education/curriculum	-	N/A	Japan	2008
JW7	(Wiek et al. 2011)	D	iii	29	Sustainability Science education/curriculum	-	N/A	USA	2011
JW12	(Wright et al. 2009)	D	iii	29	Sustainability Science education/curriculum	-	N/A	USA	2008
JY11	(Yarime et al. 2012)	D	iii	29	Sustainability Science education/curriculum	-	N/A	Japan	2012
JA15	(Ascher 2007)	D	iii	30	Policy science	-	N/A	USA	2007
JR13	(Rodriguez and Montalvo 2007)	D	iii	30	Policy science	Continent	Europe	Netherlands	2007
JB3	(Beck 2010b)	D	iii	31	Cosmopolitanism	-	N/A	Germany	2010
JB4	(Beck 2010a)	D	iii	31	Cosmopolitanism	-	N/A	Germany	2010
JB5	(Beratan 2007)	D	iii	32	Decision making	-	N/A	USA	2007
JB6	(Berger et al. 2001)	D	iii	33	Ecological modernization	-	N/A	Austria	2001
JJ4	(Jänicke 2008)	D	iii	33	Ecological modernization	-	N/A	Germany	2007
JB21	(Burian 2001)	D	iii	34	Case studies for sustainability science	-	N/A	USA	2001

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JB23	(Bursztyn 2008)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	USA	2008
JB25	(Benessia et al. 2012)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	Italy	2011
JB27	(Buter and Van Raan 2013)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	Netherlands	2012
JC3	(Cash et al. 2003)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	USA	2003
JC10	(Clark 2003a)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	USA	2003
JC12	(Clark and Dickson 2003)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	USA	2003
JC22	(Costa and Kropp 2013)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	Germany	2012
JE1	(Eakin and Luers 2006)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	USA	2006
JG10	(Gieryn 1983)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	USA	1983
JG16	(Goldman and Schurman 2000)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	USA	2000
JG19	(Gotts 2007)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	UK	2007
JG27	(Gardner 2013)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	USA	2012
JH1	(Haapasaari et al. 2012)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	Finland	2012
JH3	(Hadorn 2004)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	Switzerland	2004
JH17	(Hiramatsu et al. 2008)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	Japan	2008
JJ2	(Jäger 2006)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	Austria	2006
JJ3	(Jäger 2011)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	Continent	Europe	Austria	2011

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JK1	(Kajikawa et al. 2007)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	Japan	2007
JK23	(Kauffman 2009)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	France	2009
JK36	(Komiyama and Takeuchi 2006)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	Japan	2006
JL23	(Lang et al. 2012)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	Germany	2011
JL24	(van der Leeuw et al. 2012)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	USA	2011
JM4	(MacMynowski 2007)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	USA	2007
JM17	(Mihelcic et al. 2003)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	USA	2003
JM22	(Morioka et al. 2006)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	Japan	2006
JM25	(Mulder 2007)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	Netherlands	2007
JN4	(Nelson 2006)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	USA	2006
JO9	(Orecchini et al. 2012)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	Italy	2011
JP8	(Pauwels 2011)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	USA	2011
JR3	(Rapport 2007)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	Canada	2006
JR8	(Reitan 2005)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	USA	2005
JS14	(Schoolman et al. 2012)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	USA	2011
JS41	(Shiroyama et al. 2012)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	Japan	2011
JW1	(Wallerstein 2010)	**D**	**iii**	**35**	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	USA	2010

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JW3	(Westley et al. 2011)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	Canada	2011
JW14	(Wuelser et al. 2012)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	Switzerland	2011
JW17	(Wiek et al. 2012b)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	USA	2011
JY1	(Yarime et al. 2010)	D	iii	35	Inter-/multi-/trans-/Disciplinarity of Sustainability Science research	-	N/A	Japan	2009
JC5	(Chapin III et al. 2011)	D	iii	36	Anthropocene and Earth stewardship	-	N/A	USA	2011
JS26	(Steffen et al. 2011)	D	iii	36	Anthropocene and Earth stewardship	Global	Global	Australia	2011
JS29	(2011)	D	iii	36	Anthropocene and Earth stewardship	-	N/A	Sweden	2011
JT16	(Turner et al. 1994)	D	iii	36	Anthropocene and Earth stewardship	Global	Global	USA	1994
JC15	(Clark 2007)	D	iii	37	Ontology and/or epistemology of Sustainability Science	-	N/A	USA	2007
JF16	(Forsyth 2001)	D	iii	37	Ontology and/or epistemology of Sustainability Science	-	N/A	USA	2001
JH26	(Hornborg 2003)	D	iii	37	Ontology and/or epistemology of Sustainability Science	-	N/A	Sweden	2003
JJ8	(Jerneck et al. 2011)	D	iii	37	Ontology and/or epistemology of Sustainability Science	-	N/A	Sweden	2010
JK2	(Kajikawa 2008)	D	iii	37	Ontology and/or epistemology of Sustainability Science	-	N/A	Japan	2008
JK12	(Kates 2001b)	D	iii	37	Ontology and/or epistemology of Sustainability Science	-	N/A	USA	2001
JK21	(Kates 2011)	D	iii	37	Ontology and/or epistemology of Sustainability Science	-	N/A	USA	2011
JK27	(Kerkhoff and Lebel 2006)	D	iii	37	Ontology and/or epistemology of Sustainability Science	-	N/A	Australia	2006
JK30	(Khagram et al. 2010)	D	iii	37	Ontology and/or epistemology of Sustainability Science	-	N/A	USA	2010
JK38	(Kristjanson et al. 2009)	D	iii	37	Ontology and/or epistemology of Sustainability Science	Regional	Africa and Asia	Kenya	2009
JK40	(Kumazawa et al. 2009)	D	iii	37	Ontology and/or epistemology of Sustainability Science	-	N/A	Japan	2008

Item ID	Item	Sphere	Category	Theme ID	Theme	Scale	Place	Place of authorship (corresponding author)	Temporal
JM12	(Max-Neef 2005)	D	iii	37	Ontology and/or epistemology of Sustainability Science	-	N/A	Chile	2005
JM28	(Marsden 2013)	D	iii	37	Ontology and/or epistemology of Sustainability Science	-	N/A	UK	2012
JM30	(Miller 2013)	D	iii	37	Ontology and/or epistemology of Sustainability Science	-	N/A	USA	2012
JN6	(Ness et al. 2010)	D	iii	37	Ontology and/or epistemology of Sustainability Science	-	N/A	Sweden	2010
JS7	(Sato 2007)	D	iii	37	Ontology and/or epistemology of Sustainability Science	Country	Japan	Japan	2007
JS25	(Steffen 2006)	D	iii	37	Ontology and/or epistemology of Sustainability Science	-	N/A	Germany	2006
JS31	(Strunz 2012)	D	iii	37	Ontology and/or epistemology of Sustainability Science	-	N/A	Germany	2012
JS40	(Salas-Zapata et al. 2013)	D	iii	37	Ontology and/or epistemology of Sustainability Science	-	N/A	Colombia	2012
JT19	(Turner and Robbins 2008)	D	iii	37	Ontology and/or epistemology of Sustainability Science	-	N/A	USA	2008
JT20	(Tushman and O'Reilly 2007)	D	iii	37	Ontology and/or epistemology of Sustainability Science	-	N/A	USA	2007
JW16	(Wiek et al. 2012a)	D	iii	37	Ontology and/or epistemology of Sustainability Science	-	N/A	USA	2011
JZ6	(Ziegler and Ott 2011)	D	iii	37	Ontology and/or epistemology of Sustainability Science	-	N/A	Germany	2011
JD7	(Davis 2006)	D	iii	38	Complex systems, analysis, and adaptive planning/management	-	N/A	USA	2000
JD8	(Dearing et al. 2010)	D	iii	38	Complex systems, analysis, and adaptive planning/management	-	N/A	UK	2010
JF6	(Folke et al. 2007)	D	iii	38	Complex systems, analysis, and adaptive planning/management	-	N/A	Sweden	2007
JH22	(Holling 2001)	D	iii	38	Complex systems, analysis, and adaptive planning/management	-	N/A	USA	2001
JH24	(Horan et al. 2011)	D	iii	38	Complex systems, analysis, and adaptive planning/management	-	N/A	USA	2011

Item ID	Item	Sphere	Category	Theme ID	Theme	Scale	Place	Place of authorship (corresponding author)	Temporal
JI3	(Iles 1996)	D	iii	38	Complex systems, analysis, and adaptive planning/management	-	N/A	USA	1996
JJ10	(Johnson 1999)	D	iii	38	Complex systems, analysis, and adaptive planning/management	-	N/A	USA	1999
JL6	(Lee 1999)	D	iii	38	Complex systems, analysis, and adaptive planning/management	-	N/A	USA	1999
JL16	(Liu et al. 2007)	D	iii	38	Complex systems, analysis, and adaptive planning/management	-	N/A	USA	2007
JM16	(Meadows 1999)	D	iii	38	Complex systems, analysis, and adaptive planning/management	-	N/A	USA	1999
JP7	(Parsons 2007)	D	iii	38	Complex systems, analysis, and adaptive planning/management	-	N/A	USA	2007
JT17	(Turner et al. 2003)	D	iii	38	Complex systems, analysis, and adaptive planning/management	-	N/A	USA	2003
JY9	(Young et al. 2006)	D	iii	38	Complex systems, analysis, and adaptive planning/management	-	N/A	USA	2006
JD14	(Douglas 2007)	D	iii	39	Cultural theory	-	N/A	UK	2007
JO2	(O'Riordan and Jordan 1999)	D	iii	39	Cultural theory	-	N/A	UK	1999
JT6	(Thompson 1997)	D	iii	39	Cultural theory	-	N/A	Norway	1997
JD15	(Drechsel and Dongus 2010)	D	iii	40	Urban agriculture	Local	Tanzania	Sri Lanka	2008
JF10	(Fotopoulos 2007)	D	iii	41	De-growth	-	N/A	UK	2007
JK28	(Kerschner 2010)	D	iii	41	De-growth	-	N/A	Spain	2009
JL3	(Latouche 2007)	D	iii	41	De-growth	-	N/A	France	2007
JG25	(Grey 1993)	D	iii	42	Anthropocentrism vs. deep ecology	-	N/A	UK	1993
JG26	(Gruen et al. 2008)	D	iii	43	Sustainable health	-	N/A	Australia	2008
JH10	(von Hauff and Wilderer 2008)	D	iii	44	Industrial ecology	-	N/A	Germany	2007
JJ7	(Jerneck and Olsson 2011)	D	iii	45	Reframing	-	N/A	Sweden	2011
JJ11	(Jorgenson and Kick 2003)	D	iii	46	Globalization	-	N/A	USA	2003
JK15	(Kates 2003a)	D	iii	46	Globalization	-	N/A	USA	2003
JK32	(Kim and Oki 2011)	D	iii	47	Scenario analysis—Visioneering	-	N/A	Rep. Korea	2011
JS37	(Kosamu 2011)	D	iii	47	Scenario analysis—Visioneering	-	N/A	Netherlands	2003
JL21	(Lüdeke et al. 2004)	D	iii	48	Syndromes	-	N/A	Germany	2004

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JP20	(Potschin and Haines-Young 2006a)	**D**	**iii**	**49**	Landscape ecology	-	N/A	UK	2005