Livelisystems: conceptualising social, biological and ecosystem change and 'development'

Andrew Dorward and Rebecca Kent

SOAS, University of London

July 2012

Working paper, Centre for Development, Environment and Policy,
SOAS, University of London

Summary

Human activity poses multiple environmental challenges for ecosystems that have intrinsic value and also support that activity. Our ability to address these challenges is constrained, inter alia, by weaknesses in cross disciplinary understandings of interactive processes of change in socio-ecological systems. This paper draws on complementary insights from social and biological sciences to propose a 'livelisystems' framework of multi-scale, dynamic change across social and biological systems. This describes how material, informational and relational assets, asset services and asset pathways interact in systems with embedded and emergent properties undergoing a variety of structural transformations. Related characteristics of 'higher' (notably human) livelisystems and change processes are identified as the greater relative importance of (a) informational, relational and extrinsic (as opposed to material and intrinsic) assets, (b) teleological (as opposed to natural) selection, and (c) innovational (as opposed to mutational) change. The framework provides valuable insights into social and environmental challenges posed by global and local change, globalisation, poverty, modernisation, and growth in the anthropocene. Its potential for improving inter-disciplinary and multi-scale understanding is discussed, notably by examination of human adaptation to bio-diversity and eco-system service change following the spread of Lantana camera in the Western Ghats, India.

Keywords: socio-ecological systems, livelisystems, environmental change.

Acknowledgements: We are grateful to colleagues in the ESPA framework project 'Human Adaptation to Biodiversity Change' for stimulating discussion of issues and to Harry Biggs, Andries du Toit, EJ Milner Gulland, and Jeff Waage for helpful comments on an earlier draft of this paper. Writing up and the Western Ghats research project were supported by the ESPA programme framework grant 'Human Adaptation to Biodiversity Change' (NE/I004149/1). The views and any errors or omissions are the authors' sole responsibility and do not represent those of any other parties.

July 2012

Livelisystems: conceptualising social, biological and ecosystem change and 'development'

Andrew Dorward and Rebecca Kent

1. Introduction

The multiple environmental challenges that human activity poses for the planet's ability to support the adoption of high consumption lifestyles by increasing numbers of people are well known: widespread over-exploitation and pollution of natural systems is causing degradation and loss of local and global ecosystems and natural resource stocks and hence loss of ecosystem services on which human activities are critically dependent (for example Millennium Ecosystem Assessment, 2005; Rockström et al., 2009; Foresight, 2011; Raworth, 2012). These problems, or rather the socio-ecological systems (SES) with which they are concerned, have multiple characteristics that make them particularly difficult to understand and address: they are cross- or multi-scale, multidisciplinary, dynamic (with multi-dimensional structural changes and transformations), subject to behavioural uncertainty, involve non-linear relations and hence thresholds or tipping points, and have emergent and embedded properties (for example Holling et al., 1998, Ostrom, 2007, Perrings, 2007, Anand et al., 2010,Rounsevell et al., 2010, An, 2012,Rammel et al., 2007).

Addressing these problems needs (1) better analytical and management processes for diagnosis of problems and development and implementation of solutions and (2) better understandings of the fundamental SES processes as they respond to different stimuli. Better cross disciplinary integration of theory, language and information is a key challenge in this (Millennium Ecosystem Assessment, 2005; Norgaard, 2008; Ostrom, 2009; Waring and Richerson, 2011; Milner-Gulland, 2012).

This paper draws on complementary insights from social and biological sciences to propose the foundations for a unifying conceptual framework of dynamic change across social and biological systems. After this introduction the paper is structured in four parts. We begin by reviewing existing frameworks that span, or attempt to span, the social and biological sciences. This leads on to the description of what we term a 'livelisystems' framework and then consideration of potential applications of the framework. The paper concludes with a brief discussion of strengths and weaknesses of the framework and ways in which it could be taken forward.

2. Existing SES frameworks

A range of different cross-disciplinary frameworks and models have been developed and applied for diagnosing problems and developing and implementing solutions. One of the earliest was perhaps the 'sustainable livelihoods approach' (Chambers and Conway, 1992; Carney, 1998). Developed and applied from a largely social science perspective, this was originally a broadly atheoretical checklist of issues to consider in analysing sustainable rural livelihood constraints, opportunities and interventions. As an analytical or development aid this had its value, but was subject to criticism that even on socio-economic issues it omitted key issues (such as markets, institutions and politics, Dorward et al. (2003)) and lacked theory regarding processes and pathways of change and detailed linkages across different scales (Scoones, 2009). It also lacked any specification of linkages across the natural and social sciences.

Another framework that has gained wide and enduring traction is the EcoSystem Services (ESS) framework. Building on early work by Costanza and Daly, 1992; Perrings et al., 1992) the Millennium Ecosystem Assessment set out a formal EcoSystem Services framework to demonstrate the importance of ecosystems and ecosystems threats. Although it has strong roots in ecology, it is criticised for its limited conceptualisation of ecosystems as stock flow systems, its application to partial rather than general equilibrium analysis, and its facilitation of the commoditisation of ecosystem services (Gómez-Baggethun et al., 2010; Norgaard, 2010). However, beyond its conceptualisation of human drivers and ecosystem stocks and flow, and the opportunity it provides for valuing flows and hence the stocks they are derived from, it is largely atheoretical as regards socio-economic influences on and responses to change.

A framework whose terminology relates closely to the ESS Framework (with 'drivers' and 'pressures' equivalent to the ESS 'indirect' and 'direct' drivers, (Fisher et al., 2012) is the Drivers-Pressures-State-Impact-Response (DPSIR) which has been further developed into the Framework for Ecosystem Service Provision (FESP) (Rounsevell et al., 2010). Although in many ways similar to the MEA ESS framework, these frameworks place more explicit emphasis on the possibility of adaptation by ecosystem service providers (key ecosystem elements or communities providing specific services) and, in the case of FESP, on responses by ecosystem beneficiaries. However such feedbacks are also allowed for in research frameworks that explicitly seek to operationalise the MEA, for example Collins, 2007.

These frameworks are useful in setting out checklists of the elements of SES that need to be considered. Their weaknesses arise from (a) the elements that they omit, (b) the limits of the system behaviour theories (or lack of theory) underpinning them, and (c) implementation difficulties in obtaining reliable information linking the behaviour of different elements (arising from both theoretical and data difficulties). A key weakness is that although both social and ecological elements may be in included in the framework, we seldom find both social and ecological theory underpinning them[1].

Frameworks that consider both social and ecological theory are more analytically and politically challenging to implement. Ostrom and others have developed a valuable framework for identifying and organizing relevant variables that affect self-organization by resource users in SESs (Anderies et al., 2004; Ostrom, 2005; Ostrom, 2007; Ostrom, 2009). These variables describe features of resource units, resource users and resource and governance systems, the core subsystems for analysis of SESs, and are identified and brought together to allow integration of knowledge from biophysical and social science studies for use in data collection, fieldwork, and analysis of SES sustainability. Valuable though this framework is, this work emerges from an institutional analysis and Anderies et al., 2004 note a limitation that the original design principles do not explicitly address ecological dynamics and that attention is needed to 'mechanisms related to the match between the spatial and temporal dynamics of ecological and social systems'.

This match, perhaps the core problem in cross disciplinary integration in SES, is the subject of a review by Milner-Gulland of the implications of work on the interactions between human behaviour

[1] A possible exception here is the application of the ESS framework to design schemes for payments for ecosystem services – but this raises fundamental objections about the inadequacy of considering social relations only in market exchanges and about insufficient consideration of possible indirect effects and feedbacks (Milner-Gulland, pers.comm.).

and ecological systems for predictive systems ecology (Milner-Gulland, 2012). She reports considerable work examining one way impacts – of humans on ecosystems or of ecosystems on humans - but much less work that examines dynamic two way interactions. Where such work has been done, it has been very valuable in showing the important effects of these interactions (for example Holdo et al., 2010)– but tends to involve detailed and system specific modelling and modelling tools, rather than general theory. Agent based modelling can, however, provide a common tool and methodological framework for such modelling. It is interesting that coming at the problem from more of a conservation perspective, Milner-Gulland reaches symmetrical conclusions to those of Anderies et al., 2004 reported above, observing that 'indirect effects of conservation interventions on biodiversity, modulated through human decision-making, are poorly studied' and calling for 'an inter-disciplinary approach .. to quantify these interactions, with an understanding of human decision-making at its core'.

Social and natural scientists engaged in cross-disciplinary work on SESs therefore recognise the need for integration of 'the spatial and temporal dynamics of ecological and social systems', but struggle to achieve this. The symmetry of thwarted aspiration suggests that attempts to 'bolt together' disciplinary understandings and methods face serious difficulties. Instead an alternative, more fundamental integration may be needed in terms of (a) metatheoretical understanding and (b) methodological approaches and tools.

A core explanation for the 'symmetry of thwarted aspiration' is likely to be the way that different disciplines operate with different conceptual frameworks regarding basic processes of change (Gintis, 2007; Hodgson and Knudsen, 2010). This is undesirable from at least three perspectives. First, different disciplines may not only have different concerns and perspectives (which is valuable), but also incompatible models (Gintis, 2007), leading to incompatible analyses and difficulties in mutual comprehension. Second, even if the different frameworks do not lead to incompatible models, it may be that a framework in one discipline has great analytical power in another discipline, and failure to use that framework within the second discipline is therefore missing opportunities for expanding analytical opportunities in that discipline (this is a major thrust of arguments by Hodgson and Knudsen, 2010 for the adoption of generalised Darwinism across the social sciences). Third, and drawing on the first two points, work across disciplines, a fundamental requirement for work on socio-ecological systems, becomes significantly more challenging if the two disciplines do not share a common metatheoretical framework to unite and interface their different work and perspectives on different topics (Hodgson and Knudsen, 2010). To address these challenges Mollinga calls for three types of 'boundary work': the development of boundary concepts (cross disciplinary terminology and multi-dimensional thinking), tools (analytical models and assessment frameworks), and settings (institutional arrangements for inter-disciplinary work) (Mollinga, 2010). This first need is echoed by Schluter et al. who recognise considerable achievements in SES modelling but note 'the need for a common analytical framework for SES' (SchlÜTer et al., 2012, p251)

Interest in evolution has been a dominant theme in work on the development of such metatheoretical frameworks. Hodgson has been a strong proponent for the adoption of 'generalised Darwinism' as a uniting metatheoretical framework for the social sciences (see for example Hodgson and Knudsen, 2010). Hodgson and co-authors develop this in substantial depth and detail, dealing with a variety of objections to the application of Darwinian evolution to the social sciences and addressing specific difficulties raised by developing principles for the application in analysis of evolution in social systems. Gintis, 2007 proposes 'evolutionary theory, covering both genetic and cultural evolution, as the integrating principle of behavioural science 'in a 'framework for the unification of the behavioural sciences'. In both of these cases evolutionary theory is being proposed as a unifying theory for the social sciences (Gintis includes biology within an initial list of behavioural sciences, but it is clear that his interest is in human behaviour).

Norgaard has proposed 'coevolutionary' theory as a way of linking analysis of social and ecological change initially as 'an appeal for theoretical pluralism' (Norgaard, 1984) but more recently as a framework for explanation of sociocultural evolution in social sciences and for linking this to the biological sciences (Gual and Norgaard, 2010). Although this has faced a number of criticisms (for example regarding the role of group selection and processes of variation, selection and inheritance) many of these criticisms arise because evolutionary concepts are being lifted out of a narrower biological context (concerned with biological processes, mechanisms and variables) to fit in a wider context (concerned with social processes, mechanisms and variables) and in this does not distinguish, for example, between co-dynamics and Darwinian co-evolution (Winder et al., 2005, Kallis (2007)). Co-evolutionary theory is also proposed for the conceptualisation and understanding of uncertainty inherent in economic development processes, involving the co-evolution of technical and institutional change (Nelson, 2011). Rammel et al., 2007 explicitly draw on ideas from complex adaptive systems theory, evolutionary theory and evolutionary economics to develop a co-evolutionary perspective on natural resource management.

Waring and Richerson, 2011 argue that Norgaard's framework could provide a basis for a unified framework for SES analysis, and propose that with the addition of three traditions of mathematical theory (the Lotka–Volterra interactions of ecological theory, niche construction models of population genetics, and gene–culture coevolution theory) this could form the basis for an operational 'theory of socio-ecological coevolution' with coupled models of environmental change and human behaviour. Gene-culture coevolution also features in Gintis' unifying theory (Gintis, 2007) while Laland and Boogert, 2010 propose niche construction – both gene-based and cultural niche construction - as a dominant process in SESs dynamics. Niche construction provides the basis for the 'extended evolutionary theory' proposed by Odling-Smee et al., 2003, while Jablonka and Lamb, 2005 put forward a related but different 'extended evolutionary theory' in their exposition of 'evolution in four dimensions' (the four dimensions being genetic; epigenetic; behavioural; and symbolic variation, selection and inheritance).

Other metatheoretical frameworks approach SESs in very different ways. Living systems theory, developed by Miller (Miller, 1978; Miller and Miller, 1992) adopts a systems approach in a formal description of hierarchical arrangements of nested and integrated biological and social systems arranged, from single celled organisms to supranational social systems, with formal functional sets of critical subsystems. Living systems theory has had limited application to SESs. This contrasts with widespread interest in the concept of panarchy, which focuses on linked, hierarchically arranged adaptive cycles representing cross-scale dynamic interactions and the interplay between change and persistence in a system (Holling et al., 2002).

While these frameworks provide ways of conceptualising the 'spatial and temporal dynamics of ecological and social systems', Gintis, 2007 and Waring and Richerson, 2011 also include methodological approaches or tools in the operational proposals for their frameworks – respectively the use of evolutionary game theory and the coupling of specific mathematical modelling approaches. Actor network theory and agent based models provide two other, closely related methodological approaches to conceptualising and modelling agents in social and ecological systems (Hird, 2010 and Rounsevell et al., 2012) – with the significant but unusual advantage that agent based modelling is a technique that is independently being increasingly used in both social and biological sciences. Modelling of adaptive cycles has both theoretical and methodological significance in panarchy, but potential for wider application (Widlok et al., 2012) and for links to agent based modelling.

3. A livelisystems framework

We now set out, in stages, a general conceptual framework describing social and biological systems. Our review of the challenges facing such a framework suggests that if this is to provide a truly cross-disciplinary and valid model of these systems it requires the following characteristics:

- It must be able to represent the characteristics of complex, coupled systems, describing multi-scale, dynamic interactions between and within partially decomposable sub-systems, allowing for emergent and embedded properties , a variety of types of structural change and transformations, uncertainty, non-linear relations, and thresholds or tipping points,
- It should draw on insights, concepts and language from across the social / natural science divide,
- It should not be inherently anthropocentric or ecocentric, but should be capable of both anthropocentric and ecocentric application,
- It should be able to accommodate and mediate a variety of different disciplinary perspectives and investigational approaches,
- Ideally it should make separate contributions to the social and biological sciences apart from aiding their integration in the analysis of SESs, and
- It should stimulate innovative and valid conceptual and researchable questions and investigation.

In pursuit of this we postulate a set of nested frameworks which set out, with increasing detail, the elements and processes that constitute what we term 'livelisystems'. Figure 1 sets this out at a broad level of abstraction. We define a 'livelisystem' as

'a combination of the resources (or asset functions) used and the activities undertaken by open, structured and actively self-regulating systems to maintain their negentropy (negative entropy) and/or increase it with information transfer mechanisms for replication or reproduction' .

This draws on conceptualisations of livelihoods (Chambers and Conway, 1992), living systems (Miller, 1978) and generative replication in complex population systems (Hodgson and Knudsen (2010a)). It focuses attention in social or ecological system analysis on resources or asset functions (Kent and Dorward, 2012), on activities, on processes maintaining or increasing system order and negentropy, and, as open systems, on relations with external systems. The broad processes and elements of a framework representing these features are set out diagramatically in figure 1.

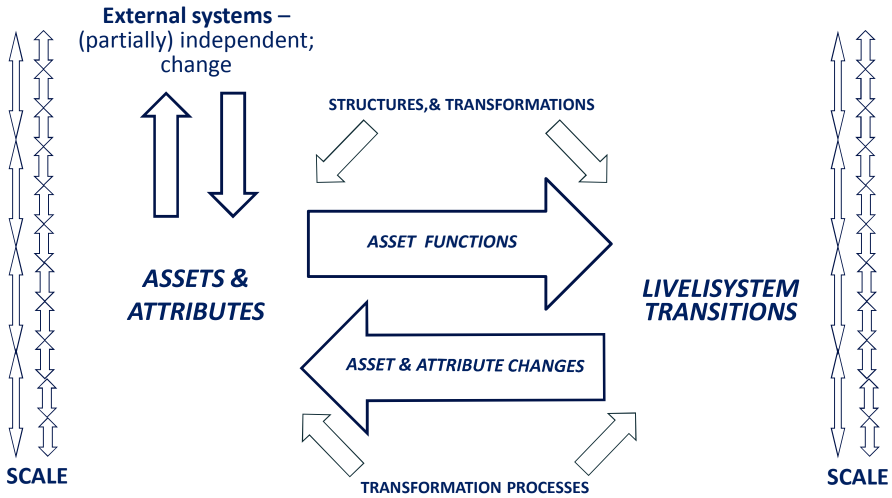

Figure 1. Livelisystems: broad processes and elements

This represents processes maintaining or increasing system order and negentropy as 'livelisystem transitions' (on the right) , and links these to resources (on the left) termed 'assets and attributes'. Assets, their properties and their attributes are affected by and may or may not affect external systems (shown in the upper left of the figure)[2]. are Assets by their attributes perform functions which effect livelisystem transitions, and they are themselves affected by these transitions. These processes operate at different scales, with lower level systems operating within higher level systems and affected by other livelisytems within higher level hierarchies. However they are also components of and therefore affect higher level hierachies, often with 'sub-livelisystems' acting as assets within a higher level livelisystem. These cross scale interactions are indicated by the vertical arrows on the sides of figure 1. Finally, livelisystem transitions and assets and attributes are arranged in structures which may be transformed by a variety of processes.

We now develop this conceptualisation further by detailing categories of livelisystem transitions, asset functions, asset changes, assets and attributes, and flows between livelisystem s and external systems. These categories are set out in figure 2 and we discuss them in turn.

[2] An important distinction is made between asset properties (their essential and potential features) and asset attributes (the expression of an asset's properties in a particular ecological and social context). In the remainder of this section we consider asset properties synonymously with assets themselves.

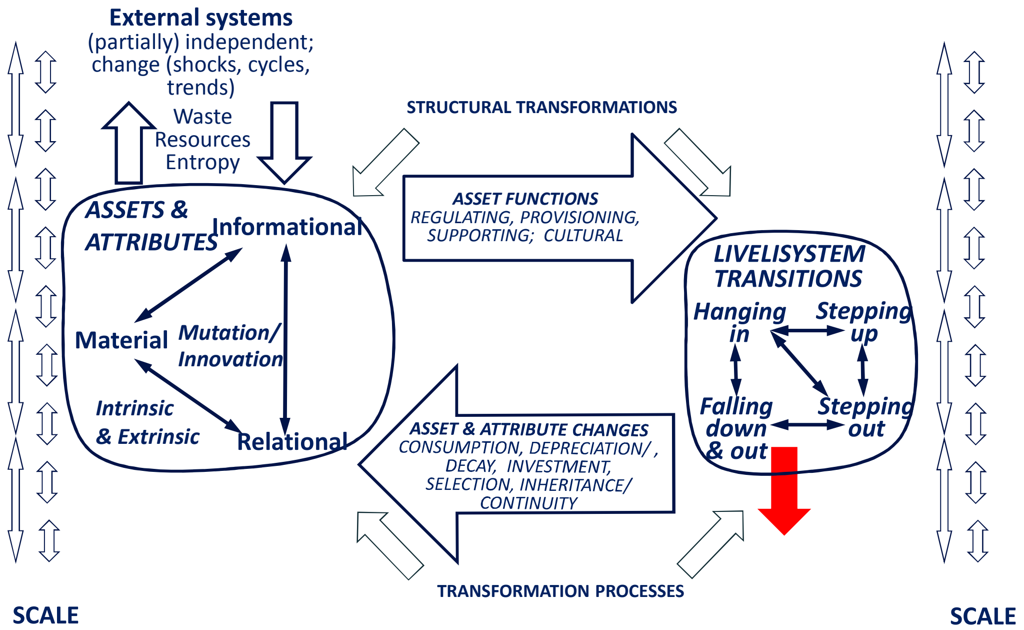

Figure 2. Livelisystems: categories within broad processes and elements

Building on a conceptualisation originally of livelihood aspirations and transformations (Dorward, 2009), four possible livelisystem transitions are defined – hanging in (maintaining the status quo), stepping up (increasing levels of existing sets or subsets of activities and/or assets and asset functions), stepping out (engaging in new activities with different assets and asset functions), and falling down and out (failing to maintain the status quo and falling back to a livelisystem with lower attainment of sets or subsets of activities and/or assets and asset functions, possibly failing to maintain the livelisystem and survive). As noted earlier, these livelisystem transitions draw on asset functions and cause asset changes. The concept of asset functions is discussed more fully in Kent and Dorward, 2012. It is related to and includes ecosystem services, and following the MEA these functions are categorised as regulating, provisioning, supporting and cultural (Millennium Ecosystem Assessment, 2005) as it is recognised that this is a helpful classification of functions performed by all forms of capital – for example physical, social, and human as well as natural capital (Waage et al., 2010). Asset functions can be classified into more detailed categories: Dorward et al., 2005, for example apply the concept to analysis of livestock roles in poor rural people's livelihoods in Mexico and Bolivia and categorise these in terms of production, consumption , accumulation, buffering, insurance, protecting and social integration functions.

Livelisystem transitions affect assets (their properties) and their attributes in a variety of ways. Asset and attribute depletion (including loss of properties needed for particular functions) may occur where asset stocks are directly consumed or decay/ depreciate at a faster rate than they are generated or renewed within or outside the livelisystem or where processes (for example generation of waste) undermine them. On the other hand there may be accumulation where investment or other positive effects lead to faster generation and renewal than consumption or decay/ depreciation. Processes of asset (and property) and attribute gain or loss lead to differential selection of assets and attributes and, with the information transfer mechanisms for replication or reproduction inherent in our definition of livelisystems, this leads to inheritance ('the passing of information concerning adaptive solutions from one entity to another', Hodgson and Knudsen, 2010 p239).

Selection and inheritance constitute two of the three necessary processes of Darwinian evolution, the third being variation. This is a characteristic of assets, which are hierarchically embedded combinations of material, informational and relational resources (they are hierarchically embedded in that relational resources are normally embedded in some form of informational resource, and informational resources are always embedded in some form of material resource). Informational and material resources coincide with the two core elements identified in Miller's living systems theory, matter-energy and information (Miller, 1978) and with Odling Smee's (Odling-Smee, 2007; Odling-Smee, 2010) conceptualisation of informatic and physical (material and energy) resource components of ecological inheritance systems (though these are then separated from not integrated across genetic inheritance systems). Relational elements describe claims and obligations that systems or sub-systems have on or to other systems or subsystems, and will be embedded in material and informational elements.

The 'material, informational and relational' categorisation of assets can be applied in two ways. First, as is implicit in the outline above, as regards asset composition – assets are made up of material, informational and relational elements. The categorisation also applies in a second way in describing the mode of operation of the asset – does an asset make material, informational and/or relational contributions to livelisystems in its performing its functions in a livelisystem? While the material, informational and relational categorisation is useful in examining the fundamental composition and operation of assets, assets may also be categorised in a variety of other ways. Thus, for example, it may be helpful to categorise assets as natural, physical, social and human capital in some analyses of social or socio-ecological systems.

It is also helpful to categorise asset attributes. No categorisation is shown in figure 2, for reasons of space, but it is clear from the framework that differences in asset properties and their expression in different contexts mean that assets will vary in the extent and way that they contribute to different services, and hence in their attributes.

Drawing on and adding to livestock attributes identified by Dorward et al., 2005 (see also Alwang and Siegel, 1999) suggests, as an illustrative starting point, a list of attributes set out in table 1. Attributes will vary with both the nature of the asset and its properties (and many assets will be 'sub-livelisystems' with their own emergent, embedded and non-linear properties) and with the services / functions they provide. They and their components must therefore be defined relative to asset functions, as illustrated in table 1. Different functions and attributes may have more or less relevance to different social and ecological processes and analysis. Their specification will thus vary substantially between different livelisystems and analyses and, depending on their essential properties, will be both contextually and socially defined (Kent and Dorward, 2012). The 'second tier system variables' identified by Ostrom, 2007 and others in their framework for analysing SES provide further options for specifying and categorising asset attributes.

Table 1. Asset attributes

Main Attribute	*Contributing to which function(s)*	*Components*
Productivity	Production, income,	Productivity (or throughput) under expected, average or 'normal' conditions; variability; sensitivity to and resilience under different conditions; probability of these different conditions occurring; appreciation of asset value
Utility	Income, consumption,	'Normal' utility or wellbeing; variability; sensitivity to and resilience under different conditions; probability of these different conditions occurring
Security	All, especially saving	Risk of theft, loss of control or access; susceptibility to pathogens or other 'natural' event. For debts: risks to collateral or collateral substitutes
Holding costs	Detracts from all	Maintenance and input costs (including time, claims, etc) borne by different stakeholders: under normal conditions; variability under different conditions; probability of different conditions Depreciation in time and in use: under normal conditions; variability under different conditions; probability of different conditions
Life	All	Expected period over which asset will be held: under normal conditions; variability under different conditions; probability of different conditions Asset value profile (seasonal, lifecycle changes)
Depreciation	All	Rate of loss of function / service, affected by use, investment, environment, etc
Convertibility	Sales income, savings, buffering, insurance	Exchange costs: under normal conditions; variability under different conditions; probability of different conditions Access: under normal conditions; variability under different conditions; probability of different conditions Lumpiness: related to unit value of sale and ease of sale
Complement-arity	Production, income	Effects on and of other assets and their functions
Ownership/ control	All	Private (individual, household); communal; public; gendered rights and responsibilities for disposal, acquisition, costs and returns
Divisibility	All	Minimum functional scale (may vary across services), variation of other attributes with scale
Dispersion/ concentration	All	Spatial & temporal distribution, could also be applied to ownership

Adapted from Dorward et al., 2005

Two further categorisations of assets and attributes are included in figure 2. The first recognises that assets and attributes are subject to endogenous changes. These differ from the changes effected by livelihood transitions (as described earlier) as these endogenous changes affect the core characteristics, composition and structure of assets and their attributes rather than the expression of these in particular contexts – the genotype rather than the phenotype or replicator rather than interactor (Hodgson and Knudsen, 2010). Endogenous changes arise as a result of mutation, innovation, and recombination (where mutation describes random changes generally arising in processes of replication, innovation describes intentional changes and recombination describes new combinations of core characteristics, composition and structure of assets and their attributes). Mutation and innovation may act in combination or singly, and may affect material, informational or relational elements. These broad mechanisms of endogenous change are critical to livelisystems as they allow variation, the third of the three necessary processes of Darwinian evolution mentioned above.

The second further categorisation of assets and attributes in figure 2 applies principally to assets rather than their attributes, and distinguishes between assets that are intrinsic and those that are extrinsic to (integral or not integral parts of) organisms in a livelisystem. Examples of extrinsic assets might include animals' nests and burrows, machinery, information technology systems, and, by definition, relational assets. This distinction may or may not be usefully applied to other livelisystem entities.

Consideration of extrinsic assets and relational assets raises questions about livelisystem boundaries and relations with external systems. Defining boundaries of open systems is commonly difficult and requires problem and context specific determination. Feedbacks between systems depend upon the extent of coupling and relative scales and numbers of interacting systems – hence their partial independence. It is helpful, however, to recognise different categories of change in external systems ('normal' apparently random variation, shocks, cycles and trends) as these will have different impacts on livelisystems, and to recognise different types of flows between livelisystems and their environment, with material, informational and relational resources and waste flowing in and out, and a maintenance of negentropy by taking in resources with lower entropy than the 'waste' they emit or expel.

The categorisations in figure 2 should not be seen as rigid, tightly defined, separate and mutually exclusive. On the contrary, the boundaries between them will often be fuzzy and overlapping, both within and across hierarchies of scale. Thus the four categories of livelisystem transitions may be present together, and the same processes (take for example a switch from less intensive to more cropping systems in an socio-agro-ecological system or a species transition from crawling to running) might be seen as stepping up (of agricultural productivity or mobility respectively) or stepping out (from one crop to another or from one form of locomotion to another). Similarly asset services might be categorised differently in different types of analysis or at different scales of analysis (for example a service categorised as 'supporting' at a higher scale of analysis might be considered a 'provisioning' service at a lower scale of analysis). This is one way of addressing difficulties in defining and distinguishing between direct and indirect services and functions in the ecosystem services framework (Jax, 2010). These categorisations also need further development and definition within the context of the overall conceptualisation. The concept and roles of 'relational assets', for example, while providing useful insights need better specification.

We conclude our introduction to the livelisystems framework by introducing illustrative potential characteristics of livelisystem, most importantly in terms of the nature of livelisystems behaviour and of structural transformations and transformation processes. The introduction of these leads to some unavoidable crowding of figure 3, but highlights important features that may or may not be present in different livelisystems. Specification of these demonstrates the richness and variety of the processes and systems that may be captured with a livelisystems framework. The centre of the figure lists critical ecological, social and SES features that can be captured by cross scale contextualised analysis of livelisystem transitions and their interactions with evolving assets and attributes. At the top of figure 3 a range of different types and dimensions of structural transformations are listed, while at the bottom of figure 3 is a list of different types of processes which may be involved in these transformations. Similarly lists of hierarchical scales of analysis are added on the right of the figure. It is important to note that these also define types and scales to which various livelisystem concepts (such as transitions, transformations, and asset functions and attributes) may be applied. As with our earlier discussion of asset functions and attributes, these lists are not intended to be either prescriptive or exhaustive (they do not set out a typology of transformations or processes which will apply to all livelisystems) but illustrative of the richness of the potential range that may or may not be considered and may or may not be helpful when using the framework to analyse particular livelisystems.

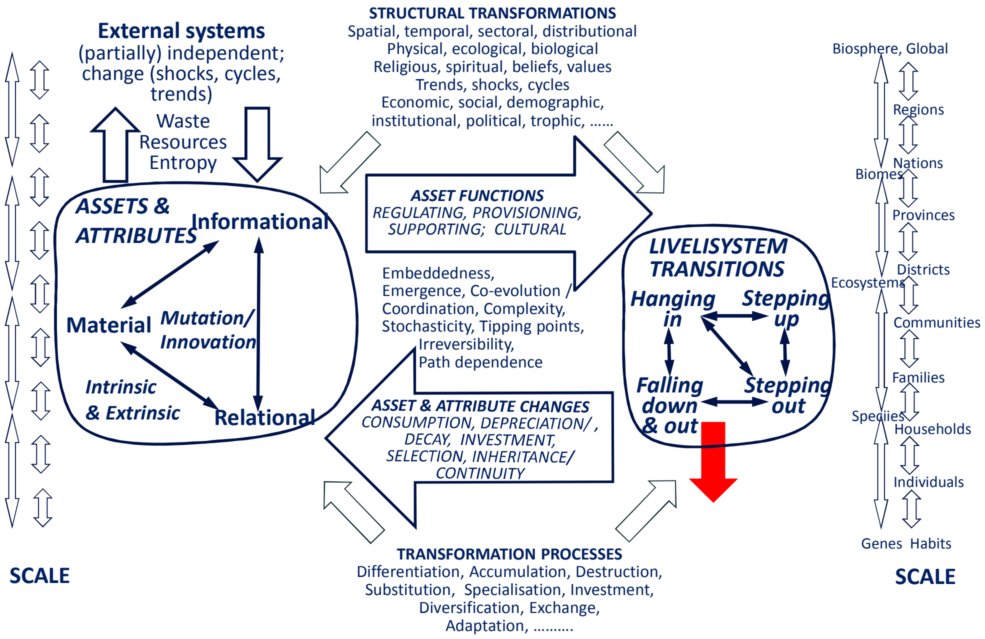

Figure 3. Livelisystems: potential characteristics

4. Application and discussion

The conceptual framework set out in the previous section can be applied in a number of ways. Paradoxically it's metatheoretical nature means that specific applications of the whole framework will be relatively rare: in providing a framework for bringing together understandings, analysis and investigations across SES it allows a holistic but more general integration of different parts, as called for by SchlÜTer et al., 2012.

Limited experience in broader use of the framework suggests that it can provide a valuable starting point for investigation of particular livelisystems by defining core research questions within an integrating structure (du Toit, pers.comm.). These core research questions could, for example, iteratively examine where livelisystem boundaries can be drawn, the main hierarchical and overlapping components, what resources and attributes provide what services, what livelisystem transitions are occurring, what options or possibilities there are for different livelisystem transitions, how asset attributes and livelisystem transitions are mediated by their location in the system, the vulnerability and resilience of livelisystems and of different elements in livelisystems and the causes of their vulnerability, what structural transformations and processes are unfolding and their drivers and feedback effects, and key relations with external systems and how may these be changing. These questions have been posed in ways that are applicable to both natural and social systems and subsystems. More specific question topics that might be appropriate to social systems might concern institutional or knowledge change or power, while topics more appropriate to ecological systems might for example concern trophic pathways or environmental change.

A specific example of more focussed application of part of the framework is its use in investigating impacts of and responses to biodiversity change in the Western Ghats, India. This involved a fairly rapid study of the impacts of the invasive spread of *Lantana camera* and of human adaptation to this in Kombudiki in the Male Mahadeshwara Hills Forest Reserve, southern Karnataka. In accordance with the livelisystems framework, this was conceptualised in terms of impacts on assets and their attributes, as shown in figure 4.

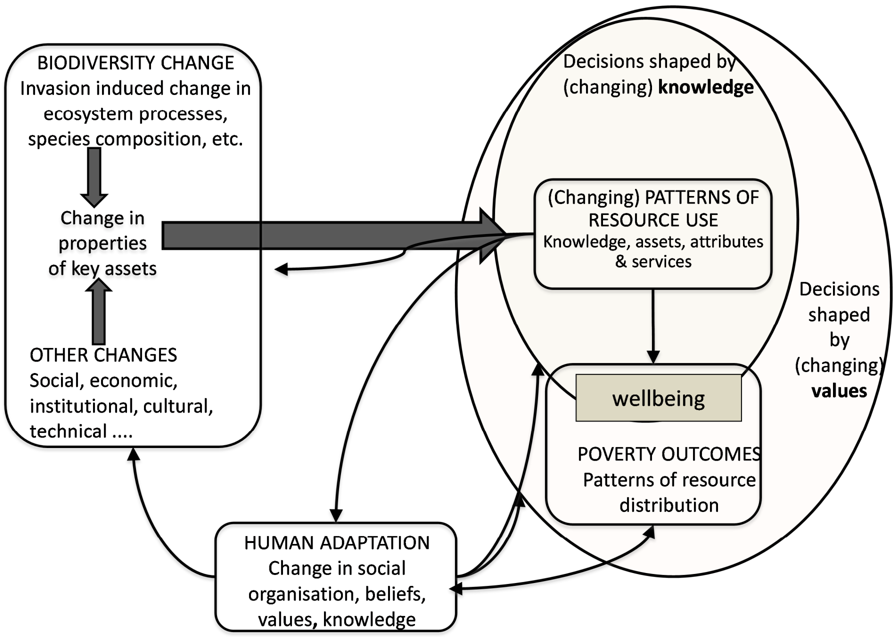

Figure 4. Livelisystems: potential characteristics

Kent and Dorward (2012)

This framework focuses on the effects both of invasion induced changes in forest ecology and of other social and ecological changes on the properties of key forest and other assets important for people's livelihoods. These changes lead to changes in livelihood strategies and asset attributes, and these lead to changes in wellbeing outcomes. There are multiple feedbacks, including through human adaptation.

Four sets of assets affected by *Lantana camera* invasion were investigated: forest grasses and cattle grazing; bamboo for basketry; broomstick; and wild foods (Kent and Dorward, 2012). Changes in the attributes of each of these were investigated, allowing for both the effects of *Lantana camera* and other processes of change. For all these assets some attributes (productivity, holding costs, reproduction, risks, costs of physical access), were affected by *Lantana camera's* spread in the forest while others (complementarity, productivity and substitutability) were more affected by wider changes in the community or wider economy (for example increasing land pressure, increased off farm employment outside the community as migrant labourers, the public distribution system, and availability of tractor hire services). Some of these attributes vary between social groups (for example between members of two different ethnic groups and between men and women within these groups). This leads to differences in households' and individuals' ability to substitute important functions of lost or declining assets. It also affected their adaptation options and abilities, and hence their vulnerability to the impacts of *Lantana* invasion.

The case demonstrates the value of focussing on analysis of changes in asset properties, functions and attributes in response to external changes, with this focus proving both 'boundary concepts' and 'boundary tools' (Mollinga, 2010) to structure the integration of ecological, anthropological and livelihoods analysts work. Critical to this is the separation of (ecological) asset properties from contextually determined and socially constructed and differentiated asset attributes.

An example of a multi-scale application of the framework is provided by the early stages of work positioning a characterisation of a 'low maize productivity trap' in Malawi (Dorward and Chirwa, 2011) within a livelisystems conceptualisation linking this to wider processes of social, economic and environmental change at household, community and national scales. It is inevitably difficult to briefly summarise this. However its essential features are a focus on three scales of analysis (household, community and national, where 'community' can represent a variety of different intermediate scales), with aggregation of lower scale livelisystems into higher scales livelisystems, together with other components that do not exist at lower scales. Within each livelisystem, analysis focuses on assets, asset properties, functions and attributes. External in and out flows for each livelisystem can then be linked in different ways (for example with sink, rationing, cost and/or price mechanisms). Aggregation across different livelisystems and their linkages at lower scales then make up higher scale livelisystems. Similarly changes in asset properties and attributes and livelisystems transitions at lower scales (for example soil properties and run-off, land productivity and stepping out of agriculture into other activities) drive structural transformations at higher scales (for example in agricultural and other sector balances, agriculture and forest land uses, Lake Malawi's trophic systems, demography, and institutions). Livelisystems at all scales are then affected by new opportunities and constraints as a result of these transformations.

Again, this approach provides both boundary concepts and boundary objects to facilitate analytical work within and integration across different social and ecological livelisystems and scales of analysis. Technical and institutional change also demand explicit consideration of exogenous and endogenous (innovational and mutational) change and of informational and relational composition and operation of assets.

Beyond suggesting a general structured approach to investigation of specific biological and social systems, the framework also raises questions about and provides insights into specific topics and processes. We illustrate this with discussion of a major challenge with development policy and practice: conceptualisation of the multi-scale, multi-dimensional dynamics of structural change. The conceptualisation of hanging in, stepping up, and stepping out transitions addresses this and indeed emerged from consideration of changes in peoples' livelihoods and in wider economies (Dorward et al., 2009, Dorward, 2009). A key insight highlighted by this is the need in socio-economic development for coordinated change at different scales of analysis, in demand and supply across a range of complementary activities, services, and investments – across technical, institutional, human, physical, and natural capital.

Core evolutionary processes involve similar multi-scale, complementary and interacting 'co-evolutionary' change across different genes, cells, organisms, species and ecosystems (there are, for example, interesting biological evolution and socio-economic development parallels in the importance of and links between 'hanging in', 'stepping out' and some spatial movements). Social and biological evolutionary processes may be distinguished from each other by the greater importance of culture in social processes, but these interact in gene-culture evolution in human systems, while the importance of social learning and stable trans-generational culture in non-human species is increasingly recognised (Laland and Boogert, 2010). There are also parallels and continuities as regards changes in the relative importance of intrinsic and extrinsic assets and of material, informational and relational capital, and of their interaction. These differences may be seen as key elements of socio-economic development - for example more developed societies tend to be characterised by greater reliance on extrinsic informational assets. It may, indeed, be possible to trace a global SES evolutionary pathway in terms of the interactions between and relative importance of extrinsic, informational and relational assets. Alternatively, at a more micro level, the framework has the potential to take forward work on asset based poverty and poverty measures (for example Carter and Barrett, 2006, Liverpool-Tasie and Winter-Nelson, 2011) through its emphasis on a wide set of assets, the different functions they perform, and their related and contextualised attributes.

The increasing importance of relational capital as systems develop suggests potential insights from cross disciplinary investigation of the concept of 'niche construction'. Laland and Boogert, 2010 note the importance of niche construction in human societies and their interactions with the natural environment. In the livelisystems framework this raises questions about system boundaries between and definitions of relational assets and external systems, and about the role of power in defining boundaries and relations (as well as in innovation and selection processes). Concepts of 'roving and stationary bandits' may have widespread value and validity across their original application in political and economic development (Olson, 1993) to natural resource management (Ostrom, 2007) and wider predator-prey and parasitic relations.

5. Conclusions

In evaluating the framework we consider its match with the desirable specifications set out earlier – and it appears to perform relatively well. Its structure is explicitly multi-scale and dynamic, with multiple components and subsystems that provide potential for emergent and embedded properties, for multiple structural transformations, and for a variety of disciplinary perspectives and investigational approaches. Its cross disciplinary roots, concepts and language (drawing on livelihood and other development studies and economics concepts, ecosystem service categorisations, and living systems, panarchy, niche construction and extended evolutionary theories) are an explicit strength which, with its system components, allow mediation and integration between perspectives and investigational approaches from different disciplines. In this it is not inherently anthropocentric or biocentric, but capable of application in both contexts. It also has the potential to provide a metatheoretical framework for contributions to individual disciplines and to stimulate conceptual development and research within disciplines and at their interface with other disciplines.

Its cross disciplinary roots and multi-scale structure should make it methodologically flexible and inclusive, as subsystems can be defined and investigated in a variety of ways. There may, however, be particular opportunities for the use of nested agent based models to describe multiple and multi-scale interactions between systems' different subsystems and components.

We conclude by suggesting two ways in which the framework can and should be taken forward – further conceptual development and wider application. First, there is a need for further conceptual development. Perhaps the most obvious weaknesses in the exposition in this paper are the need for a clearer conceptualisation of relational assets (with specific regard to theories of niche construction, the definition of system boundaries, and conceptualisations of power, as touched on earlier) and the need for development of a more holistic set of asset attributes concerned with regulating, supporting, and cultural functions.

Conceptual advances on these and other topics will both benefit from and contribute to wider application of the framework. There is a wide range of systems where the concrete application of the framework could potentially improve both understanding and management of or responses to change. These might include climate, food or agri-health systems (at local and wider, up to global scales), specific resource, conservation or eco- systems, and particular species in different contexts. There are also opportunities for more theoretical applications. As an example, these might investigate the hypothesis that more 'advanced' evolution and development involve increasing relative importance of relational and extrinsic assets and of change through teleological selection and innovation. This hypothesis raises questions about the need for and nature of new 'anthropocenic processes' of livelisystem evolution and development in an increasingly globally organised and environmentally challenged society.

References

Alwang, J. and P. B. Siegel (1999). *An asset-based approach to social risk management: a conceptual approach*. Social Protection Discussion paper 9926. Washington DC, World Bank.

An, Li (2012). "Modeling human decisions in coupled human and natural systems: Review of agent-based models." *Ecological Modelling* **229**(0): 25-36.

Anand, Madhur, Andrew Gonzalez, Frédéric Guichard, Jurek Kolasa and Lael Parrott (2010). "Ecological Systems as Complex Systems: Challenges for an Emerging Science." *Diversity* **2**(3): 395-410.

Anderies, J. M., M. A. Janssen and E. Ostrom (2004). "A framework to analyze the robustness of social-ecological systems from an institutional perspective. ." *Ecology and Society* **9**(1): 18.

Carney, D, Ed. (1998). *Sustainable Livelihoods: What contribution can we make?* London, Department for International Development (DFID).

Carter, M.R. and C.B. Barrett (2006). "The economics of poverty traps and persistent poverty: an asset-based approach." *Journal of Development Studies* **42**(2): 178 — 199.

Chambers, R. and G.R. Conway (1992). *Sustainable rural livelihoods: practical concepts for the 21st century*. IDS Discussion Paper No 296. Brighton, IDS.

Collins, S.L. (2007). *Integrative science for society and environment: a strategic research initiative*.

Costanza, R. and H. Daly (1992). "Natural capital and sustainable development." *Conservation Biology* **6**: 37–46.

Dorward, A.R. (2009). "Integrating contested aspirations, processes and policy: development as hanging in, stepping up and stepping out." *Development Policy Review* **27**(2): 131-146.

Dorward, A.R., S Anderson, Y. Nava, J. Pattison, R. Paz, J. Rushton and E. Sanchez Vera (2005). *A guide to indicators & methods for assessing the contribution of livestock keeping to livelihoods of the poor*. London, Department of Agricultural Sciences, Imperial College London.

Dorward, A.R., S. Anderson, Y. Nava, J. Pattison, R. Paz, J. Rushton and E. Sanchez Vera (2009). "Hanging In, Stepping up and Stepping Out : Livelihood Aspirations and Strategies of the Poor." *Development in Practice* **19**(2): 240-247.

Dorward, A.R. and E. Chirwa (2011). "The Malawi Agricultural Input Subsidy Programme: 2005-6 to 2008-9 " *International Journal of Agricultural Sustainability* **9**(1): 232-247.

du Toit, Andries (pers.comm.). *Email 3rd November 2011: livelisystems framework lectures*.

Fisher, J.A., G. Patenaude, P. Meir, A. Nigthingale, M. Rounsevell, M. Williams and I.H. Woodhouse (2012). *Strengthening conceptual foundations: a review of frameworks for ecosystem services and poverty alleviation research*. submitted to Global Environmental Change.

Foresight (2011). *The future of food and farming* Final project report. London, The Government Office for Science.

Gintis, Herbert (2007). "A framework for the unification of the behavioral sciences." *Behavioral and Brain Sciences* **30**(01): 1-16.

Gómez-Baggethun, Erik, Rudolf de Groot, Pedro L. Lomas and Carlos Montes (2010). "The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes." *Ecological Economics* **69**(6): 1209-1218.

Gual, Miguel A. and Richard B. Norgaard (2010). "Bridging ecological and social systems coevolution: A review and proposal." *Ecological Economics* **69**(4): 707-717.

Hird, Myra, J, (2010). "Coevolution, Symbiosis and Sociology." *Ecological Economics* **69**(4): 737-742.

Hodgson, Geoffrey and Thorbjørn Knudsen (2010). *Darwin's conjecture: the search for general principles of social and economic evolution*. London, University of Chicago Press.

Holdo, Ricardo M., Kathleen A. Galvin, Eli Knapp, Stephen Polasky, Ray Hilborn and Robert D. Holt (2010). "Responses to alternative rainfall regimes and antipoaching in a migratory system." *Ecological Applications* **20**(2): 381-397.

Holling, C.S., F. Berkes and C. Folke (1998). Science, Sustainability, and Resource Management. *Linking Social and Ecological Systems*. F. Berkes and C. Folke. Cambridge, UK, Cambridge University Press 342–362.

Holling, C.S., L.H Gunderson and G.D. Peterson (2002). Sustainability and Panarchies. *Panarchy: understanding transformations in human and natural systems*. L. H. Gunderson and C. Holling, S, . Washington, DC, Island Press**:** 63-202.

Jablonka, Eva and Marion J. Lamb (2005). *Evolution in Four Dimensions: Genetic, Epigenetic, Behavioral, and Symbolic Variation in the History of Life*. Cambridge, Mass., MIT Press.

Jax, K. (2010). *Ecosystem functioning*. Cambridge, UK, Cambridge University Press.

Kent, R. and A.R. Dorward (2012). *Conceptualising assets and asset services in livelihoods and ecosystem analyses: a framework for considering livelihood responses to biodiversity change* Working paper,Human Adaptation to Biodiversity Change.

Laland, Kevin N. and Neeltje J. Boogert (2010). "Niche construction, co-evolution and biodiversity." *Ecological Economics* **69**(4): 731-736.

Liverpool-Tasie, Lenis Saweda O. and Alex Winter-Nelson (2011). "Asset versus consumption poverty and poverty dynamics in rural Ethiopia." *Agricultural Economics* **42**(2): 221-233.

Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-being: Synthesis.* Washington, DC., Island Press.

Miller, J.G. (1978). *Living systems*. New York, McGraw-Hill.

Miller, J.L. and J.G. Miller (1992). "Greater than the sum of its parts: Subsystems which process both matter-energy and information." *Behavioral Science* **37**: 1–38.

Milner-Gulland, E. J. (2012). "Interactions between human behaviour and ecological systems." *Philosophical Transactions of the Royal Society B: Biological Sciences* **367**(1586): 270-278.

Mollinga, P. P. (2010). "Boundary Work and the Complexity of Natural Resources Management." *Crop Science* **50**(Supplement_1): S-1-S-9.
Nelson, Richard R. (2011). "Economic development as an evolutionary process." *Innovation and Development* **1**(1): 39-49.
Norgaard, R.B. (2010). "Ecosystem services: From eye-opening metaphor to complexity blinder." *Ecological Economics* **69**(6): 1219-1227.
Norgaard, Richard B. (1984). "Coevolutionary Development Potential." *Land Economics* **60**(2): 160-173.
Norgaard, Richard B. (2008). "Finding Hope in the Millennium Ecosystem Assessment." *Conservation Biology* **22**(4): 862-869.
Odling-Smee, John (2007). "Niche Inheritance: A Possible Basis for Classifying Multiple Inheritance Systems in Evolution." *Biological Theory* **2**(3): 276-289.
Odling-Smee, John (2010). Niche inheritance. *Evolution—the Extended Synthesis*. M. Pigliucci and G. B. Müller. Cambridge, Massachusetts, MIT Press**:** 175-207.
Odling-Smee, John, Kevin N. Laland and M. Feldman (2003). *Niche construction. The neglected process in evolution..* Pinceton, NJ., Princeton Univ. Press.
Olson, Mancur (1993). "Dictatorship, Democracy, and Development." *The American Political Science Review* **87**(3): 567-576.
Ostrom, E. (2005). *Understanding Institutional Diversity.*, Princeton University Press.
Ostrom, Elinor (2007). "A diagnostic approach for going beyond panaceas." *Proceedings of the National Academy of Sciences* **104**(39): 15181-15187.
Ostrom, Elinor (2009). "A General Framework for Analyzing Sustainability of Social-Ecological Systems." *Science* **325**(5939): 419-422.
Perrings, C., C. Folke and K.G. Mäler (1992). "The ecology and economics of biodiversity loss: the research agenda. ." *Ambio* **21**: 201–211.
Perrings, Charles (2007). "Future challenges." *Proceedings of the National Academy of Sciences* **104**(39): 15179-15180.
Rammel, Christian, Sigrid Stagl and Harald Wilfing (2007). "Managing complex adaptive systems — A co-evolutionary perspective on natural resource management." *Ecological Economics* **63**(1): 9-21.
Raworth, K. (2012). *A Safe and Just Space for Humanity* Oxfam Discussion Paper, February 2012.
Rockström, J., W. Steffen, K. Noone, Å. Persson, F. S. Chapin, E. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. Schellnhuber, B. Nykvist, C. A. De Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sörlin, P.K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen and J. Foley (2009). "Planetary Boundaries: Exploring the Safe Operating Space for Humanity." *Ecology and Society* **14**(2): 32.
Rounsevell, M. D. A., D. T. Robinson and D. Murray-Rust (2012). "From actors to agents in socio-ecological systems models." *Philosophical Transactions of the Royal Society B: Biological Sciences* **367**(1586): 259-269.
Rounsevell, M., T. Dawson and P. Harrison (2010). "A conceptual framework to assess the effects of environmental change on ecosystem services." *Biodiversity and Conservation* **19**(10): 2823-2842.
SchlÜTer, M., R. R. J. McAllister, R. Arlinghaus, N. Bunnefeld, K. Eisenack, F. HÖLker, E. J. Milner-Gulland, B. MÜLler, E. Nicholson, M. Quaas and M. StÖVen (2012). "New horizons for managing the environment: a review of coupled social-ecological systems modeling." *Natural Resource Modeling* **25**(1): 219-272.
Scoones, Ian (2009). "Livelihoods perspectives and rural development." *The Journal of Peasant Studies* **36**(1): 171-196.
Waage, J., R. Banerji, O. Campbell, E. Chirwa, G. Collender, V. Dieltiens, A. Dorward, P. Godfrey-Faussett, P. Hanvoravongchai, G. Kingdon, A. Little, A. Mills, K. Mulholland, A. Mwinga, A.

North, W. Patcharanarumol, C Poulton, V. Tangcharoensathien and E Unterhalter (2010). "The Millennium Development Goals: a cross-sectoral analysis and principles for goal setting after 2015 " *The Lancet* **376**(9745): 991 - 1023.
Waring, Timothy M. and Peter J. Richerson (2011). "Towards unification of the socio-ecological sciences: the value of coupled models." *Geografiska Annaler: Series B, Human Geography* **93**(4): 301-314.
Widlok, Thomas, Anne Aufgebauer, Marcel Bradtmöller, Richard Dikau, Thomas Hoffmann, Inga Kretschmer, Konstantinos Panagiotopoulos, Andreas Pastoors, Robin Peters, Frank Schäbitz, Manuela Schlummer, Martin Solich, Bernd Wagner, Gerd-Christian Weniger and Andreas Zimmermann (2012). "Towards a theoretical framework for analyzing integrated socio-environmental systems." *Quaternary International*(0).
Winder, N., B.S. McIntosh and P. Jeffrey (2005). "The origin, diagnostic ttributes and practical application of co-evolutionary theory." *Ecological Economics* **54**(4): 347–361.