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Sustainable development goals – an analysis of outcomes

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Abstract

Purpose – The concept of sustainability evokes a multiplicity of meanings, depending on the field. Some authors have criticized the concept for its vagueness. Notwithstanding this criticism, worldwide efforts to meet the sustainable development goals (SDGs) are in progress and are expected to yield results by 2030. This paper aims to addresses two issues and make two primary contributions. First, the concept of sustainability is revisited to develop its integrative understanding. This concept is built on systems thinking – specifically, on the concepts of synergy, emergence, recursion and self-organization. Second, an approach is developed to help determine whether the efforts being made towards the SDGs can be expected to be effective (i.e., whether the world can hope to soon be a system that self-organizes towards sustainability).

Design/methodology/approach – Based on the assumption that the SDGs and their respective targets are systemically interrelated, the data on the progress towards the SDGs are correlated and the outcome is analysed.

Findings – The emerging pattern of correlations reflected the systemic coherence of the efforts as an indication of self-organization towards sustainability. This pattern also revealed that the efforts are still spotty and that the systemic synergy has not yet taken place. This correlation approach to Brazil is then applied. The data about Brazil's progress towards the SDGs from the World Bank's Word Development Indicators (WDI) database are gathered. The outcomes indicated that Brazil as a whole cannot yet be seen as self-organizing system that is evolving towards sustainability.

Research limitations/implications – To enable the calculation of the correlation matrix, the data series were not allowed to have missing values. Some of the WDI data series had many missing values and had to be eliminated. This unfortunately reduced the variability of the original data. In addition, the missing values in the remaining data series had to be calculated by means of interpolation or extrapolation. There are alternative algorithms to perform such functions. The impact of the interpolation and extrapolation of the missing values on the study, as well as the pros and cons of different algorithms, required investigation. It is important to remark that the WDI series was the only global and open data set that aligned with the SDGs.

Social implications – In Brazil, it is important to maintain the public policies that affect SDG 1-6, but it is necessary to develop policies geared towards SDG 12. Environmental goals also need more public policies (SDGs 14 and 15). To achieve this 2030 Agenda, much effort will be required for SDG 17, which is related to greater synergy through partnerships.

Originality/value – Three qualitatively distinct levels of efforts to sustainability are identified: individual, organizational and world activities. At the individual level, progress regarding sustainability depends on personal attitudes, including the willingness to abandon a self-centred lifestyle in favour of a more cooperative way of living and making decisions, and to embrace a new approach to ethics, which replaces self-interest by self-denial and self-sacrifice (de Raadt & de Raadt, 2014). At the organizational level, a paradox of the need to

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internalize environmental and social costs into generic strategies and the sustainability strategy that involves core businesses are challenges for systems working towards sustainability. When it comes to global level, in this paper, the authors tried to make a contribution to push forward the frontier of knowledge by proposing an approach to understand whether the progress made towards the SDGs in the past 25 years indicates that the world is, after all, organizing for sustainability (Schwaninger, 2015).

Keywords Sustainability, Synergy, Recursion, Emergence, Self-organization, Systems thinking

Paper type Research paper

1. Introduction

The roots of the concept of sustainability can be traced far back in history. The ancient Egyptian, Mesopotamian, Greek and Roman civilizations experienced environmental problems, and the ancient Greek writers recommended practices that today would be called sustainable (Du Pisani, 2006). While the Oxford English Dictionary introduced the terms "sustainability" and "sustainable" in the second half of the twentieth century, they had already existed in other languages for centuries. The threat of a wood shortage, which was extensively used by in the eighteenth century, "stimulated a new way of thinking in favour of the responsible use of natural resources in the interest of the present and future generations" (Du Pisani, 2006, p. 85). This thinking is essential to the current understanding of sustainable development, which is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland *et al.*, 1987).

In spite of this early understanding, the concept of sustainability has changed over time. The discussion about sustainability was once a debate between the romantic, preservationist perspective and the utilitarian, conservationist approach; during the past three centuries, this has evolved to the current understanding that social and economic issues and environmental degradation must be addressed in conjunction (Robinson, 2004, pp. 371-372).

The result of this understanding has turned out to be "a curious combination of radical and reformist elements", to use Robinson's (2004, p. 372) terms. The radical aspect that Robinson referred to is the proposal that "the vast and complex issue of environmental deterioration" and "the equally vast and complex issue of human development and poverty" have to be resolved "simultaneously and in a mutually reinforcing way" (2004, p. 372). The reformist element lies in the suggestion that, to address environmental concerns, it is necessary to promote human development by increasing gross industrial activity across the world. In the so-called Brundtland report (Brundtland *et al.*, 1987), the UN Commission on Environment and Development captured this combination of elements by proposing a balanced approach to development that could mitigate the risks of both underdevelopment and overdevelopment.

Discussions about sustainable development often present this phenomenon in three dimensions: economic, environmental and cultural. The concept of the "triple bottom line" introduced a vision of sustainability that connected social, environmental and economic dimensions (Elkington, 1998). These three dimensions of the sustainability vision were reinforced at the Sustainable Development Conference that was held in Johannesburg in 2002. Extensive efforts have been made to ensure that 2030 Agenda incorporates the cultural dimension into the sustainable development goals (SDGs; Soini and Birkeland, 2014).

The cultural aspect can be presented as a fourth dimension of sustainable development (Nurse, 2006) or embedded within its social dimension (Murphy, 2012). The 2030 Agenda is a cross-cutting view of the cultural dimension for all 17 SDGs, bringing an integrated vision of this dimension across the 2030 Agenda (United Nations, 2017b).

As the discussion about sustainability developed, the concept became more complex and more challenging to define. Today, the term evokes a multiplicity of meanings, depending on the field. Some authors have argued that the concept of sustainability is so vague that it can be conveniently and opportunistically misinterpreted (Mebratu, 1998; Missimer *et al.*, 2017a, 2017b; Robinson, 2004).

Other authors have responded that the vagueness and pluralism of the term's definition is unavoidable and even preferable over a single, atomized conceptualization. These authors have argued that the concept of sustainability embodies many concerns and that it thus transcends disciplinary boundaries (Abson *et al.*, 2017, p. 494; Missimer *et al.*, 2017b, p. 2). They have seen value in sustainability as an integrative concept and as an interdisciplinary science (Missimer *et al.*, 2017a, p. 7; Robinson, 2004, p. 378).

The discussion above does not reflect a solely theoretical concern, as it has consequences in practice. Some authors have pointed out that the improvements have been spotty (Schwaninger, 2015); that the magnitude and velocity of the changes have not been sufficient (Nunes *et al.*, 2016); that the translation of sustainability from concept into practice is difficult (Taisch *et al.*, 2015); and that it is also difficult to define a measure of sustainability performance (Nunes *et al.*, 2016).

Mebratu (1998, p. 518) pointed out that one consequence of the effort to interpret sustainability according to the tenets of specific groups is that people have a narrow understanding of sustainability and are incapable of capturing the whole picture. Mebratu invited the scientific community to overcome the influence of institutional and group interests and to develop an understanding of sustainability, as this understanding is a prerequisite to achieving a sustainable world. We interpret the viewpoint of these authors as a claim that sustainability should be defined in terms of systems.

Independently of Mebratu's concern, the efforts towards sustainability at the global level are centred on the SDGs (United Nations, 2017b). The deadline to achieve these goals is 2030.

The purpose of the present work is twofold. The first research question is conceptual and regards the nature and process of sustainability.

RQ1. How can we understand the concept of sustainability in a broad yet operational and integrative way? What process leads to sustainability at a global level?

The second research question is practical and refers to the effectiveness of the current efforts towards sustainable development.

RQ2. Has the progress made towards sustainable development at the global level resulted from integrated efforts that are leading the world (as a system) towards sustainability, or do the results seem to indicate that these efforts are isolated and that they can, therefore, produce only local and temporary improvements? In short, is the world self-organizing towards sustainability?

The latter question is at the heart of this research because it concerns the feasibility of achieving the SDGs by 2030 based on the efforts of autonomous agents, including business organizations, countries and individual citizens. Is the world really heading in that direction? Is there any hope that the SDGs can be met that quickly?

Sustainable development is a multi-dimensional concept that incorporates different aspects of society, seeking the environmental protection and the maintenance of natural capital to achieve economic prosperity and equity for present and future generations.

Sustainable development recognizes the inseparable link between people, the planet and wealth. Sustainable development is related to national and international policy development, making it the core element of the policy documents of governments, international agencies and business organizations (MEBRATU, 1998).

Thus, the term sustainability has emerged to address the issue of renewable resources, with a much greener connotation, and has been adopted by the ecological movement. The concept refers to the existence of ecological conditions necessary to support human life in a specific level of well-being through future generations, and this is ecological sustainability and not sustainable development (LÉLÉ, 1991).

Sustainability is a normative concept about how humans should act in relation to nature, and how they are responsible towards each other and future generations (AYRES, 2008).

Regarding *RQ1*, our intent here is not to provide a definitive definition of sustainability but rather to contribute to an interdisciplinary discussion of this concept based on systems thinking. In doing so, we automatically connect sustainability with systems practice, thus making available several systems methodologies, many of which are rooted in the solid ground of operational research. In other words, we find in systems thinking both a theoretical understanding and practical guidance – the latter of which, many of the aforementioned authors have noted, is missing in the concept of sustainability.

In terms of theoretical contribution, we develop in this paper an integrative understanding of sustainability that consists of three overall levels of human activity: individual, organizational and global. We consider sustainability in terms of systems concepts, such as recursion (Beer, 1979, 1985), emergence (Checkland, 1981), synergy (Beer, 1979) and self-organization (Malik and Probst, 1984; H. Ulrich, 1984). We based the idea of understanding sustainability in terms of levels on Beer's viable system model (VSM) and its application in sustainable development, as promoted by de Raadt and de Raadt (2014) and Schwaninger (2015).

Addressing *RQ2* necessitates data on the SDGs. Even though these goals were defined very recently, in 2015, the World Bank made available its World Development Indicators (WDIs; The World Bank Group, 2017) database, which can be used to assess nations' current progress on the SDGs (World Bank Data Team, 2017). By correlating SDGs to each other – using the WDIs to measure the progress on each SDG in the past 25 years – and by applying multivariate data analysis (Johnson and Wichern, 2007) to those indicators, we attempted to figure out whether the efforts towards sustainability are in fact systemic or whether they are spotty. For the sake of illustration, we selected the Brazil data set from the WDI database.

Testing the correlations between SDGs rests on the assumption that the SDGs and their corresponding targets are systemically interrelated. The correlations between the goals are thus expected to reveal the coherence, or lack thereof, in the efforts that have been dedicated to fostering the development of the system as a whole. Thus, for instance, education and health goals are expected to be strongly positively correlated, and poverty is expected to be strongly negatively correlated with both education and health goals. In summary, the emerging pattern of correlation is expected to reflect coherent systemic relationships among goals.

In the following section, we developed the approach to sustainability based on systems concepts. In Section 3, we provide a description of the methodology that we envisaged to answer the question above. We describe the results in Section 4. In Section 5, we present the conclusions and discuss some final considerations.

2. Towards an understanding of sustainability based on systems thinking

2.1 System thinking and sustainability: a brief review

Some systems thinkers believe that the efforts to achieve sustainability at a global level have not been effective. Despite the well-intentioned declaration in the Brundtland Report, not much positive change has occurred: some localized improvements have been made, but the web of life continues to be disrupted (Schwaninger, 2015). In addition, the magnitude and velocity of these improvements have not been sufficient (Nunes *et al.*, 2016). Furthermore, translating sustainability from concept into practice is difficult, so companies have had little guidance on how to define their manufacturing strategies and sustainability measures (Taisch *et al.*, 2015). It is also difficult to define a measure of sustainability performance that encompasses all three aspects of the triple bottom line: economic, social and environmental (Nunes *et al.*, 2016).

Business researchers have mainly focused on reducing the unsustainability of manufacturing systems and business models. Limited insight has been provided regarding how to create a manufacturing system that is both economically viable and, at a minimum, harmless; preferably, it would have positive or regenerative impacts on social and environmental systems (Taisch *et al.*, 2015).

Two major questions remain unclear; they summarize the concerns about sustainability at two levels: first, "How [can humanity] create truly sustainable manufacturing systems" (Taisch *et al.*, 2015); second, "How must humanity organize itself in order to develop sustainably?" (Schwaninger, 2015).

Systems thinkers claim that systemic and cybernetic approaches can help to address those questions. The complex issues within sustainability require a paradigm shift so that problems created at one level of thinking can be approached from a higher (or meta) level of thinking (Espinosa *et al.*, 2008). Systems thinking can leverage such a paradigm shift.

Missimer *et al.* (2017a, 2017b) developed principles for social sustainability to further the development of the social dimension, which is the least developed dimension of sustainability. Missimer *et al.* based their principles on the complexity theory approach and developed an understanding of a social system as a complex adaptive system. This work is part of a broader effort to develop the framework for strategic sustainable development, which is intended to both provide a unifying structure for strategic sustainability work and serve as a systematic redesign that will promote societal compliance with the three principles of ecological sustainability.

Researchers have provided many examples of how best to approach sustainability problems by applying systems thinking and methodologies. System dynamics, for instance, have long been applied to various levels of human life: industries, cities and the world (Forrester, 1961, 1969, 1971).

Systems methodologies, such as soft systems methodology and critical systems heuristics, have also been applied. The latter, for instance, has been applied to an evaluation study of natural-resource-use appraisal in Botswana and to support participatory environmental decision-making among geographically distributed stakeholder groups in the remote, rural areas of Guyana (Ulrich and Reynolds, 2010, p. 248). In another application, both of the methodologies listed above were used to operationalize the concept of sustainability in a development project focused on Nordhavn, a new urban area of Copenhagen; this study had a particular focus on sustainable transport planning (Jeppesen, 2011).

Beer's (1972, 1979, 1985) VSM, in particular, has been a source of inspiration for many authors. The VSM has been used as a conceptual tool for explaining sustainability (de Raadt and de Raadt, 2014; Espinosa *et al.*, 2008; Schwaninger, 2015), as a reference model for manufacturing-strategy implementation (Taisch *et al.*, 2015) and as a hermeneutical tool for establishing a self-organizing process that would restore the viability of Cloughjordan ecovillage, an Irish community founded on the principles of cooperation, democracy and sustainability (Espinosa and Walker, 2013). Schwaninger (2015) proposed a holistic structural framework based on the VSM to provide sustainable renewal. This framework covers several levels – individual human, organizational, local–regional and global. The VSM is a particularly suitable model for understanding sustainability because, as de Raadt and de Raadt (2014, p. 241) remarked, it "has been inspired from nature rather than built on utilitarian and positivist assumptions"; it "aims at sustaining life rather than making profits"; and it is proving useful "for managing a community with the common objective of preserving its long-term viability".

However, accelerating the changes towards sustainability may not be a matter of just better defining the concept or ensuring better comprehension of it. De Raadt and de Raadt (2014) emphasized that sustainability issues reflect the lack of viability in the modern human lifestyle, and that the current worldview and approach to ethics are threats to the world's natural and cultural aspects (de Raadt and de Raadt, 2014, p. 69). The authors also argued that a different way of thinking and new approaches to ethics and management are needed.

Ensuring the long-term viability of communities requires an integrated view of all aspects of life, including the ethical, aesthetic, juridical, operational, economic, social, epistemic, informational, historical, credal, psychic, biotic, regulatory, physical, kinetic, spatial, numeric and logical aspects (de Raadt and de Raadt, 2014, p. 197). These aspects are the backbone of multimodal systems thinking. In multimodal systems thinking, the underlying approach to management is built on the VSM.

Long-term viability, therefore, depends particularly on shifting the approach to ethics. People should not expect to achieve a sustainable world while insisting on getting more from the natural and social environments than they deliver to them. This means dismissing utilitarian ethics, which is centred on self-interest, and embracing a new approach to ethics that is based on self-denial and self-sacrifice. Ethics, as de Raadt and de Raadt (2014, p. 105) stated, is "the art of self-denial whereby we devote our life and work to serve and make up for the shortcomings of our fellow man hoping that someone will make up for our own shortcomings".

2.2 The understanding of sustainability as an integrative concept based on systems

In this section, we addressed *RQ1* of our work, which regards the understanding of sustainability as an integrative concept. We based this integrative concept of sustainability on systems concepts: recursion, emergency, synergy and self-organization.

2.3 Sustainability as a recursive process

The concept of recursion has its origin in a branch of mathematics called number theory and is widely applied in computer science to develop computer algorithms. A recursive definition is one that calls itself. The recursive definition of a factorial, for instance, illustrates the power of the concept to create synthetic definitions when an unlimited number of recursions are involved: factorial (n) = n * factorial (n – 1)

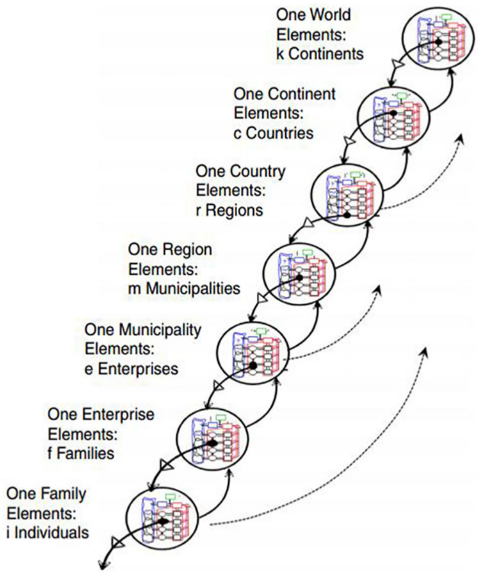
The systems concept is itself recursive when stated in this way: a system is a set of subsystems that interact. Each subsystem can itself be understood as a system, which, in turn, has its own interacting subsystems, and so on. Beer (1979, 1985) brought the concept of recursion to management science and proposed the VSM a general model of any viable system. The VSM is recursive.

Viability is the ability to maintain a separate existence (Beer, 1979, p. 113). It does not mean that a viable entity – whatever it is – must be able to live in isolation; rather, it must be able to survive as a singular entity and maintain its own identity and limits while in interaction with a complex and challenging environment. Based on cybernetic principles, Beer (1979, 1985) identified five essential functions that are necessary and sufficient for the viability of any organization:

(1) implementation of an essential purpose;
(2) coordination;
(3) operational monitoring and control;
(4) adaptive control; and
(5) supervisory control.

Thus, a system is viable if and only if it has all five of these functions. In addition, for a system to be viable, all of its subsystems must be viable. Therefore, each subsystem must also have all five functions (which are necessary and sufficient conditions for viability). Beer (1985, p. 2) thus established the recursive nature of viability; he argued that the term "recursion" was a reminder that he was not talking about a loosely coupled set of systems and subsystems, but about "an absolutely precise definition of viability".

Beer's insight can be transferred to sustainability. Figure 1, which Schwaninger (2015) elaborated on, provides a glimpse of sustainability as a multilevel, recursive process. Understanding sustainability as a recursive process means taking into account that, for a system to be sustainable, all of its subsystems must be sustainable. An organization, for instance, can be considered sustainable only when all of its essential processes are themselves sustainable. The advantage of this definition is that it does not leave room for



Source: Schwaninger (2015)

Figure 1. Structural preconditions for sustainable development – a multilevel view

claims that cosmetic actions make an organization sustainable when they are actually concealing unsustainable processes.

The consequence of the recursive definition is that reaching sustainability at a global level requires integration of efforts across levels, including changes in individual attitudes and values, as well as in organizational strategies, governmental policies and international initiatives. Schwaninger (2015) described this multilevel understanding of sustainability as a precondition for sustainable development and explained how the principles embodied in VSM, such as autonomy and recursion, provide a powerful framework for pursuing sustainability.

The model in Figure 1 is not intended to provide only a structured view of sustainability; it has more profound implications. For instance, it implies connections across all levels, as part of a wholly integrated process. This is a truly integrative approach to sustainability. Beer (1979) explained that recursive logic consists of a process that runs through all levels of an organization and that has no limits. Beer saw the problems of his time as the result of managers cutting short this process by saying, for instance, "My responsibility ends here". This attitude on the part of managers at all levels explained the problems that the world faced at that time: "dust bowls, pollution, city decay, starvation, violence, social revolution, and international warfare" (Beer, 1979, p. 312). Beer thus emphasized the importance of keeping this process running across recursion levels and without breaks. Non-business spheres of society are included in the sustainability equation, as shown in Figure 1, so the responsibility for keeping these recursive processes running falls on governors, as well as on managers. Not even individual citizens can escape their share of responsibility for these processes.

Thus, sustainability efforts at every level are needed to make the entire system a sustainable entity (i.e. to make the whole planet viable). Ignoring this recursive process and neglecting to responsibly contribute to it are among the root causes of all sorts of unsustainable situations. To paraphrase Beer (1985, p. 2), the concept of recursion is essential to an absolutely precise definition of sustainability.

2.4 Sustainability as an emergent property

The discussion in the previous section was intended to show that sustainability is not an accidental, isolated happening that takes place at a particular level. Sustainability at any level can be understood as an emergent property that results from the processes carried out on lower levels.

The concept of emergence is derived from the study of systems in terms of organized complexity (Checkland, 1981, p. 78). Organized complexity, as a general model, consists of a hierarchy of levels of organization, with the higher levels being more complex than the lower ones that comprise them. Each level is characterized by emergent properties that do not exist (and do not even make sense) at the lower levels. As an example, Checkland (1981) explained that the shape of an apple is indeed the result of processes that happen at the level of the cell, but it can hardly be explained using the language of that level. It is an "emergent property" that is usually expressed in a different language and using abstract concepts that belong to the "apple" level of recursion.

Similarly, sustainability at the global level emerges from processes that run at lower levels, including those of continents, countries, communities, organizations and even individuals, as illustrated in Figure 1.

2.5 Sustainability and synergy

Synergistic behaviour derives from mutual support between a system's operational elements, with the intent to get "a higher total pay-off for the total system than the sum of independently acting elements could produce, even if one or more of the elements is thereby rendered less profitable than it might be without invoking synergy" (Beer, 1979, p. 203). The manifestation of synergy depends on the existence of mutual interactions between a system's elements. Totally independent elements do not comprise a system and thus cannot give rise to synergy. In this sense, the concepts of system and synergy are inseparable.

When efforts towards sustainability are isolated and sparse, they cannot interact and thus cannot create synergy. On the other hand, when efforts become so widespread across a certain recursion level that either the autonomous agents or the outcomes of their efforts start to interact, synergy can then be engendered, and the outcome can be expected to be more than the sum of the individual contributions. Proliferating initiatives is, therefore, a way to foster and take advantage of synergy, thus amplifying the magnitude and increasing the velocity of change.

If no synergy is created at any recursion level because the efforts are isolated, no emergent results will appear at the upper levels. The levels themselves will then remain separate with regard to sustainability, and the recursive process across levels will not take place. In other words, isolated efforts can never comprise a system and can never produce systemic outcomes, so they cannot make for a sustainable world.

2.6 Sustainability and self-organization

The structure depicted in Figure 1 is not intended to imply hierarchical control. Neither is it intended to presume that decisions emanate from a top-level entity. Coping with the challenges of sustainability requires agents – be they individuals, organizations or countries – to adjust and adapt to a large number of factors when facing complex issues in the context of a dynamic environment that is constantly changing in unforeseeable ways. Systems based on a command hierarchy are not effective at achieving their goals in such circumstances, as they cannot adapt rapidly enough. Polycentric systems, on the other hand, can process more information and adapt to a larger number of relationships. Polycentric systems are self-organizing and display considerably more adaptability; they, therefore, possess considerably more ability to overcome complexity (Malik and Probst, 1984, p. 110).

The fact that there is no centralized decision-making does not mean, however, that sustainability goals cannot be defined at the upper levels of recursion or that they cannot be enforced at lower levels to guide decision-making. As we noted above, autonomous agents that carry out isolated sustainability efforts do not comprise a system. Coordination of efforts is necessary to engender synergy. Although this does not entail a submission to command, it means that the lower recursion levels must accept some interventions from the upper levels (Beer, 1979, p. 203). Minimum intervention takes the form of synergistic planning, which means, in this context, the sustainability goals and their related targets.

Now, regarding Figure 1, imagine an ideal scenario in which the agents at the various recursion levels act autonomously but pursue the same sustainability goals. As they interact in a synergistic and coordinated fashion in the pursuit of those goals, they behave as a self-organizing system and are guided by the shared purpose of contributing to sustainability at a higher recursion level. In this ideal scenario, the individual agents are imbued with an ethical sense of self-denial and self-sacrifice on behalf of the greater good (de Raadt and de Raadt, 2014, p. 105), which aids in achieving sustainability at a global level. This is the ideal picture of a global system organizing itself for sustainability. Schwaninger (2015) stated that the viability of humanity in the long term depends upon its ability to organize for sustainability.

2.7 Towards a systemic understanding of sustainability

Schwaninger (2015, p. 937) proposed that "every viable system is sustainable, but that a sustainable system is not necessarily viable". When Schwaninger asserted that a sustainable system is not viable, he was probably referring to the consequences of a vague concept of sustainability. Robinson (2004, pp. 373-374), for instance, warned that vagueness leaves room for stakeholders who are mainly concerned with their short-term political or business interests to take cosmetic actions intended to conceal unsustainable activities. Mebratu (1998, p. 493) warned that vagueness provides an opportunity for a variety of skewed definitions and interpretations that favour institutional and group prerogatives rather than those that promote traditional beliefs and practices.

What we propose here goes a step further. The understanding of sustainability as a systemic process, as presented in this section, suggests that sustainability and viability are two aspects of the same concept. Thus, a system is viable if and only if it is sustainable. After all, how can life on earth be viable otherwise? This seems to be in accordance with de Raadt and de Raadt (2014, p. 69, 233), who used the terms viable and sustainable interchangeably:

> As Mebratu concluded:

> If sustainability is to mean anything, it must act as an integrating concept. In particular, it is clear that the social dimensions of sustainability must be integrated with the biophysical dimensions. [. . .] But it is also increasingly obvious that solutions that address only environmental, only social or only economic concerns are radically insufficient. What is needed is a form of interdisciplinary thinking that focuses on the connections among fields as much as on the contents of those fields; that involves the development of new concepts, methods and tools that are integrative and synthetic, not disciplinary and analytic; and that actively creates synergy, not just summation.

We have thus far provided a description of the nature and the process of sustainability to address Mebratu's concerns. Systems thinking, by means of concepts such as synergy, emergence, recursion and self-organization, helps explaining sustainability as an integrative concept. Similarly, systems practice, which is implied from systems thinking, provides the tools and the integrative and synthetic methods that Mebratu called for.

We described sustainability at the global level as an emergent property that results from a recursive process initiated at the personal level. At each level, synergistic interactions take place among the autonomous agents at that level, allowing sustainability to emerge at the next level. Sustainability is thus leveraged level after level until it emerges as a property of a global system that is self-organizing and that has sustainability as its essence. Sustainability is a necessary and sufficient condition for viability at all levels. Sustainability thus defined remains a broad concept, but it is now backed up by systems thinking, which provides a sound theoretical basis for the interpretation and operationalization of that concept at any recursion level.

We thus have addressed *RQ1* of our work and are left with *RQ2*. Are the current efforts enough to ensure sustainability's emergence at the global level? Is the world self-organizing towards sustainability? In the next section, we prepare to address those questions by identifying the ongoing efforts towards sustainability.

2.8 Sustainability efforts at each level of recursion

The recursive definition of sustainability, as described in the previous section, suggests that a sustainable system can be understood as a set of recursive levels, as depicted in Figure 1. Each level of recursion has its own concerns, which are expressed in terms of language particular to that level.

2.9 Sustainability efforts at world level

At the global level, the challenges of sustainability are being addressed by means of international cooperation. The efforts to define a global agenda to deal with these sustainability challenges can be traced back to the 1972 United Nations Conference on the Human Environment, which was held in Stockholm. In consonance with what we have argued above, the conference, in its declaration, recognized that "Through ignorance or indifference we can do massive and irreversible harm to the earthly environment on which our life and well-being depend" (United Nations, 1972, p. 3). In this declaration, the conference proclaimed that defending and improving the human environment for present and future generations – in harmony with the traditional goals of peace and worldwide economic and social development – demand "the acceptance of responsibility by citizens and communities and by enterprises and institutions at every level, all sharing equitably in common efforts" (United Nations, 1972, p. 3). The recursive concept of sustainability, as described in the previous section, uses systems thinking to provide a rich interpretation of this declaration.

About a decade later, in 1983, the United Nations (UN) created the Commission on Environment and Development, also called the Brundtland Commission. In its report, which is officially entitled Our Common Future, the commission recognized the exceptional challenge stemming from the systemic changes that the goals demand (Brundtland *et al.*, 1987, p. 305). The report included a definition of sustainable development that has become widely accepted and cited: "Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland *et al.*, 1987, p. 27).

In 1992, the first United Nations Conference on Environment and Development, held in Rio de Janeiro, Brazil, developed the first agenda for Environment and Development. Of note, 20 years later at the Rio + 20 Conference, the member states agreed on a resolution known as The Future We Want whereby the participants reaffirmed their commitment "to making every effort to accelerate the achievement of the internationally agreed development goals, including the Millennium Development Goals (MDGs) by 2015" (United Nations, 2012, p. 1).

The MDGs (United Nations, 2017a) were adopted in September 2000 by 189 world leaders who attended the Millennium Summit at the UN headquarters in New York City. From 2000 to 2015, the eight MDGs became the overarching development framework for the world. Ban Ki-Moon, then the general secretary of the UN, reported that "The MDGs helped to lift more than one billion people out of extreme poverty, to make inroads against hunger, to enable more girls to attend school than ever before and to protect our planet" (United Nations, 2015, p. 3).

On 25 September 2015, the UN General Assembly adopted a new agenda to guide global action over the next 15 years. The 2030 Agenda for Sustainable Development consists of 17 SDGs and 169 associated targets (United Nations, 2017b). The SDGs focus on five themes: people, planet, prosperity, peace and partnership. This new agenda builds on the achievements of the MDGs and extend their scope.

2.10 Sustainability efforts at organizational level

Unlike their predecessor, the SDGs clearly link with efforts at the level of business organizations. As stated in the SDG Compass, the goals "explicitly call on all businesses to apply their creativity and innovation to solve sustainable development challenges" (GRI, UN Global Compact, & WBCSD, 2015, p. 4). The SDG Compass was launched in September 2015 at a business event at the UN headquarters in New York (Global Reporting Initiative, 2015).

The SDG Compass (GRI *et al.*, 2015) was intended to help companies align their strategies with the SDGs, and measure and manage their impacts, so as to maximize their contribution to the goals.

For the first time, a sustainability initiative at a global level of recursion can be connected to efforts at a lower level, in this case, the business organizations. Furthermore, it represents an opportunity to establish a recursive process across all levels, as companies represent one way to reach individuals in the society, and to expedite the achievement of sustainability goals at a global level.

To achieve this, the declared vision and the mission of firms must include sustainability as a primary concern. At that level, for instance, the organization's vision and strategy matter that will guide the organization's decisions, such as its approach to promote consumption through marketing actions.

A different way of thinking, as proposed by de Raadt and de Raadt (2014), must include a review of traditional business strategies. Generic strategies such as Porter's (1985) cost leadership, for instance, which was so widespread by business strategists at the turn of the millennium, needs to be revisited and reviewed. The mangers' interpretation of such a strategy, and particularly the means that are used to achieve the lowest price, must be reconsidered to include social and environmental costs, if one intends to avoid slavery and labour abuses, and the depredation of nature.

At the organizational level, the Responsible Care initiative maintained by the global chemical industry is noteworthy (American Chemistry Council, 2013; The International Council of Chemical Associations, 2005). Responsible Care is an environmental, health and safety initiative that supports cooperative and voluntary actions with government and other stakeholders. Through Responsible Care, the International Council of Chemical Associations has undertaken actions that are consistent with the environmental principles of the UN Global Compact.

2.11 Sustainability efforts at personal level

At the personal level, small things matter. These include aspects such as the personal attitude towards the usage of water and energy and consumption habits. That level seems distant from the planetary level where one can feel disheartened to start an individual effort. But, like the proverbial hummingbird attempting to put out a forest fire with water she carried in her beak, everyone must be encouraged to take his or her share of the responsibility. This is the level where a new approach to ethics, which replaces self-interest by self-sacrifice, as suggested by de Raadt and de Raadt (2014), must start, because efforts at the individual level, when recursively summed up, may result in significant contributions to sustainability at the upper levels of recursion.

3. Methodology

In the introduction, we made the point that sustainability is important as an integrative concept. In the previous section, we developed such an integrative understanding of sustainability by interpreting the world as a self-organizing system with multiple recursion levels. The model conveys the idea that the improvements expected at the global level depend on the efforts undertaken at the lower levels of recursion. We then identified the SDGs and the SDG Compass as ongoing efforts towards sustainability. We also pointed out the need for a shift in the dominant approach to ethics.

Now we are prepared to address the second research question of our work. Is there hope that ongoing efforts are leading the world system towards sustainability, or do the outcomes seem to indicate that efforts are still isolated and can, therefore, produce only local and temporary improvements? In other words, is the world, as a system, self-organizing for sustainability, or are the efforts at each recursive level enough to create synergy and make sustainability emerge as an intrinsic property of the world?

To investigate that question, we need to measure the progress made towards sustainability at a global level; to do so, we need data on that progress, and we need a method. Regarding current progress, the SDGs seem to be an obvious choice. Investigating whether the progress that is being made towards the SDGs is the result of an integration of efforts that is leading to a sustainable world or not is appealing.

Because the definition of the goals dates to 2015, no historical data were directly collected for the SDGs. However, The World Bank Group (2017) provided the data series for its primary collection of WDIs. These WDIs are the most current and accurate global development data available, compiled from officially recognized international sources. They include national, regional and global estimates from 1990 through 2015. Experts from the World Bank selected a set of WDIs for each of the 17 SDGs and corresponding targets. A dashboard presents data from the WDIs that help monitoring the SDGs.

To calculate the correlation matrix of the SDG-related data series, a multivariate method was chosen. Sterman (2000) explained that, even though correlations among variables do not represent the structure of the system, they represent past behaviour and emerge from the behaviour of the system. The intent was to analyse the correlations between the SDGs and assess whether those correlations corroborated the idea that the progress made towards the SDGs was the result of an integration of efforts that is leading to a sustainable world, or whether they conveyed the idea that the efforts were isolated.

The data analysis involved the following steps:

(1) removal of data series with too many missing values (fewer than 20 values);

(2) interpolation and/or extrapolation of missing values in the remaining data series that were still incomplete;

(3) scaling of data

(4) applications of multivariate data analysis:

- principal component analysis (PCA) to reduce the number of variables; and
- factor analysis to determine which factors were responsible for the data variability

(5) calculation of the correlation matrix for the reduced data set.

The steps were programmed in R language (Crawley, 2013), which is a programming language and environment for statistical computing and graphics. It is an alternative implementation of the S language and environment developed by John Chambers and his team at Bell Laboratories. R is a GNU project and is available as free software under the terms of the GNU General Public License. R is an integrated suite of software resources that, besides the programming language itself, includes data handling and storage facilities, calculations on vectors and matrices, a variety of tools for data analysis, including graphical analysis, and presentation of data (The R Foundation, 2018).

We used RStudio (RStudio Inc, 2016) to support R programming and run the data analysis. RStudio is an integrated development environment that supports R programming. It includes a console, a syntax-highlighting editor, code execution and debugging, among several other features. It is available both in open source and commercial editions (RStudio, 2018).

The raw data series for all the WDIs, with data from 1990 to 2015 for several countries, were downloaded from the World Bank's website to a Microsoft Excel spreadsheet. Data series for Brazil were retrieved from the raw data spreadsheet by means of R programming, resulting in 291 data series. Brazil was chosen, in principle, because it is the native country of the authors. Also, it is an appropriate choice for the exercise in question because it is a country with a continental dimension that faces significant challenges regarding sustainability.

4. Results

The WDIs for Brazil were selected, grouped into SDGs according to the mapping suggested by the World Bank's experts and sorted by SDG. As an example, Table I shows the mapping of Target 1 and Target 2, under Goal 1, onto the WDIs. The complete mapping of the SDGs onto the WDIs is not shown here for lack of space (it involves 263 WDIs).

A few SDG targets were mapped onto one WDI. Other SDG targets were mapped onto several WDIs. This step resulted in 263 data series. There were several data series that rendered useless for the purpose of this study because they had too many missing values. Any data series with less than 20 valid values was removed. Only 109 data series that had at least 20 values were kept.

There also were redundant data series, such as data series for men, women and the combination of both; or data series for rural areas, urban areas and the combination of both. Such combined data series were removed to eliminate redundancy. After the removal of redundant data, 94 data series were left.

The remaining data series had a few missing values, either in the middle or at the beginning or end. The intermediate missing values were interpolated. Missing values at the beginning or the end of the data series were inferred by extrapolation. A combination of "na.aprox" and "na.locf" functions from the zoo library of the R language was used to perform the extrapolations. The na.aprox function was used to replace each missing value in the middle of a data series with interpolated values. Then, the na.locf function was used to fill in the missing values at the beginning of a data series by carrying backward the first available observation and to fill in the missing values at the end of a data series by carrying forward the last available observation. Once the data series were complete, i.e. without any missing values, the data were scaled by using the scale function from the R language.

Table II shows the correspondence between each SDG and the 94 WDI data series after the data treatment.

The number of variables (data series) was still too high to allow a study of the correlations. To reduce the number of variables, we performed a PCA for each SDG. The PCA allowed us to aggregate data for several WDI series into fewer SDG components.

However, before performing a PCA, for the sake of coherence, many WDI data series had to have their signs switched (i.e. it had to be multiplied by –1) to make them consistent with the meanings of their corresponding SDGs. Thus, for instance, the WDI index SI.POV.

Table I.
Example of mapping of SDG 1 and Targets 1 and 2, onto WDI

Goal 1: End poverty in all its forms everywhere	
SDG targets	WDI indicators
Target 1.1: By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day	Poverty headcount ratio at $1.90 a day (2011 PPP) (% of population)
Target 1.2: By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions	Poverty headcount ratio at national poverty lines (% of population)

#	Sustainable development goal	+/−	WDI data series code	Reduced data set
01	No poverty	−	SI.POV.DDAY	SDG01
02	Zero hunger	−	SN.ITK.DEFC.ZS	SDG02.PC1
		+	AG.YLD.CREL.KG	
		+	EA.PRD.AGRI.KD	
03	Good health and well-being	−	SH.STA.MMRT	SDG03.PC1
		−	SH.DYN.MORT	
		−	SH.DYN.NMRT	
		+	SH.IMM.HEPB	
		−	SH.TBS.INCD	
		−	SP.ADO.TFRT	
		+	SH.IMM.IDPT	
		+	SH.IMM.MEAS	
		+	SH.MED.NUMW.P3	
		+	SH.MED.PHYS.ZS	
04	Quality education	+	SE.PRM.DURS	SDG04.PC1
		+	SE.PRE.DURS	
		−	SE.TER.ENRL.TC.ZS	
05	Gender equality	+	SG.GEN.PARL.ZS	SDG05
06	Clean water and sanitation	+	SH.H2O.SAFE.RU.ZS	SDG06.PC1
		+	SH.H2O.SAFE.UR.ZS	
		+	SH.STA.ACSN.RU	
		+	SH.STA.ACSN.UR	
		−	SH.STA.ODFC.RU.ZS	
		−	SH.STA.ODFC.UR.ZS	
07	Affordable and clean energy	+	EG.ELC.RNEW.ZS	SDG07.PC1
		+	EG.FEC.RNEW.ZS	
		−	EG.EGY.PRIM.PP.KD	
08	Decent work and economic growth	+	NY.GDP.MKTP.KD.ZG	SDG08.PC1
		+	NY.GDP.PCAP.KD.ZG	SDG08.PC2
		+	NY.GNP.MKTP.KD.ZG	SDG08.PC3
		+	SL.AGR.EMPL.ZS	
		+	SL.GDP.PCAP.EM.KD	
		+	SL.IND.EMPL.ZS	
		+	SL.SRV.EMPL.ZS	
		−	SL.UEM.1524.FE.NE.ZS	
		−	SL.UEM.1524.MA.NE.ZS	
		−	SL.UEM.1524.NE.ZS	
		−	SL.UEM.1524.ZS	
		−	SL.UEM.TOTL.FE.NE.ZS	
		−	SL.UEM.TOTL.MA.NE.ZS	
		−	SL.UEM.TOTL.NE.ZS	
		−	SL.UEM.TOTL.ZS	
09	Industry, innovation and infrastructure	+	IS.AIR.GOOD.MT.K1	SDG09.PC1
		+	IS.AIR.PSGR	SDG09.PC2
		+	IS.RRS.GOOD.MT.K6	
		+	NV.IND.MANF.CD	
		+	NV.IND.MANF.ZS	
		−	EN.ATM.CO2E.KD.GD	
		−	EN.ATM.CO2E.PP.GD	
		−	EN.ATM.CO2E.PP.GD.KD	
10	Reduced inequalities	+	DT.ODA.ODAT.KD	SDG10

(*continued*)

Table II. Reduction of the data set by means of principal component analysis

#	Sustainable development goal	+/−	WDI data series code	Reduced data set
11	Sustainable cities and communities	−	SP.URB.GROW	SDG11.PC1
		−	SP.URB.TOTL	
12	Responsible consumption and production	+	NY.ADJ.SVNX.GN.ZS	SDG12.PC1
		+	NY.GDP.COAL.RT.ZS	SDG12.PC2
		+	NY.GDP.FRST.RT.ZS	
		+	NY.GDP.MINR.RT.ZS	
		+	NY.GDP.NGAS.RT.ZS	
		+	NY.GDP.PETR.RT.ZS	
		+	NY.GDP.TOTL.RT.ZS	
13	Climate action			
14	Life bellow water	−	ER.FSH.AQUA.MT	SDG14.PC1
		−	ER.FSH.CAPT.MT	
		−	ER.FSH.PROD.MT	
15	Life on land	+	AG.LND.FRST.K2	SDG15.PC1
		+	AG.LND.FRST.ZS	
16	Peace, justice and strong institutions			
17	Partnerships for the goals	+	GC.TAX.TOTL.CN	SDG17.PC1
		+	GC.TAX.TOTL.GD.ZS	SDG17.PC2
		+	NE.EXP.GNFS.ZS	SDG17.PC3
		+	TM.TAX.MANF.SM.AR.ZS	SDG17.PC4
		+	TM.TAX.MANF.WM.AR.ZS	
		+	TM.TAX.TCOM.SM.AR.ZS	
		+	TM.TAX.TCOM.WM.AR.ZS	
		+	NY.GDP.MKTP.CD	
		+	NY.GDP.MKTP.CN	
		+	.NY.GDP.MKTP.KD	
		+	NY.GDP.MKTP.KN	
		+	NY.GDP.MKTP.PP.CD	
		+	NY.GDP.MKTP.PP.KD	
		+	NY.GNP.MKTP.KD	
		+	NY.GNP.MKTP.KN	
		+	NY.GNP.MKTP.PP.CD	
		+	NY.GNP.MKTP.PP.KD	
		+	IE.PPI.ENGY.CD	
		+	IE.PPI.TRAN.CD	
		+	IE.PPI.WATR.CD	
		+	DT.ODA.ALLD.CD	
		+	DT.ODA.ODAT.CD	
		+	BX.KLT.DINV.CD.WD	
		+	BX.KLT.DINV.WD.GD.ZS	
		+	BX.TRF.PWKR.DT.GD.ZS	
		+	DT.TDS.DPPF.XP.ZS	
		+	IP.PAT.NRES	
		+	IP.PAT.RESD	
		+	IT.NET.USER.ZS	
			94 variables	22 variables

Table II.

DDAY (poverty headcount), which is a measure of the tendency towards poverty, had its sign switched to comply with SDG 1, which requires a measurement of the tendency towards No Poverty (refer to Table II). In other words, instead of measuring how much the poverty is decreasing, we were interested in measuring how much No Poverty is increasing.

By switching signs in this way, we eliminated mismatches between the meaning of the WDIs and the meaning of their corresponding SDGs. Furthermore, this procedure helped make the interpretations of the correlations more straightforward.

As Table II shows, SDGs 1, 5 and 10 corresponded to a single WDI data series. They were kept as they were. SDGs 13 and 16 had no data left. Their corresponding WDI data series were removed because they had many missing values.

All other SDGs corresponded to two or more WDI data series. SDG 3, for instance, corresponded to ten data series, and SDG 17 corresponded to 29 data series. For each of those SDGs, a PCA was performed – and the corresponding scores were calculated – by using the "prcomp" function from the stats library of the R language – to be used in the place of the original expanded data. The prcomp function was used to perform a principal component analysis on the data set by means of a singular value decomposition of the data matrix, not by using the eigen or covariance matrix. This is generally the preferred method for numerical accuracy. A factor analysis was also performed to determine what factors were responsible for the data variability. By doing so, the number of variables (data series) was reduced, as shown in the last column of Table II. After that procedure for each SDG, the data set was reduced to 22 data dimensions.

The prefix "PCi" was appended to the names of the data series to denote that they were the result of the principal component analysis. Most of the SDGs were reduced to a single principal component, with the prefix "PC1". The only exceptions were SDGs 8, 9 and 17, for which three, two and four principal components were necessary, respectively, to convey the variability of the original data. No principal components had to be calculated for the SDGs with no prefixes, as their corresponding data consisted of a single data series.

The correlation matrix for those 22 dimensions was then calculated using the "cor" function from the stats library of the R language. Figure 2 shows the correlation matrix that

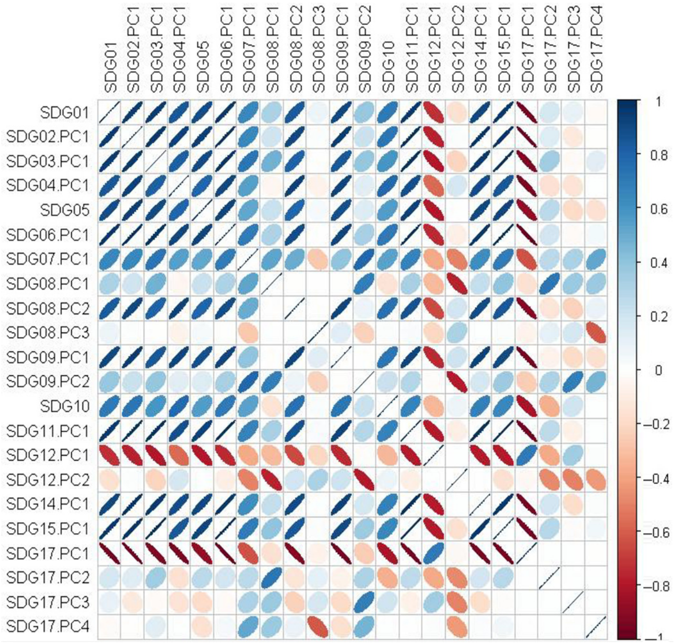


Figure 2.
Correlation matrix for the 22 SDG dimensions

was generated using the "corrplot" function from corrplot library of the R language. The area and the intensity of the colour of the ellipses corresponded to the magnitude of the correlation coefficient: the larger the area and the more intense the colour, the larger the correlation. The slope of the ellipsis' axis stands for the signal of the correlation coefficient: slope to the right (/) stands for a positive correlation, whereas slope to the left (\) stands for a negative correlation.

It is important to call attention to the meaning of these correlations. They are not correlations between random variables but rather between data series. All the data series have the same time basis. The values of the series were aggregated by year. What these correlations express, by considering its mathematical nature, is a correlation between tendencies:

- A high positive correlation means that the data series exhibited similar tendencies with time, i.e. as one index increased, the other tended to increase, and vice versa.
- A high negative correlation means that data series exhibited opposite tendencies with time, i.e. while one index increased, the other tended to decrease, and vice versa.
- A low correlation means that the tendencies did not seem to have any relation.

High positive correlations were expected, for instance, between health and education, whereas high negative correlations were expected, for instance, between education and poverty or between poverty and health. A negative correlation between health and education goals might be an indication that investments are not enough to cover both goals and that oscillation is taking place as efforts are allocated to either one or the other. This would indicate a need to dig up the root causes of such oscillations in the lower levels of recursion. An emerging pattern of correlations that seems highly coherent might be interpreted as a signal of synergy and self-organization towards sustainability. Similarly, a highly incoherent pattern of correlations might be an indication that efforts are spotty, uncoordinated and not enough to give raise to synergy.

It is assumed that the transients that are typical in the dynamic behaviours of systems – such as undershoot, overshoot and high-frequency oscillations – do not significantly affect the correlations. The fact that the data series are aggregate in a yearly basis is assumed to eliminate such high-frequency transients, so as to smooth the tendency curves.

In addition to the correlations matrix, we performed a factor analysis using the "fa" function from the psych library of the R language. The factor analysis was performed on the correlations matrix by choosing the minimum likelihood method with a varimax rotation. The result of the factor analysis is reported in Table III, where "MLi" is the factor loading, h2 is the communality and u2 is the uniqueness. The number of factors (4) corresponds to the number of eigenvalues that are greater than 1. They explain 93 per cent of the variability of the data. The first eigenvalue alone explains 58 per cent of the variability of the data.

The correlation matrix indicates a very strong correlation among the first six dimensions. A high correlation assumed by the first six SDG dimensions seems to attest that there is a relevant relation between the SDGs progress along those 25 years. We did not build a dependency model in a way that exploratory correlations could arise. The results showed that efforts existed and they were strongly correlated in the cases of "No poverty", "Zero Hunger", "Good health and well-being", "Quality education", "Gender equality" and "Clean water and sanitation" dimensions. In fact, the tendency curves for SDGs 1-6 in Figure 3 illustrate what has been described. Data, thus, show a subsystem of the entire system that

22 dimensions	Adopted description	ML1	ML3	ML2	ML4	h2	u2
SDG01	No poverty	*0.95*	0.10	0.22	−0.09	0.97	0.03
SDG02.PC1	Zero hunger	*0.99*	0.04	0.02	0.06	0.99	0.01
SDG03.PC1	Good health and well-being	*0.94*	0.29	0.12	0.08	0.99	0.01
SDG04.PC1	Quality education	*0.93*	−0.25	−0.02	0.10	0.93	0.07
SDG05	Gender equality	*0.92*	0.19	−0.09	−0.05	0.89	0.11
SDG06.PC1	Clean water and sanitation	*0.99*	0.10	0.12	0.06	1.00	0.00
SDG07.PC1	Affordable and clean energy	*0.59*	0.19	0.51	*0.58*	0.99	0.02
SDG08.PC1	Decent work and economic growth	0.17	*0.81*	0.43	0.11	0.88	0.12
SDG08.PC2	Decent work and economic growth	*0.92*	−0.20	−0.10	0.07	0.91	0.09
SDG08.PC3	Decent work and economic growth	0.04	0.01	0.07	−0.59	0.35	0.65
SDG09.PC1	Industry, innovation and infrastructure	*0.97*	−0.13	−0.10	−0.17	1.00	0.01
SDG09.PC2	Industry, innovation and infrastructure	0.18	0.32	*0.80*	0.35	0.91	0.10
SDG10	Reduced inequalities	0.73	−0.47	0.30	0.07	0.86	0.14
SDG11.PC1	Sustainable cities and communities	*0.98*	0.17	0.05	0.03	1.00	0.00
SDG12.PC1	Responsible consumption and production	−0.77	−0.34	0.25	0.07	0.77	0.23
SDG12.PC2	Responsible consumption and production	0.05	−0.57	−0.58	−0.22	0.71	0.29
SDG14.PC1	Life bellow water	*0.98*	0.11	−0.05	0.06	0.97	0.03
SDG15.PC1	Life on land	*0.97*	0.21	0.12	0.04	1.00	0.00
SDG17.PC1	Partnerships for the goals	−0.99	0.09	−0.13	−0.01	1.00	0.00
SDG17.PC2	Partnerships for the goals	0.08	*0.93*	0.02	0.03	0.87	0.13
SDG17.PC3	Partnerships for the goals	−0.13	−0.01	*0.96*	−0.16	0.95	0.05
SDG17.PC4	Partnerships for the goals	−0.02	0.11	0.17	0.74	0.59	0.42

Table III.
Factor analysis of SDG indicators

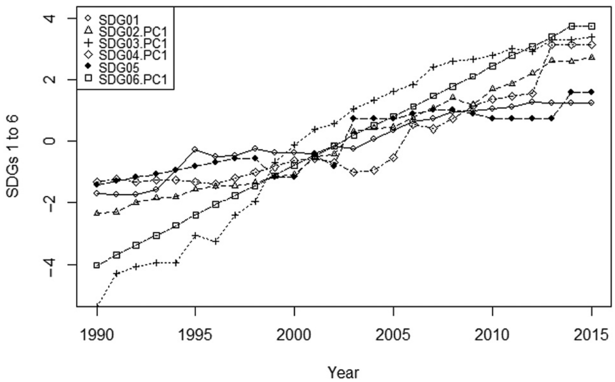


Figure 3.
Scaled tendency curves for SDG 1-6

may be self-organizing towards meeting the goals. This subsystem can be characterized as men and women, with no hunger, in good health and sanitary conditions, who can both enjoy and contribute to positive results as they have access to education of good quality.

In addition, SDGs 1-6, 9, 11, 14 and 15 seem to comprise a group of systemic results. Their results add to the first axis of relation in the "Industry, Innovation and Infrastructure", and "Sustainable Cities and Communities" extends to a second axis of results in which educated men and women, in good health and sanitary conditions, that live in sustainable cities and have access to technology work are a point of change in consistent actions over time.

Moreover, results from SDGs 1-10 correlations show medium to high positive correlation, which means that Goals 1 (No Poverty), 2 (Zero Hunger), 3 (Good Health and Well-Being for people), 4 (Quality Education), 5 (Gender Equality), 6 (Clean Water and Sanitation), 7 (Affordable and Clean Energy), 8 (Decent Work and Economic Growth), 9 (Industry, Innovation, and Infrastructure) and 10 (Reduced Inequalities) are tending to have coherent results. They have exhibited consistent behaviours, reinforcing their positive effects on each another. The third factor, or axis, represents a broader conception, according to which energy, decent work and reduced inequalities emphasize the power of the first two axes.

When it comes to Goals 14 and 15 (Life below Water and Life on Land), there is also a strong positive correlation exposing that life conditions perform the same behaviours of the Axes 1 and 2, as confirmed on communality results of the factor analysis (Table III). It seems like these two aspects are being neglected in comparison with efforts on other dimensions and are thus producing positive impacts on overall results. The behaviours of these two dimensions or Axis 4 deserve deeper investigation to explore the cause-and-effect dynamic.

Therefore, Goals 1-6 (Axis 1), 1-10 (Axis 3) and 14 and 15 (Axis 4) are considered the group that presents conjoint growth with positive consistent results over the years.

On the other hand, a negative correlation in the case of the SDG 9 dimension (Industry, innovation and infrastructure) was surprising, meaning that the increase of technology and markets is not necessarily aggregating to systemic progress. The dimension alone does not provide a meaningful correlation among others, especially about CO_2 emissions. When opening the data of SDG 9, it is clear that economic data (and related variables) described in Table II present different behaviours than that of the CO_2 emission index. This dimension needs further investigation to understand its impact.

According to the matrix, SDG 17 (Partnership for the Goals) has a negative or weak correlation with almost all other variables, making clear the difficulty of integrating efforts to sustainability as a viable system. Beer (1979) predicted that fragmented efforts are not efficient to system development.

In addition, SDG 12 (Responsible Production and Consumption) has a negative correlation with almost all other SDG indicators. It means that efforts carried out in lower recursion levels may not be linking to overall results. The organization's efforts to promote cleaner production and more conscious consumption do not seem to be presenting any systemic impact.

In summary, the efforts in Brazil seem to be more centred on social dimensions of sustainability, such as education, health and eradication of poverty. Economic dimensions, such as industry, innovation and investments do not appear to be presenting promising results. The results on the ecological dimensions are not encouraging either.

Four axes of data behaviour and systemic change tendencies were identified through the factor analysis and multivariate regression. Axis 1 (Goals 1-6), Axis 2 (Goals 1-6, 9, 11, 14 and 15), Axis 3 (Goals 1-10) and Axis 4 composed of SDG 14 and 15 are the understandings of the overall data results during the 25 years of progress. The first factor (ML1) in Table III seems to indicate that most goals are synergistically interrelated.

5. Final considerations

In this paper, we proposed the understanding of sustainability as an integrative concept, more specifically as a systemic concept. The importance of systemic understanding of sustainability can be stated on the basis of the contribution that systems thinking and systems practice can provide to make sustainability more scientific – if we consider the contributions that a cybernetic insight can bring (Beer, 1979, 1985; Forrester, 1961, 1969, 1971) – more participative (Checkland, 1981, 2000), more democratic (Ulrich, 1983; Ulrich and Reynolds, 2010), more critical (Flood and Jackson, 1991; Jackson, 1991; Ulrich, 1983) and more ethical (Churchman, 1968, 1971, 1979; de Raadt and de Raadt, 2014).

Four main aspects could represent the linkage between systems and sustainability: recursion (Beer, 1979, 1985; Schwaninger, 2015), emergence (Checkland, 1981), synergy (Beer, 1985) and self-organization (Malik and Probst, 1984; H. Ulrich, 1984). Recursion is an aspect of systems thinking that allows people to understand and explain the complexity behind sustainability. It also allows people to see sustainability as an organized set of levels, one on top of the other, the higher levels being progressively more complex than the lower ones that produce them. The concept of emergence states that, in this complexity organized as layers, sustainability at a certain level of organization relies on processes that run in the lower levels. At each level, the manifestation of synergy depends on the existence of mutual interactions between autonomous agents at the respective levels. Independent efforts on the part of those agents cannot give rise to synergy, cannot make desired sustainability to emerge at the upper levels and cannot recursively link all processes across the levels. This process is not expected to be controlled by a centralized source of command, but it is expected to work as a self-organizing system, whereby autonomous agents work synergistically in the pursuit of sustainability.

Three qualitatively distinct levels of efforts to sustainability are identified: individual, organizational and world activities. At the individual level, progress regarding sustainability depends on personal attitudes, including the willingness to abandon a self-centred lifestyle in favour of a more cooperative way of living and making decisions, and to embrace a new approach to ethics, which replaces self-interest by self-denial and self-sacrifice (de Raadt and de Raadt, 2014). At the organizational level, a paradox of the need to internalize environmental and social costs into generic strategies and the sustainability strategy that involves core businesses are challenges for systems working towards sustainability. When it comes to global level, in this paper, we tried to make a contribution to push forward the frontier of knowledge by proposing an approach to understand whether the progress made towards the SDGs in the past 25 years indicates that the world is, after all, organizing for sustainability (Schwaninger, 2015).

The proposed approach has been demonstrated by applying it to data for Brazil. The outcomes showed mixed results. Efforts in Brazil seem to be more centred on social dimensions of sustainability. For those dimensions, the correlations seem to indicate that systemic self-organization might be taking place. This means that there seems to be a subsystem of the whole that is consistently and coherently making progress towards meeting the goals and, possibly, self-organizing towards sustainability. However, for the economic and the ecological dimensions, the results do not show such systemic consistency.

The vision of the SDGs as an integrating concept from a systemic perspective is the main contribution of this paper. As we mentioned above, earth's long-term viability requires an integrated view of all aspects of life. Our results reinforce the understanding that public policies are needed to increase adherence to the SDGs. At the industry recursion level, public policies that encourage adherence to the UN Global Compact are important to foster greater synergy and better results.

In Brazil, it is important to maintain the public policies that impact Goals 1-6, but it is necessary to develop policies geared towards Goal 12. Environmental goals also need more public policies (Goals 14 and 15). To achieve this 2030 Agenda, much effort will be required for Goal 17, which is related to greater synergy through partnerships.

In conclusion, the correlations seem to provide a rough indication that Brazil as a whole is not yet self-organizing as a system towards sustainability, even though significant progress has been made in the social dimensions. The explanations for these outcomes must be further investigated at the lower level of recursions.

If humanity is to build a sustainable world over the next decades – as implied in the SDGs – and if de Raadt and de Raadt (2014) were correct that, to achieve sustainability, a shift in the dominant approach to ethics is needed – then major global changes are imminent in the ways cities are organized, in the ways people do business and in the ways people think and live. The recursive model of sustainability, as described in this work, suggests that, by proliferating initiatives, governors and managers can wisely take advantage of synergy and recursion to amplify the magnitude and increase the velocity of these changes.

6. Research limitations

To enable the calculation of the correlation matrix, the data series were not allowed to have missing values. Some of the WDI data series had too many missing values and had to be eliminated. This unfortunately reduced the variability of the original data.

In addition, the missing values in the remaining data series had to be calculated by means of interpolation or extrapolation. There are alternative algorithms to perform such functions. The impact of the interpolation and extrapolation of the missing values on the study, as well as the pros and cons of different algorithms, required investigation. It is important to remark that the WDI series was the only global and open data set that aligned with the SDGs.

7. Future research

Regarding the method used in this research, because the data analysis was programmed in R language, it will allow other countries or even entire continents for which the WDIs are available to be analysed by running the program. In this way, the study can be repeated for different countries and continents, and the results can be compared. In addition to the findings regarding the progress towards the SDGs for different countries, such an exercise can be useful to refine the method developed in this work and to ensure its validity.

The conclusions presented for Brazil are based on aggregate data. They represent an overall result for the entire country. As Brazil is a large country comprising different regions with very contrasting characteristics, these results may not reflect the reality of a particular region of the country. Further investigation at the lower levels of recursion is necessary to understand how the special characteristics of particular regions of the country contribute to the underlying dynamics that produce the emergent results found at the aggregate level. Such an investigation can also be extended to include the contributions added by the business organizations and individual citizens.

Regarding the application of the VSM, its design and diagnosing features have not been fully explored in this work. It can be used to further investigate the lower levels of recursion. At each level of recursion, an effort to identify and describe the subsystems of the VSM might be an interesting alternative to both identify and investigate issues related with autonomy (S1), coordination (S2), synergy (S3), adaptability (S4) and vision (S5).

Other aspects to consider include homeostasis (Chrousos and Gold, 1992, p. 2) and the dynamic capability of adaptation of sustainability systems along the same time period.

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