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SPECIAL FEATURE: NOTE AND COMMENT

People, Technology and Governance for Sustainability: The Contribution of Systems and Cyber-systemic Thinking

Sustainability: definition and five core principles, a systems perspective

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Abstract

A systems perspective is used to discuss the concept of sustainability. From this perspective, it is argued, sustainability can be regarded as a system state that is mediated by specific structures. This is fundamentally different from regarding sustainability merely as a normative goal, as it is presently regarded by most. Insight into the kinds of structures which mediate a system's state open the door to proactive design of new structures and mechanisms, which are necessary for yielding effective change: in this case, promoting the sustainability agenda. The kind of change required to transform the prevailing trajectory of human affairs is presented as a second order change: a change that requires a major shift, and a complete transformation of the system itself, not only in a few aspects of its behavior. A new definition of sustainability is offered, anchored in the interaction of a population and the carrying capacity of its environment. From this definition, five core sustainability principles are derived, along with their respective policy and operational implications. Together, these principles prescribe the conditions that must be met to attain sustainability as an enduring state. The principles themselves form an integrated, systemic set, which requires them to be acted on simultaneously. A piecemeal approach—focusing on one aspect while neglecting others—is not likely to yield effective results for the whole.

Keywords Sustainability · Systems thinking · Cybernetics · System state · First and second order change · Sustainability principles

Introduction

In this brief article, I would like to explore an important topic: the essential nexus between sustainability, systems thinking and cybernetics.[1] For this purpose, I would like to offer a new definition of "sustainability" that is anchored in a systems perspective. I would then like to review a set of underlying principles, conditions which cannot be compromised if "sustainability" is to be attained. Along the way, I would also like to highlight some of the significant implications of taking the systems–cybernetic view.

In recent years, the term "sustainability" has all but lost its meaning. It seems to have become the buzzword of our time, in fashion and implicated at every possible occasion. Thus, we hear about "sustainable financing", related to questions of whether loans given out will actually be repaid. We hear about "corporate sustainability", code for long-term corporate success, usually emphasizing financial results with little regard for broader adverse impacts inherent to the related

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[1] This exploration joins other attempts to emphasize the significance of taking a system perspective when addressing the question of "sustainability." For example: Clayton AMH, Radcliffe NJ. Sustainability. A systems approach. London: Earthscan, 1996. p 258; Espejo R, Stewart ND. Systemic reflections on environmental sustainability. Systems Research and Behavioral Science, 15: 483–496, 1998; Gallopin G. A systems approach to sustainability and sustainable development. Santiago: United Nations—Sustainable Development and Human Settlements Division, 2003. p 38; Hansen JW, Jones JW. A systems framework for characterizing farm sustainability. Agricultural Systems, 51:185–201, 1996; Schütz J. Sustainability, systems and meaning. Environmental Values, 9: 373–382, 2000, to name a few.

core business activities. We hear reference to the question of whether a particular government policy is sustainable, meaning whether a particular policy would actually accomplish its goals. Even a yoga instructor in a class I was taking recently insisted on talking about sustainable *asanas* as a way of emphasizing the maintenance of correct yoga postures.

In all such cases, the use of the term is grammatically correct, implying the sense of a desired continuity. All miss, however, a deeper and more important connotation associated with our unfolding global crisis, a crisis that is generated by the adverse impacts of human activities, combining to increasingly destabilize the very system upon which our lasting wellbeing depends.

Even the prevailing definition, as advanced by the United Nations Commission on Environment and Development does not help. To paraphrase, it defines sustainable development as development which takes care of current needs, without jeopardizing the needs of future generations. This may sound satisfying at first glance, yet, on closer examination, it does not offer any clear operational guidelines. Since it is difficult to establish economic utility values for future generations, it remains vague. And, since future generations cannot participate in deciding what might be best for them, it is flawed from the viewpoint of process. The unhappy result allows for multiple interpretations, and it encourages key players to avoid making unambiguous commitments or taking decisive actions to achieve professed, common goals.

Taking the systems perspective

With their emphasis on the question of relationships between parts and wholes, on understanding the cause-and-effect relationships between components that make a whole, and on disclosing the underlying structures which make for system identities, the system sciences have much to contribute to formulating a rigorous concept of sustainability.

Critical sustainability issues occur in a context that is exceedingly complex, constituting a dynamic, multivariable universe involving multiple social, political, economic, and cultural aspects interacting among themselves, across sectors, and with the physical and non-human living parts of the world. This systemic reality is fundamentally irreducible and it will not yield to a simple, linear, analytic approach. Using reductionist tactics when dealing with systems is fundamentally flawed and yet, it is common in conceptualizing and attempting to address sustainability issues. Approaching complex systems as though they were simple, clock-like mechanisms simply will not work. It will often lead to unintended results and is even likely to exacerbate the very adverse conditions that it attempts to resolve.

Most political leaders, policy makers, development professionals and others who are involved in promoting the sustainability agenda, however, are not trained in the system sciences and lack the appropriate tools for addressing complexity in an effective manner. The result is a consistent tendency to fall back on simplistic, fragmented, non-systemic approaches when developing policies, strategies, and action initiatives in the context of a complex world.

The Millennium Sustainable Development Goals are a case in point. While these goals represent a positive and welcome commitment to the wellbeing of humanity, they are basically expressed as a list of unrelated parts. The list catalogues “good things to have”, but it does not explicitly recognize critical interaction and other important systemic limitations that would become apparent if a genuine systems view was taken. Moreover, there is a hidden and dangerous paradox involved in the way these goals are currently conceived. Simply put, attaining all the millennium sustainability development goals under current conditions—with conflicting, often self-interested values; fragmented governance; limitations in technology; and under prevailing concepts of economic accounting, and growth-at-all-cost economic goals—could put us in a deeper sustainability hole, if only by stimulating an ever-expanding, unlimited demand on resources.

In the broader context of general system theory, cybernetics can be particularly helpful in sharpening the definition of sustainability, bestowing new rigor to a term that has been so watered-down.

Cybernetics theories focus on questions of how systems regulate themselves, how they adapt and evolve, how they self-organize and, more specifically, what the structures and mechanisms are that mediate their operation, performance, and conduct. The link between underlying structure and ultimate behavior is critical in this regard. The idea goes back to Norbert Wiener and his colleagues who, in a seminal 1943 paper, *Behavior, Purpose and Teleology*, established the indispensable connection between a system’s output—its observed behavior—and its internal structure. Today, the idea may seem obvious, but think about how often, in attempting to reform or improve situations, efforts are directed at manipulating outcomes rather than reconfiguring the structures responsible for bringing these outcomes about.

As it turns out, in complex dynamic systems, the structures that drive ultimate behavior—ultimate results, if you will—take the form of intricate networks of loop-like interactions, dominated by the now-familiar feedback loops, that restrain or amplify specific conditions. In true ecosystemic fashion, these interactions combine to produce that which ultimately appears to an observer as the system’s very identity. From the viewpoint of cybernetics, the crux of any system, any organization, any prevailing condition, is stability of some sort. Some form of dynamic equilibrium, tantamount to a system’s state, remains invariant, even as underlying conditions continue to change. At any given moment,

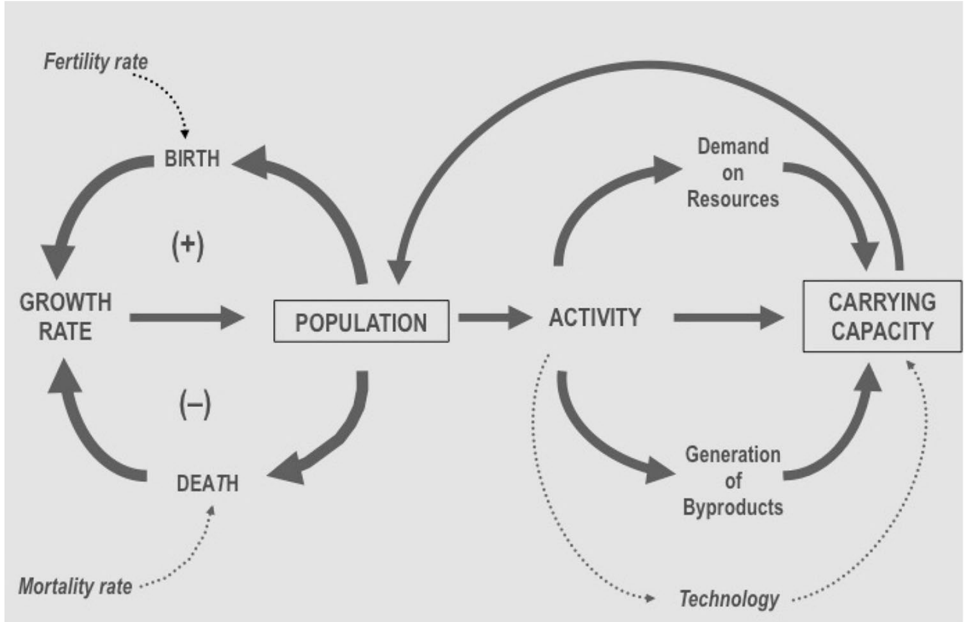

Fig. 1 Population and carrying capacity

such a point of equilibrium is born by specific structures and mechanisms—specific wirings—which make the very condition under review possible in the first place.

Sustainability, from this point of view, can be regarded as a system state and, as such, we should expect it to be mediated by specific internal structures. This is very different from regarding sustainability merely as a normative goal, as it is presently regarded by most. The emphasis on underlying structures can help us move a long way from manipulating words and intentions towards proactive design of the new structures and mechanisms necessary for yielding effective change with the corresponding desired results.

A definition of sustainability

Henceforth, the term "sustainability" will be used in the context of our whole planet, the integrity and health of its biosphere, and the future wellbeing of humanity. In general, it can be regarded as a type of stability characterized by some quantity that remains invariant. The condition that remains invariant is defined by a specific kind of dynamic equilibrium in the interaction of a population and the carrying capacity of its environment. It could be any population and any environment: amoeba in a petri dish, algae in a lake, elephants in their habitat, or humans on the planet.

This interaction is characterized by a circular two-way loop, a structure that is very familiar to cybernetics, in which two sides of an equation, two key variables—in this case population and carrying capacity—continuously affect one another. The two sides are involved in a process of continuous co-creation, producing, as the process unfolds, a state of dynamic equilibrium in which, at least temporarily, they hold each other in check. A particular environment defines what kind of population is possible in the first place, and populations modify and remake the environment itself in an ongoing process of continuous mutual adaptation. The long history of the biosphere bears witness to this kind of interaction.

The basic two-way loop of population and carrying capacity is depicted at a higher resolution level in the diagram shown below (Fig. 1). The population status, indicated at the left of the diagram, is determined by the interaction of a number of variables, including growth rate, birth rate, death rate, and other factors, not all of which are yet completely understood. Population dynamics is dominated by amplifying and balancing loops as indicated by the positive and negative signs in Fig. 1. The environment, in turn, exerts its own shaping pressure on the population, a fact that can be ascertained in experiments with simple organisms in closed environments, such as aquariums, where changes in patterns of food availability can produce changes in the actual physical size of individual creatures and whole groups.

As shown in the diagram, a population's impact on the carrying capacity of its environment is a function of the rate and intensity of its activity. The latter can take many forms, which ultimately boil down to two main channels: the demand on resources and the generation of byproducts. A state of sustainability for the system as a whole requires that the rate of consumption and regeneration of resources, as well as the rate of production and absorption of byproducts, are at equilibrium. Technology, incidentally, can act to increase the carrying capacity by actually expanding the available environment, increasing the performance levels from each unit of resource, and more.

Viewing sustainability as a system state—the result of the interaction of identifiable, specific variables—and anchoring the concept in the interaction of population and carrying capacity, leads to a more rigorous definition. It contains measurable components and can offer clearer actionable guidelines. Accordingly, I am suggesting the following definition of sustainability:

> *A dynamic equilibrium in the process of interaction between a population and the carrying capacity of its environment such that the population develops to express its full potential without producing irreversible adverse effects on the carrying capacity of the environment upon which it depends.*

It is this equilibrium that is being driven ominously out of balance in our time as the result of an explosive increase in population and the related intensification of human activity. The familiar graph depicting a geometric increase in population over recent centuries is mirrored by representations of exponential increases in rates of activity, as related, for example, to increases in industrial production, consumption of goods of all kinds, energy consumption, and concentration of CO_2 in the atmosphere, to name only very few. Being out of balance, the system exhibits many signs of stress, manifest in what are erroneously referred to as "environmental problems": loss of biodiversity, soil erosion and desertification, shrinking forest cover, diminishing freshwater resources, climate change, social strain and more.

What is going on?

Systemic patterns of stress in all parts of the biosphere, resulting from mushrooming and often careless human activity, can be viewed from essentially three different perspectives. The first claims that this is nothing new or unusual, that there is no real cause for alarm and that we can, therefore, continue with business as usual. This view is contrary to scientific evidence, and we accept it at our peril. Another perspective claims that we have reached absolute limits, that we are essentially exceeding the planet's carrying capacity and that, as a result, we must drastically cut back future development. This may appear to be a logical conclusion, except that it would be difficult to implement peacefully, when in many parts of the world, a vast majority of humans are still deprived of the most basic prospects. The third perspective, which I believe opens the way to positive, proactive engagement, suggests that the prevalent signs of stress we are experiencing are symptoms of blocked possibilities trying to manifest. Stress is produced by a growing tension between an emerging new consciousness, by new evolutionary prospects struggling to be born, while the old ways of doing things are stubbornly blocking the way.

Either way, one thing is clear: during the last few centuries, by virtue of its numbers alone, humanity has entered a whole new chapter in its relation to the planet. Throughout its long history, humans have never reached the one billion mark. The dramatic spike, which is quickly leading to a tenfold increase in magnitude, is relatively very recent and represents an entirely unprecedented shift. There is simply no precedent or prior experience relevant to managing nine or ten billion people on the planet in harmony and peace. Most existing tools, concepts, institutions, frameworks and mechanisms available to address these new challenges are not adequate to the task. They evolved to accommodate an entirely different reality and most now stand in the way of the necessary change. "Rethink everything!" ought to be the central mantra of our time.

Understanding change

Change is thus of the essence. Yet, the idea of change too, despite all the fashionable rhetoric, is not always well-understood. Here too, classical cybernetics can come to our aid with an elegant theoretical formulation developed by Ross Ashby. According to Ashby's formulation, basic elements in a change situation include an operand, acted on by an operator, to produce a transform. A transformation event is thus defined by a starting state, a decision rule which acts on it, and an end-result. Different types of transformations are produced, accordingly, by different kinds of relationships among these three basic elements. A significant consequence of this formulation involves a fundamental distinction between two essentially different types of transformations: changing states under a given decision rule and changing the decision rule itself.

This distinction, which has important practical significance for crafting change strategies, was seized upon and further developed by Paul Watzlawick and his colleagues. In their pioneering work in psychotherapy, they establish the terms first order and second order change to refer to these two types of change situations. First order change pertains to changes which occur within a given system while the system itself remains unchanged, whereas second order change relates to cases wherein a major shift occurs, a fundamental change in the very nature of the system under consideration.

The connection to our topic should be clear. The challenge of transforming the current trajectory of human affairs and ensuring a sustainable future of peace and abundance calls for a second order change of unprecedented scope and magnitude. Yet, most sustainability-related initiatives today, including many excellent projects and international efforts, and even the Framework Convention on Climate Change itself, are typically "first order change" endeavors. Second order change would require a deep, simultaneous transformation in consciousness, worldview, values, and culture, as well as radical changes in the structure of the economy, the priorities in development and use of technology, and our current modalities of governance. Nibbling at the margins will not suffice. Ultimately, the objective of establishing the concept of sustainability as the organizing principle on the planet must be to foster a well-functioning alignment between individuals, society, the economy and the regenerative capacity of our planet's life-supporting ecosystems.

The five core principles of sustainability

In the diagram depicting the interaction of population and carrying capacity, the central axis represents a vector comprising all the myriad factors that influence the ways a population impacts its environment, and that ultimately shape the state of equilibrium at any given time. Many of these factors relate to the basic, physical paths of metabolic exchange, but others include cultural, institutional and other societal factors that are non-physical in nature. I find it convenient to cluster all the involved factors in relation to five essential domains[2], defined as follows:

- *The Material Domain*, which constitutes the basis for regulating the flow of materials and energy that underlie existence.
- *The Economic Domain*, which provides a guiding framework for defining, creating, and managing wealth.
- *The Domain of Life*, which provides the basis for appropriate behavior in the biosphere in relation to all other species.
- *The Social Domain*, which provides the basis for social interactions.
- And, *the Spiritual Domain*, which identifies the necessary attitudinal, value orientation and provides the basis for a universal code of ethics.

From each domain, a single sustainability principle is derived, along with its own policy and operational implications. The resulting set of five principles is systemic in nature. All five domains are interdependent, with each domain affecting all the others, as it is being affected by each in return. All the related factors and key variables interact as one whole system. In this context, each sustainability principle prescribes a condition that must be fulfilled to maintain the viability of the whole. The implications for initiatives intended to bring about meaningful change are profound. The systemic aspect, which reflects the interdependent nature of reality, requires that the five core principles are acted on simultaneously. A piecemeal approach, focusing on one aspect while neglecting others, is not likely to yield effective results for the whole.

In the context of these comments, it will not be possible to fully examine the premises behind each of the five core sustainability principles, nor would it be possible to explore the complete list of policy and operational implications that follow as a consequence. The relevant materials can be found in the references provided below. I would like, however, to briefly provide at least a hint of each premise, along with each principle itself.

Material domain

Premise

Our current industrial economy is wasteful, destructive, fragmented, and grossly inefficient. With the appropriate intention, it could be reimagined, redesigned and reconfigured to deliver an enduring, regenerative advantage for all.

The first principle

Contain entropy and ensure that the flow of resources, through and within the economy, is as nearly non-declining as is permitted by physical laws.

Economic domain

Premise

The accounting framework presently used to guide the economy distorts values by systematically ignoring important cost components like the impacts of depletion and pollution, for

[2] In their recent review of research topics in sustainability science (Rakaya, P., Sheikholeslami, R., Kurkute, S., et al. Multiple factors that shape sustainability science journal: a 10-year review. Sustainability Science (2017), Vol 12, pp 855-868.), the authors refer to the goal of integrating the natural and social sciences and the humanities. These categories, reflecting broad clusters of academic disciplines, roughly overlap with the five domains proposed here. In their review, the authors classify the distribution of research papers published by the journal over the last 10 years, in relation to the social sciences, the natural sciences, economics, and engineering and applied sciences. Issues raised by such contributions would inevitably relate to aspects of the five domains. Engagement with the Spiritual, or Value Domain seems to be lacking but the Journal's recent volume on cultural evolution and sustainability is a welcome move in this direction. See, for example, Wansler, C., Brossmann, J., Hendersson, H., et al. Mindfulness in general sustainability practices. Sustainability Science (2018). 13:143. A central tenet of the current paper is that the five domains represent one whole system, and that key aspects of each domain need to be simultaneously integrated in any attempt to effectively implement desired change. The Spiritual Domain, or Value Domain, moreover, is fundamental to the integrity and coherence of the whole.

example. Inadequate measures, and the regulations and subsidies that often accompany them, drive markets and continue to fuel adverse effects on people and ecosystems.

The second principle

Adopt an appropriate accounting system, fully aligned with the planet's ecological processes and reflecting true, comprehensive biospheric pricing, to guide the economy.

The domain of life

Premise

Complex, self-organizing living systems depend on their very complexity, their internal variety, for long-term viability. Lasting stability in all such systems is a direct function of an inherent redundancy, allowing for the emergence and reemergence of different configurations in response to changing events. Monocultures, by contrast, are brittle—the antithesis of vibrant life.

The third principle

Ensure that the essential diversity of all forms of life in the biosphere is maintained.

The social domain

Premise

Societies, like all ecologies and living systems, depend on diversity and internal variety for robustness, long-term viability and health. This alone reinforces the still-fragile idea that open processes, responsive structures, plurality of expression, and the equality of all individuals ought to constitute the cornerstone of social life.

The fourth principle

Maximize degrees of freedom and potential self-realization of all humans without any individual or group adversely affecting others.

The spiritual domain

Premise

The human spirit has consistently sought to transcend limitations, taking progressively more into its field of vision, integrating an increasingly more comprehensive reality, and reaching for a sense of wholeness and completion. The extent to which this deep-rooted drive is allowed to manifest in daily affairs, underscores the difference between a greedy, egocentric, predatory orientation, and a nurturing, self-restrained, inclusive view of the world.

The fifth principle

Recognize the seamless, dynamic continuum
Of mystery, wisdom, love, energy, and matter
That links the outer reaches of the cosmos
With our solar system, our planet and its biosphere
Including all humans, with our internal metabolic systems
And their externalized technology extensions;
Embody this recognition in a universal ethics
For guiding human actions.

As already mentioned, for each domain and from each principle, a number of policy and operational implications can be derived. Together, these combine to sketch out a comprehensive blueprint for the future. They range from striving for highest resource productivity; to implementing a waste-to-resources approach and a closed-loop global production infrastructure; to employing only clean, renewable sources of energy; to establishing a comprehensive concept of wealth that simultaneously optimizes all key forms of capital; to embodying a measure of wellbeing in economic calculations; to harvesting species only to regeneration capacity; to shaping land-use patterns in ways that reduce human encroachment on other forms of life; to fostering tolerance as a cornerstone of social interaction; to outlawing war and trade in weapons technologies; to acknowledging the transcendent mystery that underlies existence; to seeking to understand and fulfill humanity's unique function in the universe; and more. Even a casual review will reveal that every one of the implications derived from the principles is being ignored or worse, actively violated, every day and everywhere. This is why our current path is not sustainable.

Conclusion: the five principles as a systemic whole

Deeper reflection on the concept of sustainability and the five core principles which prescribe it, reveals that the Spiritual Dimension, the Spiritual Principle, is fundamental to the integrity and coherence of the whole. Lacking the ethical commitment implied by the Fifth Principle, considerations related to the other four domains, no matter how elaborate, are reduced to mere technicalities. The Spiritual Principle sets the tone for the whole.

As already mentioned, a balanced, simultaneous, and full integration of all five principles is essential for conceptualizing and realizing sustainability as a consistent system state. Only when the principles are thus integrated to seamlessly inform choices and actions can we hope to realize such a state. The fundamental significance of the systems perspective cannot be overstated. The five domains not only interact and co-define one another, but, as in a holographic image, each embodies the whole scheme in its own sphere.

The principles themselves are expressed in an abstract, general fashion, but they can take on specific interpretations in relation to particular cases—sectors of the economy, development issues, investment guidelines, business strategies, and more. They inform all the work of The Sustainability Laboratory and are at the heart of The Lab's signature approach. An important contention in this regard is that from the viewpoint of a holistic and systemic concept of sustainability, at each level of intervention, major elements of all five domains need to be addressed simultaneously. Such a comprehensive application of the principles in Lab work is demonstrated in our flagship, community-based development project, Project Wadi Attir, which has been gaining increasing international attention. This project, with a Bedouin community in Israel's Negev desert, has been designed to produce significant innovations, simultaneously, on a number of fronts, corresponding to the five domains.

Thus, in relation to the Material Domain, the project's system of integrated green technologies and waste-to-resources approach maximizes the use of renewable resources, reduces harmful emissions, and aims at low levels of waste. At the heart of this system, a first-of-its-kind hybrid wind, solar and storage energy system is being implemented. In relation to the Economic Domain, the project goes well beyond "job creation" by launching new enterprises and developing and empowering a group of entrepreneurs who take responsibility for their own economic future. In relation to the Domain of Life, the project takes a humane and low-impact approach to raising farm animals, while demonstrating an effective approach to combating desertification and enriching the biodiversity of a previously barren site. In relation to the Social Domain, the project has created a unique coalition of individuals and groups representing all sectors of Israeli society, and featuring cooperation between different Bedouin tribes, women in leadership roles, and a cooperative organizational and governance structure. And finally, in relation to the Spiritual Domain, the project is anchored in a value proposition, upheld by members of the community and articulated in the project's own Declaration of Principles.

In closing, I would add one more brief comment: with some further research, and with the computation and imaging resources available today, the suggested framework, including the definition and five core principles, can provide the basis for developing an accurate, biospheric sustainability index. By computing total carrying capacity at any given time and for any system boundary, and comparing it with cumulative rates of resource consumption and a rate of producing and accumulating waste, a single value could be obtained, representing where we stand. It should thus be theoretically possible for every human being on the planet to watch, in real time, how well or badly we are doing with respect to advancing the sustainability agenda. Sustainability is a critical issue that touches every one of us and will impact our children and their children. The future can be one of worsening deterioration on the one hand, or sustainability on the other.

Websites

The Sustainability Laboratory: http://www.sustainabilitylabs.org.

Project Wadi Attir: http://www.wadiattir.sustainabilitylabs.org.

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