sustainability

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Operationalizing Sustainability as a Safe Policy Space

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Received: 17 September 2018; Accepted: 11 October 2018; Published: 15 October 2018

Abstract: It is possible to frame sustainability as occurring when the global or local system is within a set of limits and boundaries, such as the concept of safe operating spaces within planetary boundaries. However, such framings, whilst highly useful conceptually, have been difficult to translate into operation, especially in the development of policies. Here we show how it is possible to define a safe operating space, bounded by sets of constraints. These constraints can be of a variety of forms (e.g., income, or biodiversity), and, importantly, they need not all be converted to a single common metric such as money. The challenge is to identify a set of policy options that define the "safe policy space" which maintains the system within the safe operating space defined by boundaries. A formal methodology, Co-Viability Analysis (CVA), can be used to do this. This provides a coherent framework to operationalize sustainability and has a number of extra advantages. First, defining a safe policy space allows for a political choice of which policies and so is not prescriptive—such as would be the case if a single policy option were defined. Secondly, by allowing each boundary to be defined with its own scale of measurement, it avoids the necessity of having to value natural capital or ecosystem services in financial terms. This framework, therefore, has the potential to allow decision-makers to genuinely meet the needs of their people, now and in the future.

Keywords: sustainability; biodiversity; viability; land use; agriculture

1. What Does "Sustainability" Mean?

The concept of "sustainability" has a long history in many cultures, associated with stewardship and maintaining access to resources [1]. However, it was crystallized in the Brundtland Report in 1987 [2] as "meeting the needs of the present without compromising the ability of future generations to meet their needs". This definition, whilst conceptually adequate, is imprecise enough to be meaningless, becoming something of a "container term" for a vague notion of economic activity with some appropriate stewardship [3]. How are "needs" defined, and how do they differ from "wants"? How does technological progress allow future needs to be met, even with a decline in environmental goods? Instead, the notion has become enmeshed with the idea of "sustaining" in the sense of "maintaining": sustaining economic growth for governments [4] or "sustaining the environment" for environmentalists.

To acknowledge the different elements of sustainability, the Agenda for Development of the United Nations [5,6], articulated three dimensions—the economic, social, and ecological. The economic dimension includes criteria such as social welfare, household income, public expenditure or unemployment rate. The social dimension is also diverse, including for example issues around food security, education, social equity, public, or gender inequality. The ecological dimension addresses utilitarian issues of environmental goods and services (direct and indirect use, option, heritage, and existence values encompassed in the notion of ecosystem services) and also includes non-utilitarian issues (such as the intrinsic value of biodiversity).

The UN documents explicitly do not make a case that any dimension is more important than any other. Clearly, it is desirable to have a secure income, but what if the air you breathe is polluted and the society you live in is dysfunctional? Weighting the dimensions equally calls for a systemic approach to sustainability. Considering these criteria equally is all the more difficult as they depend on local social contexts and vary greatly in space and time.

The three dimensions cover a range of potential variables, each with their own problems of how to measure them. This creates a condition of such operational inexactitude that it is difficult to imagine how the Brundtland concept can be used operationally in policy formulation. Instead, and in order to simplify operationalizing the concept of sustainability, policy-makers often weight the three dimensions. This can be an explicit weighting by putting the greatest value on economic sustainability; or it can occur implicitly, by converting all metrics into a single metric: economic value. Many aspects of the environment are not valued by the market and may have little social value because they are unknown or uncharismatic biodiversity. Converting "ecology" into "natural capital" so it can be incorporated into economic decisions is problematic, uncertain, and arbitrary.

2. Sustainability Operationalized in Reality

As an example of the implementation of sustainability in a policy domain, take the European Common Agricultural Policy (CAP). In its early days, the common agricultural policy was only guided by a perspective of production growth. This was considered necessary and sufficient to guarantee Europe's food sovereignty, to offer European consumers cheap food and, at the same time, to improve farmers' well-being. This production-oriented paradigm, based on the generalization of technical models entirely oriented towards increasing yields and labor productivity, has gradually been undermined. Since the 1970s, it has been necessary to implement policies in favor of disadvantaged areas, particularly mountains, to correct the inequalities in development between regions that it had caused. In the years 1980–1990, policies to control overproduction, which were ruinous for the European budget, were put in place (milk quotas, compulsory set-asides, etc.). At the same time, the first actions to reduce environmental externalities were proposed, which were reinforced with each CAP reform (agro-environmental schemes in 1992, cross-compliance linking subsidies to environmental conditions after 2003, measures to "green" the CAP as Ecological Focus Areas in 2014...). Nevertheless, it must be noted that all these measures have always been considered as obstacles to the achievement of the "essential goal" of agriculture: to produce and produce more and more. The corresponding subsidies were and still are interpreted as corrective measures proportionate to the loss of yields and, thus, of the income that this "irruption" of environmental issues inevitably caused. Even today, economic efficiency remains the organizing principle of the CAP. The relative importance of the economic dimension of sustainability vs the other dimensions is indicated by the monetary amount spent on them. In 2013, €52 billion was allocated to support economic efficiency, compared to €4 billion allocated to the promotion of environmentally friendly practices [7]. The balance of spend to achieve equal environmental, social, and economic outcomes need not be 1:1:1, as it depends on a rate of gain per unit of investment, but with a budget allocation ratio of 13:1, support for the different dimensions of sustainability in the CAP is for now, unbalanced.

Framing sustainability primarily as a constraint to economic growth reinforces two underlying assumptions that make achieving sustainability even harder. The first premise emerges from the idea that social progress is a natural and immediate consequence of economic progress: the more production increases and the economy grows, the better the quality of life for all. This leads to the assumption that the reconciliation of production growth and ecological objectives is of higher priority than the reconciliation of economic growth and social objectives because society is assumed to improve anyway with economic growth. As a consequence of this worldview, sustainability principally comes down to one of greening rather than sustainable rural development: indeed, the last reform of the CAP was widely referred to as the "Greening of the CAP" [8].

The second assumption that is reinforced from seeing the environment as a constraint on production is that there is necessarily a trade-off between economic and environmental objectives: satisfying new ecological objectives (like biodiversity) will lead to economic losses. This reflects the paradigm that the socio-economic system is seen as radically disconnected from the natural world. This trade-off is further reinforced by framing the CAP's agri-environmental incentives as compensation for lost income rather than as the payment for ecosystem services provided.

From this, it is therefore apparent that the EU's decision-makers interpret preserving the environment as a simple binding externality associated with economic costs for farmers. There are many examples that show this is not necessarily the case: ecosystem services and biodiversity can support agricultural production and even be positively correlated with economic growth at a landscape scale [9]. For example, lower yielding organic farming can be as, or more, profitable than higher yielding conventional farming and also provide significant benefits to wildlife [10] and local social cohesion and even, perhaps, public health [11]. Clearly, also, satisfying ecological objectives can have important long-term benefits despite having short-term costs.

3. Moving from "Sustainability" to Safe Spaces

In the face of the well-known problem of "defining sustainability", the concept of "safe operating spaces" was developed. This concept is based on the widespread agreement that sustainability implies the existence of limits, thresholds, tipping points or constraints (indeed, the existence of environmental limits is explicitly part of the reasoning of the Brundtland Commission underlying its definition of sustainability.); "sustainability" is about maintaining the system within these constraints or boundaries. Such safe operating spaces have been well articulated for environmental dimensions: Rockström et al.'s [12] planetary boundaries (Figure 1a) are evidence-based estimates of thresholds beyond which the functioning of the Earth system may be irreversibly and negatively altered.

Going beyond the environmental dimension alone, Raworth's [13] donut concept (Figure 1b) integrates socio-economic well-being into this original planetary boundary framework. It defines a safe and just space for humanity between socio-economic boundaries including income, energy, education, social equity or health, and planetary ceilings such as climate change, biodiversity loss, freshwater or ozone depletion. Maintaining the system within Raworth's donut comes close to being a graphical representation of being "sustainable" in the sense of the UN definition. By identifying safe operating spaces for humanity on Earth, these frameworks have provoked stimulating discussion in the science and policy communities [14–16] and have made valuable conceptual contributions to articulating sustainability's multi-dimensionality. These safe operating spaces are also directly in lines with the alternative conception of sustainability, derived from a Buddhist perspective, the sufficiency sustainability. Indeed it is defined as achieving economic objectives consistent with the principle of right livelihood, ensuring the preservation of the natural environment and the welfare of each individual and society-at-large [17].

The concept of sustainability is difficult to operationalize in any meaningful sense for decision-makers for a range of reasons (for example, see References [18,19]). In principle, however, the concept of a safe operating space is perhaps intrinsically more straightforward to define in a real-world context, through defining the boundaries. To make the concept operational, we then need to have a concrete methodological framework to translate safe operating spaces into a set of policy options which will maintain the system within the safe operating space. We term the set of policy options that maintains the system within the safe operating space the "safe policy space". In practice, the safe operating space is a "sustainable space" so that the methodological framework becomes an operational definition of sustainability.

Moving from the concept of safe operating spaces to the safe policy space requires dealing with the diversity of limits, constraints, and thresholds that define the boundaries of sustainability. As exemplified by the Kyoto Protocol or the Conference of Parties to the Convention on Biological Diversity, a large range of people, including scientists and politics, have a stake in sustainability. These are reflected by a very heterogeneous set of requirements, encompassing all aspects of the three dimensions of sustainability (Figure 1b). To operationalize the donut, we need rigorous definitions of the boundaries and a formal methodology for defining the safe policy space.

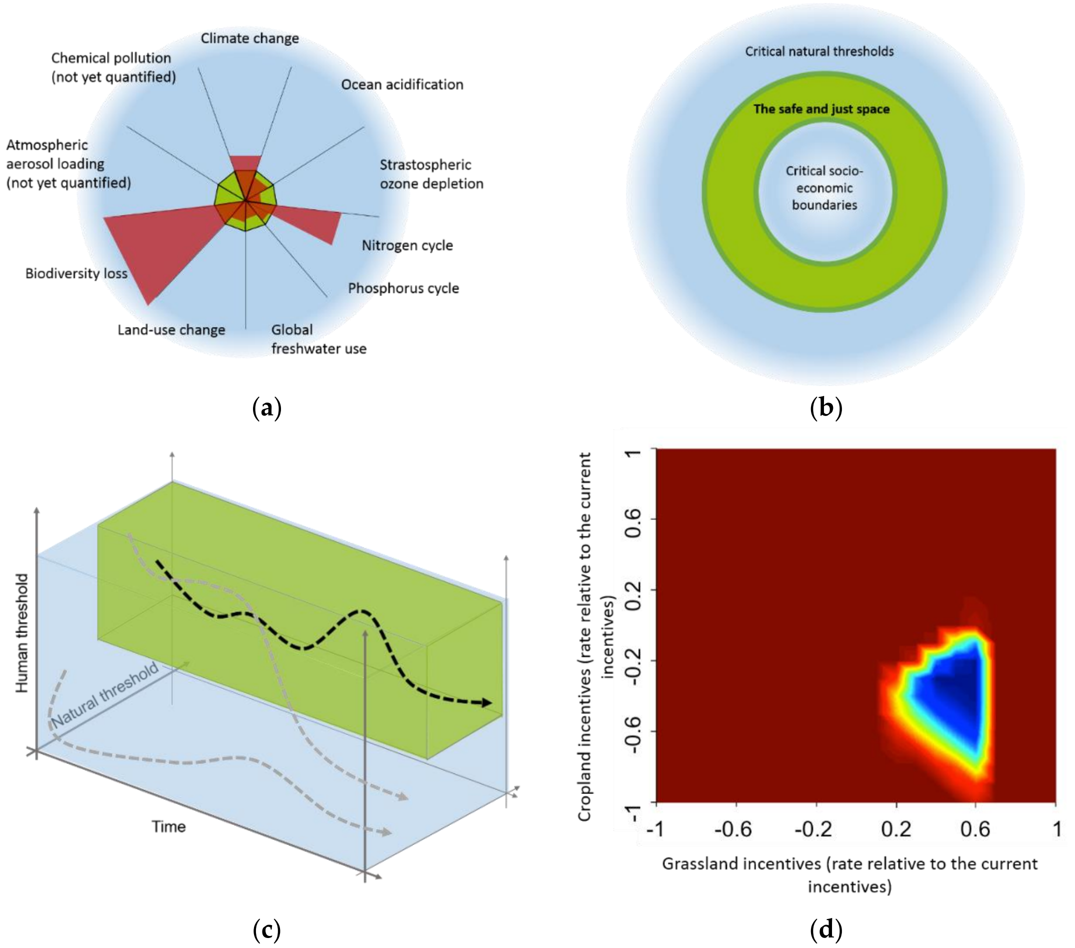

Figure 1. Sustainable spaces. (**a**) The nine planetary boundaries [12]; (**b**) The safe and just operating space [13]; (**c**) Temporal space; (**d**) Policy space (worked example [20]). (**a**) The nine planetary boundaries. In green is the proposed safe operating space and in red is the estimated current position for each variable. (**b**) Raworth's donut conceptualizes humanity's safe operating space in green (based on social and environmental thresholds). These dimensions can be plotted in a joint parameter space (**c**) and the aim is to manage the system through time so as to stay in the safe operating space (in green). The black trajectory is managed sustainably, but the grey trajectories are unsustainable as they are all, or part, outside the safe operating space. (**d**) represents a concrete example based on policy options that maintain French agriculture within a safe operating space defined by economic and environmental criteria. The blue area is the safe policy space (based on subsidies and taxes) that maintains the system above the thresholds over time and, therefore, is managed sustainably. Successive colors represent when the system crosses SMSs in number or frequency, with red representing policy space that never leads to sustainability.

4. Making to Donut Operational: From Boundaries to Safe Policy Space

Developing a formal methodology in designing the safe policy space first requires a way to deal with the diversity of components involved in the boundaries of safe operating spaces.

In the 1950s, the German natural resource economist von Ciriacy-Wantrup [21] described an irreducible set of standards, such as the size of the reproducing population or the size of the suitable habitat, as necessary for conservation. Building on this idea, we formally define the boundaries of the safe operating space in line with the Brundtland definition of sustainability, as the irreducible set of basic needs identified by society, related to the economic, social and environmental dimensions, and necessary to maintain its development without compromising subsequent generations. The boundaries, or basic needs, can be thought of as a set of criteria which we term the Safe Minimum Standards (SMS).

Safe Minimum Standards can be scientific, i.e., quantifiable and accountable (such as income, food provision, atmospheric carbon, or species richness), or they can be normative (such as ethical statements or some societal considerations related to identity, history, or policy, for example). They can be universal (such as levels of atmospheric carbon) or more local (such as local constraints on soil erosion or groundwater, or social representation of some emblematic species). The number, as well as the definition and type of standards, can vary from place to place. An advantage of formally thinking of safe policy spaces for a given context is to analyze in depth the diversity and heterogeneity of standards.

Identifying the set of Safe Minimum Standards within which the system is sustainable is the first challenge of operationalizing sustainability. The second challenge is the methodology to relate the performance of the system relative to the boundaries, and how the position of the system can be adjusted by policies. Co-Viability Analysis (CVA), based on the mathematical framework called viable control theory or viability theory [22,23], meets this objective, as an extension of Population Viability Analysis [24] to bio-economic contexts [20,25–29]. If we have only quantifiable standards, CVA is a formal route to define the safe policy space able to maintain ecosystems or socio-ecosystems within a safe operating space.

More technically, CVA explores and evaluates a range of alternative scenarios defined by diverse control drivers. These control drivers can be public policy tools such as economic instruments, for example, tax or subsidy affecting the behavior of economic agents, but also normative instruments such as quotas, or informational tools such as eco-labels. The CVA does not aim to identify optimal paths for the co-dynamics of resources and exploitation; instead, it provides acceptable trajectories that satisfy different kinds of constraints over time. For example, ecological constraints are defined as guaranteed levels of different biodiversity indicators. Economic constraints can be relative to the minimum thresholds of profitability, welfare, or production, for instance. The co-viability approach evaluates the bioeconomic risk of different policy scenarios, defined by the probability of satisfying a set of ecological constraints up to a determined time horizon (2050 or 2100, for instance). We thus identify the values of the control drivers that maintain the system within the set of constraints over time with a high enough probability (Figure 1c). Using CVA, it is thus possible to identify the safe policy space defined as the subset of control drivers that maintain the system within the boundaries of sustainability (Figure 1d and below). CVA constitutes an extension of existing techniques such as goal programming and decision matrices. These approaches deal with multi-criteria but require quantitative or lexicographic hierarchies between them. They aim at optimizing an objective function built as a weighted sum of several criteria according to their relative importance for the decision-maker. The optimal solution emerges from a substitution between the criteria function of their rank in the hierarchy. This solution is a specific solution of the solutions highlighted by CVA, contingent to a specific hierarchy relationship. Other relationships can be investigated by changing the weight dedicated to the criteria in the objective function. Without specifying any hierarchy between the criteria, CVA depicts a set of solutions and thus characterizes a range of hierarchy orders.

5. A Worked Example of CVA: Agricultural Sustainability in France

Expanding and generalizing works in agroecology portrayed in Groot et al. [30] and applied in Sabatier et al. [31] at the farm scale, CVA has been used to reconcile economic and ecological dimensions in agricultural public policies at the French national scale [20]. The objective was to define the safe operating space within a set of five bio-economic constraints along time. These five SMSs included two economic criteria (a budgetary constraint related to decision-makers and a national agricultural income constraint related to farmers) and three ecological criteria (different indices of biodiversity in birds found in agricultural land). The set of these five constraints, with a maximum tolerance of 5% decrease in the current performance, has to be satisfied at each year, between 2009 and 2050. In other words, the study aimed at avoiding the ecological and economic degradation of French agricultural systems over the next 42 years with a tolerance of 5%.

The study investigated a safe policy space for agriculture based on two policy levers. The first was a tax which created negative incentives and the second was subsidies (positive incentives); together these incentives could change a farmer's willingness to manage agricultural land-uses (such as croplands or grasslands). A bio-economic model was constructed to couple the stochastic dynamics of biodiversity, farmers' choices of land management and economic dynamics with national public policies [20]. Using this bio-economic model, the ecological and economic consequences of policy options were assessed in a stochastic context over the specified time period against the required five SMSs and maps out the levels of the tax/subsidy incentives that maintain the system within the constraints defined by the SMSs (blue areas in Figure 1d).

Whilst this example is a relatively simple one, with a small set of SMSs, it illustrates the potential of CVA to be an adequate framework to operationalize sustainability, as it translates thresholds into a sustainable policy space and provides options for maintaining the system within the thresholds. To go further, other policy instruments can be investigated, and other SMSs can be added.

6. Why Is CVA Appropriate to Operationalize Sustainability?

As outlined above, the CVA framework enables the translation from the boundary space ("safe operating space") to operational space ("safe policy space"). We argue that this transition is relevant for the challenge of operationalizing sustainability since it fits with both the fundamental and applied requirements of sustainability.

Firstly, CVA respects the three fundamental characteristics of the SMSs, underlying the definition of sustainability:

(1) Non-substitutability: It deals with the irreducibility of the standards: each criterion is equally addressed on its own right, without needing conversion to a common scale of measurement. This meets a major criticism of the "ecosystem services valuation" approach about converting nature into monetary values in order to allow a cost/benefit analysis alongside other goods and services [32].
(2) Equality: This approach allows no a priori hierarchy between the standards: on the contrary, considering all the SMS as constraints puts them at the same level of priority. Such a requirement strongly relates to strong sustainability Neumayer [33] as pointed out in Baümgartner and Quaas [34].
(3) Plurality: CVA designs a space which allows the opportunity to discuss and compare policy options according to the normative standards which are impossible to quantify (such as aesthetics, human dignity, morality, justice, liberty). This is in contrast to optimization approaches, which, by defining a single solution, offer little conceptual space to discuss normative standards alongside quantitative ones.

Secondly, CVA is able to deal with the context-dependency issue of underlying the implementation of sustainability in reality:

(1) Intergenerational equity: CVA promotes the balance between the present and future since the standards need to be similarly satisfied over time, and discount rates on monetary values do not need to be applied. Such a finding strongly relates to the strong mathematical links between the viability and maximin (or Rawlsian) approaches [35].
(2) Spatiality: CVA can be applied at any spatial scale to define safe spaces globally or locally, and can even be applied at multiple scales. A first policy space can be defined from universal, global, or national, standards; within this, local standards can be applied and a second CVA conducted to provide solutions which are consistent to both sets of standards. It is, therefore, possible to derive multi-scale solutions (that are both locally and nationally appropriate). For example, Figure 1d represents a "national space" for France, but within the option sets, there is potential for tailoring solutions appropriately adapted to local contexts.

To go further, we suggest that if the boundaries of the safe policy space define sustainability, this framework permits the debate to move beyond the classical issues of trade-offs. Within the safe policy space, all strategies are, at least for some standards, above the boundaries and can thus be interpreted as "win-win" solutions. The CVA framework, therefore, underlies an a minima point of view of sustainability and creates a new economic paradigm well appropriated to the conceptual definition of sustainability.

To conclude, CVA provides a methodological framework to identify the policy options within which the standards that matter to society are met rather than a single, best policy or set of policies. It, therefore, is not prescriptive about how societies should develop, rather it allows space for context-dependent political decisions. However whilst providing a new framing of old debates, and perhaps removing some of the constraints that typically get in the way of developing sustainability policies, this methodology does not provide all the answers. In particular, there is often considerable debate and uncertainty about where thresholds and tipping points may be. Equally, if a desirable property of the system is to maintain biodiversity, it does not provide an answer as to what level of biodiversity is "enough". Our aim here is simply to show that there are robust analytical routes to making sustainability an operational concept, rather than such a "woolly" concept that it is essentially undefinable. We can consider different applications of the CVA method. On the one side, they help the operationalization of the safe operating spaces and donut spaces at a very large scale. However, on the other hand, they can also be very helpful in the small scale when combined with sensitivity models, a system approach developed by Vester and Hesler [36] which provides pertinent characteristics of sustainability for local communities. We can also imagine that this CVA approach can be used with the private sector and articulated with SAFE-COMPASS models (Sustainability Assessment For Enterprises—Companies and Sectors in the Path for Sustainability).

7. Conclusions

Ensuring economic growth is sustainable, and thus meets the needs of current and future generations, is a significant global challenge. The difficulty of defining sustainability operationally—due to sustainability's three dimensions (and the multitude of aspects within any one)—has implicitly created the conditions whereby it is seen as a costly constraint to economic growth. Therefore, too often, sustainability has been seen as a "nice to have" property, rather than something essential. This framing makes sustainability ignorable if it appears too expensive; or has encouraged the simplification of the concept into two axes connected by a trade-off (e.g., economic growth trades off against carbon emissions). Here we reframe sustainability, away from a brake on economic growth, to being based on safe minimum standards, which can be defined by a large set of variables, each measured on its own scale and the set appropriate to local contexts. Furthermore, we show how this can be made operational, and so provide a new approach for governmental policy by making them able to identify safe policy spaces. This has the potential to allow decision-makers to genuinely meet the needs of their people, now and in the future.

Author Contributions: L.M. and T.G.B. conceived the presented idea and drafted the manuscript. L.D., F.L. and F.J. provided critical revisions.

Funding: This paper has been supported in 2018 by the CNRS in the "OASIC" challenge within the project SENTIER.

Acknowledgments: We acknowledge the anonymous reviewers for their stimulating suggestions. Significance Statement: From a systems' perspective, sustainability can be defined by a "safe operating space". We show it is possible to operationalize this concept and formally identify the policy space that maintains the system within the safe operating space.

Conflicts of Interest: The authors declare no conflict of interest.

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