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J. David Tàbara

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Regenerative sustainability. A relational model of possibilities for the emergence of positive tipping points

J. David Tàbara [a,b]

[a]Geography Department, Autonomous University of Barcelona, Berlin, Germany; [b]Global Climate Forum, Berlin, Germany

ABSTRACT
Global environmental change problems are relational problems, so individual and collective actions aimed at dealing with them need to address fundamental changes about how we relate to social and biophysical systems. In this contribution, I suggest that current attempts to theorise and act on sustainability transformations would benefit from a relational perspective characterising individuals, organisations and societies as coupled social-ecological systems set in the context of accelerating global environmental change. Using a whole-life-systems' non-exemptionalist worldview, a conceptual model is presented to help explore the theoretical possibilities for creating regenerative sustainability pathways. Learning to restore and improve the life-support conditions that ensure long-term sustainability will require enacting positive synergies between social and biophysical capitals as well as reframing anthropocentric conceptions of agency and of individual emancipation. In particular, regenerative sustainability pathways entail synergising different kinds and levels of agency in non-dualistic ways and tackle at *the same time* transformations in: social and institutional arrangements (S), energy and natural resources (E), information and knowledge systems (I) and accumulated environmental change (C) -the SEIC model.

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Introduction

In theory, moving contemporary societies towards sustainable development pathways is possible.[1] However, a comprehensive systems' theory able to specify what kinds of deliberate actions would be needed to transform present unsustainable practices coherently towards sustainability has yet to be created. Whilst the purpose of this contribution is not to provide such an overarching full-fledged social-environmental theory, here I argue that current attempts to theorise and act on sustainability transformations would benefit from a non-dualistic perspective characterising individuals, organisations and societies as coupled social-ecological systems set in the context of accelerated global environmental change. Provided that global environmental problems can be understood as relational problems, moving toward sustainable development pathways requires learning to enact profound reconfigurations in the way humans understand and materialise their relationships not only within and among themselves, but also with the biophysical world (Tàbara and Pahl-Wostl 2008).

The stance elaborated follows the early preoccupations shown by pioneering environmental sociologists on the need to overcome human exemptionalist worldviews and models in social sciences. On this, Dunlap and Catton (1979) distinguished between researchers working within the 'human exemptionalism paradigm' (HEP) and those embracing the 'new ecological paradigm' (NEP; Catton and Dunlap 1978a, 1978b, 1980; Dunlap 2002; Dunlap and Catton 1979) and stated that: 'if sociology is to develop a deep and enduring interest in the relations between humans and our environment (. . .), we need to overcome our deep-seated assumption that our species is separate from the rest of nature and exempt from ecological constraints' (Dunlap and Catton 1994, 24); and claimed that 'replacing human exemptionalism with an ecological paradigm will yield a truly "ecological sociology"' (Dunlap and Catton (1994), 11).

However, progress towards ecological sociology had been scant, and even less so when trying to address grand challenges such as those of global unsustainability. This may be due to the absence of explicit analytical tools (see Lidskog and Waterton 2016) and models able to translate those broad worldviews into operational modes - both for analytical and policy purposes. Complexity increases even further when asking difficult questions such as what ought to be sustained, who has the agency to decide, who benefits or becomes negatively affected by those decisions that inevitably have distributional and biophysical effects (Lockie 2016, 2012).. This is even more so when one sets the challenge to consider the

CONTACT J. David Tàbara jdt@sustainabilogy.eu

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possibilities for a regenerative global sustainability tipping point - the hypothetical but plausible moment in which humans stop depleting and degrading the conditions that make human life possible on Earth and enact self-propelling processes of restoration and improvements in social and biophysical capitals.

In this contribution, I address the foundational sociology question on 'how societies are possible' by first underlying the role of individual freedom and emancipation as a major force of global environmental change. Originally influenced by Simmelian sociology, the emphasis is placed on the *relationships* between individuals and their systemic contexts and how their motives and aspirations are mediated by systems of socially-created artifacts – such as the money economy – that profoundly alter the quantity and quality of such relationships. In this regard, the notion of social–ecological practices and a non-exemptionalist, whole-life perspective of agency are introduced. Then, a social-ecological theoretical framework is presented, the SEIC model, to help identify the kind of social–ecological interactions, main systemic components and conditions that would make the continuation of human societies possible on Earth. These ideas are then preliminarily operationalised by arguing that situated transformative options contributing to regenerative sustainability tipping points would require enacting virtuous, self-propelling synergies between the improvement and the restoration of social capitals including equity and just governance arrangements- and biophysical ones -those that ensure the long-term resilience and enhancement of life-support systems. Finally, the current work of the Earth Commission aimed at finding a safe and just corridor for humanity by 2050 is interpreted using these conceptual tools to explore what it would mean to achieve a global positive tipping point towards regenerative sustainability. Finally, some initial propositions derived from the SEIC model are provided.

How are societies possible? The SEIC model

Individualisation, emancipation and agency - A social-ecological perspective

To explain how societies are possible and how change occurs has been a question for sociology since its inception (Simmel 2009 (1908)), a question which could simply be answered by saying that societies are only possible in the long term to the extend that they are sustainable. However, to provide the large ambiguities of the notion of sustainability, a more nuanced and theoretically grounded response is needed (Lockie 2012; Schlüter et al. 2022). In this regard, Blühdorn (2022) explains the lack of prospects for a profound social-ecological transformation of our contemporary predatory societies, including the rise of many negative trends regarding growing inequalities and authoritarian governance, resulting from individual emancipation perceived as free from biospheric restraint. As pointed out by Arias-Maldonado (2022), biophysically embedded ways to understand individual emancipation are needed to cope with humanitarian challenges in the context of planetary boundaries. This is evidently even more the case as we learn about the growing risks of pandemics, zoonosis, and other potentially impending global environmental adverse trends. Instead, as pointed out by Murphy (2008, 2018), humans are becoming increasingly interpenetrated with the biophysical world, and influenced by autonomous forces, with climate change perhaps the most poignant example of this. The 'inner' and 'outer' parts of human beings cannot be separated, even if only because trillions of non-human beings, in the forms of bacteria, viruses, fungi and other microscopic forms of life, already inhabit our own bodily biomes (Hird 2010a, 2010b). In fact, *we live in the natural environment as much as the natural environment lives in each of us*, and this is why ideals, ambitions and practices about our bodies affect the natural environment and vice-versa, consciously or not.

To this end, Simmel's perspective is particularly relevant to understand the complex relationships between individuals and systems, and as argued by Matthias Gross (2000), also to trace useful conceptual heuristics to think about human interactions with the natural world. According to Simmel, the content and forms of social interactions depend on endless dynamics between individual intentions, aspirations and interests that materialise in particular contexts. The reason why these situations or contexts exist and have been created in the first place is because they serve the immediate purposes of those engaged in the interactions, although in recursive ways, the effects of such interactions eventually end up affecting their original purposes. In this guise, social interactions create new mediating mechanisms that in turn modify the scale and content of future interactions. The emergence of the money economy, in contrast to the 'natural economy', is one of the most poignant examples of such mechanisms that explains the relationship between individualisation and the expansion and reconfiguration of social systems (Simmel 2009 (1908):651–52):

> The emergence of the money economy provides the greatest example in world history of the correlation between social expansion and the individual emphasis of life in content and form. The natural economy produces small economic circles relatively closed in on themselves; … [and it] does not allow much of a differentiation and individualization of activities to come about. The money economy [...] causes an immense individualization of economically active

> people: The form of the money wage makes the worker infinitely more independent than any natural-economic payment; possessing money gives the person a previously unheard of freedom of movement, and the liberal norms that are regularly linked to the money economy place the individual in open competition against every other individual [. . .]. Money is the bond within the economy that sets the maximum expansion of the economic group into a relationship with the maximum differentiation of its members

However, Simmel (p.394–472) also warned that:

> 'the money economy reduces the importance of personal ability entirely to its financial value [and] . . . the modern suppression of the natural economy by the money economy . . . actually converted land ownership into a matter of possessing money. (p 472)

Hence and even though the search for individualisation or self-realisation constitutes a major force of systemic social change, following Simmel, , eventually, the former, in material terms, can never be fully achieved or even in many cases may only constitute a liberal illusion. For him, the monetary economy tends to engender the cultural tragedy or paradox whereby individuals, in search of their individual distinctiveness, become increasingly similar but just have different things. And although the money economy may provide greater degrees of freedom and options for individualisation and emancipation, the kind of forms and contents created by such modes of emancipation are tragic and end-up creating the opposite: greater and more complex forms of social control.

All in all, Simmel also provides relevant insights to think about human interactions with the nature and in particular about ecological systems restoration. Matthias Gross (2000) sees in the concepts of *Wechselwirkungen* 'a picture of society as a web of reciprocal interactions between people and people, as well as between people and the material world' and in *Wechselwirkung* 'the individual embeddedness in nature and the reciprocal interaction or reciprocal effect'. According to Gross such concepts could serve to integrate restored nature into sociological nature as well as descriptions that include nonhuman and human elements. And to do so in a way that other species and nonhuman forces would be considered relatively independent subjects in a network of social–ecological relationships. Hence, as argued by Gross, 'Simmel did not try to incorporate nature into society, but allowed both sides to have voice with rights of their own'.

Understanding the intertwined processes of individualisation and self-realisation together with the social mechanisms that influence their content and forms, is thus crucial to understanding the main drivers of social and global environmental change – and to potentially design the required social-ecological transformations. In this regard, the intersecting approach of social practices (Bourdieu 1990, 1998; Schatzki 1996) are being increasingly postulated as a robust way to explain the challenges facing sustainability transformations (Haberl et al. 2021; Ollinaho 2016; Rau 2018; Shove, Pantzar, and Watson 2012). *Social-environmental practices*, like high-energy intensive consumption of goods and services, are normalised habits and clustered routines that entail material interactions with the biophysical world, not necessarily stemming from fully conscious decisions by individuals. They are reproduced and intelligible acts, to a large degree taken for granted that create new conditions in the form of institutions or generally accepted procedures, that in turn affect the reproduction of these same acts. Social-environmental practices have their own logics-to-be, so they are difficult to change unless the reason for the existence of those contexts disappears, which depends on many factors. For instance, the overexploitation of whale populations made the practice of using whale oil for home lighting unattainable; but that practice was abandoned, for reasons that include new emerging economic, institutional and political interests, as well as because alternative sources of energy were becoming available.

Attempts to think and act about how to transform presently unsustainable practices would therefore need to consider these intertwined and complex dynamics that occur between the formation of practices, individualisation processes and large systems' reconfigurations. What needs to be changed, when actions need to be taken, to what direction, by and for whom is not independent from the recognition of the existence of multiple cosmologies (Robinson 2022; Giner and Tàbara 1999) and ontologies about what societies are and what is the place that humans occupy in the whole milieu of living and environmental relationships. Hence, here, I argue that adopting a more relational perspective to human–biophysical interactions, whereby biophysical phenomena are not understood just as happening 'out there' but as inseparable experiences inside our bodies within a whole web of life systems could help to better frame and orient such transformations. Under a relational non-dualistic stance (Jamieson 2020), the ideal of human agency as independent from the natural world vanishes in favour of a more nuanced conception of individuals, organisations, and societies as different kinds of *social-ecological systems or interactants* (Baerlocher and Burger 2010; Burkitt 2016). Multiple micro and macro social and biophysical dynamics and feedback processes, both internal and external to peoples' bodies, constantly and inevitably shape human agents' motives, desires, feelings and intentions. In so doing, they provoke multiple recursive consequences and new structural patterns of interaction and socio-environmental practices that further amplify or restrict the opportunity spaces for sustainable living of other agents or societies. Hence, from this relational non-dualistic perspective, agency is understood as the capacity to influence the interactions of others, but where these 'others' also include non-human actions (cf Latour) that affect human agents' motives, socio-environmental practices, and system' structuring forces. Thus, individuals, human societies and their organisations, although recognised as distinct entities, are understood to possess common patterns of environmental interactions whereby biophysical components influence, though do not fully determine, their reasons, ambitions and practices structuring processes.

This perspective leads to the possibility that all living organisms, and especially to the extent that non-human beings are considered as sentient beings, and should be allowed and encouraged to express their regenerative potential in the ecosystems in which they evolved. From such a worldview, the environment would not only be defined for what is 'outside' individuals or societies, but *also* for what is present and living in our own bodies as inescapable biophysical relationships with all living organisms on Earth. In the same guise that mind and body cannot really be separated – a mind cannot function without a body (Midgley 2006) – social-environmental analyses may better see life systems as a holistic continuum. From this perspective, regenerative capacities can be understood as emergent properties derived from positive synergistic interactions of agents both human and non-human able to influence the multiple social-ecological conditions and processes in which they live and that live within them.

Moreover, it can be argued that alternative forms of emancipation and associated practices are possible and necessary if we are to deal with global unsustainability. They could eventually be enacted by open processes of reflexive learning - able to challenge existing power and institutional arrangements - if adequately considering the human interactions with the biophysical world in non-exemptionalist holistic ways. Research aimed at further understanding and implementing the required sustainability transformations thus requires a profound repositioning and reframing of what is understood as agency and emancipation and their relationship with socio-economic and institutional systems in the context of accelerated global environmental change. For instance, mainstream marginalist general equilibrium economic models that guide national growth accounts, are still framed in a very narrow, anthropocentric and atomised set of assumptions about individual freedom and self-realisation that largely ignores the cumulative and depletive processes between social and biophysical systems, treating nature as an inert object for commodification. In contrast, next I propose an alternative simple theoretical model to help explore some of the key social-ecological mediating and recursive mechanisms that critically affect human interactions with the natural world.

The system needs to be transformed . . . but what is the system?

Following a whole life-systems view, the formations of individual identities, social organisations or nations are possible thanks to energy and information, and are structured following some explicit or tacit rules, and create cumulative environmental impacts. Comprehensive environmental sociology analyses need to consider the interactions between these broad dimensions *at the same time*. My contribution does so by building upon several strands of interdisciplinary work within social-ecological sciences, originally from human ecology (Catton 1994; Duncan 1961, 1964; Freese 1997), evolutionary sociology (Lenski 2005), and other more contemporary attempts that explore the conditions for resilience, sustainability and the transformability of complex and adaptive social-ecological systems (Biggs et al. 2022; Folke et al. 2010; Ostrom 2007, 2009; Preiser et al. 2022; Walker et al. 2020), complexity in social sciences (Byrne and Callaghan 2014; Castellani and Hafferty 2009; Wells 2013), and social metabolism (Haberl et al. 2021). However, some perspectives that also use a complex systems' view in sociology have not been considered here where they retained a largely exemptionalist, anthropocentric view of human interactions with life-support systems, such as with Luhmann (1989; see Graf 2016; Papadakis 2002). The approach proposed here aims to identify, using a non-exemptionalist perspective, the main domains in which social-ecological interactions and feedbacks create new forms and contents affected or affecting by the possibilities for deliberate transformative action.

Many approaches in social-environmental science and transformations research have often lacked an explicit and operational characterisation of what constitutes the 'system' they refer to. From an integrated, non-dualistic and non-exemptionalist perspective, the analysis of human agents' relationships with the biophysical world can focus on four related realms of environmental interactions or *subsystems*: social rules (S), energy and resources (E), information and knowledge systems (I), and cumulative biophysical change (C). In a nutshell, this can be expressed by the SEIC model (Tàbara (2011); Tàbara and Pahl-Wostl (2008) representing these main kinds of agents' interactions:

- *The S-subsystem* (S): composed of social norms, rules, and institutions.
- *The E-subsystem* (E): constituted by the energy, biodiversity and natural resources that are used, available and interact with a given social-

ecological system of reference, e.g. an organisation or society.

- *The I-Subsystem* (I): formed by the information and knowledge pools, including the symbolic representations and communication artifacts for their transmission, available to, or being used or communicated by that society.
- *The C-Subsystem* (C): constituted by the anthropogenic, human-driven cumulated environmental change that at one point becomes an autonomous force of change that affects the structure and dynamics of the whole social-ecological system in which humans live.

Each of these subsystems contains both dynamic components or *flows* as well as structural or relatively stable ones or *stocks* that affect, in an iterative way future social–ecological interactions. Cumulative and depletive processes as well as qualitative structural changes in form and configuration occur in each of the four domains. For instance, this is the case with the increase in national regulations (S), the loss of information derived from traditional practices (I), the depletion of non-renewable energy stocks (E) or growth GHG emissions and chemical pollutants (C). In that, all human actions always produce some kind of cumulative or reconfiguring consequences that translate into new or altered socio-environmental practices and structuring system' patterns that end up influencing human actions in recursive, mediating modes. Human agency and degrees of freedom are expanded or constrained by all the interactions occurring within the four SEIC subsystems. Moreover:

- Each one of these subsystems can be conceptualised and analysed as distinct entities that follow their own autonomous dynamics. This is so as they are constituted by different types of *contents* that express and evolve themselves through different quantitative and qualitative *forms*, thus generating their own unique and differentiated dynamics. However, each subsystem also influences and is influenced to some extent by the other subsystems, although the internal and ultimate dynamic configuration of each one is never fully determined by the others. In this way, multiple intersections occur among the SEIC subsystems, each one also provoking its own distinct hybrid dynamics and recursive processes and varying according to the system of reference to be analysed.
- Large parts of the content, forms and dynamics of each subsystem are not known, nor can be known by humans (see Arponen 2013); and in this way, they also lie beyond human deliberate action, communication or control. However, the fact that given the present knowledge or information systems, some of their components and dynamics cannot be communicated, this does not mean that they do not exist or influence human action, as they do.
- Each subsystem tends to increase in complexity, although such complexity is also expressed in different ways in each of these subsystems (e.g. with growing complexity of rules, more interlinked energy systems, new forms of synthetic and nano-pollution, or AI information systems).

Therefore, whilst all the SEIC subsystems affect how societies and individual interactions in them unfold, none of these subsystems alone can fully determine the configuration of the whole society nor express the dynamics of each individual, organisation or collective grouping within it. Human actions' contents and forms develop as relational hybrid outcomes, e.g. in the form of social-material hybrid practices, routines and normalised habits, and the capacities, opportunities and constraints provided by all these subsystems' interactions. Graphically, this perspective is represented in Figure 1:

However, the SEIC model, as a theoretical construct, does not refer to any particular or single 'real' bounded social or biophysical system. In the case of individuals, organisations or societies, is it only a representation of *their social–ecological relationships*, components and dynamics. Thus, the SEIC model constitutes a heuristic tool aimed at helping to *characterise in qualitative ways*, the kinds of socio-environmental interactions that humans in their distinct forms of

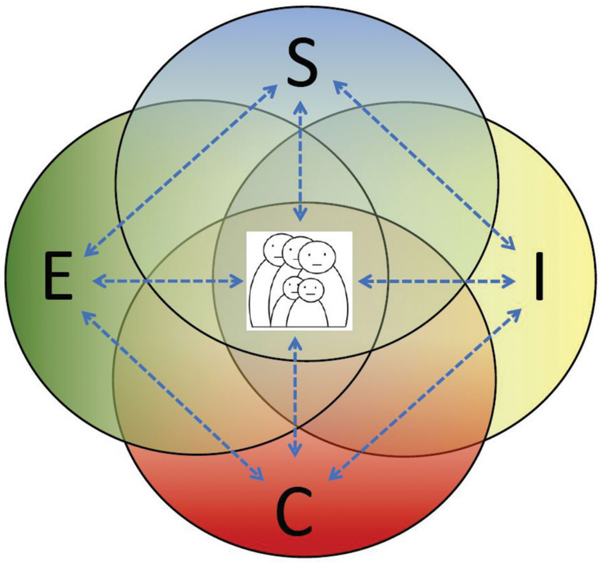

Figure 1. The SEIC model (revisited) representing four main kinds of socio-environmental interactions [based on Tàbara (2011); and Tàbara and Pahl-Wostl (2008)]. Individuals and their organisations can all be conceived as social-ecological systems that operate in a continuum of living forms, contents and dynamics that encompass bodily biomes to large and biophysical systems.

agency, engage with the biophysical world. These different types of socio–environmental relationships exist across and between individuals, families, and social organisations to large systems such as nations or multinational corporations. Whilst the role and influence of the researcher is unavoidable, the SEIC approach is only a non-dualistic, non-exemptionalist analytical tool to help define and examine, often in a deliberative, learning and knowledge co-production mode, the contours, goals, and visions for alternative social-ecological systems' development pathways. It is a proposal that puts special emphasis on unveiling the unavoidable feedbacks derived from human worldviews, interests, and practices. Therefore, it is only a designed to facilitate the co-creation of sustainability knowledge, a situated knowledge generated with strong engagement of those constituting the context of research and/or transformative actions.

These different subsystems are briefly described below, together with a few considerations as to the extent to which certain configurations within them can contribute to building the necessary transformative conditions for positive tipping points towards regenerative sustainability.

Structure, institutions, and norms (S-subsystem)

The S-subsystem refers to the kinds of structuring norms, implicit or explicit, formal or informal, voluntary or imposed, which shape individual interactions and socio-material practices (see Haberl et al. 2021; Rau 2018; Schatzki 1996). Laws, conventions, and institutions mediate the types of transactions of resources and information among agents, although agents through purposeful action, can in some instances modify such structural conditions. This is the case, for instance, with market regulations, educational settings, property regimes or political and governance arrangements which can expand or constrain the degrees of freedom of individuals and their reflexive or transformative capacities (Hölscher and Frantzeskaki 2020). The S-subsystem enables, constrains, and mediates the different kinds of social-ecological systems' flows, and it is through institutions that people can adapt and modify their behaviours to changing conditions accordingly – and by doing so alter the original system conditions in which they operate. However, structural and normative elements should not be conceived as external mechanisms imposed upon individuals (Bourdieu 1998). Their existence is taken for granted, and their acceptance is not necessarily questioned. Rules and structures are as much ingrained within our bodies and minds as they are reproduced formally 'outside' them.

The S-subsystem has also many other intersections and hybrid zones with other subsystems, both humanly created (as information systems) and non-human ones related to biophysical forces. New forms of E and I tend to create new forms of structural inequality as they change the position of individuals and groups within the overall landscape of interactions that occurs between each of the SEIC components. Additional environmental inequality can emerge from differentiated access to information and resources that in turn can also create differentiated exposures to global change, hence reinforcing or creating new unequally distributed vulnerabilities.

The S-subsystem is also the normative outcome of past social–ecological interactions and feedbacks. In effect, some of these institutional arrangements may contribute to building the conditions for regenerative sustainability while others may do the opposite. It can be argued that most Western national-scale institutions prove not to be fit-for-purpose when addressing global environmental change and their obsolescence and lack of adaptability explained by historical reasons. This is why, the scales and configurations of social institutions rarely fit to the biophysical scales that make possible the proper function of life-support systems in the long term. Whilst most institutional arrangements and logics tend to be environmentally alienated from biophysical rhythms and dynamics, it may, however, be possible to demonstrate the feasibility of alternative institutional configurations, such as those with more polycentric forms (Ostrom 2007, 2009). 'Less-than global' approaches that, in combination with other actions taken at smaller scales, may critically contribute to 'small but positive steps' (Ostrom 2012) to global systems' solutions, regeneration, and renewal.

Energy and biophysical resources (E-subsystem)

The E-subsystem refers to those kinds of human interactions with all life forms and biophysical elements not originally created by humans that are used (or potentially available in the future) as resource stocks or flows designed in a given social-ecological system to maintain, improve the quality of, consolidate or expand its organisational structure. Hence, preserving a rich biodiversity is an essential component of the E-subsystem that is necessary to ensure the long-term quality and durability of any given whole social-ecological system.

Given that social structures are inevitably dissipative structures (see Van der Leeuw 2020), the organisation of social-ecological systems depends on the constant inflow of materials and energy, -as well as of new sources of regenerative forms of information and knowledge. Hence, all social-ecological systems remain potentially open and permeable to other systems' interactions and to the use of their resources, as otherwise they would disappear. In effect, human societies, understood as social-ecological systems, create structures that must remain necessarily open to access new forms of resources (E) or knowledge (I) to keep the necessary system's complexity and prevent an inherent tendency to entropy and disorganisation. It is this continuous import of external potential energy and information flows, turned into kinetic social-ecological energy, that allows the functioning and growth of a given social-ecological system, which in turn, generates new forms of waste, unusable energy, or environmental change (C).

Whilst the uses of certain resources have greater impact upon biophysical systems (the E and C-subsystems) than others, it is also obvious that a society that depends on the continuous consumption of non-renewable forms of energy and materials is not likely to last very long, so adaptation is inevitable if that society is to survive. However, once the consumption of certain resources and materials become part of structural routines and become high-intensive resource practices (Haberl et al. 2021; Rau 2018), then it is very difficult to stop or reduce their use, because such consumption is then perceived as objectively necessarily to continue their social interactions or further extend them.

Within the E-subsystem there are many interactions between energy and biodiversity. Industrial societies use large amounts of non-renewable energy sources such as fossil fuels to produce certain 'life-forms useful for human consumption, production or trade' (e.g. food and feedstock crops), whereas certain forms of biodiversity are used in other societies directly as energy (e.g. wood). In this way, it is possible to think of alternative uses of energy to restore global ecosystems, instead of increasing our dependence on non-renewable ones, and in this way contribute towards regenerative pathways.

Information and knowledge systems (I-subsystem)

The I-Subsystem includes all the information and knowledge relational artefacts produced and used by the agents of a given social-ecological system. These artefacts and communicative practices are employed by individuals and organisations to represent, make sense of and intervene in their contexts of action and to attain their perceived goals and aspirations. The I-subsystem encompasses all kinds of symbolic constructs which are used to value the world around and within us. They are the result of cultural evolution and expressed via oral languages or via other technological means in the form of ordered collections of codes, signs, or symbols. The I-subsystem does not refer to the rules and institutions generating and regulating such information and knowledge outcomes, nor the structures derived from them as in the case of educational, research or market regulations. For example, the price of a commodity is an information unit used to represent the economic value of a given object (i.e. the selling of a plastic bottle); however such monetary value is provided by the overall market regulations - or the lack of them thereoff- as well as other embedded power relationships that make such a transaction possible. The market rules, whenever they exist, operate as an institution that establishes what can or cannot be traded, and in what qualities and quantities and under what conditions. Interactants attempting to modify the price of a given good or resource – such as the price of CO_2 - would need knowledge and capacities as well as a position of influence within the corresponding S-subsystem to do so; this, in turn, would depend on the overall configuration of the S-subsystem, influenced, for instance, by the level of public intervention it undergoes.

Cultural diversity constitutes a stock of information and knowledge accumulated by human societies in their evolution with the environment. Preserving and considering such ethnodiversity is essential when attempting to find transformative values and criteria contributing to global regenerative sustainability. Such alternative worldviews are therefore fundamental for achieving high levels of reflexivity, fostering sustainability learning, and reorienting modern habits, beliefs and patterns of behaviour. However, the expansion and acceleration of information flows and new forms of knowledge via new technologies or mass media also tends to negatively affect cultural diversity. Larger I-subsystems and languages that allow greater or faster access to resources or provide larger degrees of freedom for individual emancipation tend to replace those that tend to do the opposite. In this way, knowledge is not only generated but also lost by the expansion of larger and more complex and powerful knowledge systems and the institutional systems associated with them.

I-subsystems allow agents to gain greater consciousness of their own system, anticipate change, and reorient and adapt their individual and collective behaviours and those of their governing institutions. The I-subsystem is also the main source of transformative creativity and imagination (Galafassi 2018), and therefore is the main source for regenerative visions, worldviews and societal alternatives aimed at deliberately transforming existing unsustainability practices. In this regard, the I-subsystem is also affected by the institutional conditions in which individuals operate, which can be more conducive and open to allow free expressions of the mind and of the arts; or in contrast, when authoritarian and illiberal policies suppress such sources of social reflectivity, critique and innovation that constitute the fundamental underpinnings for sustainability learning. So trustful and good quality information systems can help to provide a more accurate understanding of the environmental processes and implications of natural resource consumption and, if inserted within adequate deliberative processes providing a diversity of perspectives, incentives, options and resources, also help the emergence of effective and equitable development pathways able to deal with global environmental change.[2] In contrast, I-subsystems dominated by an overload of banal, distracting, and superficial information, or mostly directed to increase the superfluous and inequality-provoking consumption of individual non-renewable resources, can thus be detrimental to regenerative sustainability.

Social-ecological change (C-subsystem)

The C-subsystem is the result of all the SEIC social–ecological interactions (e.g. anthropogenic GHGs) and does not include environmental changes not originated or influenced by human or social forces (e.g. earthquakes emerging from tectonic forces). The C-subsystem comprises the cumulative or depletive processes and effects on the biophysical world of anthropogenic origin, thus created mostly from E-subsystem human interactions, and that at some point become autonomous forces of whole-systems' change on their own. As in the other subsystems, it also includes stock and flow components. For instance, the stocks of pollutants include vectors such as greenhouse gases (GHGs), nuclear waste, plastic or synthetic residues derived from daily socio-economic exchanges or the use of energies, technologies and materials. These elements, often referred to as negative externalities, usually remain in the ecosystems for longer periods than those usually considered during individual interactions, acts of consumption or market rationalities. The accumulation of harmful pollutants within the C-subsystem not only affects the quality of ecosystems but also reduces their capacity to act as sinks, safety nets or resilience buffers in the event of systemic shocks, so the deterioration of the C-subsystem compromises human future options for sustainable development.[3] In this regard, the SEIC model is compatible both with historical/longitudinal analyses of socio-environmental relationships, and in fact to understand the origin of anthropogenic change in a particular context of research or system of reference, we need to look at how such cumulative anthropogenic changes where originally created in the first place. This is indeed important for those also trying to address issues of justice and equity, as is the case of GHGs emissions and the current discussions of climate loss and damage.

Nevertheless, not all changes in the C-subsystem need to be understood as detrimental for human development. Whilst systemic changes always have an irreversible qualitative character, conscious action derived from social and sustainability learning may be able to restore or create new conditions in the C-subsystem in a way that may have positive and regenerative effects on the overall functioning of a social-ecological system. In theory, it is plausible to conceive a moment – a positive tipping point – in which the confluence, coordination and synergies derived from multiple deliberate interactions and reconfigurations within and between all SEIC subsystems could finally lead to the progressive restoration and regeneration of the basic conditions for life-support systems (in the E- and C-subsystems). This would allow the emergence and improvement of the life-support systems conditions necessary for human populations to live sustainably on Earth, even though these new conditions would never be as they were originally in the first place

Growth, environmental decline, and systems regeneration

Social-ecological systems are constantly changing, and this change, in qualitative terms, is irreversible (e.g. due to biodiversity loss), cumulative (e.g. from GHG emissions), and largely indeterminate as it is subject to multiple feedbacks, cross-scale effects and non-linear interactions. Some social-ecological systems may be regenerated to some extent, although in new reconfigured conditions. This is why the evolution of each of the SEIC subsystems always alters the original conditions of the whole-system development, creating new properties and qualitatively different structural conditions, which are very hard to predict. Larger social-ecological systems dynamics tend to: (i) increase the scale and complexity of social institutions and their social–ecological interactions, e.g. via extended markets or social-environmental practices or policy agreements, (ii) increase the consumption of energy and natural resources, (iii) increase the scale and complexity of their information and knowledge systems, thus negatively affecting cultural diversity in the I-subsystem or other social-ecological systems and (iv) reduce the existing biological diversity in the E-subsystem and increase the accumulation, dissipation and complexity of the forms of pollution in the C-Subsystem. In this guise, the growing complexification of each of the SEIC components in a given society or organisation can only be maintained by a constant inflow of energy and resources and more complex forms of information and institutional configurations.

From the perspective presented here, the growth in size or scale of a social-ecological system depends on the increase in the number of socio-environmental interactions of a given population. However, population is not the only indicator of size, as this also includes the total amount of materials and energy necessary to make them viable at a given moment in time, which in turn is also dependent on affluence levels and the kinds of technologies available (e.g. following the classic IPAT and STIRPAT human ecology approaches, not developed here). Therefore, the size of a social-ecological system is not only given by the number of people that belong to an administrative jurisdiction or country. Nor is it defined by the physical distances travelled by individuals or the flows of products produced or consumed by a given number of people or by the culture shared by a particular population. Size is constituted by *all these interactions and dimensions at the same time*, some of which cannot be fully known by humans as they are part of the 'hidden' or presently unknowable parts of the SEIC subsystems. It is therefore the whole milieu of stocks and flows of energy, information and environmental change mediated by the existing political, economic and institutional arrangements, which makes up the actual size of a society.[4] In this respect, growth, once consolidated, tends to prompt further cycles of growth, and absorb other social-ecological systems of a smaller size or with less capacity to get access to resources or generating new forms of knowledge. This allows larger systems to avoid congestion or the depletion of necessary kinetic resources upon which they depend. Anticipating and correcting such negative path dependencies is therefore crucial in moving towards regenerative sustainability. In particular: (i) In periods of overall SES systems growth, each subsystem increases in complexity, although this complexity is expressed uniquely in each subsystem; (ii) in periods of whole-systems decline or organisational entropy, complexity may stop increasing, although the system may still retain several of its complex traits for some time, and (iii) periods of decline, or even system breakdown, may occur whenever interactants of a system can no longer boost their institutional complexity to access additional resources (E), develop new forms of coupled information and knowledge (I), or when the accumulated biophysical conditions (C) deteriorate to a point that eventually eliminates the available degrees of freedom for innovation and system renewal, eventually leading to growing institutional entropy and disorganisation.

As a society grows, so do the quality and intensity of the potential risks that it confronts. Larger, denser, and more complex social-ecological interrelationships also tend to generate more complex and greater potential risks. These changes can occur faster than the capacity of agents to anticipate, react and adapt to them, in time leading to a systemic tipping point. In these situations, downsizing or slowing down growth may be seen as an adaptive strategy, although the system inertia may entail that the overall system may still be growing or evolving with the same patterns and trends. This is why diversity and redundancy in the I, S and E – e.g. sometimes by containing systems' growth – are essential traits to ensure a resilient functioning of the social-ecological system in the long term and is also why preserving redundancy instead of short-term efficiency may be desirable to ensure the resilience and adaptive capacity of a whole social-ecological system.

Walker et al. (2020), following the ideas of panarchy and adaptive cycles (Gundersen and Holling 2002), argued that 'social-ecological systems exhibit cycles of change consisting of sequential patterns of growth, development, crisis and reorganisation'. However, such integrated attempts looking at social-ecological systems transformations also tend to avoid making a clear characterisation and combined analysis of the four crucial subsystems dimensions selected here and their interactions. This comprises the role of information and knowledge systems in the configuration of institutional systems or an explicit non-anthropocentric characterisation of human agency in relation to institutional system transformations. In fact, they seem to assume that a system's transformation is possible without a transformation of the actual understanding and nature of individual agency. The SEIC approach does not assume co-adaptive equilibrium, nor does it expect eventual system's reorganisation or self-regulation either. This may happen, but it will not necessarily happen. Mostly because social-ecological interactions and dynamics are in constant evolution, many following complex dynamics which cannot be known beforehand – as they depend on human will and unpredictable decisions. Collapse may also occur, for instance, when the growth of a system surpasses certain biophysical limits, or when the intensity or scale of changes create the kinds of risks and system conditions that are no longer able to be tackled with the available knowledge, resources, or governing capacity of institutions.

In this respect, Joseph Tainter proposed the collapse of complex societies would result from decreasing marginal returns of increasing sociopolitical complexity (Tainter 1988; following Boserup; see also Wells 2013). Nevertheless, an abrupt simplification of a system, parallel to a sudden increase in structural entropy and dissipation can occur in institutional or economic systems dynamics (part of S and I subsystems), or of whole SEIC subsystems interactions, albeit expressed in different modes. Moreover, the complexification of one subsystem, such as the I-subsystem derived from financial innovation or in the E and C subsystems by nuclear technologies and waste, may not only respond to the need to solve social problems (as pointed out by Tainter) but it also responds to political and economic interests. It may be driven by the individuals' wishes to gain a more advantageous position within the existing power structure or upon other societies. All in all, the possible whole systems collapse, or regeneration (Schwartz and Nichols 2006) depends on the interlinked dynamics of all these subsystems. In fact, societal-ecological regeneration may also occur in theory, e.g. as a result of experimentation and learning (Carperter, Brook, and Ludwig 2002; Tàbara 2013), but only if all the interactions between the SEIC subsystems are considered and reoriented towards a transformative vision of society.

Although each of the socio-environmental interactions represented by the SEIC subsystems components can be configured in different ways, the transformation of social-environmental practices take time, and some take more time than others. Also, some practices may be changed simply at individual level, while others need to be done at organisational or large systems levels. For instance, becoming vegetarian to reduce carbon footprint may be done immediately, while restoring a large ecosystem may take several decades.[5] The actionable understanding of regenerative sustainability challenges requires the coupling of human information and knowledge systems practices with global environmental change (Tàbara and Chabay 2013).

Towards regenerative sustainability pathways

On positive tipping points, capitals, and regenerative pathways

A mounting strand of social and interdisciplinary research is looking at how our social-ecological systems conditions and interactions could fast be reconfigured in a deliberate way to cope with accelerated global environmental change by focusing on the notion of tipping points (O'Riordan 2013; Otto et al. 2020; Tàbara et al. 2018) Traditionally, tipping points have referred to the thresholds that occur when a small additional change or event provokes a sudden, profound and qualitative change in a system of reference. Tipping points can be either negative or positive, induced and deliberately brought about by conscious action or resulting from forces beyond human awareness, intention, or reach. They are never induced or activated by one single action but emerge from the combination of numerous forces and previous changing conditions within many social-ecological systems components. These may also be the result of relatively slow processes that once combined activate abrupt, fast and larger systemic changes. Research is still needed into the most adequate incentives, capacities, knowledge, and governance systems configurations able to reorient massive amounts of human, technical and economic resources towards global systems' transformations. On this, there is an incipient but growing number of research examples showing that there is a potential for the emergence of positive tipping points at large-system levels derived from micro-solutions and actions taken at smaller scales of human action, including those that have to do with local regime innovations and polycentric arrangements encouraging continuous learning and experimentation (Fesenfeld et al. 2022; Ostrom 2012; Tàbara et al. 2019, 2021; Winkelmann et al. 2022). From these experiences, it may then be possible to learn how to build the transformative conditions and processes for social-ecological systems to tip towards deliberate sustainability trajectories or whole life-systems' attractor.

As possible straightforward strategy to translate this broad systems' thinking and explain the notion of regenerative sustainability and its connections to tipping points is to look briefly at the notions of social and biophysical capitals (related to social-ecological systems stocks). On the one hand, social capital can simply be understood as those individual and social capacities derived from past learning interactions and processes that allow for continuously building of the necessary conditions for human dignity, self-realisation, and welfare. These social conditions include dimensions such social trust, governance capacities, equitable institutional arrangements or other socially constructed mechanisms that help create further social cohesion, inclusiveness, and cooperation. On the other hand, biophysical capitals relate to the biophysical conditions that make possible the flourishing of all diverse forms of life. Nevertheless, the conceptual distinction between social and biophysical capitals is only a methodological heuristic, because ultimately the building of regenerative conditions of sustainability will depend on the extent to which hybrid dynamic socio-environmental practices bringing the two together can be materialised.

A positive tipping point would occur when, following the confluence of deliberative transformative social actions aimed at transforming unsustainable practices, a relatively small cumulative effect would move a social-ecological system away from a trajectory that keeps on losing or degrading its social and biophysical capitals that make the conditions for regeneration impossible, to improving and renewing them through continuous self-propelling regenerative learning feedbacks and processes. For instance, applied sustainability research and action shows that strategies aimed at empowering women and the young through transformative forms of governance in ecosystems restoration processes can yield multiple collective benefits and catalyse virtuous processes of positive social and biophysical improvements.[6] Regenerative sustainability is therefore based on the assumption that the cumulative anthropogenic effects on the C-system do not necessarily need to be negative or depletive but can actually contribute to ecological restoration (see Gross 2000) or more broadly to social-ecological system renewal. Net-positive outcomes, in contrast to approaches that understand sustainability improvement as 'reducing harm' or 'achieving neutral outcomes (e.g. carbon neutral), need to be considered at the core of regenerative sustainability discourses. Such

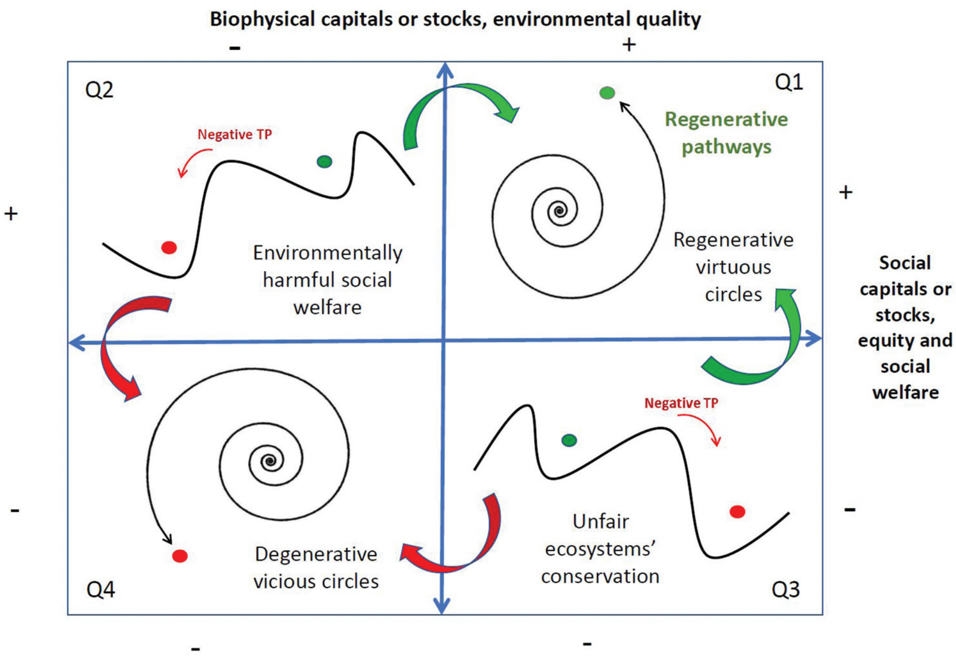

Figure 2. Moving towards regenerative development pathways depends on the extent to which human-systems interactions contribute to improving and restoring both social and biophysical capitals *at the same time* (Q1). In quadrants Q2 and Q3 social-ecological systems are instable and tend to move toward negative development pathways or negative basins of attraction, eventually leading to degenerative vicious circles of development (Q4). In Q4 not only future opportunities for human welfare, dignity and equity are reduced, but also the basic conditions that make life possible on Earth are undermined. Achieving a net-positive tipping point leading towards Q1 requires deep transformations in social-environmental practices at different levels of agency and also in the ways humans conceive and perform all SEIC subsystems' interactions.

approaches should also help to avoid many of the ambiguities that have created much confusion around this concept so far by mainly focusing on procedural components rather than on actual outcomes, e.g. in restoring social-ecological stocks or capitals. This is represented in Figure 2:

Moreover, environmental research also shows that in a *given context of research and in a given moment in time*, well-managed co-produced restoration processes can reverse ecological degradation and yield many net-positive outcomes. Nonetheless, yielding and securing such positive outcomes can only be achieved in the long term by improving access, equity and participation, and therefore the definition and assessment of such net-positive outcomes require strong local engagement (Muhar et al. 2018). This entails, in terms of the SEIC model, that more inclusive and accountable institutional regimes (S) that tend to support individual reflexivity and more open and social-ecologically coupled knowledge systems (I) are more conducive to create the enabling conditions for tipping a given system toward sustainability transformations than those that do not deliberately intend to become so. In contrast, negative tipping points would then occur whenever the scale, pace and intensity of accumulated global environmental impacts (C) and social disruptions would irreversibly overcome the existing capacities – individual, organisational, informational or institutional – to cope with them; while negative tipping points would reduce the opportunities for development and, globally, put at risk the continuity of human life on Earth, positive ones would lead to new opportunities for whole-system regeneration and renewal.

On this note, it is also important to underline that human interactions with the biophysical world are not necessarily synchronic. When consuming fossil fuels (E), for example, we interact with plants and animals that were alive millions of years ago in ecosystems that may no longer exist although their altering agentic forces become 'alive' again through existing technologies and knowledge systems (I), institutional arrangements (S) and routinised practices. This consumption is not without consequences, as it also creates new socio-environmental conditions (C), some of which can only be known partially, that affect back future interactions. The interactions that the SEIC model addresses are dependent on the accumulative and depletive processes that occur in all of the four kinds of subsystems, and on the effects that they have on their life-support systems dynamics. For this reason, and from a regenerative perspective, humans are not inevitably 'running out of time' (Adam 1998; Lockie and Mei Ling Wong 2018); time, in its multiple dimensions and conceptions, can also be 'gained' whenever such conditions can be improved instead of being deteriorated, even though the new social-ecological conditions may not be the same as the original ones. The SEIC conceptual tool avoids trying to impose a priori any single or linear conception of temporality for all kinds of diverse social-ecological systems in which sustainability transformations may be discussed. In contrast, it allows researchers or practitioners to decide the relevance and most suitable scales and metrics of time to be used in the systems of reference in which they operate. In sustainability research, the SEIC model may be used to anticipate negative consequences of alternative configurations of socio-environmental practices, e.g. using pathways scenarios that consider multiple time frames.

This idea of regenerative sustainability is not only about 'what happens in systems out there' but also lies on a fundamental conception of the individual, of their social interactions and responsibilities with other individuals, as well as with the organisations and institutional or communicative settings in which they operate. Different regenerative lifestyles, sustainability-oriented practices and organisations may be developed around distinctive processes aimed at restoring, improving, and rebuilding both the individual and collective conditions for *socio-environmental quality interactions*. For instance, when agents learn how to rebuild trust within communities and their public communication systems, or where education systems enhance multi-sensorial capacities to discover and connect with the diversity of other life forms on Earth (see Galafassi, Tàbara, and Heras 2018; Heinrichs 2018).[7] Regenerative sustainability comprises a full set of relational whole life-systems' qualities and attitudes, both social and biophysical, in which alternative ideals of individual emancipation, the collective and the interactions with the biophysical world coalesce. Instead of ignoring biophysical systems in the social world, an alternative attitude that searches for mutual cooperation and learning with the natural world may be able to unleash the dynamic structural forces necessary to regenerate the basic conditions that make the diversity of life on Earth possible, including that of human societies in the long term.

The SEIC subsystems refer to distinct clusters of relevant social-ecological interrelationships (flows) that generate their cumulative and structural components (stocks) that influence and are influenced by human action. Ultimately, the ability for humanity to steer towards more sustainable development pathways will depend on the extent individuals and social organisations learn to implement moral visions able to create synergistic cooperations between social and biophysical systems and translate these visions into practical transformative governance arrangements (Hölscher and Frantzeskaki 2020).

A vision for global regenerative sustainability

Deliberate systems' transformations often start with a vision about what *kind of system we want to live in*. Visions influence social-ecological practices and interactions and are directly influenced by cultural worldviews, from which specific transformative capacities may then emerge in particular contexts (Tàbara et al. 2018). The elicitation and co-production of visions is crucial in the design of sustainability futures that can in itself be considered an essential form of sustainability knowledge.[8] As pointed out by Fazey et al., (2020), explaining how the world works 'in reality' or providing evidence-based knowledge and arguments or what 'we already see' is not enough to think about sustainability transformations:

> Relying on knowledge from the past to envision a new transformed future is not sufficient because it can constrain imaginations of what might be possible, analogous to driving forwards while looking through a rearview mirror (. . .). Such futures oriented normative knowledge is still a truth in the sense that it is 'true' to those who express it but is not a truth in the way evidence is usually conceived

Conventional general equilibrium economic growth models that have huge disciplining and practical influences on national and world politics are also based on implicit visions and paradigms about individuals and their relations with global systems. In these models, rational economic actors are often conceived of as totally independent individuals, as a kind of abstract environmental aliens and utility maximisers playing a never-ending predatory competition game in which the position of humans over life-support systems is mostly of dominance, property and immediate use. People adhering to these formal and very sophisticated mathematical models, taught at top universities around the world, must necessarily find it very difficult to think about non-exemptionalist, synergistic, and collaborative relational strategies between humans and natural systems. In such models, access to natural resources or dealing with issues like climate change are often framed as win-lose games, or as burden-sharing situations (Tàbara et al. 2013), rather than the search for multiple and regenerative wins. In such reductionist views of human agency, dominant dualisms between nature versus society, between the individual and the collective or between present versus future (e.g. through discount rates) are culturally reinforced.

However, a completely different vision of the economy, and of societies and models representing individuals' roles within them, is possible: a regenerative vision (Hestad, Tàbara, and Thornton 2020; Reed 2007; Robinson and Cole 2015), of collaborative practices that emerge within coupled social-ecological systems (Tàbara and Chabay 2013) and that takes into account a global, long-term and equity-enhancing perspective. Under this perspective, the contextual configuration of individual rationalities, practices and emancipation aspirations would not be driven by the desire to maximize short-term utilities but rather, on improving and restoring the quality of human and biophysical relationships. In a would-be regenerative society, deliberate actions are mainly oriented to unfold mutual synergistic forces between coupled life-support and social systems -or capitals. In this theoretically plausible better-off situation, the opportunities for just, inclusive development would be constantly extended and improved. This would be so because the necessary biophysical stocks and conditions to ensure the adequate functioning of life-support systems on earth would be constantly improving and their social and biophysical capitals expanding, instead of being continuously degraded and shrunk as is currently the case.

Related to this vision, the Earth Commission, an international team of concerned natural and social scientists associated to with the Commons Alliance,[9] is working to scientifically define and assess a 'safe and just corridor for people and the planet' where synergies and trade-offs between social and ecological targets and aspirations are being considered. It is argued that safeguarding the Earth's life support systems while ensuring that Earth benefits, risks and responsibilities are equitably shared constitutes the grand challenge for humanity, recognising that the human development needs will remain for a world population of possibly 10 billion people in 2050 (Rockström et al. 2021). Under these circumstances, moving towards such a hypothetical corridor would require endless kinds of interlinked transformative strategies and development pathways at different levels of agency and temporal and spatial scales. Such clusters of transformative solutions and capacities aimed at transforming present unsustainable practices would also need to combine the most robust knowledge about the kinds of systemic global risks and how to address them. And do so in a way that the opportunities to increase planetary ecosystems resilience consider different notions of justice, e.g. global, intergenerational, and interspecies justice (Gupta et al. 2023) in ways that are respectful to diverse cultural contexts. In particular, four main kinds of global systemic transformations have been identified by the Earth Commission (Gupta et al. In press) to ensure a safe and just corridor for humanity: in economic systems, in governance, in technologies and in consumption - although a more relational worldview of human action and system interactions to attain such transformations may be needed. On this basis, it seems obvious that the world will only become ecologically safe by becoming just at the same time, a vision that can be represented using the previous reasoning on restoring social and biophysical capitals[10] in Figure 3:

From this perspective, there is no reason to believe that unsustainability is a necessary or inevitable outcome of human development, but only one of the possible ones, and that ultimately depends on our perceptions, understanding and awareness about how we interpret the systems in which we live and what we think the role of individuals are in them. Inevitably, the social and ecological conditions of future world situations will be of a very different nature from those we know today – as many species will have already disappeared and climate change will have already generated many unavoidable impacts. But even in these largely altered conditions, realising such regenerative vision may be a plausible way out (Milbrath 1989) and perhaps the only one for the continuity of human societies on Earth.

Possibilism, not probabilism

The SEIC model can be used to discover and identify alternative transformative development pathways that could not have been considered otherwise, but it cannot be used to assess the probability of their success. Theories and practical pathways aimed as exploring how to build the conditions for positive tipping towards regenerative sustainability – those that would restore and constantly improve social-ecological stocks and capitals to ensure that life-systems flourish in the long term – must necessarily be based on possibilism, not probabilism. Each social-ecological system around the world is different, which means that sustainability challenges and the possible strategies to tackle them must always be contextually and relationally constructed; and that the plausibility of their success cannot be assessed until engaging in situated research into the nature and dynamics of the various SEIC components and interactions.

This perspective, based on possibilism, should also help to develop more realistic and cautious interpretations about sustainability transformations. First, because it would acknowledge the large complexities of social-ecological systems and the relatively limited human cognitive capacities to deal with them; second, because it would provide an operational conceptualisation that can be used in transdisciplinary sustainability research and action; and third, because it would also acknowledge the central role of individuals' reflectivity and freedom, and of the crucial role of changes in worldviews and ethics through systems learning when trying to increase the number of alternatives for sustainability transformations. In a nutshell, positive tipping points towards regenerative sustainability could happen, albeit we may not be able to anticipate whether or when they will happen. However, conscious and responsible interactants may be able to contribute deliberately to building transformative

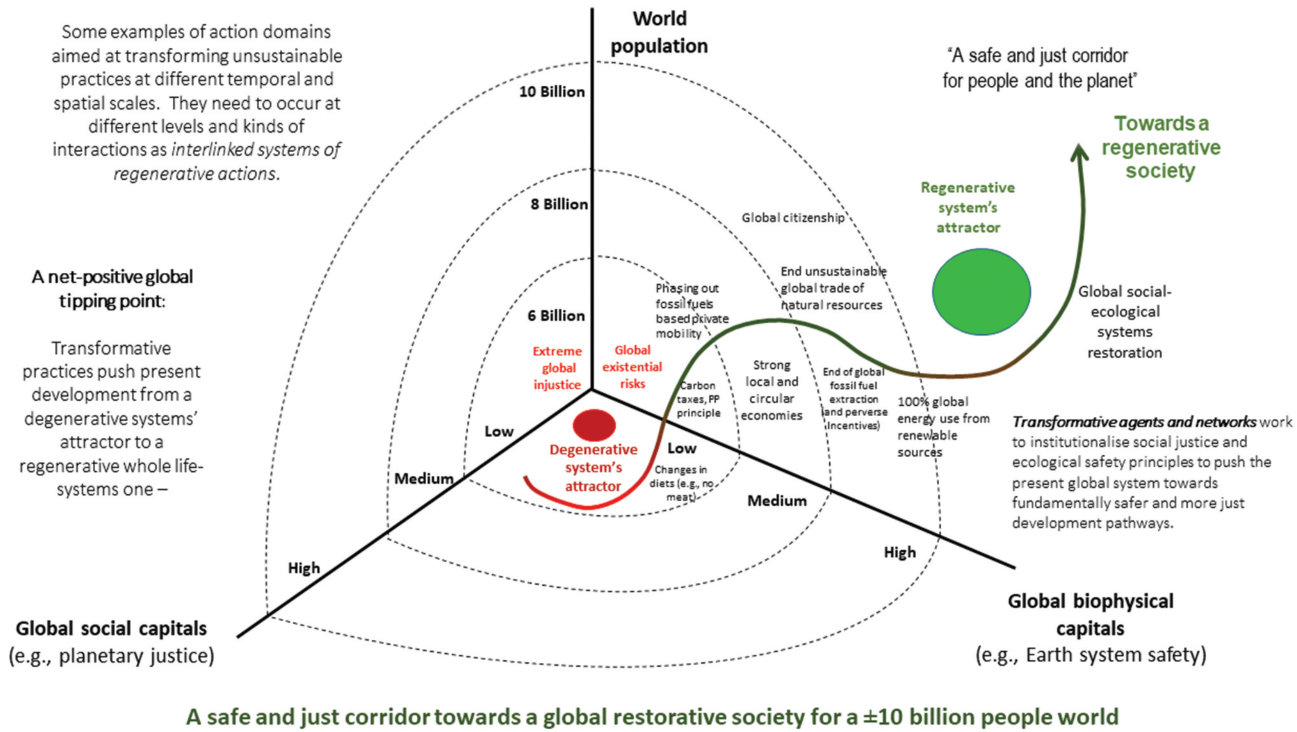

Figure 3. A plausible global positive tipping point towards a regenerative societal attractor (green dot) that considers a safe and just corridor for people and the planet and a world population of possibly 10 billion people by 2050. Note that the opposite development, the descent into a degenerative global system's attractor (red dot) where social and biophysical capitals are depleted, is also possible.

conditions for their emergence considering all the SEIC socio-environmental components and interactions *at the same time*.

Five initial propositions

In acknowledging that a central challenge for regenerative sustainability is to turn general conceptual models into guidance for action, from the previous conceptual analysis it is now possible to offer some first propositions towards this end. In particular, and at the level of social organisations and societies, creating the conditions and capacities for the emergence of net-positive tipping points would need to consider the following:

(1) *Accelerating deliberate change will require combining regenerative-oriented actions in all SEIC subsystems in a co-evolutionary synergistic way*. Positive tipping points may emerge from synergies and mutual beneficial effects derived from regenerative strategies aimed at transforming socio-environmental practices at different classes and levels of action and temporalities. Thus, interventions limited to one subsystem alone (such as internalising carbon costs in price systems) will not be sufficient to prompt such kind of fast uptake of self-propelling cycles of positive systemic changes.

(2) *Increasing the possibilities for regenerative sustainability may entail reducing the size and speed of social-ecological systems' interactions to secure life-support systems resilience and restoration*. Adapting SEIC subsystems interactions to respect life-support cycles and processes could create the necessary conditions for multiplicative virtuous regenerative feedbacks and effects and new opportunities for just transformations at large-systems' levels.

(3) *Justice in its multiple dimensions, because it is a major driver and outcome of positive tipping points, and needs to be considered at the core of all regenerative transformative actions. However, ideas of justice are also dependent on notions and models about individual emancipation, agency, and systems' configurations*. Moving towards safe and just global sustainability development pathways necessitates deep transformations in cultural worldviews, conceptual models, and beliefs (e.g. moving towards more relational ideas of justice) that acknowledge the fragile, relational and dynamic qualities of the conditions that make life-support systems viable.

(4) *Long-term sustainability would require maintaining structural complexity, diversity, and degrees of freedom in all the SEIC subsystems to ensure that positive synergies between social and biophysical systems can be generated and enhanced*. Too rigid, hierarchical or sclerotic institutional regimes are likely to constraint the mutually creative forces that need to be unleashed to restore and regenerate the social and biophysical capitals that constitute the basic conditions for sustainability.

(5) *Second-order learning is the only way to ensure positive tipping points towards global regenerative sustainability*. This entails acting differently following non-exemptionalist and coupled social-ecological visions of individual and collective agency, following relational paradigms of net-positive sustainability that take into account all the SEIC socio-environmental interactions under a whole life-systems perspective.

(6) *Available time for avoiding a global negative tipping point is dependent on the intertwined cumulative or depletive processes occurring in all the SEIC kinds of interactions*. Our time is 'lost' to the extent business-as-usual unsustainable pathways and socio-environmental practices continue to deplete social and biophysical capitals, instead of being restored and continuously regenerated.

Conclusion: the conditions of sustainability

Moving contemporary societies toward regenerative sustainability is theoretically possible. However, the non-exemptionalist conceptual tools able to explore in an integrated mode the necessary conditions and possibilities for the emergence of a global regenerative future are still largely lacking. New cohesive approaches and analyses, possibly leading to the development of ecological sociology, may help towards that end. In this contribution, it has been argued that such deliberate transformation processes, and in particularly those aimed at activating positive tipping points understood as those relatively small and effective individual but relational actions or policy interventions that at one moment trigger deliberate, large and self-propelling processes of positive qualitative structural change ought to occur across different forms and levels of agency and integrate principles of whole life-systems' safety and justice.

The SEIC conceptual model constitutes only a heuristic proposal aimed at reinterpreting social-ecological interactions in a relational, non-dualistic, non-exemptionalist ways towards this end. The SEIC model does not refer to any particular society, organisation or individual, but only to the kinds of social-ecological systems relationships that they necessarily maintain. Moreover, it conceives the reconfiguration of the interactions between human actors and non-human actants as fundamental of regenerative processes. In practice, the specific kinds of biophysical and social components and how they affect social groupings will depend on the context and purpose of study and/or interventions in which the SEIC model could be applied. The SEIC model is only a tool where situated (ground-theory) explanations could emerge from the actual implications of researchers and/or practitioners in their particular contexts or systems of reference. This implies a humble and limited epistemological stance: in any context of action, we cannot know beforehand whether or when positive tipping points and substantial transformations will occur. However, we create the learning spaces, capacities and conditions for such situated practices, strategies or broader regenerative transformations to emerge.

Replacing an antagonistic worldview of societal interactions with collaborative and regenerative ones searching for positive synergies beneficial effects between biophysical and social dynamics has profound implications in many domains of human action. These include areas such as medicine (e.g. in finding alternative treatments to antibiotics), agriculture (e.g. phasing out pesticides and biocides in favour or regenerative agriculture), individual health and lifestyles (by transforming diets to those improving personal well-being and creating net-positive impacts on global food systems), education (in how economics is taught in universities around the world) or in urbanism, land use planning and housing. However, whilst broad-systems transformation towards regenerative sustainability seems possible, it is not necessarily likely. The arguments posed here constitute only a conceptual tool to help discover the possibilities for systemic transformations, even at the global level. But *it does not assume probability, only plausibility*. It only asserts all the SEIC subsystems *can be reorganised following regenerative principles and that such an endeavour needs to be done in all subsystems at the same time*. From the above rationale, there is no reason to believe that societies or any kind of social-ecological system necessarily has to be configured in unsustainable modes. Positive tipping points may be possible, but only as emergent, hybrid outcomes of the confluence and coordination of multiple regenerative transformations across and within each of the four main SEIC subsystems. On this note, transformative worldviews, paradigms and ethical principles are crucial in such coordination, even though they may differ in different social-ecological systems or contexts. However, the opposite is also possible: the global society, understood also as a total social-ecological system, may also descend down the corridor and attractor of degenerative development, by continuing to deplete and degrade the social and biophysical capitals upon which its long-term sustainability depends on.

In short, global environmental problems are relational problems that is, about how each of us relate to each other and to global social-ecological systems. Deliberate transformations and pathways intended to address them also need to be relational. The perspective proposed in this contribution is also a theory of emancipation, based on a greater awareness and reflectivity on the requirements necessary for improving the quality of systems' relationships. This requires continuous learning, reflectivity, and individual and collective regenerative development pathways aimed at transforming the recursive mechanisms that now mediate our social-ecological interactions. This approach particularly underscores the importance of individual and collective agency in creating transformative dynamics. The SEIC model, together with a relational worldview, such as the one presented here, extends and situates the idea that conscious individuals are ultimately free to choose (at least in liberal democracies) their own futures although this is always done *in relation* to others and their broader biophysical and institutional contexts. Moving away from individualistic, utility-maximising, and atomising modes of understanding human agency to others perspectives based on the idea of conscious interactants' contributing to personal and collective regenerative capacities, also entails a deep change in identities, self-perceptions and a whole new repositioning of what is understood by being human in the context of accelerated global environmental change. From this perspective, the new mode of social-ecological relational emancipation is not about consuming more and faster or more efficiently; but instead about *becoming better*, and collectively becoming a wiser and more environmentally conscious society. Or, by extending Georg Simmel's thoughts to the environmental realm, by finding out that at the end of our quest for individual freedom and self-realisation, we find out that this is inevitably done and shared with others[11] but in which these 'others' also include the rest the living beings on Earth.

Notes

1. For instance, the UNEP report *Making Peace with Nature* (2021:104) asserts that 'A sustainable future is achievable'. However, it does not provide a comprehensive theory of change on how to achieve it: 'https://doi.org/10.18356/9789280738377
2. No direct causality between knowledge and action or the 'knowledge sharing paradigm' is assumed here, as transformative action needs a lot more than just system's knowledge to be realised (Arponen 2013) and many other issues such as situational logics, incentives, options, resources and recursive institutional changes also play a crucial role (Tàbara et al. 2010).
3. In the C-subsystem, accumulation -or depletion- is referred to as direct qualitative and quantitative changes mostly in biophysical systems, even though the loss of biodiversity also negatively affects the information pool upon future sustainability may depend on. Hence, it does not refer to cumulative

processes of social practices and routines, that lead to new structural contents and forms, being that these are part of the S-Subsystem (see Ollinaho 2016).
4. In economics a dominant measure of the growth size of an economy is the GNP. But it is clear that such quantitative measure omits many other fundamental qualitative changes in social-ecological stocks and flows, like those between information and biophysical components or the loss of biodiversity, which are critical for human development and sustainability. Determining the content, forms or size of a social-ecological system is not an independent or objective task that can be separated from its observer. Size and configuration of a systems are as much social constructs as material ones, and in this respect, it is also a relational endeavour. Transdisciplinary and participatory research can help to develop processes of knowledge co-creation to bring in multiple perspectives so as to decide these temporal, spatial and qualitative aspects of a given system (Tàbara et al. 2021).
5. http://www.highendsolutions.eu/page/transformative_solutions
6. https://www.devalt.org/
7. A whole set of environmental senses which have been largely annihilated as a result, among other reasons, by the prevalence of urban and industrial lifestyles, the monetary economy, the unfulfilling division of labour and competitive-oriented education.
8. It can also be argued that in non-causal complex systems, in which a large part of social dynamics may follow, the configuration of present systems also depends on future inputs or states, and even of those states that are presently unknown.
9. https://earthcommission.org;
10. The vision representation provided in Figure 3 is only a personal interpretation of the Earth Commission safe and just corridor and does not represent the views of the Earth Commission.
11. G. Simmel. *Das Individuum und die Freiheit*. Spanish Translation by S. Mas 1986. El Individuo y la Libertad. Barcelona: Península.

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Notes on contributor

J. David Tàbara, Independent Associate Researcher, Autonomous University of Barcelona and Global Climate Forum, info@sustainabilogy.eu.

ORCID

J. David Tàbara http://orcid.org/0000-0002-3086-5414

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