ENVIRONMENTAL RESEARCH
LETTERS

PERSPECTIVE • OPEN ACCESS

In complexity we trust: learning from the socialist calculation debate for ecosystem management

IOP Publishing Environ. Res. Lett. 18 (2023) 051001 https://doi.org/10.1088/1748-9326/accc45

ENVIRONMENTAL RESEARCH
LETTERS

CrossMark

OPEN ACCESS

RECEIVED
9 December 2022

REVISED
24 March 2023

ACCEPTED FOR PUBLICATION
12 April 2023

PUBLISHED
19 April 2023

PERSPECTIVE

In complexity we trust: learning from the socialist calculation debate for ecosystem management

Nicolas Salliou[1,3,*] and Ana Stritih[2,3,*]

[1] ETH Zurich, Institute for Landscape and Spatial Development, Planning of Landscape and Urban Systems (PLUS), Stefano-Franscini Platz 5, 8093 Zürich, Switzerland
[2] Technical University of Munich, TUM School of Life Sciences, Chair of Ecosystem Dynamics and Forest Management, Hans-Carl-von-Carlowitz-Platz 2, 85354 Freising, Germany
[3] Shared first-authorship.
[*] Authors to whom any correspondence should be addressed.

E-mail: nsalliou@ethz.ch and ana.stritih@tum.de

Keywords: complexity, uncertainty, restoration, ecosystem management, self-organization, socio-ecological systems, central planning

1. Introduction

Protecting, restoring, and adapting ecosystems will be crucial for addressing the global challenges of the Anthropocene, but managing complex ecosystems under changing conditions is far from simple. Functioning ecosystems supply a wide array of ecosystem services and provide nature-based solutions to reduce climate-related risks, but their capacity to do so is jeopardized by the impacts of climate change and biodiversity loss. The importance of managing ecosystems for nature-based solutions is increasingly recognized by many governments, who have committed to ambitious top-down pledges, such as restoring 200 million hectares of degraded ecosystems within the Bonn challenge or planting 3 billion trees in the European Union's biodiversity strategy for 2030. However, planning effective nature-based solutions is challenging. Simplified top-down solutions, such as large-scale tree planting, have shown limited success, sometimes even resulting in a loss of biodiversity and ecosystem services or exacerbated wildfire risk (Fleischman *et al* 2020).

Managing ecosystems is challenging because of their complexity, their spatial and temporal variability, the diversity of agents with different values and perspectives that interact within these systems, and the uncertainty about how they will develop in the future. Questions about how to manage complex systems under uncertainty have long been debated in other fields, such as economics. The 20th century witnessed a prolonged debate between liberal and socialist economists, with different views about the capacity of a centralized authority to successfully plan an economy, based on divergent assumptions about knowledge, uncertainty, values, autonomy of individuals and complexity. We believe that some of the lessons from this 'socialist calculation debate' can provide a relevant perspective on the contemporary challenges of ecosystem management. In this paper, we briefly synthesize the 'socialist calculation debate', draw parallels between managing an economy and managing an ecosystem, and derive relevant lessons for ecosystem management. We argue that centralized, top-down optimization of socio-ecological systems is unlikely to be feasible, and analogous to a liberal economy, ecosystem management should focus on ensuring the conditions for socio-ecological systems to function and self-organize as complex systems. We also discuss the implications of this perspective for researchers that aim to support better ecosystem management, such as ecologists, landscape planners, socio-ecological scientists, or land-system modellers.

2. A brief summary of the socialist calculation debate

The 1920s saw the beginning of the socialist calculation debate between liberal economists, most notably Ludwig von Mises and Friedrich Hayek, and socialist economists such as Oskar Lang and Abba Lerner (Rothbard 1991). They disagreed about the capacity of a central authority to manage an economy efficiently, and this disagreement was particularly important during the cold war. Socialist economists believed that with sufficient information and a trial and error strategy, a centralized state would be able to plan production and satisfy the needs of its citizens. This strategy relied on Leon Walras' general equilibrium theory, according to which an economy under perfect market conditions would stabilize at a price equilibrium, optimizing supply and demand. The trial and error mechanism of socialist economists assumed that a central authority could progressively reveal this price equilibrium point and set the economy accordingly.

In contrast, liberal economists believed that planning an economy is impossible due to the high level of complexity and innumerable interactions of the system. They believed that the assumption of a general equilibrium was flawed, as the theory of equilibrium is disconnected from uncertain and ever-changing real-life markets. In addition, they did not believe that a single institution has the capacity to keep track of the enormous amount of day-to-day decisions made by millions of autonomous and diverse economic agents, and to calculate optimal prices and production rates accordingly. Hayek argued that the uncertainties and scale of such a calculation would make it practically impossible. Instead of centralized planning, liberal economists believed that the role of a government was only to provide boundary conditions for free interactions of economic agents, such as clear property rights enforced by a fair judiciary system. Under such conditions, agents such as consumers and entrepreneurs can have maximum autonomy in their decision-making to integrate information and influence price signals locally. The decentralized interactions of many agents would lead to the emergence of a functioning market and improved economic outcomes (Hayek 1982). This understanding of the economic system became dominant with the collapse of the Soviet Union, as the inefficiency of Gosplan, its central planning authority, demonstrated the impracticalities of centrally managing a complex economy (Rothbard 1991).

3. Parallels to ecosystem management

Similar to markets, ecological and socio-ecological systems are complex systems where innumerable human and non-human agents interact, and their distributed interactions lead to the emergence of patterns at a higher scale. For example, in river ecosystems, local-scale interactions between plants and water flow result in patterns of heterogeneous habitat patches at the stream level, providing diverse habitats and regulating streamflow (Cornacchia *et al* 2020). In socio-ecological systems, local stakeholders with clearly defined property rights self-organize to develop institutions, enforce sustainable management practices, and cope with social and ecological uncertainties (Ostrom *et al* 2012).

Diversity is an important condition for well-functioning markets and socio-ecological systems, which are prone to similar structural inefficiencies when facing monopolies and oligopolies. In markets, overly dominant companies can lead to inefficient markets by manipulating prices, eliminating competitors and reducing innovation. Similar inefficiencies have been shown for socio-ecological systems, as their resilience is reduced when the diversity of actors is limited (Grêt-Regamey *et al* 2019), while biodiversity is generally linked to improved ecosystem functioning (Gonzalez *et al* 2020).

The mismanagement of economies and socio-ecological systems often stems from similar policy mistakes: simplifying a system to gain in predictability rather than accepting uncertainties to allow for complexity. While socialist decision-makers were attempting top-down control to establish a fair and stable post-capitalist economy according to the simplified model of the general equilibrium theory, many ecosystem managers have attempted to control ecological processes to achieve a stable and predictable provision of natural resources. Attempts to reduce ecosystem heterogeneity and complexity made these systems less resilient and more vulnerable in the face of extreme, unexpected events (Holling and Meffe 1996). For example, the suppression of forest fires and disruption of indigenous land-management practices in western North America led to more homogeneous landscapes and a higher risk of extreme fires (Hagmann *et al* 2021).

There are also some dissimilarities between economies and socio-ecological systems. Markets are shaped by one species—humans, who interact using price as a signal. Ecosystems consist of a wide range of species, and the signals they interact with can be physical, chemical, or biological, and as such, more difficult to monitor than prices in a market. In addition, while self-organizing markets tend to efficiently provide private goods (e.g. cars), they tend to be ill-suited to deliver public goods (e.g. air quality), and regulation by a state or other authority is often needed to secure the provision of public goods or reduce harmful effects on the environment (Hayek 1944). In contrast, complex and self-organizing ecosystems often efficiently provide public goods, such as air purification and climate regulation. These dissimilarities further underline the need to foster complex, functioning ecosystems.

4. Implications for ecosystem management—support self-organization of complex ecosystems

Fostering complexity and self-organization in ecosystems means giving space to processes such as stochastic disturbances (e.g. fires, floods, or insect outbreaks), trophic complexity (including the presence of large predators) and connectivity across space (Perino *et al* 2019). These processes can make ecosystems more resilient and capable to cope with future changes (Bullock *et al* 2022). Their importance is increasingly recognized, especially in the context of rewilding. However, giving space to ecosystem complexity is also possible in the context of natural resource management. For example, ecosystem-based approaches to forest management aim to maintain ecosystem processes and biodiversity while managing forests for timber and other ecosystem services (Messier *et al* 2015). In the context of rapid global change, this type of management requires that individual ecosystem managers have the agency, capacity, and flexibility to adapt their local management to changing ecological and social conditions.

In both markets and socio-ecological systems, self-organization occurs at different scales, which are nested from the smallest to the largest scale. The recognition of this nestedness in socio-ecological systems led to the promotion of the subsidiarity principle, where the relevant scale of governance should be the smallest possible scale (Marshall 2008). This principle is consistent with liberal economics, which promotes the highest possible level of agency to individuals and freedom to contribute to higher levels of organization.

In many cases, giving space to self-organization means less rather than more intervention in ecosystems. For example, in the restoration of tropical forests, natural regeneration has been shown to be more successful and faster than active regeneration (i.e. tree planting) (Crouzeilles *et al* 2017). Similarly, removing constraints on natural regeneration is likely to outperform planting in mangrove restoration (Su *et al* 2021), and removing anthropogenic barriers to restore connectivity in river-floodplain systems improves flood regulation, water quality, and freshwater biodiversity (Wohl *et al* 2015). However, hands-off approaches are often overlooked as valid policy options, perhaps due to people's preference towards additive intervention (Adams *et al* 2021). While initiatives to 'plant a billion trees' might sound more appealing than 'allowing forests to regenerate', hands-off approaches to ecosystem management may often be more effective (and cost-efficient) than active interventions.

Sometimes, active interventions are necessary, particularly when complexity is decreased and the conditions for self-organization are not met. In economies, many liberal economists agree that states should intervene to break up monopolies and enable diversity and fair competition. Similarly, interventions in ecosystems are needed when ecological processes are disrupted to the extent that self-organization is not possible. For example, when dispersal is prevented by a lack of connectivity between forest patches in a fragmented landscape, planting trees can kickstart forest regeneration. Such active interventions are more likely to be successful on the long term if they prioritize strengthening complexity and self-organizing processes in ecosystems (Bullock *et al* 2022), and ensure the agency and land rights of local communities (Fleischman *et al* 2020).

5. The role of research

Many researchers aim to support better decisions in ecosystem management. As more data becomes available at higher spatial and temporal scales, and as modelling techniques progress, it has become increasingly popular to produce models and maps that could inform policy decisions, such as optimising regional ecosystem services or prioritising global ecosystem restoration actions. While such large-scale datasets are interesting from a scientific perspective, they often neglect the diversity and autonomy of agents (e.g. local land users) that would be affected in case these models were translated into policies (Wyborn and Evans 2021). We therefore believe it is important to remain humble about our capacity to predict and optimize the development of socio-ecological systems under uncertainty. Instead of proposing large-scale top-down solutions to the complex problems of climate change or biodiversity loss, scientists can engage in participatory processes and explore future scenarios together with other stakeholders. Such transdisciplinary research can support the autonomy of local agents and strengthen the self-organizing capacity of socio-ecological systems (Lang *et al* 2012).

Although the relevance of participatory approaches in decision-making is increasingly recognized, many decisions regarding ecosystem management are still ultimately taken in a top-down manner. In this context, parallels between economies and ecosystems could serve as a tool to better communicate the limitations of such command-and-control approaches, the importance of complexity, and the utility of hands-off approaches in ecosystem management to decision-makers that may be more familiar with economics rather than ecological theory. Therefore, further research is needed to understand the system characteristics and processes that are essential for ecosystems' complexity and self-organization capacity, and to understand in which cases interventions (or lack thereof) are needed to strengthen these characteristics. While many experiments have demonstrated relationships between biodiversity and ecosystem functioning at small scales, it is still unclear how these relationships change over spatial and temporal scales (Gonzalez *et al* 2020). A better understanding of how relationships between diversity, resilience, and self-organization can be translated across different ecological and socio-ecological systems could help inform more targeted and efficient conservation and restoration actions.

Data availability statement

No new data were created or analysed in this study.

Acknowledgments

We would like to thank Kristin Braziunas, Alexandre Baron, Adrienne Grêt-Regamey, Rupert Seidl, and two anonymous reviewers for their thoughtful feedback on earlier versions of this manuscript.

ORCID iDs

Nicolas Salliou https://orcid.org/0000-0003-3960-2175
Ana Stritih https://orcid.org/0000-0001-5323-8176

References

Adams G S, Converse B A, Hales A H and Klotz L E 2021 People systematically overlook subtractive changes *Nature* **592** 258–61

Bullock J M, Fuentes-Montemayor E, McCarthy B, Park K, Hails R S, Woodcock B A, Watts K, Corstanje R and Harris J 2022 Future restoration should enhance ecological complexity and emergent properties at multiple scales *Ecography* **2022** 1–11

Cornacchia L, Wharton G, Davies G, Grabowski RC, Temmerman S, Van Der Wal D, Bouma TJ and Van De Koppel J 2020 Self-organization of river vegetation leads to emergent buffering of river flows and water levels *Proc. R. Soc.* B **287** 20201147

Crouzeilles R, Ferreira M S, Chazdon R L, Lindenmayer D B, Sansevero J B B, Monteiro L, Iribarrem A, Latawiec A E and Strassburg B B N 2017 Ecological restoration success is higher for natural regeneration than for active restoration in tropical forests *Sci. Adv.* **3** 1–8

Fleischman F *et al* 2020 Pitfalls of tree planting show why we need people-centered natural climate solutions *BioScience* **70** 947–50

Gonzalez A *et al* 2020 Scaling-up biodiversity-ecosystem functioning research *Ecol. Lett.* **23** 757–76

Grêt-Regamey A, Huber S H and Huber R 2019 Actors' diversity and the resilience of social-ecological systems to global change *Nat. Sustain.* **2** 290–7

Hagmann R K *et al* 2021 Evidence for widespread changes in the structure, composition, and fire regimes of western North American forests *Ecol. Appl.* **31** e02431

Hayek von F A 1944 *The Road to Serfdom* (Chicago: University of Chicago Press)

Hayek von F A 1982 *Law, Legislation and Liberty: A New Statement of the Liberal Principles of Justice and Political Economy* (London: Routledge)

Holling C S and Meffe G K 1996 Command and control and the pathology of natural resource management *Conserv. Biol.* **10** 328–37

Lang D J, Wiek A, Bergmann M, Stauffacher M, Martens P, Moll P, Swilling M and Thomas C J 2012 Transdisciplinary research in sustainability science: practice, principles, and challenges *Sustain. Sci.* **7** 25–43

Marshall G R 2008 Nesting, subsidiarity, and community-based environmental governance beyond the local level *Int. J. Commons* **2** 75–97

Messier C, Puettmann K, Chazdon R, Andersson K P, Angers V A, Brotons L, Filotas E, Tittler R, Parrott L and Levin S A 2015 From management to stewardship: viewing forests as complex adaptive systems in an uncertain world *Conserv. Lett.* **8** 368–77

Ostrom E, Chang C, Pennington M and Tarko V 2012 The future of the commons—beyond market failure and government regulation *Indiana University, Bloomington School of Public & Environmental Affairs Research Paper No. 2012–12-02* (https://doi.org/10.1017/S0140525X11001282)

Perino A *et al* 2019 Rewilding complex ecosystems *Science* **364** eaav5570

Rothbard M N 1991 The end of socialism and the calculation debate revisited *Rev. Austrian Econ.* **5** 51–76

Su J, Friess D A and Gasparatos A 2021 A meta-analysis of the ecological and economic outcomes of mangrove restoration *Nat. Commun.* **12** 5050

Wohl E, Lane S N and Wilcox A C 2015 The science and practice of river restoration *Water Resour. Res.* **51** 5974–97

Wyborn C and Evans M C 2021 Conservation needs to break free from global priority mapping *Nat. Ecol. Evol.* **5** 1322–4