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Archetypes in support of tailoring land-use policies

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1. Introduction

Many policies in agriculture, forestry and other sectors aim to reduce social or environmental risks and enhance sustainable land use. For example, the European Union (EU) has implemented agri-environmental schemes to support farmers in managing their land in an eco-friendly manner and increasing biodiversity. However, implementing the same policy uniformly in different jurisdictions can undermine its effectiveness (Ostrom *et al* 2007, Sietz *et al* 2022). For example, the limited effectiveness of agri-environment schemes (Batary *et al* 2015) can be attributed to the pronounced variability and non-linearity in relationships between agriculture and farmland biodiversity, e.g. in protecting farmland birds (Whittingham *et al* 2007, Concepcion *et al* 2020, Roilo *et al* 2023). Therefore, land-use policies that are tailored to fit the characteristics of specific land systems are more effective than homogeneously implemented measures (Young 2013, Nolte *et al* 2017).

We define the tailoring of land-use policies here as a process that seeks to create a fit between instruments and processes of land-use policy on the one hand and properties of land-use systems in a particular place on the other hand (Epstein *et al* 2015). Tailoring influences policy effectiveness. For example, forest clearing practices in the Brazilian Amazon shifted from large-scale clearing to more extensive small-scale clearing (Assunção *et al* 2017). This shift in clearing practices made it more challenging for established policy and associated monitoring mechanisms to govern forest development in a sustainable way. This calls for tailoring policies over time to better address evolving land-use practices (Assunção *et al* 2017).

Land system science has made notable progress in recent years to support tailoring of land-use policies (Meyfroidt *et al* 2022). For example, middle range theories are creating illuminative explanations of land change processes such as agricultural intensification, land-use transitions or spillovers (Meyfroidt *et al* 2018). The normative foundations and implications of land system science are increasingly reflected (Nielsen *et al* 2019, Schneider *et al* 2019). Archetype analysis and other methodological approaches that generate and validate generalized knowledge claims are maturing (Magliocca *et al* 2018, Oberlack *et al* 2019, Eisenack *et al* 2021, Piemontese *et al* 2022a).

Archetypes of (un)sustainable land use and governance depict patterns of factors and processes that commonly shape the (un)sustainability of land-use systems across cases and contexts. Archetype analysis is a methodological approach to generalize knowledge from cases and case studies in context-sensitive ways and to build middle-range theories of land use systems (Oberlack *et al* 2016, Magliocca *et al* 2018). It can draw on a portfolio of methods (Sietz *et al* 2019) and design criteria (Eisenack *et al* 2019). Insights into archetypes can help transfer knowledge about solutions for sustainable development across contexts (Vaclavik *et al* 2016, Sietz *et al* 2017, Rocha *et al* 2020).

The Focus Issue on 'Archetypes of sustainable land use and governance' in *Environmental Research Letters* presents a collection of recent advances in archetype analyses within land system science. The Focus Issue aims to advance archetype analysis in the following ways: (i) enhance our understanding of recurrent patterns of land-use (change) processes such as deforestation or agricultural practices; (ii) promote methodological innovations in

archetype analysis; (iii) provide insights into governance strategies for more sustainable land use systems and (iv) inspire change agents to facilitate transformations towards sustainable land use systems. Based on these thematic and methodological advances, this Focus Issue critically reflects on using the notion of 'archetypes of land use' to tailor policies in a context-sensitive way and facilitate cross-context learning.

This editorial provides an overview of the key insights presented in the articles in this Focus Issue (section 2). It then describes three methodological advancements made by contributions to this Focus Issue (section 3). Finally, it explores how archetype analysis can support tailoring of land-use policies to land system properties (section 4), and it concludes with an examination of emerging frontiers, challenges and future research needs of archetype analysis in land system science (section 5).

2. Key themes across contributions

Tailoring policies to specific properties of land systems is crucial because the system properties can influence the effectiveness of policy implementation and the resulting outcomes. This Focus Issue explores how archetype analysis can inform policy tailoring based on four key properties of land systems.

First, archetypal patterns of social–ecological contexts deliver essential information for the tailoring of policies. For instance, Piemontese *et al* (2022b) analyzed 82 cases of sustainable land and water management practices in Uganda to demonstrate how archetypal social–ecological conditions influence the cost-effectiveness of management practices. Ceddia *et al* (2022) investigated how policy implementation differs across regions in Argentina due to specific configurations of pro- and anti-deforestation coalitions of actors, the presence and extent of capital-intensive agriculture and differences in forest cover.

Second, multi-tiered archetypes identified at different spatial scales can support the tailoring of policies that address land-use systems at various levels. For example, Beckmann *et al* (2022) identified archetypes of agri-environmental potential in Europe based on spatial clustering of variables that reflect land suitability and agricultural production capacity. Their typology can be adapted both for Europe in its entirety as well as smaller geographical extents. Thus, the resulting archetypes can be used to spatially target agricultural policies to agri-environmental potential, especially in the context of the EU Common Agricultural Policy. Similarly, creating multi-tier characterizations of farmland and farming practices can allow decision makers to harmonize agricultural production and delivery of ecosystem services at different intervention scales. To address this issue, Goodwin *et al* (2022) identified landscape and agricultural management archetypes at three levels, defined by opportunities for adaptation in Great Britain. Such multi-scale approaches can aid our understanding of the level at which policy interventions are most effective, from incentivizing changes in farmer behavior to policy drivers of broad land-use change (Piemontese *et al* 2021).

Third, understanding recurrent nexus relations between land use and other sustainability issues, including goals related to water, climate, food, biodiversity, and energy is crucial for tailoring policies (Ehrensperger *et al* 2019). Policymakers need to account for systemic interactions across sectors to prevent unintended consequences such as leakage or spillovers (Meyfroidt *et al* 2020). Sietz and Neudert (2022) conducted a systematic review of the archetypal interactions at the nexus between land, biodiversity, food and climate. Their findings revealed thematic (e.g. land-food nexus) and regional (e.g. central and western Europe) foci and the need to address knowledge gaps on interacting thematic aspects (e.g. biodiversity–climate interlinkages), social dimensions (e.g. governance, human behavior) and currently underrepresented regions.

Fourth, policy tailoring also needs to account for patterns in land-use trajectories over time, including newly emerging risks and opportunities (Sietz and Feola 2016, Van den Elsen *et al* 2020). Baumann *et al* (2022) conducted a study on forest frontiers in the South American Chaco region between 1985 and 2020. They identified ten different archetypal trajectories that characterize dynamics in 60% of the forest frontiers in the Chaco. The authors argued that understanding these distinct configurations is crucial to attribute deforestation to commodities in appropriate ways, and to govern different land uses in different policy fields.

3. Methodological advances

The contributions in this Focus Issue introduce three methodological advances of archetype analysis. One prior challenge in this field has been the lack of standards for validating archetypes. This gap has led to uncertainty about the credibility of knowledge claims based on archetypes. To address this issue, Piemontese *et al* (2022a) developed a practical framework for validating archetypes. It guides researchers throughout all stages of archetype analysis, providing insights both for researchers identifying archetypes and reviewers assessing their validity. By applying the assessment to 18 published archetype analyses, the authors found that the most frequently applied dimensions of validation in these analyses were conceptual (i.e. research framing and problem-driven research questions) and internal (i.e. methodological and replicability) validity, while external and application validity were less frequently applied. One reason for this finding may be that deliberate planning of validation is not yet a common practice in archetype

analysis, and many publications do not report in detail on validation procedures or lack any validation. To improve this situation, the authors recommend co-designing problem framing and hypothesis formulation between researchers and stakeholders to enhance communication, relevance, and uptake in political practice.

The second methodological advance focuses on understanding archetypes across scales (Beckmann *et al* 2022, Goodwin *et al* 2022, Sietz and Neudert 2022). Goodwin *et al* (2022) proposed a methodology that identified non-nested archetypes that act at different spatial scales. This approach differs from other multi-scale approaches of nested archetypes (e.g. Sietz *et al* 2017), allowing archetypes to overlap with or be embedded within another archetype at different scales. This approach is useful to tailor policy measures to different levels of land-use decisions (e.g. regional and continental scales). Sietz and Neudert (2022) underlined the role of cross-scale synthesis including the nestedness of feedback mechanisms across spatial, temporal, and decision-making scales as a cornerstone for the next generation of nexus archetypes.

The third methodological advance concerns the selection of input indicators for archetype analysis. To ensure a coherent and plausible selection of indicators, it is important to justify and properly link the chosen data sets with the conceptual framing and (co-designed) problem statement (Piemontese *et al* 2022a). The quality and representativeness of selected indicators determines the construct validity of archetypes. Other criteria for indicator selection encompass statistical approaches. In line with established approaches (e.g. Václavík *et al* 2013, Sietz *et al* 2017, Niva *et al* 2021), Pacheco-Romero *et al* (2022) developed a data-driven methodology that uses multivariate statistical analysis, complemented with expert knowledge, to identify the most statistically meaningful indicators for a particular region, enhancing replicability in selecting indicators.

4. Archetypes' support for policy tailoring

This Focus Issue provides insights into the potential and challenges of archetype analysis in tailoring land-use policies to systemic properties of land-use systems. We propose five dimensions of policy tailoring that could benefit from archetype analysis, as illustrated in figure 1. Although our examples focus on agriculture and forestry, this approach to tailoring can be applied to other fields as well.

The first dimension, in which archetype analysis can contribute, is in defining policy objectives in a coherent manner. Disconnected and misaligned sectoral policies remain critical barriers to achieving sustainable development (Biermann *et al* 2022, UN 2022). Therefore, trade-offs and synergies between multiple policy objectives and related sustainability goals need to be systematically considered (Nilsson *et al* 2018, Breu *et al* 2021). Archetype analysis can support this dimension by providing a deeper understanding of systemic interactions underlying trade-offs and synergies between policy objectives and sustainability goals.

For example, archetypal patterns of agricultural frontier expansion that capture recurring dynamics of deforestation and post-deforestation land use highlighted the need for more aligned policy objectives (Baumann *et al* 2022). Specific objectives to conserve and enhance biodiversity included preventing forest cover decline below a tipping point, undertaking restoration actions and incentivizing sustainable silvopasture systems. However, the archetypal patterns of agricultural frontier expansion also revealed trade-offs between these and other policy objectives related to ensuring sufficient food production and livelihood security (ibid.).

The second dimension relates to identifying context-sensitive generalizations of cause-and-effect patterns underlying land use and land-use change. When policies are designed at a higher than local level, such generalizations need to be drawn from insights into the factors and processes that determine land use in specific locations (Sietz *et al* 2011, Magliocca *et al* 2018). Archetype research reveals patterns of land system properties that can help to differentiate policies according to recurrent cause-and-effect schemes (see section 2).

For instance, Martin *et al* (2023) identified eight archetypal transitions of land-uses for shifting cultivation. They demonstrate how the drivers and consequences differ across these archetypal transitions, which need to be considered for policy tailoring. Nexus archetypes (Sietz and Neudert 2022) can inform the design of policies with a focus on recurrent trade-offs and synergies between land use, biodiversity, food, and climate. For example, fostering the cultivation of a few high-yielding crop types for the sake of improving food security undermines the capacity of agricultural systems to regulate pests and diseases and to store carbon. It can also increase the risk of harvest failure when impacted by weather extremes. In turn, the degradation of biodiversity and ecosystem services resulting from such an intensification may not be simply reversed by an equal level of extensification due to nonlinear system behavior (Sietz and Neudert 2022). Dynamic archetype analyses can help better understand the evolving needs, opportunities, and constraints of policy tailoring over time (Eisenack *et al* 2021). Insights into archetypal cause-and-effect patterns can also be used to inform scenario building about future development pathways (Sitas *et al* 2019, Thorn *et al* 2021, Sietz *et al* 2022).

The third dimension encompasses the policy instruments and processes that policymakers can use to govern a specific land-use system or problem (e.g.

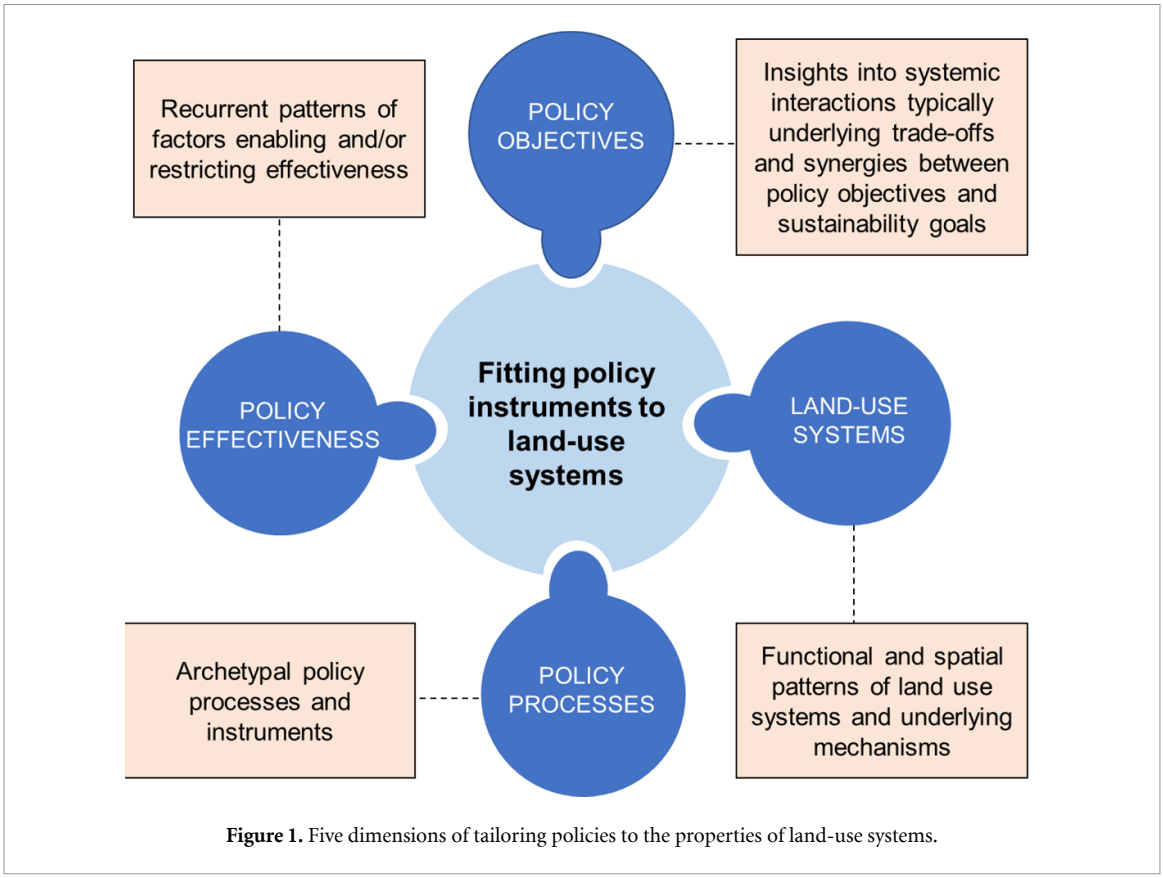

Figure 1. Five dimensions of tailoring policies to the properties of land-use systems.

Capano and Engeli 2022 for an overview). Archetype analysis has been used to gain deeper understanding of policy processes and instruments. For instance, Ceddia *et al* (2022) showed that distinct archetypal configurations of factors related to actor coalitions, type of agriculture and forest cover explain differences of forest policy implementation in Argentina. Newig *et al* (2019) identified archetypical processes associated with institutional decline and failure.

The fourth dimension relates to policy effectiveness. Effectiveness can be defined as the ability of a policy instrument to solve the problem it was created for (Young 2013). It depends on the interplay of biophysical, socio-economic and governance factors. For example, the effectiveness of biodiversity conservation in agricultural land systems is mediated by non-linear effects of both landscape complexity and land use intensity (Kleijn *et al* 2009, Tscharntke *et al* 2012). It reaches its maximum when landscape complexity and intensity are intermediate. Hence, a policy instrument that effectively enhances biodiversity in one region may not work in another if the mediating conditions are different. Understanding the archetypical configurations of underlying social–ecological factors and processes is crucial to reveal the potentials and constraints for sustainable land management in and across regions. This knowledge is a prerequisite for directing specific policy measures to regions where they are best suited. For example, archetypal patterns of agri-environmental potential (Beckmann *et al* 2022) provide an indication of mediating conditions that can be used to discuss where particular agri-environmental schemes fit best. Moreover, Piemontese *et al* (2022b) showed that the suitability of sustainable land and water management practices in Uganda varied according to archetypal land system and social–ecological conditions, as did the investment costs and benefits.

The fifth dimension covers knowledge and practice of fitting policy instruments to particular social–ecological conditions of land systems. This dimension builds on the other dimensions and encompasses three aspects: (1) contextual adaptation of policy instruments; (2) assessing the fit of policy instruments; (3) learning over time and across regions. First, generic policy instruments need to be adapted to the particular social–ecological context and region in which they are applied. For example, Lundsgaard-Hansen *et al* (2022) explained why a multi-stakeholder process (i.e. a generic policy instrument) was only partially effective in a southern region in Myanmar. In this case, the process benefitted from being well-adapted to social conditions (e.g. culturally specific leadership and communication styles), but the process reached limitations when it did not sufficiently include knowledge of institutional conditions (e.g. legal expertise about land rights reforms in the particular context). Archetypes can support this contextual adaptation by synthesizing evidence on the critical social–ecological conditions that make a difference when contextualizing generic knowledge claims about policy instruments

and effectiveness (Magliocca *et al* 2018). Second, it is essential to evaluate the effectiveness of policy measures in achieving the specified policy objectives. Therefore, policy tailoring relies on monitoring and assessing (mis-)fit to re-design ineffective policies. Although established measures of (institutional) fit exist (e.g. Lebel 2013, Epstein *et al* 2015), none of these approaches has explicitly drawn on archetype analysis yet. We argue that archetypes may contribute to future assessments of fit, because the context-sensitive generalizations synthesized in archetypes can help analysts in evaluating the fit of a policy measure with the governed land system, thereby assessing the likelihood of policy effectiveness. Finally, archetypes may facilitate learning about (mis-)fits across regions (Oberlack *et al* 2019, Sietz *et al* 2019) if multiple (science-)policy processes draw on shared knowledge about archetypes (Sitas *et al* 2019). Furthermore, archetypes may contribute to building cumulative knowledge about such (mis-)fits over time if knowledge about policy effectiveness across many social–ecological contexts is synthesized into archetypal patterns, then systematically tested, challenged and criticized, and revised over time. However, archetype analysis is not yet capable of fulfilling this potential to a significant extent, because many studies paid more attention to generating system knowledge (e.g. land system archetypes) rather than to analyze the effectiveness of policies in particular land system archetypes.

5. Challenges and future research needs

Here, we propose that archetype analysis can support policy tailoring by highlighting opportunities and challenges in the tailoring process. Several challenges and frontiers in archetype analysis deserve future research attention. First, while archetypes analysis has focused mainly on context-sensitive generalizations of cause-and-effect patterns in land systems, contributions to the targeted (re-)design of policy instruments remains largely underexplored.

Second, this Focus Issue indicates that there is no limited set of archetypes of land-use systems applicable worldwide, as the range of land systems and land change processes is too diverse to allow for meaningful generalization of a few archetypes across all types of land use. For instance, the archetypal factors, processes, and outcomes of deforestation frontiers (Baumann *et al* 2022) are quite different from the archetypal farming systems in Europe (Beckmann *et al* 2022, Goodwin *et al* 2022). Therefore, we believe a promising line of future archetype research in land system science is to synthesize archetypes for similar land-use dynamics (e.g. urbanization, forest frontier processes, farming systems, livelihood impacts of large-scale land investments, etc) that occur in different regions.

Finally, the systematic use of archetype analysis in policymaking constitutes a key frontier. Archetypes have already been used in science–policy interfaces, such as scenario archetypes applied in the IPBES science–policy interface (see Sitas *et al* 2019) and archetypes of vulnerability used in the Global Environmental Outlook-4 (Jäger *et al* 2007). Greater uptake of archetypes in policy processes has the potential to inform the matching of policy objectives and instruments with regional characteristics of land use systems balancing diversity and trade-offs between different aims and various stakeholders' demands and expectations. However, systematic integration of archetype analysis is a challenging process. It requires a common understanding of the relevance, spatial nature, and evaluation potential of the tailoring process among the decision makers and stakeholders involved. Moreover, gaps remain in quantifying the spatial heterogeneity of social–ecological costs and benefits, and the challenges for which land use policies have to be developed (e.g. land degradation, biodiversity loss, climate change) are increasingly complex, uncertain and unpredictable. Therefore, we encourage stronger efforts of transdisciplinary knowledge co-creation across cases (Adler *et al* 2018) utilizing the potential of archetype analysis for pattern recognition and cross-regional learning.

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