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Commentary: Policy challenges for global land use

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1. Introduction

Some environmental and development policies of the 1980s and 1990s were based on simplistic views on the causes and dynamics of land-use changes (Lambin et al., 2001). For example, the assumption that tropical deforestation was mainly linked to local population growth, poverty, and shifting cultivation led to a failure to address commodity-driven deforestation, which later became a dominant cause of forest conversion. The assumptions that rangelands have a fixed carrying capacity and that pastoralists overstock their rangelands, causing dryland degradation, were used to justify strategies to control and modify traditional patterns of pastoralism in sub-Saharan Africa, with negative consequences on land access and livelihoods. Since our identification, twenty years ago, of empirically-supported pathways of land-use change (Lambin et al., 2001), land system science has made major advances in its understanding of land use as coupled human-environment systems (Turner et al., 2021). This richer understanding proves essential to address current policy challenges related to land use and sustainability solutions. We briefly discuss four examples below.

2. Nature climate solutions

Land management offers a range of nature climate solutions that include avoiding deforestation, planting trees, managing soils and forests for carbon sequestration, and protecting and restoring peatlands and mangroves (Griscom et al., 2017), as well as land-cover integration with environmentally-benign infrastructure. To be effective, these solutions need to be implemented based on a deep understanding of land use systems, which requires increased attention to various research topics. For example, areas suitable for reforestation, wind, and solar energy projects need to be identified in locations that minimize competition with other land uses. Mixed use areas, such as the integration of photovoltaic solar energy production with greenhouses, specialty crops or grazing (aka agrivoltaics), provide opportunities for land use intensification. Spatially-explicit analyses of trade-offs between various dimensions of land use are also needed to identify where to promote agroforestry to provide ecosystem services on agricultural landscapes rather than agricultural intensification to spare land for nature per se. Reforestation projects in unsuitable places and using inadequate tree species, in particular monocultures of exotic species, may prevent meeting biodiversity targets, especially if local communities are not involved. Reliable and fine resolution land use models are required to project baseline future deforestation to quantify carbon credits from avoided deforestation projects. Some forest protection carbon offsets have been shown *a posteriori* to have produced no benefit to climate as inflated deforestation counterfactuals used as project baseline just generate "hot air". These issues raise a number of governance questions (see below) that can be researched through collaborative trans-disciplinary work.

3. Land-use intensification

Safeguarding critical habitats from land conversion and climate change is another policy priority as it contributes to conserve biodiversity and reduce disturbances to the hydrological cycle, among other ecosystem services, and therefore avoids harming livelihoods and Earth system functioning. The potential of land-use intensification to spare land for nature is a much debated and complex issue as it depends on the crop types, farming system, and market, all of which vary with the regional context. We still need to better understand the conditions under which intensification of small-scale agriculture in countries with a low

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productivity offers opportunities to minimize encroachment into natural habitats while also improving food security and livelihoods. For example, what is the optimal mix of food and niche commodity crops in a particular context? The design and effectiveness of interventions that aim at improving intensive cropping strategies and market access for all farmers, and at attenuating the rebound effect of large-scale cultivation of non-staple, export crops, also require further research attention. In addition, government interventions can play a key role in upscaling initiatives by private sector actors and NGOs, for example, through extension services made widely accessible, infrastructure investments, land-use zoning, and support for sustainable forms of intensification, such as efficient irrigation systems that do not deplete water resources.

4. Land-use systems and planning

Land-use planning, urban to regional in kind, has long been undertaken. Recent attention, however, has been given to land system architecture or landscape mosaics—the social-environmental consequences of the composition and configuration of land uses/covers. This architecture has a large range of implications for human and environmental well-being (Formann, 2016). Land system science has advanced this kind of assessment foremost in urban contexts, primarily as it affects extreme heat and its mitigation in the face of climate change and the urban heat island effect. While land system science's focus on urban contexts is increasing, its historical focus on rural landscapes raises the question of the architecture (or mosaic) dimension for such systems. Research needs to better address the implications of various land system architectures for ecosystem functioning and for the services rendered for agriculture and livelihoods (Raudsepp-Hearne et al., 2010). Such an emphasis also feeds into the nature-climate and intensification solutions mentioned above.

5. Land-use access and governance

Embedded with the three examples above is that of multiple stakeholders involvement in land use governance, which requires improvements in understanding of the perspectives of diverse land-use actors. Land is managed through a myriad of land-use decisions by public and private actors, the diversity of which and their interactive outcomes requiring research specificity. In many low-income countries, strengthening land access is a prerequisite for the adoption of sustainable land-use practices. Land acquisition by agribusinesses or developers leads to the conversion to industrial agriculture or forestry of large acreages of land from former agricultural estates or from land claimed by local communities, or to the conversion from agriculture to residential uses in *peri*-urban regions. This land-use restructuring requires attention to its human and environmental consequences, accounting for the entirety of the stakeholders. Demand-side interventions such a dietary changes and reductions in food loss and waste also have a large potential to reduce land use expansion.

A source of complexity in land use governance comes from the layering of interventions by multiple public, private and civil society actors, from the local, national and international levels. For example, various governments own most of the underutilized land resources, while local or international companies have the capacity to invest in land development. How these actors are coordinated in the form of private–public partnerships, often at the scale of a specific jurisdiction or landscape, have consequences for livelihoods and environmental performance.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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