

Chapter 17

Upcoming Challenges in Land Use Science—An International Perspective



Christine Fürst

Abstract This chapter provides an overview on relevant concepts, such as ecosystem services, sustainability, multifunctionality and social-ecological systems/frameworks applied in land use sciences. Current discussions, political debates and challenges in terms of methodological aspects, actor enrolment or project design are raised. Future research topics particularly related to the often non-coherent UN Sustainable Development Goals and their mutual trade-offs are raised and challenges in how to advance land use science are provided. An outlook is provided how co-development of knowledge and co-design of land use system research could be conceived in the future.

Keywords Land use science · Social-ecological systems · Co-development · Co-design · Integrated modelling and assessment

17.1 Introduction

Land use science or land system science turned out to be one of the key concepts in the recent years to integrate an inter- and transdisciplinary perspective in the sustainable management of our earth's natural resources and ecosystems (Müller and Monroe 2014; Rounsevell et al. 2012; Verburg et al. 2013, 2015). Disciplines that found entrance in this concept include geography, landscape ecology, environmental economics, behavioural sciences, social sciences, and biology, to name only a few (Zscheischler and Rogga 2015). A key aspect of land use science consists in co-developing new and integrative methods in systemic modelling, multi-actor participation and in the appraisal of potential social-ecological impacts of changes in land use and land management (Fürst et al. 2017).

A number of *concepts* is closely related and meanwhile part of the methodological toolkit of land use science that should be shortly defined at the beginning. The concepts social-ecological systems and the major approaches for assessing the impact

C. Fürst (✉)

Institute for Geosciences and Geography, Dept. Sustainable Landscape Development, Martin Luther University Halle-Wittenberg, Von-Seckendorff-Platz 4, 06120 Halle (Saale), Germany
e-mail: christine.fuerst@geo.uni-halle.de

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319

of their changes, namely sustainability, ecosystem services, land use functions and multifunctionality have been selected since they are broadly referred and often used in parallel.

Social-ecological systems or system frameworks are one of the key approaches for enhancing the understanding of complex and multi-tiered human-environmental interactions at multiple scales and their outcomes (Ostrom 2007). The transition to a “framework” approach was suggested to form an umbrella for comparing in a meta-language different theories on the systemic interactions and cause-effect relationships in social-ecological models and thus contribute to highly generic systemic approaches (McGinnis and Ostrom 2014). Related to land use science, social-ecological systems or frameworks provide the theoretical background for identifying key system components and sub-systems and classify their relationships and interactions to come from a case-study and observation based understanding to generic system architectures that are a relevant basis for modelling land (use) systems (e.g. Tett et al. 2013).

For assessing the performance of land use systems, a number of assessment frameworks can be used (O’Farrell and Anderson 2010; Wu 2013). *Assessment approaches* and frameworks closely related to land use science are, among others, sustainability, ecosystem services (and synonymous terms), land use functions and multifunctionality. All of them are used in parallel, often with similar understanding but different relevance for land use sectors. By sustainability, we understand since the Brundtland report (1987) and the Rio Declaration in 1992 the “*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*” (Brundtland report 1987) including the balancing of ecological, social and economic sustainability aspects. Anyhow, this understanding was developed more from a political and societal perspective (Lélé 1991) that missed in some aspects the relation to land use due to its high level of abstractness, even if it was broken down to sectors, using the Ministerial Conference for Pan-European Forestry (MCPFE) as an example (Mayer 2000). The novel concept of sustainability suggested by Von Carlowitz (1713) was much closer to land use since it was simply developed from a resource economic perspective to optimize over long time the harvesting of forest biomass to generate enough energy for ore smelting (Basiago 1995; Mebratu 1998; Wiersum 1995). There were manifold attempts to make the concept less abstract and break it down to indicators to support its implementation in practice (e.g.; forestry: Raison et al. 2001; agriculture: Harwood 1990; Zinck and Farshad 1995). A key criticism resulting from these attempts were the assessment efforts through too many, often redundant indicators and the high data demands (e.g. Ceron and Dubois 2003; Niemeijer and de Groot 2008; Hák et al. 2016).

The origin of the ecosystem services concept dates back to the 1970s, where Westman (1977) highlighted the social value of benefits provided by ecosystems to society (nature’s services) as a basis for informed decisions. Subsequently, ecosystem services were mainstreamed in literature with a peak in the 1990s (e.g. Costanza et al. 1997; Daily 1997). Only little later, the Millennium Ecosystem Assessment (MEA 2005) became an important milestone in the conceptual development of ecosystem services and their relevance for policy consulting by synthesizing globally knowledge on the state of ecosystems. Since then, the number of publications

addressing ecosystems and their services increased exponentially (Fisher et al. 2009; Gómez-Baggethun et al. 2010; Vihervaara et al. 2010). Ecosystem services found their entrance in political agenda setting through the UN science-policy process “Intergovernmental Panel for Biodiversity and Ecosystem Services (IPBES), which was established in 2012 in Panama (Larigauderie and Mooney 2010; Larigauderie et al. 2012) and is currently (2019) ratified by 132 countries. Since the introduction of ecosystem services as an assessment framework e.g. in the context of the European Biodiversity Strategy (Maes et al. 2012a, b; Schägner et al. 2013), a multitude of definitions have been developed and discussed (Fisher et al. 2009). Definitions that reached highest interest, are, “*Conditions and Processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life*” (Daily 1997); “Benefits human populations derive directly or indirectly from ecosystem functions” (Costanza et al. 1997); “Components of nature, directly enjoyed, consumed, or used to yield human well-being” (Boyd und Banzhaf 2007); “Aspects of ecosystems utilised actively or passively to produce human well-being” (Fisher et al. 2009); “Direct or indirect contributions of ecosystems to human well-being” (The Economics of Ecosystems and Biodiversity, see e.g. Ring et al. 2010). Still, the definition formulated in MEA (2005) is acknowledged as most important one, defining ecosystem services as “*The benefits people obtain from ecosystems*”. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other nonmaterial benefits.”

However, the division of ecosystem services as suggested by MEA (2005) is critically discussed and, for instance, The Common International Classification of Ecosystem services (CICES, Potschin and Haines-Young 2011; Haines-Young and Potschin 2012) suggest reducing the number of groups to regulating, provisioning and cultural services. They suggest assessing separately bio-geophysical structures, processes and ecosystem functions along a cascade that facilitates separating intrinsic values of nature from yielded services. Among the diverse suggestions how to best implement ecosystem services in support of policy consulting, the CICES cascade in combination with the DPSIR (Drivers-Pressures-State-Impact-Responses) framework (Müller and Burkhard 2012) and the IPBES framework (Díaz et al. 2015a, b) are promising and acknowledged suggestions. Both support strongly to separate the assessment of intrinsic values of nature and their benefits for human well-being, based on indicator sets, but also accounting for qualitative information. Anyhow, most recent terminological discussions on the use of “*Nature’s contributions to people*” (Díaz et al. 2018) instead ecosystem services and resulting critical responses (Braat 2018; de Groot et al. 2018) indicate that the concept as such is not yet in its final stage to really support the assessment of outcomes of land use systems.

Consequently, there were attempts to make the concept suitable for a more integrative systemic perspective referring to landscapes as a holistic entity were multiple land uses are meeting (Termorshuizen and Opdam 2009; Termorshuizen et al. 2007) to address better human-nature interactions and landscape configuration as decisive

Table 17.1 Comparison of the concepts sustainability, ecosystem services, landscape services, land use functions and multifunctionality

Concept	Scale	Holistic?	Comprehensive?	Indicator availability?
Sustainability	Social-ecological systems	Yes	Partially	High
Ecosystem services	Ecosystems	Partially	Yes	Still in work
Landscape services	Landscapes	Partially	Partially	Not yet fully
Land use functions	Ecosystems/land use types	Reductionist	Yes	High
Multifunctionality	Landscapes (Ecosystems)	Partially	Yes	High

factors for services generation. Other attempts, such as the concept of land use functions (Pérez-Soba et al. 2008) suggest a more reductionist approach, focusing on those functions (or services) that are decisive in a regional context.

In contrast, multifunctionality was conceived as a concept to assess land use systems and landscapes in terms of their performance from an integrative transdisciplinary perspective (Antrop 2005; Fry 2001). Their relevance consists particularly in supporting a holistic (cultural) landscape (von Haaren 2002) and land use system planning (Selman 2009) and development including sectorial applications in agricultural (Renting et al. 2009) and forest management planning (Schmithüsen 2007) and in rural development (Knickel and Renting 2000). Table 17.1 summarizes the major aspects and differences in the applicability and usefulness of the assessment concepts.

17.2 Current International Debates and Political Discourses

Land use science is highly relevant to support consulting environmental and other policies, ensure their coherence and develop governance instruments at multiple scales for ensuring a sustainable development (Sterk et al. 2009; see ongoing discussions e.g. in: Weith et al. 2019). Most relevant international debates rank currently around the topics of Climate Change, Global Change and tele-coupling, the achievement of the UN Sustainable Development Goals and biodiversity losses considering their impacts on the resilience and vulnerability of our land use systems (Allen et al. 2016; Bahn et al. 2018; Olesen and Bindi 2002). Since Climate Change (CC) was brought into the policy and public perspective through the endorsement of the International Panel for Climate Change by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988 (From Noordwijk 1990), it found most recently a culmination point in public perception through the grass root movement “Fridays for Future” (Wahlström et al. 2019). However, this

public expression of needs to start quickly with instruments to realize the outcomes and of the Paris Agreement in 2015 (van den Bergh 2017) originates and is conducted mostly in the developed world and not in the Global South, where CC impacts are much more dramatic and relevant for peoples survival. Land use systems as an intrinsic factor in regulating the global climate through carbon sequestration are not really in the focus of the public perception and adapted behaviour (van de Ven et al. 2018) yet, even if certification systems that could further afforestation or halt losses of tropical forest areas are known and proven to be highly efficient (Brancalion et al. 2017; Kongsager et al. 2016). In contrast, policy changes, for instance in Brazil, foster the degradation and destruction of the Amazonian forest (Freitas et al. 2018), while in the boreal forests, large areas are burnt, for instance, in Russia in the recent years through missing monitoring and mismanagement, whose capacities to regulate the large subsurface Carbon resources in permafrost soils are now destroyed (Schaphoff et al. 2016; Shuman et al. 2017). The current debates on stopping CC are more focussing on replacing the critical use of fossil energy and related technologies by other critical technologies (e-Mobility) with increasingly disastrous social and ecological impacts on land use systems through the extraction of rare metals and particularly of lithium (Agusdinata et al. 2018; Lee and Wen 2017). In contrast, approved and traditionally developed strategies related to land use as a means to mitigate CC or to adapt to the not-anymore manageable impacts are lost in the societal and political discourse (Eguavoen et al. 2015; Knutti et al. 2016).

Global change and tele-coupling are not yet publicly perceived topics but anyhow found entrance in the political discourse on equitable polycentric international governance and the achievement of the UN Sustainable Development Goals (SDGs) (Bowen et al. 2017; Vasseur et al. 2017), but also in the discussion on global migration trends and how to co-manage them between Global North and Global South (Oberlack et al. 2018; Radel et al. 2019). Known interactions are the increasing consumption of meat in developed and transitioning economies, the globalization of production processes, land grabbing for resource extraction, the cultivation of renewable resources for energy production and the compensation of CO₂ emissions through certificate trade (e.g. Fiske and Paladino 2016; Garrett and Rueda 2019; Harvey and Pilgrim, 2011; Hull and Liu 2018). These lead to highly negative impacts particularly on land use systems in the Global South and here particularly in weak economies in Africa or transitioning economies in Latin America, South-East and Central Asia (Liu et al. 2013; Gasparri et al. 2016). In result, highly valuable and native ecosystems are irreversibly degraded with huge consequences for the global loss of biodiversity (IPBES 2019) and its relevance for climate regulation, regulation of CC impacts and the intergenerational equity in the access to highly relevant natural resources (Cardinale et al. 2012; Redclift and Sage 1998; Tacconi and Bennett 1995). Since the role of all organisms threatened by the degradation of land use systems is not fully understood, negative consequences for the resilience not only of singular ecosystems, but the system earth and for the vulnerability of land use systems from local to global scale are not yet known (Bonan and Doney 2018).

The 17 UN Sustainable Development Goals (SDGs; UN SDGs 2015) address directly or indirectly land use systems, such as SDG 17 “*Life on Land*”. Anyhow,

the achievement of many of them provokes critical trade-offs for the sustainable development of land use systems, e.g. through soil sealing (SDG's 8 (Decent Work and Economic Growth), 9 (Industry, Innovation and Infrastructure), and 11 (Sustainable Cities and Communities)). This requires planning and policy instruments that reduce such trade-offs through spatial prioritization of areas foreseen to contribute to the SDGs and strategies to make them ecologically less problematic (e.g. through keeping green infrastructures, greening of facades and roofs, etc. (e.g. Ignatieva and Anrné 2013; Keesstra et al. 2016; Norton et al. 2015)). An open question remains, how the land use systems in highly different political, cultural, social and economic surroundings can contribute not only locally but globally to the achievement of these goals and what kind of criteria need to be defined to correspond to the diverse contextual situations when judging how far adapted land use has contributed to or improved the achievement of the SDGs.

In this complex and interwoven areas of political and societal discourse, land use science has the potential to reveal dependencies of the different political areas and the interlinkages of the land use systems and subsystems from local to cross-continental scale referring to the theories of social-ecological systems and their tele-coupled connections (Friis et al. 2016; Liu et al. 2014; Schlueter et al. 2012). This theoretical frame can help to identify which intervention strategies, either through regulating or financial governance instruments or community-efforts can be most efficient in reducing CC, CC impacts and biodiversity losses (Carter et al. 2014; Pereira et al. 2012). Policy and planning recommendations need to stretch over all the above raised topics and reflect through an assessment of their impacts on the sustainable development by the use of approaches such as sustainability criteria or ecosystem services how relevant trade-offs, but also synergies are for local populations and in a global context (Costanza et al. 1991; Kumar et al. 2013).

17.3 Topics for Future Research Areas

Land use science and its methodological concepts can contribute largely to make societies aware of future challenges and risks in their development. Refocussing on social-ecological systems, for instance, health and medical treatments are at high risk to get lost including regulating and provisioning ES, taking waterborn diseases and not yet explored medical substances as examples (Alves and Rosa 2007; Romanelli et al. 2015). This poses also a problem for the long-term achievement of UN SDG 3 "*Health and Human Well-being*". Besides the public and political discourse on such highly relevant topics, there is a number of other research areas, where land use science is called to contribute from an inter- and transdisciplinary perspective.

One of them is urbanization; currently, roughly 55% of the world's population is living in a city or in an urban/metropolitan area. This is expected to be increased in the upcoming decades to an amount of 68% (UN World Populations Prospects 2019), which means that the major part of the global population has no direct access to natural resources and no direct relation to more natural land use systems such as agriculture

or forestry. Concentration in urban areas might be sustainable from the perspective of health, education, access to clean water and energy and can boost urban and industrial development (SDGs 3 (Good Health and Well-being), 4 (Quality Education), 6 (Clean Water and Sanitation), 7 (Affordable and Clean Energy), 9 (Industry Innovation and Infrastructure) and 11 (Sustainable Cities and Communities); UN SDGs 2015) through more efficient bundling of resources and infrastructures. On the other hand, there might be huge trade-offs for poverty, hunger, gender equity, the relation between life and work, and sustainable consumption (SDGs 1 (No Poverty), 2 (Zero Hunger), 5 (Gender Equality), 8 (Decent Work and Economic Growth), 12 (Responsible Consumption and Production), 13 (Climate Action) and 15 (Life on Land); UN SDGs, 2015) through abandonment and lack of working power in rural areas as well as selective rural–urban migration of young people/young men, losses in cultural identity, and higher consumption needs in terms of changes in the diets (more meat) and energy consumption/mobility (Cutter 2017; Reckien et al. 2017; Springmann et al. 2018) (Fig. 17.1).

Related to this topic, rural–urban and cross-continental migration remains for the next decades one of the key research topics, where the question of how land use opportunities could counteract migration and how CC is driving migration are subject to recent research activities (Cattaneo et al. 2019; Pelling et al. 2018). “Attractive” land use opportunities require generally achieving a lower vulnerability and higher resilience towards climate and global change (Froese and Schilling 2019; Javadinejad et al. 2019). In many cases, cash-cropping instead of subsistence farming is considered to be an appropriate solution (e.g. Friend et al. 2019; Gentle et al. 2018). However, this provokes a higher dependency on markets considering the purchase of the seeds or seedlings, potentially higher efforts in fertilization and irrigation, and in selling the products (Amrouk et al. 2019; Robinson 2018). Globalized markets thus gain more and critical influence on highly vulnerable local systems and are prone to accelerate negative impacts on the ecological-economic resilience of the systems (Reyers and Selomane 2018; Rosa-Schleich et al. 2019). Failures in successfully cultivating cash crops due to either climate or market variabilities can destroy in very short time farming systems in the Global South and accelerate poverty-driven migration (e.g. McKeon 2018; Mustafa et al. 2019).

Fig. 17.1 Synergies and trade-offs of urbanization with the UN SDGs (2015)



A highly relevant integrative research area will thus be to focus less on agricultural adaptation strategies alone, but on the water-energy-food-biodiversity nexus (Fürst et al. 2017; Stoy et al. 2018; Venghaus and Hake 2018). The nexus approach as suggested, for instance, in the Future Earth initiative Food-Energy and Water (<https://futureearth.org/networks/knowledge-action-networks/water-energy-food-nexus>) delivers an integrative concept similar to the synergy-trade-off considerations in social-ecological systems, sustainability and ecosystem services assessments (e.g. Karabulut et al. 2018; Nhamo et al. 2019). Research in the sectors of water management, efficient energy production and accessibility, food systems and biodiversity is so far often highly segregated and solutions to overcome scarcity or losses in quality are missing to be coherent with each other sector (Fader et al. 2018) since causal interactions between these sectors are often not directly visible. The most recent calls for scoping as suggested by IPBES therefore enhance the system-overarching perspective and will trigger research that transitions from inter- and transdisciplinary approaches focussing on a specific topic or question to connecting similar disciplines and actor types across sectors regarding a multitude of questions. Part of these across-sector research demands will be the consideration of societal transformations concerning their capacities to contribute to a sustainable development and come up with related social and systemic innovations. Societal transformations are known to be key processes that impact land use systems in terms of their performance in providing a multitude of services and resources and equitable access to them (Ehrensperger et al. 2019; Long and Qu 2018) Expressions of social transformations in their land use context can range from changes in community living styles (e.g. from hunting to herding, Bergman et al. 2013), ecosystem management practices (Olsson et al. 2004), to changes from land use to land development rights (Zhu 2004). Land use planning as an integrative discipline needs to take into account such transformations concerning the prioritization of areas in regional spatial and urban planning for delivering the requested amounts of food, clean water, recreational areas and green infrastructure, areas for protecting settlements against CC driven extreme events and other demands. These can change dramatically along socio-cultural-economic transformations through rural–urban migration and informal settlements or changed diets and living styles (Bardsley and Hugo 2010; Lerner and Eakin 2011).

17.4 Challenges in Research Practice

An important challenge in land use science is an equal enrolment of social and natural sciences (Müller and Munroe 2014) and the development of an original set of inter- and transdisciplinary research methods (Rounsevell et al. 2012). Current research attempts are often either focussed on one of the disciplinary fields (natural/social sciences) and consider the other instead of coming to a fully integrative approach (Zscheischler and Rogga 2015). Reasons for this might consist in funding strategies that are in many countries worldwide still set up from a highly disciplinary point of

view and train researchers that fail to understand the philosophies and theoretical-methodological backgrounds of other disciplines (Bromham et al. 2016). A huge hampering factors for land use sciences consists in the historically separately developed research in land use sectors, such as agriculture and forestry, that often have similar disciplinary approaches, but fail in the cross-sectoral integration and fail in cooperation from a systemic, landscape perspective that is essential for deriving suitable policy recommendations (e.g. Klein et al. 2005; Mickwitz et al. 2009). The lack in a systemic understanding is another challenge in further developing land use sciences. Many of the data acquisition, monitoring and modelling approaches are still oriented towards the micro-scale, miss spatial representativeness and thus fail to contribute to integrative assessments at superior scales and decision levels (e.g. Anderson 2018; De Palma et al. 2018). There is often no real valid relation between spot-oriented sampling or monitoring regarding up-scaling approaches to regional or global scales, but vice versa, also no real attempts to down-scale and validate outcomes from global assessments and modelling approaches with regard to their local reliability (e.g. Kolosz et al. 2018; Le Clec'h et al. 2018; Malenovský et al. 2019). Most of the modelling approaches in land use sciences are purely data driven and miss making use of such theoretical frameworks as provided by the social-ecological system concept (Colding and Barthel 2019). Sustainability and ecosystem services assessments focus often too narrowly on singular ecosystems or ecosystem types and thus do not contribute to holistic and integrative landscape-oriented planning and policy recommendations (von Haaren et al. 2019). Consequently, one of the most important challenges consists in an improved implementation of a systemic perspective and in the focussing of systemic architectures including all subsystems, subcomponents, their interrelations and the quality of these interrelations (e.g. Langhammer et al. 2019). Graph-node theory based approaches such as Bayesian Belief Networks (BBN) or Artificial Neural Networks (ANN) would provide adequate solutions that can either make use of local, indigenous and expert knowledge in drafting the system architecture (BBN), or make use of artificial intelligence algorithms to harvest data sets (ANN) (e.g. Marcot and Penman 2018; Schmidt et al. 2018). While ANN are reliant on the amount and quality of the available data, BBN and similar approaches hold the huge potential to serve also as a transdisciplinary method to approach the understanding of land use systems, integrate multiple knowledge types and data sets and combine qualitative and quantitative data sets. This is of even higher relevance, since challenges for land use science called by Future Earth are the co-design of research and subsequently the co-development of new knowledge (Liu et al. 2018). Using system architectures as a starting point in the discourse between science and practice reveals knowledge gaps and research needs in understanding specific land use systems and—in the sense of social-ecological frameworks—in generalizing their structure and functioning (Gu et al. 2018). The identified “nodes” (i.e. sub-systems) can be critically reflected considering the availability of data or methods to parameterize them. Finally, by the step-wise integration of knowledge to parameterize the subsystems and describe their interactions helps to co-develop knowledge on the system, but also knowledge on potential intervention scales or decision levels to accomplish sustainable development (see e.g. Kampelmann et al.

2018). A remaining challenge will however consist in the enrolment of actors from practice to bridge or potentially close the gap between land use science and land use practice (e.g. Partelow et al. 2019).

17.5 Outlook

Transdisciplinary methods alone will not solve the problem how to realize a permanent engagement of actors from practice. There is a need for a new understanding and conception in how land use systems research should be conceived for delivering relevant practical recommendations without losing its scientific character. If co-design of research and co-development of knowledge are taken serious, traditional “project-oriented” research might not be appropriate since the period between the start, where research questions and hypotheses are (co-) formulated and the end, where outputs are presented remains often non-transparent and inaccessible for actors from practice due to time, economic or methodological constraints (e.g. Hansson and Polk 2018). Also, their priorities and questions might undergo changes during the research project. An opportunity to overcome these discrepancies between science and practice would be to agree not on singular questions or projects, but on agenda-based approaches referring to the impact pathway strategy. This would include coming to a joint agreement on final impacts expected by policy, planning and practice (e.g. achievement of the UN SDGs) in a medium to long-term perspective and on outcomes that are perceived to be relevant to accomplish them (e.g. through societal transformations and the way how these can be initiated, supported and put into action). The agreed research agenda could then start with an initial set of outputs (i.e. singular projects) that are serving to succeed in the outcomes (e.g. scenario model-based recommendations that inform on optimal intervention scales and decision levels in land use systems regarding the UN SDGs). New relevant outputs could be added and existing ones should be subject to a critical review in reasonable time spans, so that a co-learning approach can be established. This could help to overcome the difficulties between day-to-day management in practice and the time lapse in conducting research. Certainly, the coordination of such an agenda-based approach will require a higher and very holistic coordination effort, which leaves enough decision and financial space for adjustment over the agenda process and that will require conducting some pre-assessments of financial ranges including uncertainties in which final budgets will range. On the other hand, it would be much more dynamic and adaptive, would offer much larger participation opportunities from practice, but also from scientific actors and would finally benefit both sides through more synergetic results instead of segregated results in a multitude of smaller (even joint research) projects. Such agenda-based processes could also be implemented on an international scale, calling for applications that deliver expected outputs from regions where these are perceived to be requested to fulfil the agenda, so that a synthesis across continents could be supported.

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