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Towards a governance heuristic for sustainable development

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The year 2015 is setting the course for a joint global vision for sustainable development. UN member states are in the process of jointly adopting the Sustainable Development Goals (SDGs), a list of targets that are the political expression of a global understanding of what is needed to achieve sustainable development on a planetary scale. This comprehensive list covers very different human activities from the eradication of poverty and hunger to access to modern forms of energy and sustainable production and consumption patterns. When assessing the natural resource basis that is needed to achieve the SDGs, analyses reveal that they contain competing demands and critical trade-offs. Identifying these demands and trade-offs and synergies is at the core of nexus thinking. And understanding them in the context of finite resources is essential to developing pathways for integrated and socially just governance processes.

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Introduction: the nexus, a priority for integrated resource management

Water-energy-food nexus thinking was developed to foster integrated resource system management and overcome the silo mentality typical of policymaking for sustainable development: '*A nexus approach can support a transition to sustainability, by reducing trade-offs and generating additional benefits that outweigh the transaction costs associated with stronger integration across sectors. Such gains should appeal to national interest and encourage governments, the private sector and civil society to engage.*' [1]. In comparison to concepts such as Integrated Water Resource Management, the nexus concept has the advantage of bringing the different policy sectors to one table without favouring any particular sector. Furthermore, nexus thinking takes a multi-stakeholder approach to achieving sustainable development with regard to food, water and energy security. The nexus challenges of interrelated resource systems and policy sector linkages can be seen, for example, in the case of the Deccan High Plateau in India.

In the semi-arid agricultural landscape of the Deccan High Plateau in India, food and water security is undermined by poor soils and insufficient water resources. Communities have almost no access to surface water due to pollution and drought during the hot winter months and fast water run-off throughout the monsoon period. Agricultural production in this semi-arid region relies mainly on energy-intensive groundwater irrigation. The quality and quantity of soil and water resources are adversely affected by the absence of pollution control measures and electricity subsidies that result in non-stop groundwater pumping, irrespective of depleting groundwater tables. Urbanisation further reduces water availability by pumping water from rivers several hundred kilometres away [2]. Emerging megacities, migration and increasing demand for electricity from water-intensive hydro-power, affect domestic water availability and agricultural production and put extra pressure on water and soils in such semi-arid regions. It is precisely these competing demands that result in the scarcity of resources and the interdependencies of resource demands and supplies that nexus thinking describes. Competing demands result in critical trade-offs between scarce resources that manifest themselves in the loss of resilient livelihoods and high degrees of chronic poverty at community level. At the same time, these interdependencies extend from individual and community levels to regional and supra-regional institutional governance levels and are confronted with institutional silo mentality, typical of policymaking.

Nexus thinking is in literature primarily geared to achieving water security and acknowledging the interlinkages between water, food and energy security, and climate change mitigation [3–7]. Some studies stress the need to increase efficiency of resource cycles [8•,9,10], while others claim that coherent governance approaches are needed to tackle nexus resource scarcity challenges [1,11–17]. Understanding critical trade-offs, competing demands and identifying synergies for integrated resource governance is at the core of nexus thinking. These competing demands in large landscapes are illustrated in the Climate, Land-use, Energy and Water Systems (CLEWS) modelling approaches on interrelated resource systems [8•,9,10]. Rainfall patterns lead to a large diversity of agricultural conditions in Mauritius. Increased extraction of groundwater and the necessity for water transportation increase energy demands in this geographical area. Additionally, the depletion of groundwater leads to sea water intrusion, resulting in extensive environmental damage and energy intensive desalination programs. Such approaches which integrate large-scale resource models illustrate the delicate balance of competing resource demands. Both biophysical quantification and economic evaluation are taken into consideration by studies using The Economics of Ecosystems and Biodiversity (TEEB) methodologies, for example in a comparison of traditional and sustainable tea forests and highly productive tea terraces [18]. The trade-offs among multiple resources and the economic gains and losses, as well as the long term ecological benefits of sustainable agricultural systems are made transparent through these numerous TEEB case studies. Beyond these studies there remains a research desiderate on large-scale nexus studies that illustrate these competing demands.

This review article argues for systematic nexus thinking based on the intrinsically linked systems of soil, water and biodiversity. Their ecosystem services are most visibly manifested in local resource conditions and the socio-economic status of communities and regions (Section 'Nexus thinking — finite resources and their ecosystem services'). Hence, nexus thinking requires spatial reference points. The landscape approach offers a local scale and integrates an understanding of biophysical resource systems as well as the socio-economic context (Section 'Balancing securities — the need for a landscape approach'). However, nexus thinking at landscape scale is driven along the value chain by consumption patterns elsewhere. **Hence, we argue in favour of a dual nexus understanding of governance processes at landscape and global scales along the value chain of goods and services** (Section 'Landscapes in the context of global interdependencies'). Nexus thinking within spatial reference points allows us to understand local challenges and conditions and set priorities for changing governance processes as needed for implementation of the post-2015 Development Agenda (Section 'Beyond 2015: nexus thinking, a governance heuristic for sustainable development').

Nexus thinking — finite resources and their ecosystem services

Water is not filtered and cannot be transported to plants without soil; conversely, soil can only provide its nourishing functions to plants if it contains enough water [19•,20]. Soil supports a huge variety of species and bacteria and is, after oceans, the world's largest carbon sink. The overall diversity of species in soils exceeds that of rainforests and coral reefs: '*In sum, soil biodiversity is key for the species that make up the soil food chain and for soil's continued ability to serve as the foundation of the broader global food chain*' [21•]. Soil is the foundation of our resource system but closely linked with water resources and other productive vegetation such as cropland, forests and wetlands that, managed wisely, produce ecosystem services for sustainable and resilient livelihoods.

The systems of soil and water are intrinsically linked, and are only resilient, productive and efficient in concert with one another [22]. As well as being essential for our daily consumption, fresh water provides ecosystem services for agricultural food production and energy security. Water insecurity and soil degradation require immediate action in order to preserve these resources for future generations, to ensure water, food and energy security, and to mitigate climate change. A scarcity of fresh water has a direct impact on drinking water availability. Due to its fluid character, water scarcity and depletion can be overcome by technological solutions in quite short time frames, for example through water pipelines and packed, shipped or bottled water. Likewise, soil degradation has an impact on our lives. Soil resources are essential, producing all needed biomass for food, fodder and energy. Restoring degraded soil is a process that takes decades if not centuries. An acute crisis of soil degradation can be resolved through technological solutions such as the physical transport of soil but only at enormous costs and only in limited quantities. Restoration components such as land-use change and well-managed vegetation measures may have positive results within comparatively short time horizons of five to ten years, but still require immediate action. To tackle resource scarcity in the future, technology alone will not solve our problems and thus we need to focus on social and economic restoration and conservation as long-term and sustainable solutions. Water, soil and biodiversity must be governed in an integrated way if resource systems are to remain resilient, productive and healthy for future generations [23].

While the current nexus thinking focuses on achieving water, energy and food security through integrated resource management, it does not explicitly acknowledge the importance of soil resources. Water, biodiversity and soils will only be resilient, efficient and productive if the resources and the respective policy sectors are managed in an integrated manner: '*Functioning soil is necessary for ecosystem service delivery, climate change abatement, food and fibre production and fresh water storage. Yet key policy instruments and initiatives for sustainable development have under-recognized the role of soil in addressing major challenges including food and water security, biodiversity loss, climate change and energy sustainability. Soil science has not been sufficiently translated to policy for sustainable development*' [24•].

The triad of the intrinsically linked systems of water, soil and biodiversity provides the essential foundation for