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A Multiscale Transdisciplinary Framework for Advancing the Sustainability Agenda of Mountain Agricultural Systems

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Mountain agricultural systems (MASs) are multifunctional and multidimensional sociocultural systems. They are constantly influenced by many factors whose intensity and impacts are unpredictable. The recent Hindu Kush–Himalayan Assessment Report highlighted the need to integrate mountain perspectives into governance decisions on sustaining resources in the Hindu Kush–Himalayan region, emphasizing the importance of sustainable MASs. Our reflective literature review identified 3 barriers to advancing the agenda for sustainable MASs: (1) the disconnect of normative orientations for sustainability at different scales, (2) inadequate alignment between stakeholders' sustainability orientation and scientific evidence, and (3) weak integration of scientific evidence into the formulation of mountain-specific solutions for sustainability. To address these barriers, we propose a conceptual, regional (mountain specific), transdisciplinary framework with an interscale science–policy interface. This will help scientific evidence to be incorporated in future policies and programs on sustainable MASs while being responsive to the needs of mountain farming communities and stakeholders who benefit from broader services. The framework emphasizes the connection between normative orientations for sustainability, science evidence, and solutions for sustainability through the use of iterative transdisciplinary knowledge-generation and knowledge-integration multiscale feedback processes. Thus, the key to advancing the agenda for sustainability of MASs lies in aligning scientific evidence with existing normative orientations for sustainability at local, subnational, national, regional, and global levels. The alignment triggers sustainability-oriented solutions. This should highlight MASs globally, increasing investment while acknowledging MAS specificities and niche opportunities. In turn, this will strengthen national policies and programs specific to MASs and facilitate integrated farm management through interdisciplinary extension and delivery services.

Keywords: *Transdisciplinary framework; regional framework; systems approach; science–practice–policy interface; sustainability norms; sustainability-oriented solutions; mountain agriculture; Hindu Kush–Himalaya.*

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Introduction

Advancing the sustainability of agricultural systems is a complex endeavor (Kemp and Martens 2007). According to the Brundtland Report, sustainability means meeting the needs of the present without compromising the ability of future generations to meet their own needs (WCED 1987). However, the definition of sustainability is challenging, because it transcends any single discipline or agency (Kates et al 2001), and different stakeholders have distinct visions and priorities regarding sustainable development (Bacon et al 2012). Moreover, the manifold drivers of change and constantly changing contexts make agricultural sustainability extremely demanding and hard to predict (Darnhofer 2014); this is also true of mountain contexts and their specificities (Jodha 1991).

Mountain agricultural systems (MASs) are not only diverse but also developmentally marginal (Wehrli 2014). Moreover, pursuing sustainability of MASs raises ethical concerns specific to mountains and mountain farming communities (Dahl 2012). MASs are continually influenced by stakeholders' varied sustainability values and objectives and the aspirations of the younger generation of mountain farmers for greater economic development (Farrington 2000). Thus, sustainable development of MASs should consider the current balance of economic, environmental, and sociocultural pillars of sustainability (Hodbod et al 2016), as well as attend to stakeholders' expectations for broader transformative change as envisaged by the recently endorsed United Nations (UN) sustainable development goals (SDGs; UN 2017).

Sustainable development calls for science, practices, and policies that consider both current dynamics and future directions and take into account multiple scales and interactions (Scholes et al 2013; Zähringer et al 2019). The recent Hindu Kush–Himalayan Assessment Report (Wester et al 2019), which highlights the need to consider mountains in optimal resource governance in the Hindu Kush–Himalayan

(HKH) region for sustainability and the wellbeing of mountain people, has made a strong case for increasing the attention paid to the sustainability of MASs on the world's development agenda. Achieving sustainability of MASs is important to both mountain communities and stakeholders beyond, but often the relevant knowledge does not flow from one level of governance to the next, constraining the adequateness of sustainability policies and practices.

This paper proposes a conceptual multiscale transdisciplinary framework that is intended to support science–policy interactions (Cash et al 2003). It can be used to support agenda setting and solution finding for sustainable development of MASs. It aims to facilitate mountain-focused regional interventions, investments, and solutions that link systems, target, and transformation knowledge at different scales (Maani 2017). The essence is to connect scientific evidence with normative and solution-based aspects of sustainability, at the same time ensuring that sustainability-oriented science is relevant and responsive to the needs of mountain communities (Lang et al 2012). Moreover, the framework contributes to understanding and integrating wider-scale sustainability challenges to help implement holistic solutions (Baumgartner 2011).

Methodology

Agricultural sustainability is a knowledge-intensive endeavor involving a range of disciplines (agriculture, forest, energy, soil, water, biodiversity, environment, economics, culture, and politics) and discourses (poverty reduction, food and nutrition security, natural resource management, climate change, biodiversity conservation, and more; Pretty 2008). Furthermore, sustainable development of agriculture requires innovative application of research and extension services that calls for transdisciplinary engagement of actors (Flora 1992). The framework we propose is therefore founded on a structured reflection on existing literature and the current state of knowledge on MASs, the wider context influencing their sustainability, stakeholders' goals and decisions, and the transdisciplinary strategies that shape sustainability solutions. More specifically, the literature review was guided by questions related to the 3 forms of knowledge relevant to sustainability (eg, Wuelser et al 2012): (1) systems knowledge on key characteristics and dynamics of MASs, (2) target knowledge on envisaged sustainability goals and values, and (3) transformation knowledge on strategies and solutions to foster sustainability. Our contextual focus on agricultural systems mainly comes from the HKH region (eg, Tulachan 2001; Jiao et al 2018).

The literature review enabled us to embed knowledge on the sustainability of MASs within the wider context of sustainable development and to identify 3 key barriers to advancing agricultural sustainability in the mountain context. First, we identified a disconnect between normative orientations for sustainability at different scales (von Wirén-Lehr 2001). The term "normative orientation" refers to the value dimension of sustainability, expressing where future development should go (Schneider et al 2019). The term "scale" refers to institutional decision-making levels (local, subnational, national, regional, and global).

Explicit normative orientations for sustainability are primarily set at global and national scales, often as political agendas (Holden et al 2014). At a global scale, the 2030 Agenda (UN 2015) represents the most deliberated and negotiated vision of sustainable development we currently have, involving stakeholders across national governments, civil societies, academia, and business sectors. It is directed toward achieving 17 interdisciplinary SDGs. At the national level, sustainability orientations are often set by long-term national visions or strategies for sustainable development—policy instruments that capture overall national priorities for sustainable development (Bhatta et al 2019). They also contribute to achieving the 2030 Agenda. It is important that countries refer to the 2030 Agenda and consider the SDGs in agricultural policies to drive the sustainability of agricultural systems. However, such normative orientations are usually broad and often do not adequately reflect mountain-specific sustainability agendas and niche opportunities (Wester et al 2019). Likewise, they also tend to overlook normative sustainability orientations at the local scale, which are set by mountain farming communities according to their societal values and priorities (Bacon et al 2012).

The second barrier is inadequate alignment between the knowledge contributions of science and the normative sustainability orientations mentioned for the first barrier (Swilling 2014; Schneider et al 2019). Science often aims to solve disciplinary problems, rather than address societal concerns and challenges for sustainability (German et al 2017), especially those of mountain communities and marginal areas. Most contributions address technical issues (Galdeano-Gómez et al 2013), with less consideration of stakeholders' values and decisions. Furthermore, limited attention is given to the knowledge-generation processes, such as stakeholder engagement, social learning (Schneider et al 2009), and knowledge coproduction (Rosendahl et al 2015). Thus, scientific contributions often fall short of providing socially relevant evidence to adequately support decision-makers in generating appropriate policies and goals for sustainable MASs. The same is true for implementing existing sustainability norms, such as the 2030 Agenda.

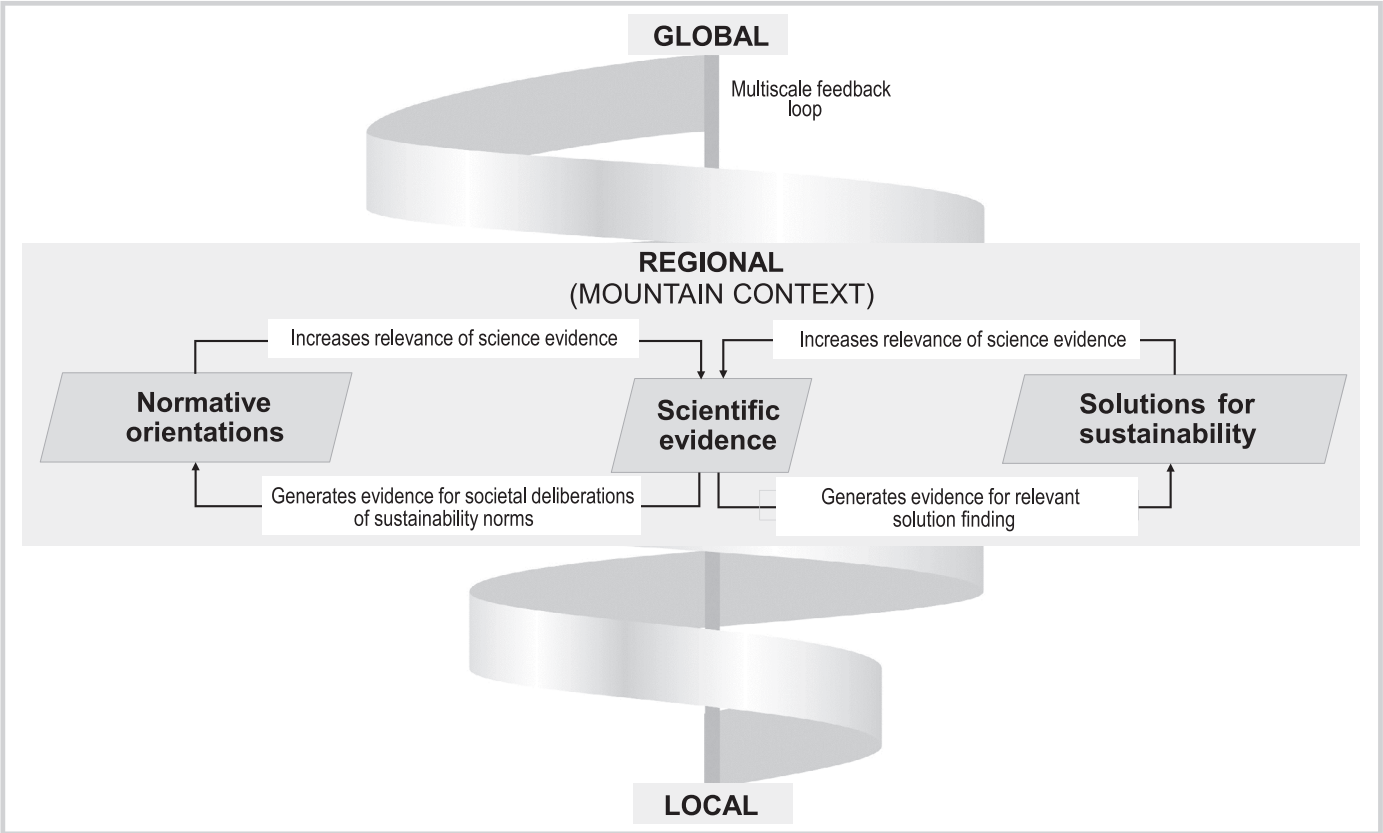
The third barrier relates to the weak integration of scientific knowledge into decision-making systems (Coe et al 2014). Most science outputs revolve around the researchers' need to contribute to disciplinary discourses; these are not always translated into meaningful evidence for informed decision-making (Brandt et al 2013). Mountain context-specific knowledge is often not considered by decision-makers at the national scale (Morse et al 2001). In other words, management and policy decisions are often made by stakeholders who do not adequately understand mountain communities' value and knowledge systems and farm-level sustainability objectives (Partap 2011).

Our paper aims to tackle the previously mentioned barriers by providing a mountain-specific framework that places regional-level MASs in a multiscale perspective and that links the generation of scientific evidence with political norm-setting and solution-finding processes through a transdisciplinary process.

The multiscale transdisciplinary framework

The proposed framework (Figure 1) conceptualizes the sustainability of MASs at the regional scale to emphasize the mountain context and facilitate integration of mountain

FIGURE 1 Regional multiscale transdisciplinary framework highlighting horizontal connections across normative orientations, scientific evidence, and solutions for sustainability, and iterative feedback across scales that links regional-scale interventions to those at local and global scales, and vice versa.



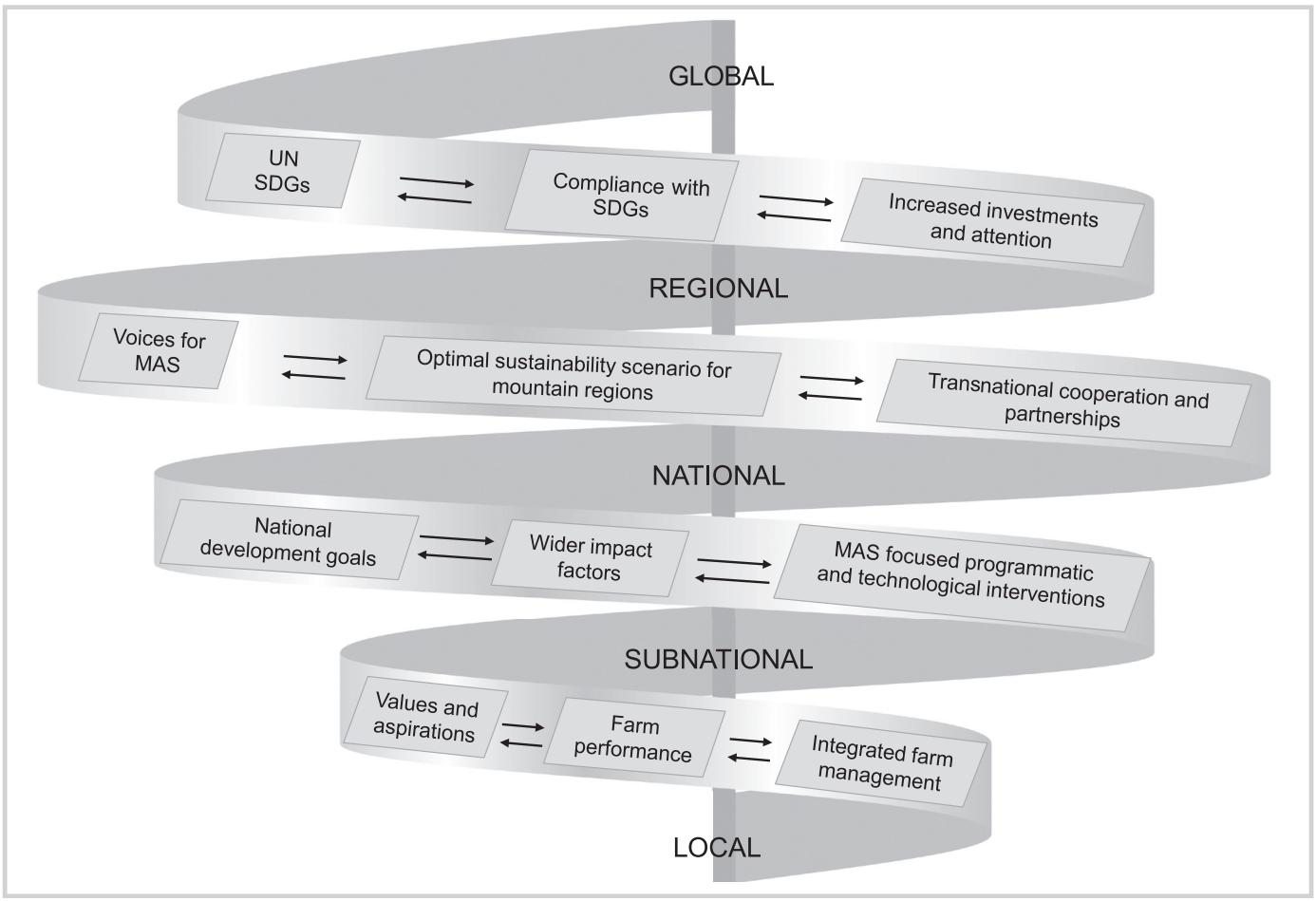
voices and perspectives within the global sustainable development agenda. It also considers local perspectives. The framework helps researchers to create scientific evidence that is relevant to sustainability-oriented decision-making. Furthermore, it helps decision-makers and development practitioners to align policy and management decisions according to the stakeholders' sustainability priorities at different scales.

The framework comprises 3 key elements that refer to the 3 forms of knowledge necessary to advance sustainability, as introduced earlier: the normative orientations, scientific evidence, and solutions for sustainability. Attributing scientific evidence to systems knowledge is a simplification. As the interlinkages suggest, scientific evidence should also contribute to target and transformation knowledge. The element concerning scientific evidence is central to the framework, catalyzing bidirectional relationships—influencing the other 2 elements and, in turn, being influenced by them. That is, when scientific evidence reflects upon normative orientations and solutions for sustainability, it becomes more responsive to stakeholders' needs and aspirations for sustainability, enhancing their relevancy to decision-making (von Wirén-Lehr 2001). Iteratively, scientific evidence complements normative orientations by generating appropriate evidence for societal deliberation of sustainability norms (Elder et al 2016). It also contributes to solutions for sustainability by generating evidence relevant to sustainability-oriented solution finding (Hadorn et al 2006).

The alignments among the 3 elements of the framework are reinforced through a transdisciplinary approach of knowledge coproduction (Pohl and Hadorn 2007), mobilization of differentiated boundary work (Clark et al 2016) to facilitate knowledge integration, and development of solutions addressing issues of societal concern (Klein 2000; Miller 2014). The transdisciplinary approach is suitable for promoting sustainability in sociocultural systems with a high degree of uncertainty, knowledge diversity, and contested societal stakes (Wiesmann et al 2011).

With regard to the feedback loops between scales, the framework stresses the need to consider insights from one form of knowledge at one scale to other forms of knowledge at other scales (Wuelser et al 2012). The iterative feedback process connects stakeholders' varied definitions of sustainability to enable coframing of research objectives (Pohl 2008) and promote collective management and policy interventions (Dale et al 2013). The framework advocates mainstreaming adaptive learning among multiple stakeholders to facilitate effective translation of knowledge into sustainability-oriented decisions (Hodbod et al 2016). The key is the engagement of stakeholders across disciplines and scales to promote collective understanding of interrelationships among factors affecting sustainability and tradeoffs among environmental, economic, and sociocultural pillars of sustainability (Polk 2015). Adaptive learning helps stakeholders to align their sustainability priorities for the future with current practices and actions and codefine integrated solutions for positive sustainability outcomes (Reytar et al 2014). The framework thus creates

FIGURE 2 Contextualization of the regional multiscale transdisciplinary framework to advancing the sustainable development of MASs. Example text relates to normative orientations, scientific evidence, and solutions for sustainability across scales.



wider constituencies and credibility among stakeholders to jointly advance systems, target, and transformation knowledge necessary to advance sustainability of MASs (Wiesmann et al 2011).

Contextualization of the framework for MASs

Figure 2 contextualizes the framework with respect to advancing the agenda for sustainability of MASs. The multiscale transdisciplinary framework emphasizes that sustainability of MASs cannot be achieved by only considering global- or national-scale sustainability norms, such as SDGs or national development goals; in addition, regional-scale normative orientations (representing MASs across the world) under the umbrella of a "Mountain Agenda" (Högger et al 1992; 235) are vital. The Mountain Agenda refers to the mountain-specific voices that place mountains at the forefront of the world's development agenda, highlighting them as unique environments that are fragile, remote, marginal, and multifunctional. This regional-scale normative agenda for the sustainable development of MASs is necessary to achieve desirable sustainability outcomes for MASs and mountain farming communities (Bhatta et al 2019). This is possible when regional interventions are linked to global- and national-scale (including subnational- and local-scale) interventions for science, practices, and policies (Sinclair 2017), as emphasized by the interscale iterative (spiral) feedback knowledge-generation and knowledge-integration processes in the proposed framework.

MASs are immensely diverse systems, with crops, livestock, soils, climate, practices, tools, and technologies varying from farm to farm and country to country. Their sustainability calls for mountain-specific and interdisciplinary knowledge bases (Schild and Sharma 2011) that incorporate multiple stakeholders' range of interests, perspectives, desires, and decisions (Rist et al 2007). Regional knowledge needs to highlight mountain-specific contexts, challenges, and opportunities; provide direction for sustainable transformations; and eventually support governments and other stakeholders to formulate sustainability-oriented policies and programmatic decisions that speak to the needs and aspirations of mountain farming communities (Cunha 2015). For example, at the regional scale, scientific evidence related to sustainability assessments of distinct agricultural production systems in mountain regions in different countries (Quintero-Angel and González-Acevedo 2018) outlines transformation trends and relevant future sustainability scenarios (Figure 2; Brown and Castellazzi 2014). This provides a credible basis for the orienting MASs toward sustainability if they are used to define necessary policies, partnerships, cooperation, and investments.

The framework uses a spiral feedback design to imply iterative horizontal connections among the 3 key elements at one scale and their vertical linkages across different scales (Figure 1). These linkages show that key stakeholders at one scale, while defining their scientific objectives for sustainability, reflect upon the system's characteristics and the sustainability norms at other scales (Wuelser et al 2012). For example, at the local scale, systems knowledge on farm performance (Paracchini et al 2015) helps farming communities to better comprehend the farm's potential to generate environmental, economic, and sociocultural benefits. This scientific evidence closely aligns with mountain communities' aspirations of having farms that sustain ecosystem services, bring economic and livelihood benefits, and promote inter- and intragenerational sociocultural equity linked to their wellbeing (Holden et al 2014). It acknowledges local-level agricultural sustainability norms defined within the mountain farmers' sociocultural context (Xu et al 2005). However, this farm-level understanding has to be built upon systems knowledge of a wider range of impact factors influencing sustainability that operate at subnational and national scales.

In the mountains, agricultural systems go beyond the farm level and integrate elements from natural ecosystems, such as forests, rangelands, and wetlands. Mountain farming communities maintain forests for farm inputs and other services, such as provision for water, soil, pollinators, and wild food (Balmford et al 2012). At these scales, wider categories of stakeholders operate and make decisions relating to synergies, interdependencies, and tradeoffs not only between farm and natural ecosystems but also between knowledge, practices, and policies, according to their respective disciplinary expertise, and institutional mandates (Francis et al 2008). Understanding wider impact factors beyond the farm would enable farming communities and other stakeholders to develop a shared understanding of current and future priorities for the sustainable development of MASs. Creation of shared understandings would enable both farming communities and national-level decision-makers to coanalyze existing science, practice, and policy actions. Such scientific evidence is important for defining strategies for integrated farm management that address the challenges concerning interdisciplinary and sectoral disconnects (German et al 2017).

The regional-scale implications are recognition of the multisectoral and cross-scale nature of sustainability, the development of demand-driven science objectives that acknowledge and use the knowledge of mountain farming communities, and the establishment of scale-level institutional connections, capacities, and partnerships. This will effectively bring MAS-specific innovations to scale and strengthen regional cooperation and long-term investments for the sustainable management of MASs (Ojha et al 2019).

The spiral specifically relates to mainstreaming of transdisciplinary processes, such as acknowledgment of mountain farmers' values, integration of interdisciplinary perspectives, knowledge coproduction, social learning, development of appropriate boundary objects, and knowledge integration (Pohl and Hadorn 2007; Rist et al 2007; Pohl et al 2010; Clark et al 2016). Such processes facilitate the capture of empirical and traditional knowledge on the one hand and experimental and academic knowledge on the other hand (Wang et al 2019). They connect the knowledge of stakeholders from different backgrounds, disciplines, and know-how (Holzer et al 2018) and across wider thematic disciplines of agricultural sciences (Pretty et al 2010). These processes help in using scientific evidence to inform, on the one hand, strategies toward achieving the global agenda for sustainability and, on the other hand, actions required at the local level to make mountain farms more resilient and responsive to the welfare of the mountain farming communities (Cash and Moser 2000).

The key here is tailoring the role of science to create a knowledge base that is responsive to the needs and values of stakeholders with different roles and functions (Clark et al 2016). For example, when target knowledge on the sustainability scenario reinforces regional stakeholders' demand for sustainability of MASs, global stakeholders pay more attention to the prospects and challenges of MASs. This promotes regional partnerships and cooperation for transdisciplinary research, joint management interventions, harmonized policy development, regional cooperation framework development, interdisciplinary institutional capacity strengthening, and cross-learning among countries (Sharma et al 2016). Regional collaborative and transdisciplinary interventions trigger enabling intersectoral policies and MAS-focused programmatic and technological innovations, together with strengthened extension services infrastructure at the national level (Wester et al 2019). Strengthening enabling mechanisms that speak to the needs of mountain farms and mountain farming communities will eventually trigger in situ support for the rural mountain farming communities (Jodha 2009). The systems knowledge on compliance with SDGs (Nilsson et al 2016) built on regional knowledge helps wider disciplinary stakeholders, including decision-makers in different countries and international actors, to collectively voice mountain perspectives on the global platform and negotiate the agenda to achieve sustainable MASs (Wester et al 2019). Thus, the insights from knowledge at one scale continually strengthen knowledge at another scale. This helps to create the demand-driven, inclusive, and integrative scientific evidence for MASs necessary to reinforce their holistic and longer-term sustainability.

Conclusion

MASs are dynamic and rapidly transforming social–ecological systems. Because sustainability objectives for MASs are not linear or unidirectional, achieving them requires a multiscale and multistakeholder approach that continually promotes stakeholder participation, reduces disciplinary knowledge barriers, and promotes integrated transformative solutions for sustainability. As emphasized in the transdisciplinary framework proposed in this paper, mountain-specific scientific evidence can trigger sustainability-oriented solutions when aligned with existing normative orientations for sustainability at local, subnational, national, regional, and global levels.

Multiscale solutions in terms of increased global investment in MASs, acknowledgment of MAS specificities and niche opportunities, strengthened national policies and programs specific to MASs, and integrated farm management facilitated through interdisciplinary extensions and delivery services can efficiently advance the agenda for

sustainability. Multiscale engagement of stakeholders with a range of interests and perspectives results in better understanding of the science–practice–policy feedbacks at global-to-farm and farm-to-global levels. This enables effective positioning of MASs and the voice of mountain farming communities in the global debate on sustainability. The multiscale transdisciplinary framework provides necessary knowledge and the governance connections across different scales. It will help stakeholders across scales to collectively catalyze the transformation of MASs into a resilient environmental, economic, and sociocultural resource base.

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