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Integrated natural resource management as pathway to poverty reduction: Innovating practices, institutions and policies

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ABSTRACT

Poverty has many faces and poverty reduction many pathways in different contexts. Lack of food and income interact with lack of access to water, energy, protection from floods, voice, rights and recognition. Among the pathways by which agricultural research can increase rural prosperity, integrated natural resource management deals with a complex nexus of issues, with tradeoffs among issues that are in various stages of denial, recognition, analysis, innovation, scenario synthesis and creation of platforms for (policy) change. Rather than on a portfolio of externally developed 'solutions' ready for adoption and use, the concept of sustainable development may primarily hinge on the strengths and weaknesses of local communities to observe, analyse, innovate, connect, organize collective action and become part of wider coalitions. 'Boundary work' supporting such efforts can help resolve issues in a polycentric governance context, especially where incomplete understanding and knowledge prevent potential win-win alternatives to current lose-lose conflicts to emerge. Integrated research-development approaches deal with context ('theory of place') and options ('theory of change') in multiple ways that vary from selecting sites for studying pre-defined issues to starting from whatever issue deserves prominence in a given location of interest. A knowledge-to-action linkage typology recognizes three situations of increasing complexity. In Type I more knowledge can directly lead to action by a single decision maker; in Type II more knowledge can inform tradeoff decisions, while in Type III negotiation support of multiple knowledge + multiple decision maker settings deals with a higher level of complexity. Current impact quantification can deal with the first, is challenged in the second and inadequate in the third case, dealing with complex social-ecological systems. Impact-oriented funding may focus on Type I and miss the opportunities for the larger ultimate impact of Type II and III involvements.

1. Introduction

Current expectations that a generic sustainable development pathway, such as either mainstream market-oriented agricultural intensification (CGIAR, 2015), or an alternative ecological intensification concept (Tittonell and Giller, 2013; Koohafkan and Altieri, 2017; Oborn et al., 2017), can simultaneously achieve 17 global Sustainable Development Goals (SDGs) is at best naïve. Tinbergen (1952)'s rule, derived from linear (matrix) algebra, that the number of independent goals defines the number of policy instruments needed still holds, with some nuance on the degree of independence of policy goals (Braathen, 2007; Knudson, 2009). The degree of intrinsic interdependence between the goals reduces the need for separate policy instruments. The opportunity to enhance synergy can make the set of policy instruments more effective in dealing with the trade-offs and suggests that a combination of instruments each targeting multiple goals can be more efficient than a direct single goal-instrument linkage, as long as the instruments are truly complementary and allow shifts between the weights of the various instruments if progress towards certain goals is falling behind. Among the 17 SDGs the world leaders accepted as agenda 2030 (UN, 2015), five deal with inter-human interactions (4: quality education; 5: gender equality; 10: reduced inequalities; 16: peace, justice and strong institutions and 17: international partnership for the goals), while the other 12 involve human interactions with the planet, often involving land use (1: no poverty; 2: zero hunger; 3: good health; 6: clean water and sanitation; 7: affordable and clean energy; 8: decent work and economic growth; 9: industry, innovation and infrastructure; 11: sustainable cities and communities; 12: responsible consumption and production; 13: climate action; 14: life below water; 15: life on land). Pathways to poverty reduction through integrated natural resource management need to consider both groups of goals, any intrinsic interdependencies and the opportunities for induced synergy. One of the networks of international agricultural research (CGIAR, 2015) has so far focused on system-level outcome targets on poverty reduction (interpreted broadly as SDG1), increased productivity (SDG1 + 2) and a natural

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resource management target that deals with all other SDGs. Shortfalls in any of the 17 SDG's will contribute to rural poverty (or 'lack of rural prosperity'), which thus has several dimensions. Narayan et al. (2000) summarized a project to listen to the voices of the poor in 23 countries under five headings. With a slight rewording of these, Namirembe et al. (2017) represented relations between rural and urban human wellbeing as a 7-layered pyramid: 1) Physical security and shelter from disasters; 2) Food, water and energy security; 3) Health; 4) Income; 5) Social relations; 6) Enterprise; 7) Identity and self-realization. Integrated natural resource management needs to consider all seven layers, and their interactions.

Where agricultural research has a long tradition of focus on increasing and realizing the 'yield potential' of crops through genetic selection and management of soil fertility, pests, weeds and diseases (other contributions to this special issue; de Wit, 1992), in the past three decades the multiple social dimensions of rural poverty reduction, and the two-way, multi-scale interactions with the environmental context (on which crops and livestock depend, but which their management also impacts) have gained importance (Izac and Sanchez, 2001; Sayer and Campbell, 2004; Sayer and Cassman, 2013; van Noordwijk, 2015). Resource management can in this context deal with water (van Noordwijk et al., 2016b), soil (Vanlauwe et al., 2017; van Noordwijk et al., 2015b), trees (Ordonez et al., 2014; Prabhu et al., 2015), forests (Reed et al., 2016), landscapes (Sayer et al., 2013; Minang et al., 2015), agro-biodiversity (Vandermeer et al., 1998; Jackson et al., 2007, 2012), biodiversity (Swift et al., 2004) or conservation and use of genetic resources and related knowledge (Mauro and Hardison, 2000; Carsan et al., 2014).

As part of a review of the pathways by which international agricultural research can reduce rural poverty (Tomich et al., 2017), we will here review the way innovation in technologies, institutions and policies have been triggered and analysed, and how adoption and reform of institutions and policies can contribute to more sustainable agricultural practices, within the wider SDG framework. It is expected that more integrated natural resource management (iNRM) can reduce uncertainty of returns for poor farmers and strengthen their capacities to cope with risks, including those related to climate change. A bias of this review towards the 43% of agricultural lands that has at least 10% tree cover and as such is a form of agroforestry (Zomer et al., 2016; Prabhu et al., 2015) is acknowledged up front (van Noordwijk et al., 2011). It may compensate for the conventional focus on annual crops and livestock in internationally funded agricultural research. Before we can expect to frame generic conclusions on the interface of poverty reduction and iNRM, we need to acknowledge and analyse spatial heterogeneity in patterns, processes and theories of change.

2. Theories of place and change

Rural poverty can be, reflecting on the layers of the pyramid (compare Fig. 8 below), caused by a combination of A) living and farming in unfavourable conditions (climate, soils, access to markets, small land holdings), B) lack of resource access rights, legal protection or recognition, C) lack of ecosystem services (provisioning, regulating, cultural/spiritual, regenerative), D) lack of income opportunities (on- or off-farm) in local economies, E) lack of investment in the (few) opportunities that exist for market-based ventures. In view of this, the next generation for most of the rural poor will have to get out of agriculture if they are to escape poverty (Alvarez-Cuadrado and Poschke, 2011). Transforming lives is a key step towards transforming landscapes (World Agroforestry Centre, 2013).

For those trained in a mechanistic cause-effect chain of thinking and project planning, it is difficult to understand how policy change can actually happen. There is ample interest in 'evidence-based policy' (Pawson, 2002), but also the realization that we currently have 'policy-based evidence', with funding for research based on predetermined political agendas (Plant, 2003). Scientific findings do not fall on blank minds that get made up as a result, as science engages with busy minds

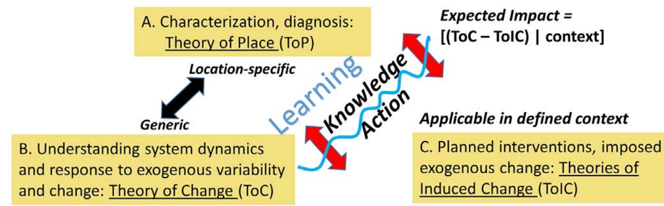

Fig. 1. Three interacting domains of knowledge and praxis that may apply from individual via community to global humanity.
(van Noordwijk et al., 2016a).

that have strong views about how things are and ought to be (Plant, 2003). Policy change is often perceived as essential to the creation of an 'enabling environment' for the adoption of improved technology, continued innovation and sustainable development (Tripp, 2003; Akhtar-Schuster et al., 2011). Research, in this perspective, provides evidence for reform of agri-food policies and institutions to make them more conducive to pro-poor development, to improve nutrition and the sustainable management of natural resources (CGIAR, 2015).

Thornton et al. (2017) described how a 'theory of change' (ToC) articulation has helped research programs become more directly attuned to realities on the ground and the need for knowledge, rules and incentives to become better aligned across scale, in dealing with the additional challenges of global climate change. A critical look at this ToC, however, suggests that it tends to downplay spontaneous (intrinsic) change in the social-ecological systems of landscapes and households, and overrate the agency of external involvement and research-based knowledge. Van Noordwijk et al. (2015a) discussed the relevance of Theories of Place (ToP) as counterpart to ToC's, as context matters and one-dimensional perspectives (as in 'agro-ecological zones') don't suffice. In further analysis the theories of induced change (ToIC) that drive the project-level investment in change, need to be distinguished from endogenous change – if only to have more credible counterfactuals for any impact assessment (Fig. 1).

Singh et al. (2016) described and analysed how the recent agroforestry policy for India was shaped and approved in a non-linear process of coalitions for change (Sabatier, 1987), more complex and less 'rational' than Thornton et al. (2017) discussed. Clark et al. (2016a) explored a three-by-three interaction table between knowledge (K) and action (A), with zero, one and multiple as levels in both dimensions. Where most development projects assume that a single, superior type of knowledge can and should inform a single, dominant decision making level (K_1A_1), a more relevant default assumption for any natural resource management issue is that there are multiple knowledge systems interacting with multiple actors, stakeholders and decision makers (K_mA_m), with a political ecology contest between which knowledge is seen as salient, credible and legitimate. In a simplified version of this typology we will for this review of integrated natural resource management focus on three situations:

I. K_1A_1 cases where a single superior knowledge can be directly applied in practice,
II. K_mA_1 cases where analysis clarifies tradeoffs and supports decision makers to use new ways to balance between their various goals in taking actions,
III. K_mA_m cases where knowledge itself is part of a contest between multiple actors, taking poorly synchronized decisions.

Before we review these three, we will discuss some further ways to analyze the knowledge-to-action linkage.

3. Linking knowledge with action in boundary work across scales

Underpinning resource management at scales from an individual to the global community is a common view on six types of knowledge-related human skills (Fig. 2): 1) observing and monitoring change, 2) understanding of the consequences of conditions and trends, 3) analysis of tradeoffs, 4) innovation in areas of recognized problems or opportunities, 5) scenario level integration and forecasting of expected consequences of change and 6) platforms and coalitions for change. The first three can be grouped as diagnosis of context, the next two as a focus on new options, the last on the social, psychological and political dimensions of 'action'.

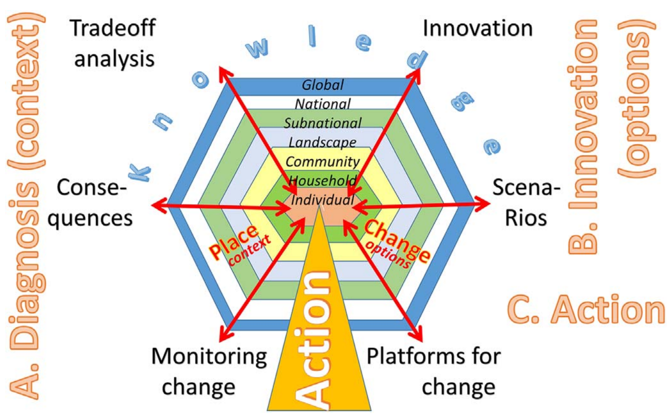

Fig. 2. Steps involved in learning loops from individual to global levels that link knowledge with action (decisions, adoption, policy change and implementation) in integrated natural resource management.

At landscape scale where multiple actors and stakeholders are involved, diagnostic and change-oriented phases of this learning cycle of Fig. 1 occur simultaneously and may not be in phase among them. Six key questions that link theory of place to endogenic change are illustrated in Fig. 3.

Having a generic framework for understanding the dynamics and specificity of context, we can look at how it interacts with a wider policy arena where change tends to occur in response to pressure, with 'evidence' initially contested in the political sphere. In the dynamics of public discourse on any 'new' topic, key questions may arise along an issue attention cycle (Tomich et al., 2004). They function as part of multiple knowledge-to-action chains (Fig. 4).

At the start of any 'new' issue entering public discourse, there is a need for defining more clearly what the nature of a problem is. The science-based knowledge-to-action chain tends to focus initially on 'understanding', and then moves to metrics for quantification and accounting, to forecasts and scenarios of the likely response to interventions to deal with the issue, or its consequences. The policy-oriented/political chain, meanwhile, will have to overcome the initial 'denial', 'victim' and 'conspiracy' interpretations of unwelcome facts, to move to willingness and abilities to act. A new government may revert back to the early stages of this, especially where polarized media and active disinformation campaigns prevented electorates from coming along in the learning process. Once solutions have been identified that have a reasonable chance of reducing the severity of the issue, combinations of the three basic policy instruments (regulation, incentives and motivation) will emerge, along with clarity on who will have to pay or invest what. 'Common but differentiated responsibility' and coinvestment in stewardship frame the delicate moral balance between the various stakeholders. Actual solutions that work, however, may remain wishful thinking, unless in a parallel process, local solutions have emerged that not only deal with the focal issue, but are aligned with other local needs, abilities and contextual factors. Seen in this light, the relationships between the knowledge/learning systems are key, with trust between the subsystems slow to build up and easy to destroy. Van Noordwijk et al. (2014a) discussed details of these relations for issues around tropical peatlands, land use change and fire.

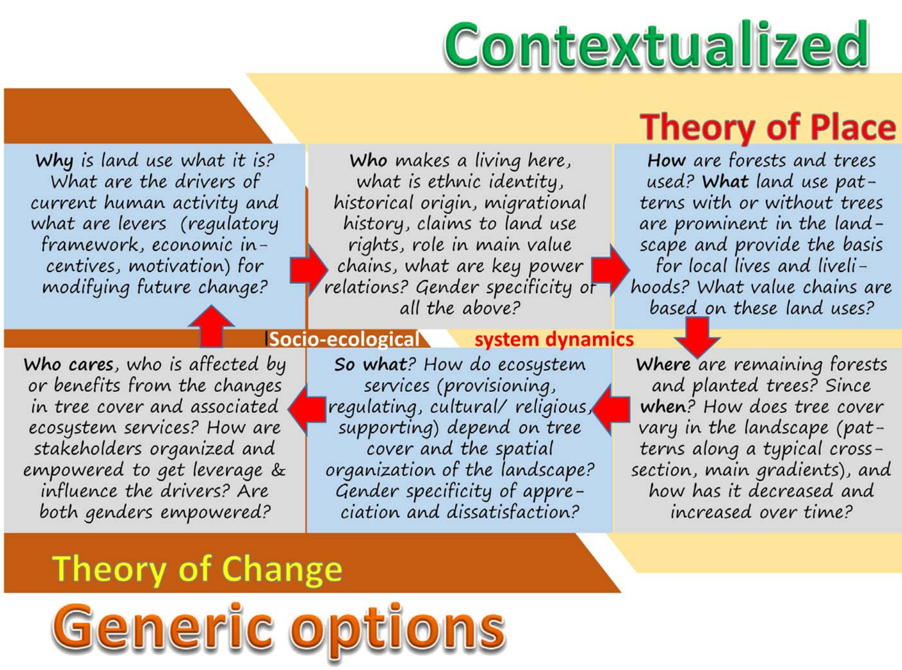

Fig. 3. Key questions to understand social-ecological systems ('landscapes') in their specific context ('theory of place'), with the currently prominent issues and drivers of change ('theory of change'); methods to appraise local, public/policy and science-based knowledge for each of these questions were described in van Noordwijk et al., 2013.

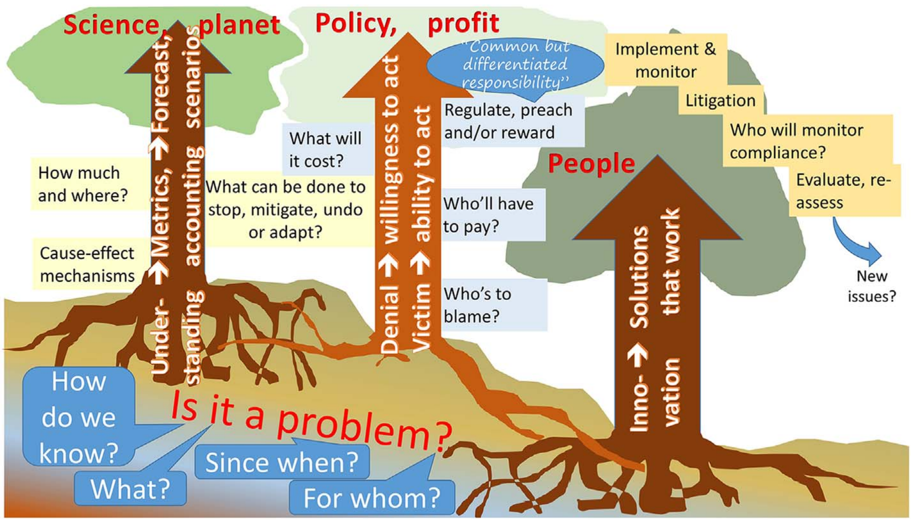

Fig. 4. Key questions in an issue attention cycle, interacting with knowledge-to-action chains in three domains (science, policy, local actors).

A further level of complexity comes from the positioning of 'boundary work' (Clark et al., 2016a, 2016b; Lebel et al., 2006; van Noordwijk et al., 2016a) on the interface of four entities: a physical and socio-political reality, value-free curiosity-driven academic science and fact-free politics that may try to shape the socio-political ambitions and aspirations with active disinformation campaigns (Fig. 5). The credibility, salience and legitimacy dimensions of science quality have yet to find an effective answer to counteract the latter.

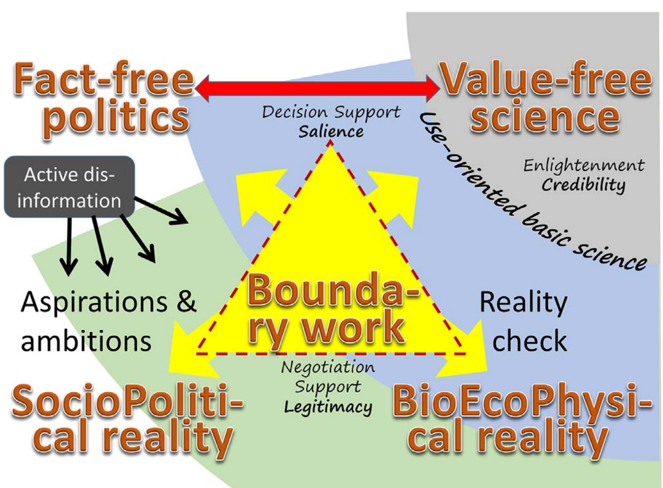

Fig. 5. Boundary work, using credible, salient and legitimate scientific knowledge in interaction with public/policy discourses and local wisdom and knowledge deals with ecological, social, economic and political realities, including active disinformation that protects private interests.

4. Type I (K1A1) cases where more knowledge can directly contribute to use and benefits

Coe et al. (2014) described the 'research in development' (RinD) concept that has been proposed as alternative to the more sequential portrayal of 'research for development' of Thornton et al. (2017). The RinD concept is acutely aware of fine scale variation in context, and works towards a more informed matching of opportunities and those who can be expected to benefit from them. It can consider a wide range of options (from using a different type of tree, crop or livestock germplasm to a change in institutions or governance structure), many descriptors of context as stratifiers for the experiments, and can look for a wide range of issues as determinants of performance metrics (Fig. 6). In practice, however, the complexity of cross-scale interactions and multiplicity of issues has to be reduced, especially if the gold standard of randomized control trials (Ferraro and Pattanayak, 2006) is to be used within a project-type timescale.

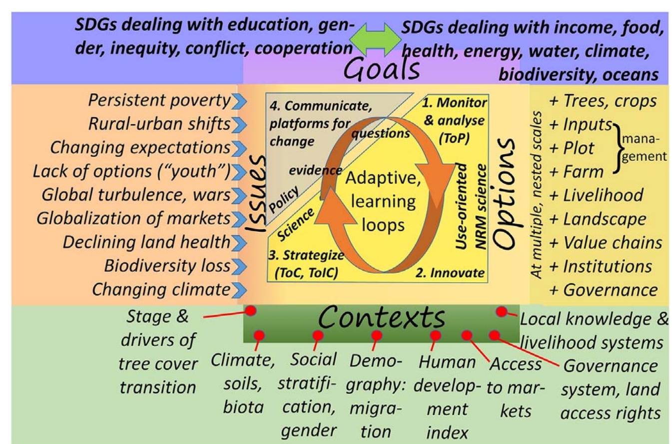

Fig. 6. Options, contexts and (exogenous) issues related to goals, as background for natural resource management learning loops; SDGs = Sustainable Development Goals.

Several examples that go beyond simple linear expectations of technology adoption were recently reviewed by Douthwaite and Hoffecker (2017), Oborn et al. (2017) and Hiwasaki et al. (2016), at the interface of land productivity and wider natural resource management issues. Land health surveillance approaches to targeting sustainable land management interventions have advanced, mostly for African contexts (Shepherd et al., 2015). Farmer-managed commercially relevant local tree species have been identified as basis for restoration in ways that benefit both farmers and the wider landscape, in given contexts (Mokria et al., 2017; Lu et al., 2017).

The extrapolation domains of empirical experience remain the primary challenge for any 'scaling out', where successes in pilot situations have been achieved. The more contextual factors are to be included, the narrower the resultant extrapolation domains tend to be. Dewi et al. (2017) recently compared the validity in representing tropical forest transitions of three CGIAR programs (the Alternatives to Slash and Burn partnership for tropical forest margins (ASB), the Poverty and Environment Network (PEN) and the sentinel landscape of the Forests,

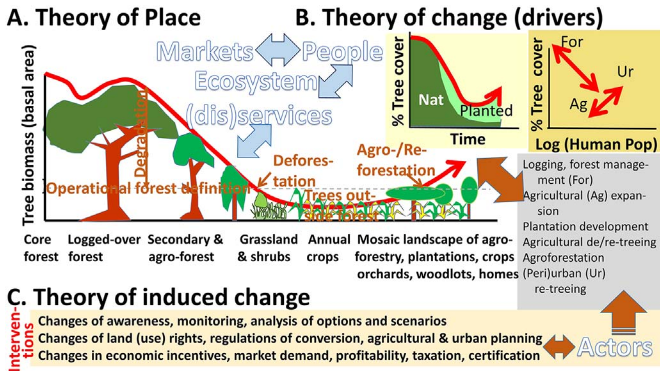

Fig. 7. Forest (or tree cover) transitions as a theory of place, change and/or induced change.
(Modified from Dewi et al., 2017).

Trees and Agroforestry research program (FTA). The latter provides a 5% sample of the pantropical area, 8% of its people, 9% of its tree cover and 10–12% of potential tree crop presence, with quantified biases across ecological zones, forest transition stages and human development index (HDI) (Fig. 7).

5. Type II (KmA1) cases where enhanced knowledge informs decisions on tradeoffs and synergies (DSS)

Decision support systems (DSS) have since long been developed on the interface of scientific knowledge and decision makers (ranging from farmers to those dealing with national policy). They often quantify tradeoffs between short and longer term planning horizons and suggest economic or regulatory interventions that 'internalize externalities' by aligning local decisions more with longer-term societal benefits. Much of the 'ecosystem services' literature is focussed on such tradeoffs and ways to deal with them. In a systematic mapping of the literature on poverty in relation to ecosystem services from 2000 to 2013 1324 potentially relevant reports were identified (Howe et al., 2014), 92 of which were selected for a review, creating a database of 231 actual or potential recorded trade-offs and synergies. The analysis of these case studies highlighted significant gaps in the literature, including: a limited geographic distribution of case studies, a focus on provisioning as opposed to non-provisioning services and a lack of studies exploring the link between ecosystem service trade-offs or synergies and the ultimate impact on human well-being. Trade-offs were recorded almost three times as often as synergies and the analysis indicated that there are three significant indicators that a trade-off will occur: at least one of the stakeholders having a private interest in the natural resources available, the involvement of provisioning ecosystem services and at least one of the stakeholders acting at the local scale. An ongoing systematic map protocol (Cheng et al., 2017) explores the evidence for forests as supporter of the livelihoods of an estimated 20% of the global population, through three primary roles in supporting livelihoods: subsistence, safety nets, and pathways to prosperity. The strength of evidence to support the various pathways by which forest protection can affect poverty outcomes is still unclear. Existing ecosystem services literature is likely biased to locations researchers frequent, rather than to where they are most important (Kuyah et al., 2016).

A deeper understanding of farmer and forest dweller decisions in the face of new options (Colfer, 2005; Garrity et al., 2010; German et al., 2013; Dumont et al., 2014; Meijer et al., 2015) generally shows complex balancing between direct livelihood benefits and wider natural resource concenrs over a longer time frame. Jackson et al. (2010) suggested that three timescales matter: efficiency, persistence (as part of sustainability), and agility (sustaingility). Adaptation and risk management start to be understood in terms of portfolio management, maintenance of diversity and balancing of on-farm and off-farm options in the rural-urban continuum (Nguyen et al., 2013; Hoang et al., 2014).

In terms of 'management swing potential' (Davis et al., 2013) palm oil can be both the best and the worst of currently used biofuels. Trade-offs between productivity and negative environmental effects can be quantified for crops such as oil palm (van Noordwijk et al., 2016c), testing and rejecting the idea that fertilizer prices can be used as policy instruments to stimulate 'sustainable intensification'.

The global water balance define many tradeoffs: on-site use versus 'water harvesting', tree-based water use versus enhanced infiltration (Ilstedt et al., 2016), water quality vs water quantity, and functioning floodplains protecting downstream areas from flooding. Over-use of groundwater for agricultural production in India has become a trade-off issue (Zaveri et al., 2016). The primary uncertainty in any water balance remains the pattern of rainfall, with its interannual variation in total amount, length of dry periods and rainfall intensity. Droughts and floods, both mostly affecting poor, less-buffered segments of society, are directly linked, as shown in the recently developed 'flow persistence' metric of watershed health, matching local concepts of loss of predictability (van Noordwijk et al., 2017a, 2017b). Similar experience in engaging local stakeholders in flood management has been obtained in the UK as alternative to 'engineering' approaches to flood prevention (Lane et al., 2010). However, the convention to treat rainfall as exogenous variable, beyond influence of local land use change has been challenged by a new synthesis on the way atmospheric moisture recycling and vegetation-derived rainfall triggers interact, necessitating new metrics, a revisit of water scarcity predictions, and a re-appreciation of the role of landscape-level tree cover increase (van Noordwijk et al., 2016b; Ellison et al., 2017).

Nearly all tradeoffs that involve forests and trees involve a need for bringing longer-term benefits into the decision making arena, as trees grow slowly, the benefits forests provide are rapidly destroyed but slow to recover, and private benefits of harvesting easily outstrip the social costs of conservation. The forest (or tree cover) transition literature (reviewed in Dewi et al., 2017) can be seen as a theory of place (as it suggests a stratification of the world on the basis of human population density and tree cover), as a theory of (nonlinear) change (as it identifies the drivers of qualitative and quantitative tree cover change, Ordonez et al., 2014), and as basis for theories of induced change.

The stage along the forest transition curve and specific landscape configuration of forests, agroforestry and open-field agriculture shape the opportunities for dietary diversity (peaking at 50% forest, Ickowitz et al., 2014). As staple-food can both be better stored and transported than other components of a healthy diet, income security based on selling (agro)forest products can help shift local agriculture to more ES friendly land uses (van Noordwijk et al., 2014b).

The right hand side of the forest transition curve deals with 'restoration', at least in the sense of an increase of tree cover. The restoration agenda was prominent at the start of agroforestry, four decades ago (King and Chandler, 1978). It has resurfaced multiple times, including different drivers of degradation that are to be stopped and reversed (Table 1). Restoration typically requires investment, and deals with the tradeoff between current and future benefits. Part of the agenda is in Type III domain, with multiple actors using multiple types of knowledge to support their claims and interests. Type II restoration knowledge for Latin America (Miccolis et al., 2017), Africa (Duguma et al., 2015, Chirwa and Mahamane, 2017) and Asia (Djanibekov et al., 2015; Ahrends et al., 2017; Widayati et al., 2016), points to similarities in the ecological dimensions and differentiation in the social and political aspects. Table 1 is provided as step towards testable hypotheses in bringing the diverse restoration situations under a common denominator.

Governance dimensions of restoration (Wilson and Cagalanan, 2016) may bring us to Type III cases, as 'procedural equity' questions in the domain of 'Free and Prior Informed Consent' (de Royer et al., 2013) are more easily framed in guidelines than that they are implemented in practice.

Table 1
Tentative importance of various forest and landscape restoration actions in dealing with restoration in dependence of the primary degradation drivers; the scores reflect hypotheses as a starting point for further discussion and synthesis of empirical evidence; the drivers and issues can interact and occur in combination.

Degradation issue & driver	Indicators	Policy change to stop degradation	Opportunities for restoration through (agro)forestry						Impacts	
			Based on farmer actions			Supported by policies on:			Productivity	Other ES
			FMNR	Tree planting	Soil inputs	Tenure reform	LU Zoning	ES-rewards		
Natural disasters	Typhoons, storm surges, tsunami, earthquakes, volcanic ash	Prevent mis-guided land grabs, salvage logging a.o.	+	+ +	+		+	+	+	+
Overlogging, overharvesting	Reduced tree regeneration, fire risk, roads	SFM enforce-ment, logging moratorium	+ + +	+ +		+	+	+	+	+ +
Overgrazing	Loss of perennial grasses	Exclosures, fodder banks	+	+	+	+ +	+		0/+	+
Defaunation, overhunting	Forest regeneration affected	Hunting controls				+ +	+ +	+ +	−/0	+
Overcropping, nutrient depletion	Loss of nutrients & soil organic matter; erosion	Organic & nutrient inputs			+ +	+ +	+	+	(+)+	+
Fire (beyond what is normal for ecozone)	Hot spot, burn scars	Restrict/ban?fire use; fire breaks	+ +	+ +		+ + +	+ +	+	−/+	+
Persistent undesi-rable vegetation, eutrophication	Arrested succession (e.g. ferns or grass persists)	Incentives to active change	(+)	+	(+)	+		+ +	+	+
Watershed over-use	Erosion/sedimentation, loss of flow buffering	Activity zoning, joint planning	+	+	+	+ +	+ +	+ +	+	+
(Over-)drainage & groundwater extraction	Groundwater table data, subsidence	Rewet (e.g. peatlands)	+ +	+ +	+	+	+	(+)	−/0	+
Salinization	Salt concentration	Control irrigation	+	+	+		+			
(Open cast) mining	Inverted soil profiles, toxic waste	Compliance with strict permits	+	+ +	+ + +		+ +		+	+
Loss of riparian wetlands	Loss of flow buffering	Activity zoning	+	(+)		+ +	+ +	+	0	+
Loss of coastal protective vegetation	Loss of protection to storm surges	Enforcement of protection	+	+		+	+ +	+	+	+
Bioglobalization	Invasive weeds, pests	Act on early warning	+ +	−/+				+	0	+

FMNR = farmer-managed natural regeneration; C-IES = co-investment in ES; ES = Ecosystem Services; LU = land use.

6. Type III (KmAm) cases where increased knowledge supports negotiations among stakeholders (NSS)

The terminology of negotiation support systems (NSS) was introduced by van Noordwijk et al. (2001). The seminal work under this paradigm started in Sumberjaya (Indonesia), a highly contested watershed of 40,000 ha where development of a hydropower plant led to evictions of coffee farmers from the remaining forest margin, in the belief that only 'forest' could provide the watershed functions for the underperforming hydropower plant. Research clarified that the feasibility study for the plant had inflated expected flows to make the project more attractive, that tenure insecurity prevented farmers from developing multistrata coffee systems that were both more profitable (at realistic discount rates) and infiltration-friendly. Research results helped farmer groups negotiate tenure agreements, conditional on watershed restoration, with forest authorities (Suyanto et al., 2007, Leimona et al., 2015b, Verbist et al., 2010). Sumberjaya ('source of wealth') finally lived up to its name again, and became exemplar for negotiated agreements between farmers and forestry authorities elsewhere in Indonesia. In this case the choice of a 'worst case' as research target proved to be effective in precipitating wider policy change. The landscape also became part of a network of sites testing rewards for enhanced ecosystem services, with 'conditional tenure' as primary reward and the profitability of coffee gardens taking care of the financial side.

This network helped to re-anchor the Payment for Environmental (or Ecosystem) Services (PES) debate, initially in Asia (Leimona et al., 2009; van Noordwijk and Leimona, 2010; Leimona et al., 2015a) but also in Africa (Namirembe et al., 2014; Lopa et al., 2012) and globally (Swallow et al., 2009; van Noordwijk et al., 2012). Rather than the simple market analogue of a buyer, a seller, a service provided and a price, agreements to enhance ecosystem services came to be seen as part of a complex multi-stakeholder arrangement in which the regulatory role of the state, economic incentives and coinvestment by the private sector and motivational efforts by development agencies all had to play their role (Fig. 8).

The innovative elements of 'performance-based' and 'conditional' rewards can be retained within a broader 'co-investment' landscape governance paradigm, as shown in experiments with auctions for voluntary actions to exceed mandatory standards. Such auctions, however, proved to be complex multiple learning events, rather than a simple way to establish 'market' value (McGrath et al., 2017; Leimona and Carrasco, 2017).

Direct poverty reduction through Payments for Ecosystem Services has been an elusive target. Only in specific combinations of demography (many beneficiaries, few ES providers) and ES-relationships (upstream – downstream) will PES oriented financial transfers from urban ES beneficiaries to upland poor within the same watersheds have a direct effect on reducing poverty. Such cases exist in Southeast Asia, but they are rare (Leimona et al., 2009). Contrary to expectations, REDD + finance has not (yet?) become a major factor for livelihoods in tropical forest margins (Matthews and van Noordwijk, 2014). Other dimensions of poverty (lack of voice, lack of rights, lack of opportunity for entrepreneurship) are more likely to be addressed, when attention to distributive, procedural and contextual equity prevails in the way PES and REDD + are implemented (McDermott et al., 2013; Corbera, 2015; Chomba et al., 2015; Minang et al., 2014). Distributive equity addresses the distribution of benefits and costs, procedural equity refers to decision-making, while contextual equity, links the two and incorporates the pre-existing conditions that limit or facilitate people's access to decision-making procedures, resources and, thereby, benefits. A combined equity framework then considers how these dimensions are shaped by the scale and target group of concern (who), the framing of goals with respect to equity (why), and, crucially, how the decisions about the content, target and aims of equity are taken. Initial attempts to implement REDD + greatly underestimated the complexity of existing and claimed rights of stakeholders in the landscape (Galudra et al., 2011).

Agent-based models of landscape change in response to policy change can be used to explore the likely consequences of changes in both rules and economic incentives (Villamor and van Noordwijk, 2011; Suwarno et al., 2016). However, surprises may occur when the gender dimensions of local land use dimensions are fully incorporated (Villamor and van Noordwijk, 2016). Market-based commodification of ecosystem services (ES) can take two forms (van Noordwijk et al., 2012): markets for 'certified' units of ES (as in 'carbon markets'), or ecosystem value associated with marketed commodities, as in forms of ecocertification. An analysis (Mithöfer et al., 2017) of the latter for five major tropical commodities (timber, coffee, cacao, rubber, palm oil) showed that 'issue cycles' (compare Fig. 4) rather than absolute ES impacts dominate the emergence and subsequent evolution of such schemes.

The balance between supply-side (land use in commodity producing parts of the world) and demand-side (consumer action to take responsibility for footprints) is a delicate one, where nationally and individually determined contributions to emission reduction interact in complex ways (van Noordwijk et al., 2016d). Meanwhile, commitments of major parts of the value chains of tropical commodities to become

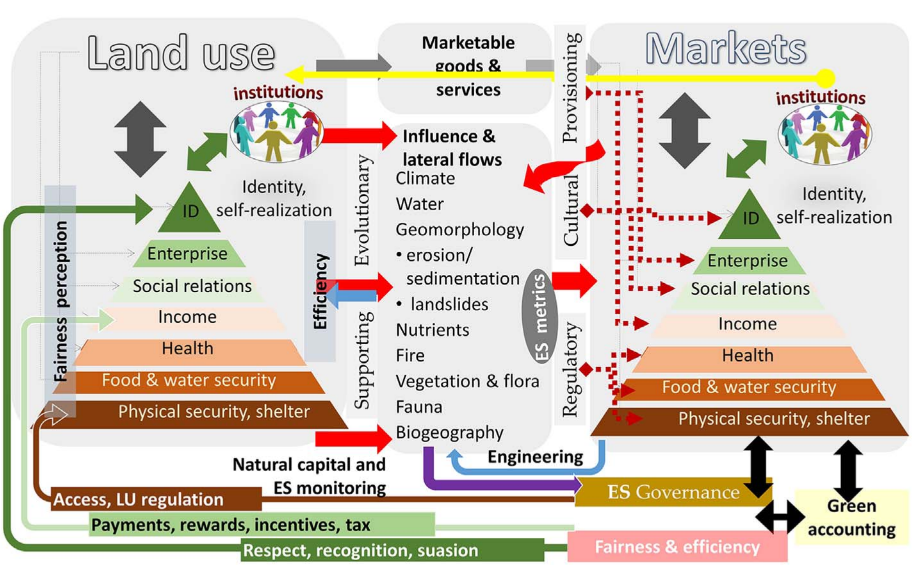

Fig. 8. Complexity of the relationships between land users who modify ecosystem services and the 'downstream' beneficiaries of these services, who may try a combination of rules, incentives and motivation to influence decisions about land use upstream.
(Modified from: Namirembe et al., 2017).

'deforestation-free' need to be critically assessed (Meyer and Miller, 2015; van Noordwijk et al., 2017c; Pasiecznik and Savenije, 2017), as multiple forest definitions can be used in a play of words (van Noordwijk and Minang, 2009; van Noordwijk et al., 2014d) rather than as steps towards substantive change on the ground.

Devolution of rights to manage forests in Indonesia has been a gradual process, where CGIAR research made contributions, but mostly in a low-key, behind the scenes manner. The first step was the recognition for the damar agroforests of Krui as being man-made (local domestication of a tree with considerable market value for its resin) rather than natural forest (Kusters et al., 2007). Following a new Forestry law that included mechanisms for community-based a('HKM') and village-level ('Hutan Desa') forest management, the Sumber Jaya watershed mentioned above became the first test ground for HKM rules in a watershed management context, refining the implementation rules in the process and taking these agreements to a 25-year (instead of 5 year) time frame. Initial pleas for a radical withdrawal of forest authority to the areas where public functions prevail (Fay and Contreras-Hermosilla, 2005; Fay and Michon, 2005; Michon et al., 2007) fell on deaf ears. Yet, initial resistance to the underlying ideas gradually transformed to a more positive perspective. The first application of the Hutan Desa rules in the rubber agroforest landscape of Lubuk Beringin (Akiefnawati et al., 2010) was followed by a slow expansion of the concept, as the approval process remained burdensome (with 28 separate approval steps at which the process can stall). CGIAR researchers again facilitated the first application of such rules in peat forests in Jambi province (video link), in an area with a complex migration history (Galudra et al., 2014). In the context of poverty reduction and green growth, the Indonesian government now has plans for over 12 M ha of forest land to be devolved to local communities. The Ministry is cautious on implementation of these targets, however, at least partly because lessons learned from the first cases where land was transferred to full community control (Sirait, 2015) imply subsequent processes of local concentration of power, similar to agrarian reform experience elsewhere in the world. Securing an appropriate natural resource management dimension of tenure reform (see also Meinzen-Dick et al., this issue) remains a Type III challenge, rather than Type I scaling up concept with a standard recipe.

A recent change in the formal forest definition, creates new space for agroforestry and community-based restoration in Peru (Robiglio and Reyes, 2016). The largest impact so far in this realm may well be the new Agroforestry policy of India (Singh et al., 2016) which levels the playing field between agricultural and forestry based regulations and frees the 70% of Indian timber production that derives from farms from the fees and administrative controls aimed at protecting remaining forests. A federal budget and joint ministerial authority to implement this policy (Singh et al., 2016) puts it on track to have a major contribution to poverty reduction. However, targeting at the scales of disadvantaged household members, poor households within a community, poor communities in a region, the marginal areas where these are most likely and low income developing countries all have different interfaces with iNRM issues that require scale-specific diagnostics.

The 'Integrated Conservation and Development Projects' (ICDPs) that were meant to address poverty reduction and biodiversity conservation issues simultaneously have, in general, not met their stated goals and have been declared a failure, be it with notable exceptions (Wells and McShane, 2004). Protected areas influence land use change over a larger distance than previously assumed (Dewi et al., 2013). Lessons learnt from the ICDP evaluations have informed the next generation of efforts to reduce emissions from deforestation and forest degradation under the REDD + umbrella (Minang and van Noordwijk, 2013). Opportunities exist for more explicitly taking such lessons on board in a process that reconciles three scales: the global interest in emission reduction, the local interest in enhanced livelihoods, and the national scale efforts to do so in a way consistent with the concept of common but differentiated responsibility. The PES-paradigms mentioned before (commoditization, compensation and coinvestment) can be used across these scales, reconciling the coinvestment properties of ICDP's with the opportunities of international carbon markets (Namirembe et al., 2014) and polycentric governance (Andersson and Ostrom, 2008; Dewi et al., 2015). Wider horizons on the way 'hydroclimates' are influenced by tree cover (Ellison et al., 2017) are yet to breakthrough in geopolitical discussions of climate change (van Noordwijk et al., 2014c). It reflects a profound 'change of theory'.

7. Discussion

The currently dominant framing of the two-way relationship between iNRM issues and poverty recognizes two pathways: 1) addressing iNRM reduces poverty (SDG1), 2) addressing poverty reduces challenges for NRM (many other SDGs), allowing escape from resource depleting poverty traps (Tittonell and Giller, 2013). The first tends to focus on 'provisioning' services of a healthy (agro)-ecosystem, but may require a multi-dimensional interpretation of poverty (beyond X USD/day) as lack of well-being (Pascual et al., 2017). The second has a more contested track record, as new aspects of resource degradation tend to emerge once basic needs are covered (Murniati et al., 2001; Stern, 2004; Bilgili et al., 2016). A recent review (Suich et al., 2015) of empirical evidence on mechanisms that link ecosystem services and poverty alleviation found results to be dominated by provisioning services and just two poverty dimensions, SDG1 (income and assets) and SDG2 (food security and nutrition). Overall, evidence is accumulating that ecosystem services support well-being, and perhaps prevent people becoming poorer. Few studies, however, provided sufficient context to understand poverty alleviation impacts (positive or negative), if any. Increased opportunities to over-exploit resources when capitals needed and/or investment required to do so become available are a recognized risk, and part of project investment criteria and safeguards by development banks. However, in the evaluation of certification schemes designed to reflect such safeguards, the lack of direct smallholder benefit from compliance has become an issue (Hidayat et al., 2016). A considerable gap thus remains in understanding the links between ecosystem services and poverty, how change occurs, and how pathways out of poverty may be achieved based on the sustainable utilisation of ecosystem services. Yet, in a systems and SDG framework, the two-way interaction between poverty and iNRM must be resolved jointly. As in the 'climate-smart agriculture' debate (Minang et al., 2015; Lipper et al., 2018) internalizing tradeoffs into a single frame may be a first step to managing them. The second will have to be site-specific diagnostics and a search for operational synergy (van Noordwijk et al., 2017d).

In a recent critique ('tyranny of averages') of the tendency of development cooperation organizations to first formulate ambitious-sounding targets and then focus on the numerically easiest ways to achieve them, Custer et al. (2017) made a plea for targets that go beyond averages. However, within the data-driven framework these authors propose, focus will remain on issues that are sufficiently advanced in terms of their 'issue cycles' that such quantification is possible. This may exclude important roles for research, as indicated before (Fig. 4). Glynn et al. (2017) recently reviewed how society at large can improve the management of natural resources and environments by (1) recognizing the sources of human decisions and thinking and understanding their role in the scientific progression to knowledge; (2) considering innate human needs and biases, beliefs, heuristics, and values that may need to be countered or embraced; and (3) creating science and policy governance that is inclusive, integrated, considerate of diversity, explicit, and accountable. A tentative list of 'progress markers' in each of the four knowledge-to-action domains (as in Table 2), may satisfy the need for accountability of research beyond the 'tyranny of numbers'. Innovative ways of integrating communication science and its concepts into research designs can help reframe solution-oriented research efforts (Lapinski et al., 2017).

Table 2
Suggested progress markers for the four interconnected knowledge-to-action chains (Fig. 4).

A. Science-based understanding of ongoing change and emerging issues	B. Societal willingness to act: from denial to responsiveness
1. Initial guesstimates of seriousness of impacts of 'emerging issues' based on current understanding of 'systems'	1. Steps from 'ignoring' to 'denial', based on conflicting evidence from 'best' and 'worst' cases in public discourse
2. Operational definitions of the entities and processes associated with the 'issue' (potentially reframing, splitting and lumping of issues based on causation and/or effects)	2. Steps from 'denial' to accepting issues as part of the concurrent 'agenda', requiring debate in a multiple stakeholder context with multiple 'knowledge' claims
3. Cause-effect mechanisms, feedback loops and system dynamics associated with the 'issue'	3. Steps from 'blaming others' and 'victim roles' to facing complex reality and taking shared responsibility
4. Agreed methods with known biases to allow replicable research and mapping	4. Initial estimates of differential (by geographic and social strata) vulnerability
5. Studies of spatial extent and temporal change of key aspects of the 'issue', its 'drivers' and 'consequences'	5. Initial estimates of differential contribution to 'causes' and likely need to change behaviour and/or pay for damage done
6. Articulation of the planetary boundaries associated with the 'issue'	6. Initial estimates of differential opportunities to adapt to consequences and reduce contributions to 'causation'
7. Using understanding of non-linearity and feedback loops, propose 'thresholds' for 'safe operating space'	7. Articulation of culture- and religion-based motivation to act in solidarity or direct self-interest
8. Agreed monitoring, reporting and verification tools for collective action at relevant scales (local to global)	8. Dynamic coalitions for change in the face of tradeoffs and synergy with other issues in various stages of their own 'cycle'
9. Scenario-evaluation tools to judge likely effectiveness of proposed and emerging innovations in their multi-dimensional characteristics (incl. tradeoffs and synergy)	9. Prioritization among concurrent issues and negotiated trade-offs between agendas of multiple negotiating parties
10. Regular re-assessment and recalibration of simplified proxies used for monitoring compliance and progress in dealing with the 'issue'	10. Sufficiently ambitious goals and adequate governance instruments (incl. monitoring compliance and effectiveness, sanctions) at all relevant scales in agreements and plans of action, with 'common but differentiated responsibility'
C. Governmentability pathways to change: from blame games to taking responsibility	**D. Technological and institutional innovation for real-life solutions**
1. Identification of current rules, incentives and motivational instruments as contributors/aggravators of the issue at stake, and options to reform them	1. Adequate grounding of potential innovators in existing knowledge and theories to explore new applications, and in lists of 'unresolved questions' for society at large
2. Reflection on an 'at least do no harm' precautionary principle in the face of remaining uncertainty and existing communication pathways with the wider stakeholder community	2. Safe spaces for innovators, in terms of resources (finances, facilities) needed and protection from micro-managers
3. Path dependency of the issue and opportunities to deal with the established context and its spatial variation	3. Support for functional diversity of pathways explored, and delayed, stepwise selection of increased support for 'likely winners', within clear societal goals and criteria
4. Relevance of and steps towards legal change in rights and responsibilities in the existing constitutional framing	4. Risk awareness and compliance with agreed safeguards by all innovators, but especially the publicly supported ones
5. Economic (efficiency) dimensions of proposed pathways for dealing with the issue (at cause and/or consequence level)	5. Early awareness of scale relations (in applicability, undesired/unexpected consequences) of emerging innovations
6. Motivational and social (fairness) dimensions of proposed pathways for dealing with the issue (at driver and/or consequence level)	6. Effective two-way feedback where existing theory ('first principles') appears to contrast with emerging practices ('Pasteur quadrant')
7. Intersectoral integration across all relevant aspects of current agenda's (i.e. beyond the focal 'issue')	7. Early feedback from potential users and stakeholders of potential consequences that are to be avoided
8. Polycentric governance dimensions of rights and responsibilities across institutional scales	8. Opportunities to evaluate likely wider consequences in scenario tools that are sufficiently robust to extrapolate beyond known empirics
9. Opportunities for new public-private partnerships (covenants, phased change, clarity on long-term goals and standards)	9. Stepwise empirical tests at relevant scales for 'promising candidates', with clarity on standards to be applied for societal risk management
10. Where necessary, adjusting governance instruments on the basis of litigation by specific stakeholder groups	10. Adequate recognition (remuneration, influence) for past success (recognizing its limited predictive skill for future successes)

International agricultural research is active across the three types of knowledge-to-action links considered here. Type I cases are open to current concepts of 'results-based management', impact assessment and monitoring. Where natural resource management in fragile areas is involved, the potential impact is far from trivial and investments by development donors in this arena are highly desirable. They require credibility and salience as primary research quality characteristics, and results should be relevant regardless of the researchers involved. The ethics of science and development may be invoked to prevent a too strong 'demand-driven' focus of research aimed at providing what end-users want. By ensuring that interventions are accompanied by mechanisms to account for and manage the full range of impacts responsible researchers in Type I case may secure greater attention for 'externalities' of current decision making (German et al., 2006).

In Type II cases, the bar for 'legitimacy' is higher, as the interests associated with the tradeoffs are likely operating at different scales and linked to different stakeholders. Impartiality of researchers is needed before advice on tradeoffs is accepted. A range of recent scenario tools and simulation games that allow decision makers to experience the consequences of their choices before they make them has been developed (Castella et al., 2007; Castella et al., 2013; Villamor and van Noordwijk, 2011) and these help both the researcher to better understand decision making, and the actors involved in making better decisions. Impact analysis of this type of research is, however, still a challenge.

Type III cases may well offer the biggest challenge to research, but also the chance to have the most profound impacts. Unfortunately, the linear models of research managers and funders don't match what it takes to be effective in this domain. It takes a long-term commitment, build-up of trust in the researchers involved (as multiple perspectives on 'legitimacy' and 'bias' are likely). Where existing conflicts can be addressed and new pathways of negotiation emerge, opportunities for livelihood improvement can get a chance – without requiring further external support. The conceptual breakthrough of the Indian agroforestry policy, opening a new chapter in the way landscape resources are managed for what they are, rather than the category (forest vs agriculture) that they belong to, cannot be easily valued in financial terms. But, the opportunity for smallholders to benefit from timber grown on farm is substantial. Minang et al. (2015) took stock of the considerable efforts expanded internationally in the 'readiness' phase of REDD + as forest-centric climate mitigation policy. As a learning phase, it has been important that many actors and stakeholders became involved, but progress has been uneven, and in the face of declining funding for this mechanism, the key question is to which extent more generic natural; resource management institutions were shaped that can play a role in the wider SDG debate. Aligned with the multiple knowledge-to-action chains and the issue attention cycle of Fig. 4, Amaruzaman et al. (2017) showed that the Q-method can be used for clarifying multiple discourses on the performance gap between ambitions for greening agriculture and reality on the ground.

In the current research-funding climate it is to be hoped that the less-predictable but potentially more important Type III efforts remain an integral part of the agenda of international agricultural research, triggering further progress in the way research management supports what is worth doing, rather than dictates what can be done.

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