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The Role of Actor Networks in Enabling Agroecological Innovation: Lessons from Laos

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Abstract: In this paper, we use conceptual insights from the actor–network theory (ANT) to explore the role of agroecological innovation systems (AeISs) in the reconfiguration of agricultural practices toward sustainability. AeISs are actor networks involving a diversity of individuals (e.g., farmers, traders, experts) and organizations (e.g., cooperatives, rural development agencies, teaching and research institutions) that mainstream agroecology principles and practices to enhance agroecosystems' resilience. Their composition and structure affect the way different agents of change interact, as well as how they access, exchange, and use knowledge as they drive the adoption of specific technologies. We document seven AeISs that were active between 2005 and 2020 in the northern uplands of Laos. Within the framework of these initiatives, action research was conducted for understanding the processes underpinning diverse technical, organizational, and institutional innovations to foster an agroecological transition. Building on a comparative analysis of AeIS, we consider how agency was distributed among collectives as they reorganized in time. Our discussion highlights the importance of configuring, enlarging, and nurturing spaces in which actors are empowered to adjust and adapt, as well as to think and act collectively in complexity. Lastly, what counts in the innovation is the underlying networking process itself, i.e., the process through which all actors of the AeIS interact and exchange. Changes in the networking processes come with a changing conception of knowledge. Moving from knowledge to knowing (i.e., knowledge in the making), AeISs no longer only promote products or technologies, but also collective intelligence based on an ethic of care.

Keywords: agroecology; agricultural innovation systems; impact assessment; actionable knowledge; Laos

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1. Introduction

The concept of agroecology dates back to the 1930s, when it was integrated into the scientific vocabulary as a reference to research on ecological processes applied to agricultural production. Starting from the 1960s, the concept of agroecology became politicized, referring first to an environmental movement and later on to a specific set of practices aiming at a more sustainable agriculture [1]. In recent years, agroecology has gained momentum with its endorsement by mainstream development actors such as the Human Rights Council [2] and the Food and Agriculture Organization (FAO) of the United Nations [3]. As emphasized during FAO's International Symposium on Agroecology for Food Security and Nutrition held in 2014, agroecology is considered a way to build on the practices and knowledge of smallholders and family farmers to address food insecurity

and malnutrition while reducing dependence on fossil fuels and the negative impacts of the current (intensive) food system on society and the environment. For that purpose, agroecology requires "a shift from 'ready-to-use' to 'custom-made' cropping systems that places the producers at the center of local innovation systems" [4]. The 2030 Agenda for Sustainable Development adopted at the United Nations Sustainable Development Summit in 2015 paves the way to a large application of agroecology as an instrument to managing the tradeoffs among the 17 sustainable development goals [5]. A new step was taken at the UN Food System Summit in 2021, when a large number of countries and organizations officially recognized the potential of agroecological principles for food system transformation [6]. High expectations toward an agroecological transition now need to translate to tangible actions at multiple scales [7,8].

Agroecology has long been associated with debates on scaling [9,10], which constitutes a problem for one chief reason. As suggested by the reference to "custom-made cropping systems" and "local innovation systems" above, agroecological applications are context-specific, i.e., adapted to and inspired by local practices, knowledge, and socioeconomic circumstances. Agroecological research and resulting evidence on what makes the application of agroecological principles successful are typically generated—and meaningful—at small spatial scales [10]. The significant gap between the scales of agroecological research and application (i.e., plot, farm, landscape level) and the scales of decision and policymaking in relation to agrifood systems (i.e., regional, national, global level) raises questions regarding the potential for scaling up successful local applications. Responding to these concerns, the research community promotes an application of the agroecology principles at the food system scale, with policies and economic mechanisms that would create enabling conditions for scaling up local agroecological innovations [11–13].

The agroecological transition called for by diverse stakeholder groups involves profound changes in agricultural innovation systems (AIS), defined as a network of organizations and individuals, together with the infrastructures and institutions that affect the way different agents interact, access, exchange, and use agricultural knowledge. Firstly, these changes pertain to the very nature of the agroecology technique (e.g., conservation agriculture, agroforestry) and the actionable knowledge [14,15] that is generated and shared within the AIS. Agroecological knowledge is locally co-constructed and is, therefore, location specific. The performance and diffusion of agroecological innovations, therefore, involve a dimension of adaptation to local contexts and depend on favorable socioeconomic and ecological conditions. In any case, agroecological innovations are never "one-size-fits-all" solutions. Secondly, the changes over time in the operational definition of agroecology [16] were associated with an enlargement of its scope from farmer fields to food systems and the society as a whole [6,12]. Transformative approaches toward agroecology consequently evolved from agricultural extension and farmer adoption of "alternative" practices to redesigning the overall socioecological system [17–19]. These scaling questions further lead to the issue of knowledge integration beyond fields and farms to consider the overall context of innovation, e.g., political economy, governance, and infrastructures. For instance, constraints to the adoption of conservation agriculture by smallholder farmers are often found beyond the field or farm scales in, e.g., project governance and market structure [20,21].

Knowledge integration exists at small scales with, for example, scientists from different disciplines engaging farmers in the co-design of conservation agriculture-based cropping systems [22] or smallholders developing complex farming systems integrating crop and livestock productions [23]. Knowledge integration across sectors and scales remains an important challenge when it comes to addressing the broader policy, social, and economic context in which agroecological applications are developed and implemented [11,24]. For Wigboldus et al. (2016), for instance [25], scaling agricultural innovations requires moving away from a sole focus on "pushed scaling" (going to scale by supporting niche expansion) and engaging more significantly with "pulled scaling" (going to scale by changing regime conditions). In doing so, they posit that transitions come about

through interaction processes within and among innovation niches and sociotechnical regimes [26]. In this context, transformative knowledge at the core of AIS is not limited to designing and nurturing alternative practices in an innovation niche (such as experiments conducted by dedicated projects). One needs to create an enabling environment for the innovative practice to find its way beyond its initial niche and to become mainstream within the prevalent sociotechnical regime. Moving from AIS to agroecological innovation systems (AeISs), agroecology becomes the norm, fully supported at political, cultural, or institutional levels, instead of being a challenge to the system in place.

In this paper, we address the issue of scaling agroecological practices, especially looking at the approaches, methods and resources employed by research-and-development stakeholders at the interface between push (incentive) and pull (enabling) interventions [18,27]. We distinguish push interventions, where financial, technical, material, and organizational support is provided to targeted actors, allowing them to modify their practices (e.g., subsidies and farm extension work), and pull interventions that target the broader social and economic conditions in which actors make decisions in order to favor desired practices (e.g., sensitization and price premiums, regulations on agricultural practices). At the interface between push and pull forces of change, we consider an AeIS as a network of organizations and individuals that contributes to sustain more ecologically-sound practices, processes, and forms of organization in agrifood systems, together with the infrastructures and institutions that affect actors' interactions and knowledge access, exchange, and use. Mapping the social and material processes through which resources and inputs are actually put into practical use is crucial to grasping the dynamics of agricultural innovation in AeIS. We use the actor–network theory (ANT) as a framework for understanding the context of workplace, technologies, organizations, and people involved in agroecology innovations. Indeed, learning for innovation is distributed among a network of actors, including researchers, farmers, extension officers, nongovernmental organizations (NGOs), credit providers, and firms, whose activities are governed by a range of formal and informal institutions including public policies and social norms. Actors come together to form temporary networks creating assemblages of relations specific to actions and events and forming a collective of actants [28,29]. Connections between heterogeneous networks in AeIS are then observed as hybrid collectives of actants (humans and nonhumans) with agency in the innovation process. ANT has been used to investigate the success of a number of technical innovations and in particular, to describe a number of heroic failure [30]. The visible results of AeIS should not be understood as the outcomes of a coherent plan or blueprint conceived in advance and implemented in a systematic manner, but as contingent results emerging from a process situated in time and space, conditioned by resource constraints and by the uncertainty inherent in a dynamic flow of events. This opens up a new perspective on agency as distributed in collectives that attempt and accomplish tasks, in practice, by interrelating humans and nonhumans [31]. Examining actor networks provides a broader understanding of the people, places, organizations, and events that mediate the innovation system. As the social context of the innovation largely shapes the AeIS structure and functioning, even more than its technical content, it should be considered when supporting the agroecological transition through dedicated interventions and transformative approaches.

In the next section, we introduce seven case studies of AeISs that constituted successive attempts to bring agroecology to scale over a period of 15 years (from 2005 to 2020) in the northern uplands of Laos. We then use a comparative framework inspired by the literature on ANT and innovation systems to analyze and draw lessons from the seven AeIS case studies. Lastly, we mobilize the lessons learnt from empirical evidence of success and failure of past interventions to guide further agroecology scaling interventions and beyond, to redefine the place of AeISs in changing sociotechnical regimes.

2. Materials and Methods

2.1. Case Studies

Starting from the early 2000s, the northern uplands of Laos have witnessed a gradual replacement of traditional shifting cultivation in mosaic landscapes by intensive annual monocropping associated with a decline in forest cover. While these developments have led to productivity gains in the short term, they have also led to negative environmental impacts, e.g., soil erosion, loss of biodiversity, exacerbated drought and flood risks, and pollution by pesticides, ultimately leading to a leveling off or decrease in yields and increased vulnerability of farmers to climate change [32]. As a response, the Lao Ministry of Agriculture and Forestry (MAF) has led successive development programs dedicated to designing and scaling agroecological practices. The practices promoted by the MAF with the support of international donors, NGOs, and research-and-development agencies were mainly based on conservation agriculture and agroforestry principles [33,34]. Beyond the technological and agronomic dimensions of agroecological innovations, the development programs promoted land management and planning, local governance, and support to farmer organizations, strengthening agricultural extension services and policymaking.

From 2005 to 2010, the Capitalization Program for Agriculture and Rural Development (PCADR) was funded by the French Agency for Development (AFD) to support conservation agriculture alternatives to intensive maize-based monocropping systems in Sayaburi and Xiengkhuang provinces (Figure 1). From 2010 to 2019, the Northern Uplands Development Program (NUDP) worked as an overarching framework to streamline activities on rural development in the northern Lao uplands. The rationale behind NUDP was MAF dissatisfaction with a large number of projects that acted without any central coordination mechanism, leading to redundancies and inefficient use of donor funding. As a multi-donor initiative, the NUDP received the support of four donors: AFD, European Union (EU), Swiss Agency for Development and Cooperation (SDC), and German Agency for International Cooperation (GIZ). Starting in 2014, AFD also supported the scaling of agroecology to the regional level through ALiSEA (Agroecology Learning Alliance in Southeast Asia, ali-sea.org) networking and learning activities across sites in Laos, Cambodia, Myanmar, and Vietnam [35]. Monitoring and evaluation systems embedded in the projects and independent studies commissioned by the donors assessed the impacts of these successive agroecology innovation systems along a 15 year period (Figure 2). The seven case studies included in the comparative analysis are analyzed here as successive learning loops along a scaling process from village to national levels (Figure 1B).

After an initial diagnosis of agricultural dynamics and their environmental impacts in the two provinces of Sayaburi (at the border with Thailand) and Xiengkhuang (at the border with Vietnam), the PRONAE Project (#1 in Figure 2 "Programme National Agro-Ecologie") developed and tested conservation agriculture (CA) practices with farmers for sustainable intensification of their farming systems [22,24]. Among other technical innovations, the action research promoted direct seeding in crop residues or mulch from cover crops as alternative to soil eroding tillage-based maize monocropping. On-farm testing, demonstration plots, and exchange visits were organized to support the dissemination of the research results among farmers of the four southern districts of Sayaburi province under the dedicated PASS component of the PCADR (Point d'Application du Sud de la province de Sayaburi) that started in 2006. In 2008, PASS set up CA farmer groups in 44 villages, involving about 1100 households and 1500 ha of land cultivated with direct seeding mulch-based cropping systems. Networking activities were encouraged within and between CA farmer groups. Agricultural fairs were organized to inform a large public about existing CA practices and policymakers were regularly invited to visit the experimental and demonstration sites conducted by local farmers with the support of extension agents from the provincial and district line agencies of the MAF, as well as national and international researchers. A monitoring and evaluation system embedded in the project conducted regular surveys of a large farm sample in target villages of the two provinces

[24,36] and fed a knowledge capitalization system funded by EU (ORCATAD—Open Resource on Conservation Agriculture for Trade and Development [37]). From 2007 to 2013, the Catch-Up Project #2 analyzed the drivers and impacts of the agrarian transition that deeply transformed the landscapes and livelihoods of the northern Lao uplands through the shift from subsistence to commercial agriculture. It collaborated with local institutions and international NGOs in developing participatory land-use planning approaches adapted to the ongoing transformation and to the capacity of the multiple stakeholder groups involved [38,39]. It also contributed to an independent multi-country evaluation of AFD-funded agroecology projects (PAMPA—Multi-Country Action Program in Agroecology).

Some key successes of these projects were pointed out by the successive impact evaluations [21,24,36,40] in terms of the (i) reduction in soil erosion permitted by the no-till system while maintaining the economic profitability, (ii) number of farmers who adopted CA practices, and (iii) interest of the MAF to promote CA techniques throughout the country. Agroecology scaling policy translated into a dedicated CA research center created in 2009 and a call for agroecology to be included in the curricula of agricultural university and vocational schools. A subcomponent of the AFD support to MAF entitled the Sector-Based Agroecology Program (PROSA) worked from 2007 to 2011 on co-designing and implementing, with a large range of stakeholders, national agroecology action plans aligned with MAF's agriculture development policy. This project promoted the Conservation Agriculture Development Fund (#3—CADF) that was developed in Sayaburi province as a financial mechanism to sustain the CA-related extension activities beyond the end of the PASS project. It consisted of collecting a provincial tax on maize export across the province border with Thailand to support the district agricultural services in scaling CA across the whole province. It financially supported traders and farmers associations, built the capacity of farmers and district staffs in the field of CA, and promoted contract-farming systems for maize-based agri-input supply. The MAF local network of technical service centers supported by the NUDP Program (#4 TSC-NUDP) at the village cluster and district levels was strengthened by the successive projects through specific trainings on CA and financial support to agroecology demonstration activities. Some of the centers later specialized in agroecology such as Ban Poa in Xiengkhuang or Muangmuay in Luang Prabang [35].

In 2014, the EFICAS project (Eco-Friendly Intensification and Climate-Resilient Agricultural Systems—#5) conducted an evaluation of the CA extension and CADF governance related activities to guide the scaling process to three more provinces [41]. Co-funded by AFD and EU, EFICAS activities were geographically split, with the EU funding activities in Phongsali, Luangprabang, and Huaphanh, while AFD-funded activities in Sayaburi and Xiengkhuang were carried over from previous projects, ensuring continuity. The project built, on the one hand, on the lessons learnt from the succession of CA projects in Sayaburi and Xiengkhuang provinces and, on the other hand, on participatory land-use planning activities conducted under the Catch-Up project and a GIZ funded component of NUDP. Action research was conducted in 12 intervention villages, and the monitoring and evaluation system included a control village for each intervention village. A participatory innovation network engaged village communities and development stakeholders in co-designing and testing agroecological practices adapted to local contexts. A project attempt to hand over extension activities to local institutions took the form of the "land regeneration initiative" (#6). It supported capacity building of the Xiengkhuang Provincial Agriculture and Forestry Office (PAFO) in implementing autonomously and through an integrated approach a range of activities previously promoted by diverse projects operating in the province, e.g., land-use planning, organic farming, pesticide use awareness campaign, and soil restoration. Lastly, from 2017 to 2019, the project supported a national-level multi-stakeholder communication platform named the Lao Uplands Initiative (LUI—#7) that aimed at creating an enabling environment to broad scale dissemination of

agroecology all over the Lao uplands through knowledge sharing among multiple stakeholder groups and formulation of evidence-based policies [33].

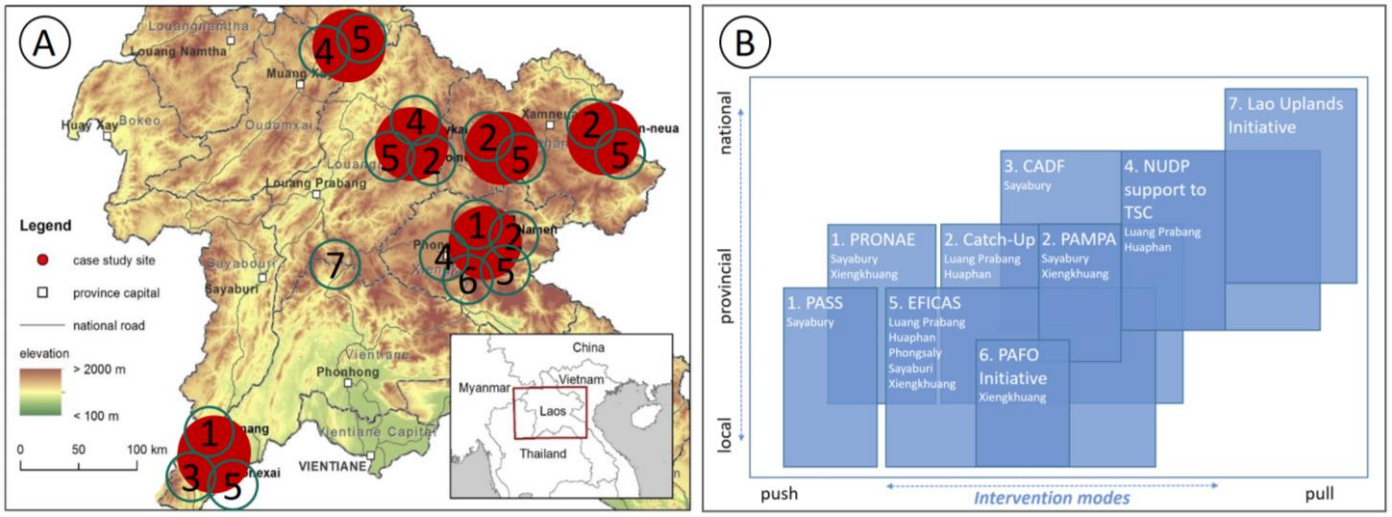


Figure 1. Case study sites in the northern uplands of Laos. (**A**) Numbering corresponds to the AeIS case study; (**B**) AeIS case studies mapped according to the scales addressed and modes of intervention.

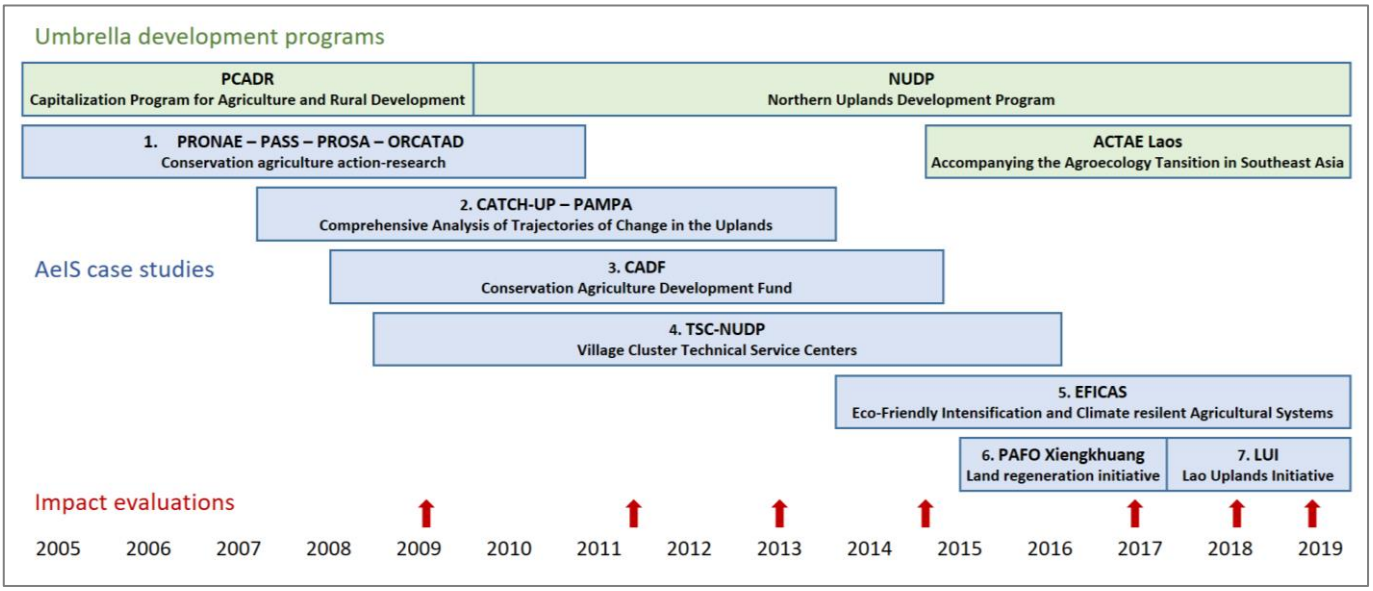


Figure 2. Agroecology support programs and case studies in the northern uplands of Laos.

2.2. Analytical Framework for Comparative Analysis of AeIS

Our proposed analytical framework builds on the actor–network theory (ANT) [29,31,42] and on work related to innovation system platforms [42–44]. Indeed, the systemic, cross-sectoral perspective put forward in this literature constitutes a strong ally when attempting to gain a comprehensive view on the actors and factors that co-determine agricultural change and innovation, including in the context of development interventions. ANT focuses on science-based innovation processes. Understanding the innovation process necessitates engagement with all the "actants" (human and nonhuman constituents of the network), their interactions, and resources mobilized in the AeIS that together determine agroecological changes away from conventional practices. Under the lens of ANT, the analysis consists of identifying the social mechanisms that the actors (individuals or group of individuals) involved in the collective action or project put forward

during collaborations with others to achieve their goals. As the network grows, they may join with others, outside the system, to pursue the innovation. In doing so, they contribute to developing discourses about the innovation, as well as its performances and constraints to adoption, which are also studied to reveal the interactions within and between networks.

The literature on agricultural innovation systems puts forward a useful typology of system components to explain the performance of innovation systems [25,42,44–46]. This literature looks for instance at the physical infrastructure (e.g., presence or absence of roads or telecommunication network for disseminating information, technical innovations and their byproducts), networks of interaction and collaboration (e.g., quality and nature of actors' relationships and their influence on knowledge and acceptance of new outside developments), or actors' capabilities (e.g., education levels influencing the potential for dissemination of complex innovations). For comparing the above case studies, these different components were turned into a descriptive index of sectors and types of intervention (Table 1). From there, we looked at the different elements of the AeIS and assessed how specific interventions addressed issues of scaling and integration, as well as, more generally, to what extent they reflected key principles of agroecology, such as the positioning of smallholder farmers at the center of the innovation process.

Table 1. Sectors and types of agroecological intervention (adapted from [43]).

Sectors	Examples of Intervention	Push-Pull
Material assets	Providing subsidies, equipment, village funds, credit schemes	Push Incentives
Organizational capacities	Strengthening farmer groups, village organizations, entrepreneurship	
Technical capacities	Providing technical training, advice	
Network configuration	Organizing farmer-to-farmer, producer-to-buyer exchanges	
Market structure	Promoting contract farming agreements	Pull Enablers
Soft institutions	Organizing awareness raising campaigns	
Hard institutions	Drafting laws, regulations	
Physical infrastructure	Building roads, schools, banks, telecom network	

2.3. Data Collection and Analysis

Relying on publications, gray literature, and expert knowledge from a pool of scientists having conducted action research on these case studies, we built a series of diagrams representing the main actor groups targeted by the different interventions as a basis for comparison (Figure 3). "Actor × intervention" matrices were completed and discussed, highlighting the different sectors and types of agroecological interventions cross-tabulated against key actor groups involved (Figure 4 and Appendix A). The matrices combine the two ideas of innovation systems as a network of actors, infrastructures and institutions, and agroecological interventions having specific push or pull characteristics depending on the sectors they target. Basically, we consider all interventions dealing with actors' material and financial assets, technical and organizational capacities as push interventions that incentivize changes, and other interventions pertaining to market structure, institutions, and infrastructures, what the World Bank (2006) refers to as the support structures of agricultural innovation systems, as pull interventions that create enabling conditions for change [47]. Building on secondary data available, we also reflected on the participation of target populations and the specific challenges that affected the success of the different AeISs under scrutiny. The overall evaluation approach involved a series of three workshops with the facilitators of the seven multi-stakeholder platforms. They were invited to comment on the results and interpretations put forward by the scientists who analyzed the case studies. Through these interactions, they gradually reached a common understanding of the role of actor networks in enabling agroecological innovations that we report in the next sections.

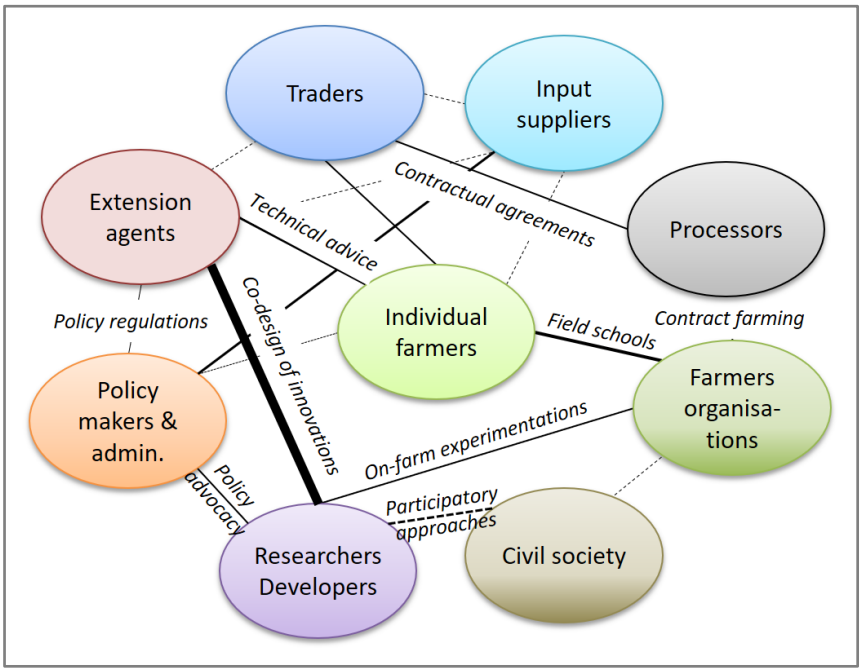


Figure 3. Example of representation of a hypothetical AeIS actor network. The nodes correspond to the categories of actors in the actor network. The size of the lines represents the strength (e.g., activities, contracts) or the frequency of interactions between actors in the AeIS.

Sectors		Material assets	Organizational capacities	Technical capacities	Network configuration	Market structure	Soft institutions	Hard institutions	Infra-structures
Actors	Individual farmers								
	Farmer organizations								
	Agri-input suppliers								
	Processors		PUSH interventions				PULL interventions		
	Traders								
	Extension agents								
	Research and development								
	Policy makers, administration								
	Civil society								

Figure 4. The "actor × intervention" matrix captures the multiple dimensions of innovation (adapted from [48]).

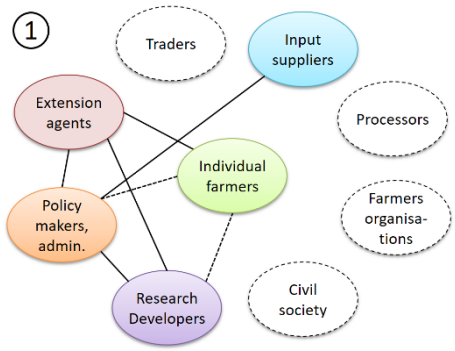
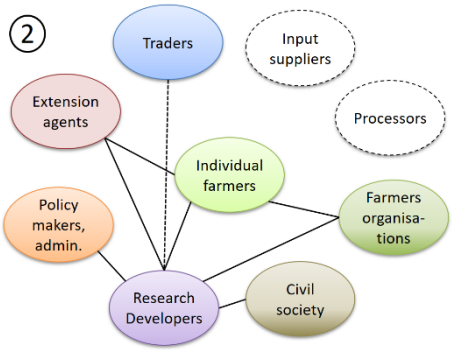
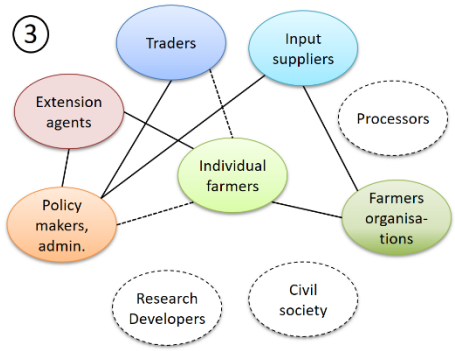
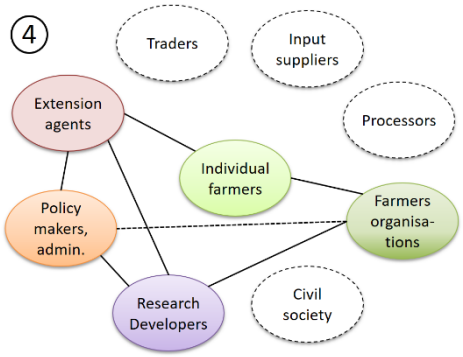
3. Results and Discussion

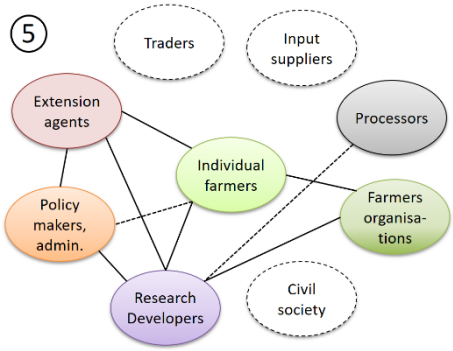
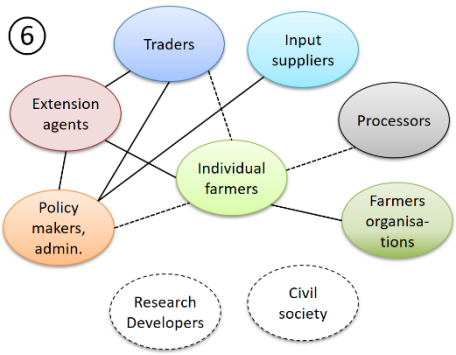
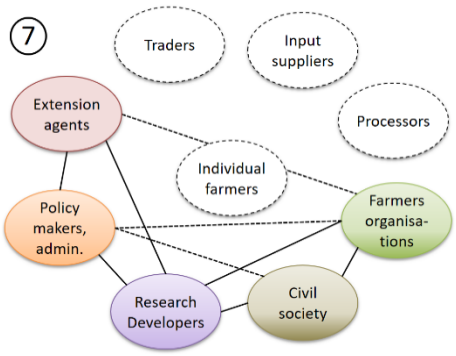
3.1. Actor Networks in Agroecological Innovations

The graphic representation of the seven AeISs in Table 2 reveals the similarities and dissimilarities in actor-network structures, thus giving a relative weight to project interventions in different sectors and/or in support of different actors. They reflect the specific challenges associated with different modalities of intervention and the gradual scaling of interventions (Figure 1B). From an initial emphasis on understanding local contexts through on-farm diagnostic surveys and developing alternative cropping systems with individual farmers, then farmer groups and extension services, the scope of the interventions gradually evolved toward increased involvement of policymakers, private sector, and civil society. While maintaining initial push activities related to technical innovations and capacity building of R&D actors and extension agents, the focus shifted toward pull activities through the inclusion of a larger range of product processors and service providers along the value chains, as well as members of the civil society (e.g., national and international NGOs) and policymakers (Table 2). This shift took place over 15 years, with each step building on the knowledge and experience acquired during the previous ones. Doing so, the AeISs enlarged the scope of agroecology by incorporating additional practices from conservation agriculture to systems of rice intensification and agroforestry, as well as principles of agroecology starting from managing diversity, synergies, and recycling through co-creating of knowledge and then moving to human and cultural values, responsible governance, and circular economy in sustainable agrifood systems [12].

Some partners who were involved in the successive stages gradually enlarged their fields of expertise (e.g., from technical to organizational innovations) and opened to new issues, actors, and postures. For example, NGOs and research institutions that initially focused on co-designing innovative cropping practices with farmers at the field level in case studies 1 and 2 [22,24] enlarged their scope to landscape level when embarking in participatory land-use planning in case studies 5 and 6 [49]. The same actors later developed a project on nutrition sensitive agriculture, bringing their jointly developed experience to new dimensions of agroecology related to human nutrition and agrifood systems. From such a long-term perspective, the evolution from one AeIS to the next can be analyzed as a learning process. Through successive loops of reflexive learning, the projects added new topics (e.g., a territorial perspective, new value chains for legume cover crops) and new actors (e.g., improved participation of local feed and food processors, private sector, policymakers) in concerted attempts to better balance push and pull dimensions and to integrate multiple perspectives and scales. When overlapping the actor networks represented in Table 2, one may notice that all actor groups and relations between actors were addressed, albeit not at the same time. Each AeIS stressed a specific issue, e.g., soil erosion (case 1), agrarian transition (case 2), agricultural extension (cases 3 and 4), climate change (cases 5 and 6), and agricultural policies (case 7), involving only the actor groups that were directly concerned. The integration of "actor × intervention" matrices in Appendix A shows the large range of push and pull interventions that were conducted with these multiple actors over time. Each AeIS learnt lessons from their time-bound experiences, which were carried over to the next ones (Figure 2).

Table 2. Actor-network description in the AeIS case studies.

Actor-Network Configurations	Issues and Innovations	Results and Outcomes
	**1—PRONAE-PASS, 2005–2010** Soil erosion due to mechanical tillage and maize monocropping on steep slopes was found responsible for yield decrease and siltation of paddy land and infrastructures. Conservation agriculture practices based on reduced tillage, permanent soil cover with crop rotation, cover crops, and mulch were combined with crop residue recycling.	The project resulted in increased awareness of the farming community and policymakers about the agronomic and environmental risks associated with intensive monocropping [24]. Farmer groups were organized around the innovative CA practices and supported by a network of trained extension agents from the government [36].
	**2—Catch-Up Program, 2007–2013** The shift from subsistence to commercial agriculture, known as the agrarian transition, produced winners and losers. A large range of organizational innovations, including participatory land-use planning (PLUP), were tested with local communities to buffer the negative impacts of the agrarian transition on local livelihood.	The project resulted in a better understanding of the role of farmer organizations in the innovation processes and the constraints farmers face to organize in cooperatives [38]. The territorial dimension of agroecology was recognized by all actor groups as a constraint to farmer adoption, and was addressed through PLUP [49].
	**3—CADF, 2008–2015** The fund was designed as part of the exit strategy of the PRONAE-PASS project to sustain the efforts of the agroecology extension network beyond the project period. This payment system for ecosystem service was very innovative in Laos. It was designed to scale-up extension activities from the initial three districts to the whole province of Sayaburi.	Despite organizational constraints faced by this initiative at the initial stages, it succeeded in engaging all actors of the maize value chain, especially the private sector, and developed strong relations across the border with Thailand. The experiment had a strong policy impact. Unfortunately, it did not resist staff turnover and entrenched economic interests of different actor groups [41].
	**4—TSC-NUDP, 2008–2016** In 2008, a MAF Ministerial Decree established technical service centers (TSC) at the village cluster level to bring extension services closer to farming communities. This policy was supported by the donors through projects that equipped this national network of extension center dedicated to sustainable agriculture.	The successive AeISs under the NUDP Program contributed to the equipment and governance of a network of TSC. These centers provided seeds, training, and advice to farming communities in their vicinity. They synergized the extension activities brought up by multiple groups of actors: administration, policymakers, researchers, NGO developers.

	**5—EFICAS Project, 2014–2019** The project aimed at developing innovative methods and intervention approaches to support farmers' adoption of climate smart agricultural systems based on agroecology. They involved the same partners as the previous projects around renewed challenges related to climate change and in larger areas (five provinces).	The project promoted landscape approaches to agroecology by combining the lessons from previous AeISs, especially technical innovations (#1 PRONAE-PASS), participatory land-use planning, and farmer network governance (#2 Catch-Up). Key outcomes relate to the capacity of village communities to transform their local institutions to enable innovation (www.eficas-laos.net, accessed on 14 January 2022).
	**6—PAFO Initiative, 2015–2017** The land regeneration initiative led by the provincial agriculture and forestry office aimed at synergizing the efforts of multiple projects active in Xiengkhuang province. It conducted an awareness campaign on, e.g., reduced and safe use of pesticides, soil fertility management, and organic farming, and it provided services to the farm networks.	The initiative was original in the sense that it was entirely managed by the provincial administration and mobilized project support without their direct involvement. They harnessed their strong ties with the private sector in supporting the reduced use of chemical inputs in agriculture. They were largely depended on project resources and, thus, had to phase out at the end of the projects.
	**7—LUI, 2017–2019** The ambition of this initiative was to capitalize on agroecology-related empirical evidence from multiple projects active in the northern uplands of Laos to inform MAF policies on sustainable agriculture. LUI promoted interactions between development partners and representatives of the government and the civil society.	The multiple actor groups involved in the initiative recognized the need for more concerted efforts toward large-scale adoption of agroecology practices. They pointed out the governance constraints (e.g., project-led development vs. foreign investment) that should be tackled collectively to enable innovation (see [33] and laouplandsforum.org, accessed on 14 January 2022).

From the comparison of the seven cases, we found that maintaining flexibility and agility in AeIS, key features of learning organizations [50], was a key element of success and impact in the context of uncertainty inherent to agroecological innovation. Such qualities were not always compatible with the constraints of higher-level management, which in some cases led to underachievement. Indeed, the umbrella programs, such as PCADR or NUDP, faced organizational challenges, turning them into mega-projects trapped into bureaucratic impediments and constrained by their huge metabolism that was consuming a large share of their human and financial resources. Strengthening the networking capacities of all actors through dedicated trainings was considered an important lever for innovation.

Our discourse analysis from proponents of the case studies calls for enhancing the reflexivity of innovation networks through participatory monitoring. Participatory types of monitoring and evaluation in which the actors have their say can help ensure that participants learn together. The flexibility of actor networks in dealing with uncertainty and the inherent unpredictability of the outcome of their actions should be mirrored by the flexibility of their monitoring systems [51]. This is especially the case when the network

develops new coordinated ways of acting to adapt to changing institutional contexts or to embark on new paths. Learning is not the end in itself. It is about learning to tackle the challenges that are encountered in innovation trajectories, by jointly developing possible solutions [48].

3.2. Actionable Knowledge in Agroecology Organizations

The ANT provided a framework for studying the active constitution of innovative practices by multiple divergent interests, desires, identities, rules, resources, technologies, and knowledge. It pointed to the competition between projects that depend on their reputation, visibility, and capacity to do things differently to capture resources from donors, thereby constraining attempts to build synergies. However, agroecological innovation is revealed as not merely invention or the doing of radically new things. It is also a regular feature of everyday sociotechnical practices, which require the continual remaking of relations and embodied knowledge. Actor networks would, therefore, largely benefit from lessons learnt by other projects, especially the previous projects. All actors agreed that it is important to develop knowledge capitalization mechanisms to keep the memory of previous AeISs, as well as successful or failed attempts to innovate.

Navigating through the successive AeISs, it became clear that actionable knowledge at the core of AeIS is not limited to design and nurture alternative practices in an innovation niche such as experiments conducted by dedicated projects. It also creates an enabling environment for the agroecology practices to find their way beyond their initial niche to become mainstream within the prevalent sociotechnical regime [21,52–54]. Indeed, combining push and pull levers of change is essential for agroecology to become the norm, fully supported at political, cultural, or institutional levels, instead of being a challenge to the system in place. The "actor x intervention" matrices specific to each AeIS case (Appendix A) show how they alternated in time between a clear emphasis on push activities (PRONAE-PASS, TSC-NUDP, PAFO Initiative) or pull activities (CADP, LUI) and a mix of both push and pull (Catch-Up, EFICAS). This succession is associated with a reflexive process, whereby the lessons learnt from one AeIS are brought to the next, gradually building up a knowledgebase about what works in different contexts. The analytical framework proposed in this paper builds on a reflexive, systemic approach involving researchers, practitioners, donors, and policymakers. Taking into consideration a time perspective longer than each individual project, it provided guidance to the multiple stakeholder groups to develop a common vision of an agroecology transition and to co-design context-specific pathways from the current situation to a more desirable one. The theory of change process applied to the next generation of AeIS (after 2019) may, thus, be seen as a legacy of the seven AeISs presented in this paper. It helps taking some distance from the inevitable small-scale and/or technical issues faced by practitioners engaged in promoting particular innovations and identifying enabling factors for higher performance.

Beyond the capacity to develop innovative agricultural systems with farming communities, the studied AeISs enhanced the capacity of actors and actor networks to think and act in complexity. We analyzed the networking process itself, the process through which actors of the AeIS interact and exchange: (i) to understand the situation in which they operate by taking into account their vision and intentions, (ii) to coproduce knowledge and deliberate in an intelligible way in order to elaborate possible means of action, and (iii) to transform and continually adjust to evolving contexts through reflexive learning loops. While this specific study is not core to this paper, we observed changes in time in the networking processes that reflect changes in the network structures. These changes came with a changing conception of knowledge in AeISs. In the most recent AeIS, knowledge was no longer understood as a "product" of science or experience, which can be taken as given and transferred to others, but as a "process" of meaning through interpretation and appropriation done by each actor. This change from knowledge transfer to knowledge co-production emerged from an overall paradigm shift in the development community, as well as, more specifically, from the regular interactions among research

organizations, international NGOs, and local communities on the ground. Moving from knowledge to knowing (i.e., knowledge in the making), AeISs no longer promote products or technologies, but processes, procedures, and collective intelligence. Lastly, reflexive processes within AeIS staff members concluded that at the heart of AeIS is learning, cooperation, and care—qualities that contrast sharply with the prevailing sociotechnical environment conducive to competition, compartmentation, and individualistic behaviors. These results were shared with a large range of stakeholders at the occasion of the Lao Uplands Initiative in 2018 (#7 LUI) that took stock of a 15 year long agroecology experiment across the uplands of northern Laos [33].

3.3. Values and Beliefs in Agroecology Transitions

Our comparative analysis of AeISs showed that transformative approaches to agroecology initially relied on developing and nurturing innovation niches (push) that were expected to influence policies and institutions (pull) toward larger shifts in sociotechnical regime, rooted in new values and beliefs [26,42]. The ANT helped appreciate how relations were made and unmade in the process of assembling the hybrid collectives that perform innovative practices. Indeed, any emergent rules and routines were immanent to relations in the AeIS, including interactions between actor groups within AeIS and links with wider societal forces that were translated into the collective. These wider societal forces took the form of new policies, such as the "turning land to capital" policy [55,56] that promoted foreign investments in the form of economic concessions, contradicting in their management modes all agroecology principles promoted by the AeIS. These policies started themselves as localized experiments in niches that were subsequently adopted as a national strategy, as in the case of the "turning land to capital" policy [55,56]. They also emerged as new perspectives in the development communities that gradually enlarged the scope of agroecology to include, e.g., circular and solidarity economy, culture and food traditions, etc. [12]. Yet this immanence of rules and routines within the AeIS raises the question how they extend beyond a specific niche or collective and become institutionalized in the wider society. It is through such institutionalization that innovations become mainstream and, thus, dissolve as innovations once dispersed in society.

While policymakers were expected to take part in the co-production of actionable knowledge, and then influence policies, it was not so clear from our study whether the civil servants from the ministries were actual agents of change who could trigger policy enabling (pull) levers. In many instances during the AeISs described in this paper, we found that government officers used projects to develop expert-based recommendations, rendering technical key political issues about societal transformations [57], such as the power given to farmers groups, associations and cooperatives, or the role of civil society in the agroecology transition [38]. As a result, projects tend to create a diversity of niches that do not challenge the sociotechnical regime but struggle to translate local successes into enabling conditions for change (pull effect). Often, they are constrained in their scaling process as soon as they stress or challenge the sociopolitical system in place. Deeply rooted in the principles of agroecology, AeISs should become instruments of a cultural evolution of the same span as the Green Revolution [58].

On the other hand, lessons from pull interventions such as CADF (3) and LUI (7) pointed to the limits of project-driven AeISs. Their mitigated success beyond the time span of the projects revealed a number of organizational challenges such as rapid turnover of competent staff and competition for resources between government agencies. Governance issues related to leadership, power, and agency came to the fore. Efforts to include more actors, creating new connections within actor networks tended to change the power balances and relations within and between networks as they grew up. We found that AeISs are constantly reinventing themselves as projects come and go, along with people turnover, struggling to keep the memory of previous successes and failures to maintain adaptive and learning capacity of the organization [54]. The stability and long-term investment

necessary to support the agroecology transition should, therefore, be anchored in a profound transformation of values and beliefs shared by network members, which requires a better understanding of the mechanisms at play in transition processes.

So far, development partners have maintained continuity and consistency in development interventions through multi-stakeholder platforms, such as roundtable meetings involving international donors, development practitioners, and government agencies. While supporting incremental changes and capacity building through development projects, the government rhetoric of societal transformation uses, e.g., gross domestic product (GDP) growth and least developed countries (LDC) graduation as indicators of success. Partnerships with foreign investors allow them to greatly accelerate the process of transformation described by [59] as the "big push" for large investment projects. The rationale for this "other push" is deeply rooted in modernization belief of the economy despite the obvious negative impacts on the environment, indebtedness, etc., more than the idea of sustainable development [56]. The dominant political culture may not be conducive to some of the changes the donor community wishes to support, as Chinese and Vietnamese investment projects, for example, bring more funds into the agricultural sector than development projects funded by institutional donors. At the same time, regulations and policies are systematically reinterpreted across national, provincial, and district levels of the state and adjusted to local contexts, to produce complex interactions between actor networks across scales.

4. Conclusions

In view of the AeISs described in this paper in the context of the Lao uplands [33], a pluralistic approach is desirable to promote innovation. Maintaining a diversity of actor-networks with different compositions, structures, and governance mechanisms is important to support both their agility and their resilience. Their capacity to reinvent themselves through a reflexive process determines largely their capacity to innovate in a changing environment. AeISs, defined as learning organizations, should provide support to multiple groups of actors, making use of diverse channels and approaches, while accepting that some interventions will succeed and others may fail. We found that bounding (within networks) and bridging (between networks) activities are essential to scaling agroecology innovations. AeISs are often born from external interventions; however, their capacity to transform the socioecological systems comes from within actor networks.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A. Actor × Intervention Matrices for Seven AeIS Cases

1. PRONAE-PASS project on conservation agriculture.

Actors \ Sectors	Material Assets	Organizational Capacities	Technical Capacities	Network Configuration	Market Structure	Soft Institutions	Hard Institutions	Infrastructures
Individual farmers	F1	O1	T1	N1, N2		S1		
Farmer organizations								
Agri-input suppliers				N2				
Processors								
Traders								
Extension agents	F2, F3	O2	T2	N1				
R&D actors	F3							
Policy and administration				N1				
Civil society								

Financial and material assets: F1. Free leasing of mechanical planters, distribution of equipment; F2. Funding of extension work and demonstration activities; F3. Funding of field experiments; F4. Credit schemes for mechanization, seeds, and fertilizers; Organizational capacities: O1. Structuring of production groups; O2. Support for programming and budgeting; O3. Structuring of associations; O4 Support to land management committees; Technical capacities: T1. Technical advice and coaching on CA; T2. Trainings on CA techniques; T3. Support to farmer-to-farmer exchanges and field visits; T4. Trainings on participatory land-use planning; Network configuration: N1. Funding of meetings and peer exchanges; N2. Facilitation of exchanges between farmers and private sector; N3. Roundtables and workshops involving multiple development projects; N4. Knowledge hub—information sharing among development partners; Market structure: M1. Promotion of contract-farming systems; M2. Direct exchanges between farmers and agro-input suppliers; M3. Facilitation of cross-border trade; M4. Support to value chains; Soft institutions: S1. Sensitization on tillage risk and land degradation; S2. Sensitization on safe use of pesticides; S3. Media communication and radio broadcast; S4. Sensitization on agroecology practices and impacts; Hard institutions: H1. Provincial decrees establishing the CA development fund; H2. Village land-use planning and land allocation; H3. Decree on farmer groups and associations; Infrastructures: I1. Tax collection system and provincial fund; I2. Funding construction of service centers; I3. Bringing water and electricity to service centers.

2. Catch-Up program on understanding the agrarian transition in the uplands of Laos.

Actors \ Sectors	Material Assets	Organizational Capacities	Technical Capacities	Network Configuration	Market Structure	Soft Institutions	Hard Institutions	Infrastructures
Individual farmers			T4					
Farmer organizations		O3	T3	N2	M1		H3	
Agri-input suppliers								
Processors								
Traders		O1		N2				
Extension agents		O3, 04	T4	N2		S4	H2	
R&D actors		O4	T4	N4		S1	H2, H3	
Policy and administration			T4	N3		S4	H2, H3	
Civil society				N3				

3. Conservation Agriculture Development Fund (CADF).

Actors \ Sectors	Material Assets	Organizational Capacities	Technical Capacities	Network Configuration	Market Structure	Soft Institutions	Hard Institutions	Infrastructures
Individual farmers	F4	O1		N1	M1, M2	S1		
Farmer organizations								
Agri-input suppliers					M2			
Processors								
Traders		O2, O3		N1	M1, M3			I1
Extension agents	F2	O2						
R&D actors								
Policy and administration		O2		N1			H1	I1
Civil society								

4. NUDP support to technical service centers.

Actors \ Sectors	Material Assets	Organizational Capacities	Technical Capacities	Network Configuration	Market Structure	Soft Institutions	Hard Institutions	Infrastructures
Individual farmers	F2	O4	T2, T4		M1	S1, S2		
Farmer organizations	F2	O1	T3	N2	M1	S3, S4		
Agri-input suppliers								
Processors								
Traders								
Extension agents	F2	O2, O4	T1, T3	N1		S3		I2
R&D actors	F2	O2	T1, T3	N3	M1	S3, S4		I2, I3
Policy and administration		O3		N4				I2
Civil society								

5. The EFICAS action research project.

Actors \ Sectors	Material Assets	Organizational Capacities	Technical Capacities	Network Configuration	Market Structure	Soft Institutions	Hard Institutions	Infrastructures
Individual farmers	F1, F2	O1	T2			S4		
Farmer organizations	F3	O1, O4	T2, T3	N1	M4	S4	H2	
Agri-input suppliers								
Processors								
Traders								
Extension agents	F2, F3	O2, O4	T3	N1	M4	S4	H2	I3
R&D actors	F2	O4	T4	N3	M4			
Policy and administration		O2	T4	N4		S4	H2	I2
Civil society								

6. The Land regeneration initiative in Kham district by Xiengkhuang PAFO.

Actors \ Sectors	Material Assets	Organizational Capacities	Technical Capacities	Network Configuration	Market Structure	Soft Institutions	Hard Institutions	Infrastructures
Individual farmers	F2, F3	O1	T2			S1, S2		
Farmer organizations	F2, F4	O1, O4	T3	N2	M1	S1, S2	H2	
Agri-input suppliers				N2				
Processors				N2				
Traders				N2	M2			
Extension agents	F2	O1	T4	N1				
R&D actors								
Policy and administration	F2, F4	O2		N3		S3		
Civil society								

7. The Lao Uplands Initiative—multi-stakeholder platform.

Actors \ Sectors	Material Assets	Organizational Capacities	Technical Capacities	Network Configuration	Market Structure	Soft Institutions	Hard Institutions	Infrastructures
Individual farmers								
Farmer organizations					M1	S3		
Agri-input suppliers								
Processors								
Traders								
Extension agents						S3, S4		
R&D actors				N1	M1	S4		
Policy and administration				N3, N4	M1, M4	S4		
Civil society				N3, N4	M1	S4		

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