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Faculty of Landscape Architecture, Horticulture and Crop Production Science

Ecosystems services in swidden agriculture in the Peruvian tropical Andes.

The Kechwa-Lamas farm-forestry system

Geannine Chabaneix

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Ecosystems Services in swidden agriculture in the Peruvian tropical Andes

The Kechwa-Lamas farm-forestry system

Ekosystemtjänster i svedje-jordbruk i de tropiska anderna i Peru - skogsjordbrukssystemet Kechwa-Lamas.

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Foreword

I decided to study agriculture after a long professional and personal journey seeking to acquire appropriate capabilities to work in the socio-environmental field. This journey started with my undergraduate Ecology course, as a food engineering student, when I thought I could study environmental issues and do without people in it. In my environmental studies I realized the complexity that global social-environmental challenges posed, how important and how little attention food and agriculture are given in relation to these matters. That's how the Agroecology SLU's master's programme has come to be central for my professional life.

Courses such as Ecology of Production Systems and Project Management and Process Facilitation allow me to "ground" and look for deeper roots in food systems. I gain specific knowledge on ecology of agriculture and food related sustainability. I got to see approaches that tied up together issues in a truly ecological perspective, with very significant connections. These studies and fieldwork, gave me the opportunity to share with Kechwa-Lamas families in San Martin, their culture and experiences, and made me realize the importance of collective identities to sustainability. Also, this experience helped me to see clearer interrelations between food, forests, culture at the local level, and larger scale phenomena, such as socio-political processes.

After some years working in climate change related in many instances to forests and agriculture, I again confirm the importance of integrative approaches, people and context in socio-environmental problems. In this research, it was important to me to consider more environmental impact categories of agricultural systems than carbon sequestration and storage, to which the climate change discussion is often narrowed to and associated solely to forests. It has been very gratifying, after these years of work experiences, to come back to agroecology.

Abstract

In the Amazon, life supporting services are importantly associated to forest areas. Nevertheless, the connection of ecosystem services to agricultural systems it is also of great importance, because agriculture is one of the most important causes of degradation and loss of these areas. Management decisions and agricultural practices can influence directly these impacts and sustain either supporting or degradation processes, that will impact on the larger landscape.

This research focuses on understanding how Amazonian swidden agricultural knowledge and practices, from the Kechwa-Lamas of the San Martin region in Peru, contribute to sustainability via ecosystem services (ES). For this, agroecological management practices of innovative farmers are identified and analysed in relation to ES provision, in their national and regional context. A qualitative exploratory approach was applied in an ecosystem-service conceptual framework in cooperation with the local grassroots organization Waman Wasi and five Kechwa-Lamas communities. A mix of desktop gathering of regional data and fieldwork techniques were applied for data collection, including Rapid Rural Appraisal participatory tools, participant observation and interviews with key actors.

It was found that Kechwa-Lamas agricultural tradition, deeply embedded in their identities, stands as a resisting force that maintains multifunctional agricultural systems that provide food security and enhance provisioning, supporting and regulating ecosystem services. This contribution is critical in the context of rapid land use change in San Martin, where there are signals of growing environmental impact of agriculture.

Using centrally trees, fallows and high levels of agrobiodiversity Kechwa-Lamas manage a dynamic provision of different on-farm and off-farm ES. Farmers combine farm and forest in their fields, in different sequential and simultaneous agroforestry arrangements. In these rotational farm-forest systems, innovative farmers perform and adapt the traditional swidden management, intensifying agroecological practices based in ecological processes. Improved fallows, intercropping, water conservation practices and degraded land recovery are some of the strategies, used along the swidden cycle to enhance and regenerate ecosystems services such as: soil fertility, nutrient cycling, hydrological services and carbon storage, among others.

Nevertheless, farmers face many challenges to secure their land, practice their traditional agroforestry and maintain their ecological knowledge. Swidden is often perceived as negative for forest conservation, as usually implied in technical and authorities' discourse, while, bypassing farmers' agroecological and adaptive management suited to the tropics, which even allow farmers with high ecological knowledge recover degraded soil. The regional and local government require rearranging priorities and strategies to improve socio-environmental dimensions of agricultural sustainability and adequately support farmers. Kechwa-Lamas agricultural and ecological knowledge must be taken in consideration to contribute to formal knowledge systems to confront environmental risk and climate change.

It is acknowledged that further research is needed, perhaps backed by quantitative and agrotechnical data, to strength even more the beneficial impacts of Kechwa-Lamas practices in ecosystems and communities.

Keywords: swidden agriculture, ecosystem services, Peru, Amazon

Resumen

Esta investigación se enfoca en comprender cómo el conocimiento y las prácticas agrícolas indígenas de los Kechwa-Lamas de la Región de San Martín en Perú contribuyen a la sostenibilidad, a través de servicios ecosistémicos. Para ello, se identifican las prácticas agroecológicas de agricultores Kechwa-Lamas innovadores y se analizan en relación a la provisión de servicios ecosistémicos, en su contexto nacional y regional. Se aplicó un enfoque exploratorio cualitativo en un marco conceptual de servicios ecosistémicos. Realizado en cooperación con la organización local de base Waman Wasi y cinco comunidades Kechwa-Lamas. Se combinó la recopilación de datos de escritorio con técnicas de trabajo de campo, que incluyen herramientas participativas de Evaluación Rural Rápida, observación participante y entrevistas con actores clave.

Se encontró evidencia de que la tradición agrícola de los Kechwa-Lamas, muy arraigada en sus identidades, se erige como una fuerza de resistencia que mantiene sistemas agrícolas multifuncionales que contribuyen a la seguridad alimentaria y optimizan la provisión de servicios ecosistémicos. Este aporte es crítico en el contexto de cambio de uso de tierra en San Martin, que muestra indicios de un creciente impacto ambiental de la agricultura, relacionado a la intensificación agrícola convencional.

Utilizando árboles, barbechos y altos niveles de agrobiodiversidad, los Kechwa-Lamas manejan una provisión dinámica de diferentes servicios ecosistémicos dentro y fuera de sus predios. Combinan chacra y bosque (finca-bosque) en diferentes configuraciones agroforestales secuenciales y simultáneas. En estos sistemas rotacionales chacra-bosque, los agricultores innovadores adaptan el manejo tradicional e intensifican prácticas agroecológicas basándose en procesos ecológicos. Barbechos mejorados, recuperación de suelos degradados, técnicas de conservación de agua y asociación de cultivos son algunas de las estrategias utilizadas para optimizar y regenerar servicios ecosistémicos como: fertilidad del suelo, ciclo de nutrientes, servicios hidrológicos y almacenamiento de carbono, entre otros.

Sin embargo, Los agricultores enfrentan varios desafíos para asegurar la tierra que trabajan, practicar la agroforestería tradicional y preservar su conocimiento ecológico. Esta agricultura rotacional (referida como migratoria) es percibida negativamente en relación a la conservación de bosques, como suele implicarse en el discurso técnico y de las autoridades. Mientras, se pasa por alto el manejo agroecológico y adaptativo adecuado a los trópicos de estas familias agricultoras, que incluso les permite la recuperación de suelos degradados. El gobierno local y regional requiere reorganizar prioridades y estrategias para mejorar la dimensión socio-ambiental de la sostenibilidad agrícola y apoyar adecuadamente a estos agricultores. El conocimiento agrícola y ecológico de los Kechwa-Lamas debe ser considerado para contribuir a los sistemas de conocimiento formal para confrontar riesgos ambientales y el cambio climático.

Se sabe que se necesita más investigación, por ejemplo, respaldada por datos cuantitativos y agrotécnicos, para fortalecer aún más la evidencia del beneficio de las prácticas de los Kechwa-Lamas en los ecosistemas y comunidades.

Palabras clave: agricultura, servicios ecosistémicos, Perú, Amazonía.

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Abbreviations

AGC	Above ground carbon
BGC	Below ground carbon
CIES	The Common International Classification of Ecosystem Services
ES	Ecosystem services
GVA	Gross value added
GHG	Greenhouse Gas
MEA	Millennium Ecosystem Assessment
SOM	Soil Organic Matter
TEEB	The Economics of Ecosystems and Biodiversity
ZEE	Ecological and Economic Zoning
ZOCREs	Regional Conservation and Ecosystem Recuperation Zones

1 Introduction

1.1 Problem definition

Worldwide, 60% of ecosystem services are in decline, many of which have been degraded as a result of pressure to increase the food production service (MEA, 2005). In the Amazon context, life supporting services are importantly associated to forest areas. Nevertheless, the expansion of the agricultural frontier (for crops such as coca, maize, rice, coffee, cacao and more recently oil palm), ranching and a long history of intensive natural resources extraction (Bunker 1984; UNEP-ACTO: 2009; Bennett et al. 2018) are direct causes of loss and degradation of the rainforest aquatic and terrestrial ecosystems. Thus, the capacity to provide critical ecosystem services is continuously undermined in many parts of the basin.

In the face of climate change and growing development of economic activities in the Amazon, there is increasing concern, from both the local and global communities, regarding interventions that can protect the remaining areas of forest, as well as, the livelihood of people living in these areas (Betts et al, 2008; Nobre et al, 2016, Marquardt et al, 2018). In this scenario, it is of great importance what kind of agriculture is practiced there. So far, conventional intensification is the dominant approach to agriculture in the Amazon, driven by a primary focus on the achievement of higher yields; while, local and traditional ways to work are overlooked (low inputs and high labour),

Swidden agriculture is an ancestral practice among farmers in the Amazon, which can be characterized as a traditional agroforestry system (Pfund et al, 2011; Cronkleton et al, 2014; Robiglio et al, 2015). Swidden is a rotational farming system that combines field crops with tree species in the same farm, while, alternating periods of farming with fallows phases long enough to regenerate soil fertility and subsequent land productivity (White et al, 2005, Altieri, 1999). Trees and agrobiodiversity are essential components of these systems. Some scholars argue that traditional swidden systems have a key role to play to enable goals directed at both forest conservation and agricultural diversity, enhancing various types of ecosystem services (Fifanou et al, 2011; Padoch & Pinedo-Vasquez, 2010; Ziegler 2012; Sears et al, 2018).

Nevertheless, swidden farming is often associated with environmental destructive practices such as deforestation, particularly in circumstances of high demographic and land use pressures, which is when the rotational system can become problematic (Kleinman et al, 1995). In Peru, this perception is very common, not only among specialists, but among many environmental and agrarian authorities working at different regional and national levels. Officially, in Peru swidden agriculture has been pointed out as the main driver of deforestation, though the deforestation data does not support this claim (Ravikumar et al. 2016).

Meanwhile, the ecological practices and adaptive responses to land use pressures of farmers carrying on swidden agriculture are ignored (Marquardt et al. 2013; Sears et al., 2018), and their locally developed alternatives to address deforestation and ecosystem services loss in the Amazon forests go unnoticed. In general, swidden farming is not taken into consideration in state initiatives and interventions as a farming system with potential to contribute to tackle today's highly complex land use situation in the Peruvian Amazon.

Tillman et al. (2002) argues that society in its way towards a more sustainable agriculture needs to recognize and support farmers' appropriately to guarantee the provision of food and other ecosystem services. The property of agricultural systems to supply different types of ecosystem services, beside food, has been proven crucial to uphold the productivity of the farming system and the larger ecosystem. Especially the provision of services that perform supporting and regulating functions, that are not easily visible and don't have market value i.e. soil formation, nutrients cycling, water purification, etc.

In this study I advocate that small-scale Kechwa-Lamas swidden farming system in San Martin already provides a diversity of functions (provision, regulating and supporting ecosystem services) to a wider landscape and that the initiatives and actions of these farmers should be taken into account in the development of strategies towards more sustainable food systems in the San Martin Amazonian Landscape.

2 Objectives

2.1 Aim of the study

The main focus of this research is to improve understanding of Kechwa-Lamas agriculture, its contributions and potential for sustainable food production, relating their tree management practices to “ecosystem services”, in order to further reveal its importance to the Amazonian highland landscape in the San Martín region in Peru.

2.2 Research Questions

Central Research question:
How can we understand small-scale Kechwa-Lamas swidden farming practices and knowledge, particularly those involving trees, in relation to ecosystem services and its contribution to sustainable agriculture in San Martín?

Supportive Questions

1. What are the environmental impacts of agriculture (land cover, erosion and chemical use) in San Martin and how are they linked to ecosystem services?
2. What agro-ecological management practices that involve trees can be identified in traditional swidden system among Kechwa-Lamas farmers, with small landholdings and limited access to primary forest?
3. In what ways do Kechwa-Lamas swidden farming practices contribute to an increased maintenance/provision of ecosystem services in the larger landscape?

2.3 Limitations

A limitation is that this is a qualitative study and I have not included any quantitative indicators of how much a certain farmer practice contribute to an enhancement in the provision of different ecosystem services. This is an explorative study investigating farmers' own practices. In doing so, I have focused on innovative Kechwa-Lamas farmers, in the local context called "*curiosos*" (curious). This sample of farmers is therefore not representative for Kechwa-Lamas in general. For practical reasons I could neither include farmers from Kechwa-Lamas villages very distant from where I was based for my field work. Also, the study focuses mostly on developing regulating and supporting ecosystem services, while, cultural and provisional services are discussed broadly along the analysis.

3 Conceptual framework

Ecosystems services can be defined as “benefits”, “contributions” or “functions” obtained from ecosystem (MEA, 2005; Mace et al., 2011) that directly or indirectly support human well-being (Daly 1997; Kremen, 2005). The ecosystems services-based approach to agriculture allows for a more holistic view of the landscape. It recognizes agricultural systems as ecosystems themselves (Declerk et al, 2016). The connection of ecosystem services to agricultural systems ecosystems is fundamental to agricultural sustainability, not only, because they receive and provide services, but also, depending on farmers management, agroecosystems sustain either supporting or degradation processes, that will impact on the larger landscape.

In this exploratory study, I follow the ecosystem services categorization of the Millennium Ecosystem Assessment (MEA, 2005), widely used in ecosystem services research (Figure 1). The supporting services category proposed in MEA have been criticised and referred by some authors as unnecessary label or considered synonyms for “ecological functions and processes” (Potchin & Haines, 2011). Supporting ecosystem services is not considered as a category in global initiatives like The Economics of Ecosystems and Biodiversity (TEEB), or is mixed with regulating services in The Common International Classification of Ecosystem Services (CIES), and rather considered part of the processes and functions of ecosystems.

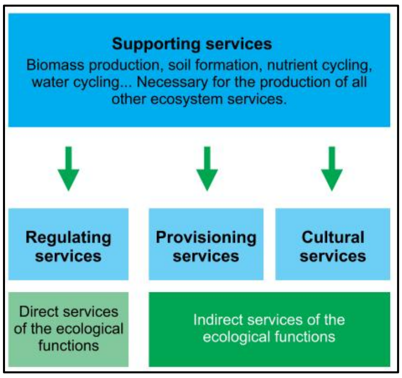

Figure 1: Ecosystem services categories (Source: Global Water Partnership, 2016)

Farmers already have ecological knowledge on many agricultural practices that can maintain or enhance ecosystem services provision, while decreasing the negative impact of agricultural activities (DeClerk et al, 2016). There are properties in ecosystems that are manageable, while other intrinsic properties are not. Farmers for instance can modify organic matter or nitrogen content in their agricultural systems (Dominati, 2010). Practices that increase organic matter and biodiversity, which for instance help to cycle nutrients and create habitats for beneficial organisms, have been consistently reported to secure multiple ecosystem services across agricultural landscapes (Smukler et al, 2012).

In agricultural-forest landscapes such as the study area with only secondary forest, interspersed patches of cropping fields and forest coexist where boundaries between agriculture and forest are less clear. Opposed to the notion of frontiers, agriculture and forest appeared to be related in a much more continuous way in these landscapes (Agrawal et al, 2014; Van Noordwijk et al, 2018). The Kechwa-Lamas ecological knowledge and practices are interesting to analyse, because as agrobiodiversed tree-based systems, their role in providing ecosystems services can be central in these spaces.

Interactions among different ecosystem services such as synergies and trade-offs are common and very dependent on scale (Fisher et al, 2009, Rodriguez et al, 2006). Generally, there are trade-offs between provisioning services with biodiversity and regulating services, while synergies arise among different regulating services (Kong et al, 2018). For example, planting trees to increase soil fertility, can improve at the same time the soil capacity to store carbon. The ''land-sparing'' and ''land-sharing'' debate on the validity of the same land sustaining multiple ecosystem services, explore these antagonisms and complementarities among ecosystem services (Mastrangelo et al., 2014; Huang et al, 2014). Advocates for ''land-sparing'' argue that the best way to minimize antagonism between intensive land uses and undisturbed natural habitats is to separate them. This prioritizes a single service to increase its provision. While, the ''land-sharing'' strategy integrates elements of the landscape, to enhance ecosystems services synergies and complementarities (Mastrangelo et al., 2014; Huang et al, 2014).

Agricultural landscapes are rapidly losing complexity affecting the supply of critical ecosystem services (Kremen and Miles, 2012). Agricultural system impacts and services provision result from both on-farm and landscapes management actions (Garbatch etal 2014). Farmers' management decisions influence directly services delivery within agroecosystems, which is also greatly shaped by the diversity of surrounding landscape, including social and ecological factors (Power et al, 2010; Fremier et al, 2014; Tscharntke et al., 2005 in Garbatch et al, 2014).

Figure 2 illustrates the conceptual framework applied to link Kechwa-Lamas agricultural practices and ecosystem services provision. In the specific setting of this study, the analysed farming systems are part of an agriculture-forest landscape.

Institutions and policies influence management, fair access and ecosystem services use, which will feedback on agroecosystems. Climate, economy and other factors are considered external but influential. Biodiversity, understood as ¨all species of plants, animals and micro-organisms existing and interacting within an ecosystem¨ (Vandermeer & Perfecto, 1995 in Altieri, 1999), is key within and around the farming system to maintain and enhance multiple services (Altieri, 1999). In this study, biodiversity or agrobiodiversity, when the term is applied to agricultural systems, are regarded as underpinning ecosystems services provision, which farmers can manage to minimize impact and enhance their agroecosystems capacity to supply multiple services. These will have an effect on the larger landscape.

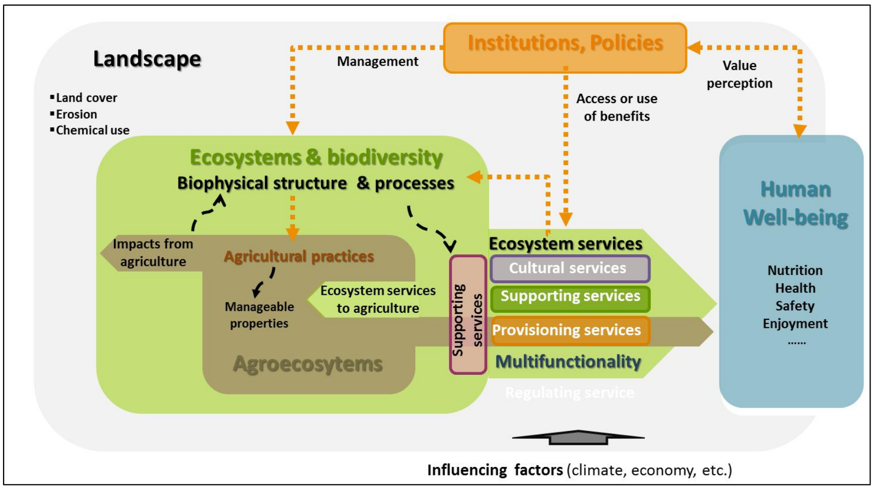

Figure 2: Conceptual Framework for Analysing Ecosystem services (Adapted from Declerk et al, 2014; TEEB, 2010.)

The conceptual framework shows that land cover change, erosion and chemical use as the major changes associated to environmental impact of agroecosystems (Daly & Pulasky, 2007). These impacts in the landscape can affect feedback to agricultural systems. Since different features and changes across the landscape would have an impact on ecosystem services flows, to both those services needed by farmers and those related to human well-being in general.

Agroecosystems need to reduce negative impacts and strengthen ecosystem services provision to contribute to the transition towards more sustainable agriculture and food systems. Sustainable agriculture "must minimize negative impacts on the environment, while optimizing production by protecting, conserving and enhancing natural resources and using them efficiently" (FAO, 2014 p 12). The conceptual model also highlights multifunctionality as a central concept. This is described as the property of farming systems and landscapes to supply multiple functions (Mastrangelo et al., 2014). Multifunctionality together with principles of resilience and diversity are emphasized as key for sustainable food systems (IPES Food, 2015; FAO, 2018).

4 Methodology

In this section I explain the methodological approach used to study Kechwa-Lamas agroecosystems located in Lamas, San Martin. This is a qualitative exploratory study, the research process and analysis were guided by an ecosystem services-based framework, applied to link agricultural practices to the provision of services, while, data collection was informed with methods and tools used in Rural Rapid Assessment.

4.1 Study area

The study took place in Kechwa-Lamas territory in Lamas, one of the provinces of the San Martin region which is part of the tropical Andes biodiversity hotspot (CEPF, 2015). The area is located in the north-eastern part of the Peruvian Andes, in the Upper Amazon basin. The upper Amazon or "Rupa Rupa" is an intersection space between the high Andes and the Low Amazon or "Omagua" that mingles ecological features of both ecosystems, whose inhabitants themselves are an expression of both Amazonian and Andean Cultures (Arévalo, 1999). This area exhibits diverse altitudes, topographies and climatic conditions that vary widely seasonally and inter-seasonally, hosting a broad diversity of species and cultivars. Overall, the climate is warm and humid with one season of marked higher precipitation between December and April (Arévalo, 1999).

Lamas is predominantly a rural province. About 75% of the labour force is employed in agriculture and a third of the agricultural land is farmed by small scale farmers that access less than 10 hectares (INEI, 2012). Kechwa-Lamas are one of the ethnic groups in the heterogeneous upper Amazon and represent the largest population of indigenous people in San Martin. They inhabit small native communities spread in the region, having next to Lamas, the largest Kechwa-Lamas town of Wayku (Waman Wasi, 2006). Spanish and kechwa are still spoken, while other local languages were gradually lost (Panduro, 1999). Kechwa-Lamas are generally smallholders that make a living from swidden agriculture (PRATEC/Asociacion Choba Choba, 2001). Mestizo and Andean migrants are two other main groups of smallholders in San Martin.

Aggressive state policies between the 40s and 70s promoted the expansion of agriculture, and stimulated massive migration, mostly Andean to set up monoculture farming systems. These agricultural systems were not suited to the local agroecological conditions and contributed to the depredation of the tropical forest (Gobierno regional de San Martin, 2008; Velarde et al, 2010). Economic booms of specific agricultural products had usually generated disestablishing effects on small-scale farmers like the Kechwa-Lamas. For instance, cotton promoted with promising high prices, sold in international markets, motivated farmers to change over to cotton farming, taking the land of a diversity of crops and even the primary forest (Rengifo et al, 2008).

San Martin landscape has a diversity of land uses from primary rainforest to long-term monoculture production; with various farming systems including different types of management, intensification levels and access to irrigation such as multiestrata agroforestry, permanent pastures and the traditional swidden agriculture. The main crops are produced in very different agroecological contexts: Rice is produced in flats areas, with access to irrigation; while cacao and coffee perennial crops are planted in slopes. These are the most important in terms of prices and number of households involved in the business (MINAGRI, 2017). In the study area in the district of Lamas and among smallholders, cacao is a common crop. Maize, cassava and plantain, that count on significantly lower prices, are common cash crops among Kechua-Lamas communities, even in the case of the self-subsistence farmers who can set aside small amounts of their production to the market.

The five Kechwa-Lamas communities that were visited are located in two different ecological zones of the Mayo river watershed: The three communities that were the focus of the study (Tinganillo, Alto Churuyaku and Alto Pucalpillo that is part of which is now Bajo Pucallpa) are located in the lower riparian zone at 250 - 600 m.a.s.l., where no primary forest is left, fallows are developing weak secondary forest and areas of degraded soil are part of the landscape (Waman Wasi, 2011); The two communities in the mid watershed (Naranjal, in the upper limit, and Morillo), at 600 to 800 m.a.s.l., are areas with more slopes, greater amount of rainfall and some primary forest cover. In the province of Lamas, 60% of the forest is kept (Gobierno Regional de San Martin, 2008; World Bank, 2006). In Lamas district, most of the forest is secondary and there is about 18% of the forest area left, almost all of it lost before 2000 (MINAM/MINAGRI, 2017). Thus, two generations of Kechwa-Lamas families have been living in areas with mostly secondary forest. In the field area there is only secondary forest.

In San Marin, agricultural activities caused 77% of forest conversion in the period 2008 - 2017 (FCPF, 2019). Perennials (mainly coffee, cacao and oil palm), rice and maize have become the main crops expanded over forest (FIP, 2012). The area of cultivated pastures and perennials has increased, while annuals area decreased. This resulted in a production decline of food crops like beans and fruits (BCRPa, 2017; MINAGRI, 2017). Higher social-environmental pressures such as, transition to cash crops, vulnerability to market fluctuations and population growth, including massive migration into the territory, have significantly increased the competition and conflict among different groups for land and resources (Egerlid et al, 2016; Marquardt et al, 2018). Many of the problems faced by small-scale farmers are derived from the agricultural intensification and disruption of the Swidden agriculture cycle (Marquardt et al., 2013).

4.2 Research Approach

This is an exploratory study using qualitative methods, complemented with secondary qualitative and quantitative data. The analysis focus on identifying and understanding traditional agricultural practices, linking them to the ecosystem services concept, well suited to choose a qualitative research strategy.

In contrast to quantitative research the imperative is placed on understanding social phenomena by analysing the participant interpretation of reality (Bryman, 2012). The approach for linking theories and data was predominantly deductive and incorporates some elements of unplanned longitudinal design. This implies that interviews are carried out with participants in more than one occasion, which according to Bryman (2012) allows for some insights regarding time order and possibly for establishing more causal connections.

For data collection I use different methods and sources of evidence in order to verify and strengthen my findings. By using triangulation, I have cross-checked information from different data sources as a way to ensure the quality and to improve the understanding of the collected information (Geilfus, 2008; Freudenberger, n.d.). Techniques within the umbrella of participatory methods used in Rapid Rural Appraisal (RRA) are applied for data collection in the study.

According to Freudenberger (n.d.) RRA can be suitable when looking at a limited number of in-depth cases in order to capture the complexity of a phenomenon. Some characteristics of RRA research procedures in comparison with Participatory Rural Assessment (PRA) are: recognition of indigenous/local technical knowledge, data collection and analysis essentially carried out by outsiders in a short time. While aiming for some participation, higher emphasis is placed on gathering information to meet the objectives of the study (Freudenberger, n.d.). These conditions meet this study time and space constraints, context and requirements.

The Kechwa-Lamas famers participating in the study come from five Kechwa-Lamas villages; Tinganillo, Alto Churuyaku, Alto Pucalpillo, Naranjal and Morillo. They all practice swidden farming and were farmers that are considered innovative, locally known as "curious" by other community members, meaning they are considered to carry out more active management and conservation efforts in their farms. They were the centre of this study.

The villages of Morillo and Naranjal were visited to have a more general idea of Kechwa-Lamas agricultural practices, but the study was centred on the Farmers living in the communities of Tinganillo, Alto Churuyaku and Alto Pucalpillo (part of which is now Bajo Pucallpa), that carried out a wide variety of tree management practices in comparison to other communities.

The premises of the civil society organization *Asociación Waman Wasi*, in the city of Lamas, capital of the Lamas province, were used as a coordination centre and to obtain additional qualitative data from participants and expert team members of the *Asociación Waman Wasi* team. Desk work was carried out mostly in Lima. The assistance and discussions with members of *Waman Wasi*, many of whom were also Kechwa-Lamas, was central for participants' selection, to get familiar with local customs and terminology and to the study internal reliability.
The *Asociación Waman Wasi* assists Kechwa-Lamas families in a process of cultural reaffirmation and biodiversity regeneration in their communities. They have been documenting Kechwa-Lamas traditions, knowledge and agricultural management since 2002.

4.3 Methods and tools

The study address research questions at the farm and the local landscape level. The identification of agricultural practices as agreoecological is guided by agroecological principles used by Nicholls et al 2017. Specific ecological processes and effects are recognized for the different practices and linked to the Agroecological Principles and specific Ecosystems Services. These linkages are built upon farmer's perspectives, local grey literature and academic research, and are explained and developed in more detailed in section 6.3.
Considering the time and resources for the study, the fieldwork was carried out in two parts. The major part of the fieldwork lasted five weeks and it was performed in 2011. This material was complemented with a shorter intensive follow-up fieldwork (10 days) between November and December of 2018.

I employed secondary sources of evidence such as academic literature, government official reports and stadistics, non-governmental organization publications. Regarding specific tools for primary data collection, I employed mainly semi-structured and non-structured interviews, which were carried out in farmers' fields that also allowed for transect walks. I carried out a total of 20 interviews, including informants. Additionally, I carried out one focus group discussion with innovative farmers ("curious"), using the farm mapping visualization technique. Previously to methods aforementioned, In the cases I cited interviewed farmers, I have changed their real names for fictitious ones to protect their identities. I also used field observation methods, including direct observation and participant observation. I participated in communal activities and gathering, where I interviewed farmers. before performing methods # 2 and 3. These methods were particularly useful in the initial part of the fieldwork for testing interview questions and adapting the research design.

The five semi-structure interviews with key informants were performed with non-governmental organizations members, government's officials and other actors in the region that could bring additional information and perspective to the research. . The list of methods used are shown in table 1.

Table 1: *List of methods used in the fieldwork of the research*

	Methods	Number	Description
1	Direct observation	4	Kechwa-Lamas communal activities
2	Non structure interviews with farmers	15	10 farmers (October 2011) (men and women) 5 farmers (November 2018) *
3	Semi-structure interviews with key informants	3 2	Waman Wasi members (November 2011) Government officials (November 2011 & 2018)
4	Transect walks and visits	10	10 farmers (6 innovative farmers)
5	Focus groups	1	6 innovative farmers (men)

*: The interviews were carried out and recorded by Gregorio Sangama in a follow-up visit.

Regarding internal validity of the study, the second part of the fieldwork, carried out in 2018, contributed in this respect, because it allowed confirming findings of the previous fieldwork in 2011. Internal validity is reported as strength of qualitative research, especially in ethnographic studies, because long participation contributes to a higher level of agreement between concepts and observations (Bryman, 2012).

5 Context

Agricultural systems in Peru are highly heterogeneous among regions and producers. With a rugged geography, it has a wide variety of ecological zones and agroecological conditions. Agricultural production is characterized mainly in relation to the natural regions "Coast, Highlands and Amazon (*Costa, Sierra* and *Selva*)", which evidences contrasting differences regarding ethnicity, history, infrastructure, market integration, technology and access to services in general.

There are 2.2 million farms in the country, 90% of the farms are small with less than 10 hectares and account for about 40% of the 7.1 million hectares of agricultural land[1]. On the other end, large commercial farms (200 to more than 3000 hectares) represent only 0.6% but control slightly more than 30% of the agricultural area (INEI, 2012). Since the 90s, national public policy is strongly focused on agro-exports development and achieving economies of scale, especially of a few high-value crops, which definitely had an impact on agriculture's overall economic performance, but in operational terms it disproportionally favours large scale agriculture (Eguren & Pintado, 2015). Whereas, small-scale[2] agriculture is not adequately supported by state interventions, and their contribution to employment, food security, agrobiodiversity and other socio environmental dimensions is overlooked (Eguren & Pintado, 2015).

[1] The agricultural land refers to the cultivated and fallowed land, excluding natural pastures and forests. According to last National Agricultural Census in 2012, there are 7.125 million hectares of agricultural land in Peru (24% in the coast, 46% in the Sierra and 30% in the Selva region).

[2] Small agriculture overlaps with the definition of family agriculture that refers to small farms owned by families that work themselves or occasionally hire labour (Eguren & Pintado, 2015). The size can be established as less than 30 hectares (Bourliaud & Eresue, sf), or less than 10 standard hectares (Eguren & Pintado, 2015), or according to the natural region less than 0.8, 5.9, 10 or 15 hectares for the *Costa, Sierra*, *Selva Baja* and *Selva Alta* respectively (Zegarra, 2009 in Robiglio, 2015).

5.1.1 Farming systems in the Amazon context

The Peruvian Amazon covers 78 million hectares in 376 districts; currently the main commercial agricultural crops produced are maize, rice, plantain and palm oil, besides coffee (the largest area in the country, covering 25% of the agricultural land in the Amazon) and cacao mainly directed to external markets. The Amazon has a long history of natural resources exploitation that has taken place through a chain of economic booms, along the expansion of the agricultural frontier with the cultivation of various crops (Bunker 1984; UNEP-ACTO: 2009; Marquardt K., 2008) and more recently palm oil, in a new cycle of private and public investment (Dourojeanni et al, 2009: Bennett et al. 2018).

Land use in agriculture in the Selva region shows a significant expansion in permanent crops and cultivated pasture, while annual crops have been reduced. Similarly, a greater orientation towards markets, monoculture and crop specialization is evidenced, especially in the *Selva Alta*. Farmers set aside larger proportions of their land for their main crops (from 35% to 45%) and for markets (from 55% to 75%). These changes also evidenced a decline of crop diversity and higher specialization towards main crops and cultivated pastures (Escobal et al, 2015).

Family producers are important actors in agricultural production and in the forestry sector. Robiglio et al (2015) estimate that small and medium family producers manage 3.5 million hectares in the Amazon mostly informally (in the *Selva* only 23% of farmers hold land titles), of which 1.45 million are forest and 0.45 million hectares are secondary forest. However, agrarian policies fail to recognize diverse fields for subsistence food production, as well as forest and secondary forests as part of a farm. Whereas, forestry policies are oriented to timber production, overlooking indigenous farmers' multiples activities associated with secondary forest management and conservation (Sears et al, 2018; Robiglio, 2015). Institutional, legal and financial incentives directly and indirectly promote forest conversion to other uses, especially agricultural use (Subsidies and schemes geared towards agriculture; regulation programs such those to eradicate coca cultivation favours obtaining titles or possession certificates for agricultural land, among others).

Smallholders, particularly indigenous farmers, are in a situation of insecurity in the face of land conflicts (Robiglio et al, 2015, Sears et al, 2018; Egerlid et al, 2016). Also, in practical terms, the state fails to recognise the ownership of various customary communal forests, because recognition as a native community is the only way to claim forest legal property rights. And, this is a long bureaucratic process and not always successful (Egerlid et al, 2016).

5.1.2 Farming systems in San Martin

In 2002, as part of the national decentralizing process, the San Martin regional government received the responsibility to plan its regional development and land use according to national policies, including forestry, agricultural strategies and promotion of forestry resources and biodiversity sustainable use (OECD, 2016). San Martin, in collaboration with Non-governmental Organizations, set the goal to become the "Green Region". It promotes this image mainly using various forest conservation categories, zoning schemes to tackle deforestation (Codato, 2015), and pilot programs like of ecosystems services payments for water resources, ecosystem services accounting, among others.

In the agricultural sector, the strategy was mostly oriented to crop specialization and market development for a few ¨flag products¨ such as coffee and cacao, to strengthen the supply chains of single crops (10 activities were prioritized in 2016), such as cacao (*Theobroma cacao*), coffee (*Coffea Arabica*), *pijuayo* (*Bactris gasipaes*), palm oil (*Elaeis guineensis*), *sacha inchi* (*Plukenetia volubilis*) (Odenanza Regional N° 008 2016 GRSM/CR)

A quarter of San Martin territory is used or has been used for Agricultural and livestock purposes (Rodriguez et al, 2009). San Martin has 7% of the agricultural land in the country and is has the largest cultivated area in the *Selva* region (Escobal et al, 2015). An important part of the agricultural production takes place in smalls farms with less than 10 hectares (70% of the farms), which cover 45% of the agricultural land (INEI, 2012a). As shown in Table 2 more than half of the cultivated area for legumes, tubers, roots and fruits is found in these small farms.

Table 2: Food crops cultivated area in small farms (less than 10 ha) in San Martin *(source: INEI (2012b)*

Food crop	Total area (ha)	Area in farms ≤ 10 ha	
		Area (ha)	Proportion of total area for each crop in the region (%)
Legumes	690	550	66
Tubers/roots	9220	5190	56
Fresh legumes	4300	2340	55
Fruits	530	260	50

Agricultural production

With a combination of several attitudinal ecological areas and good climatic conditions, San Martin is one of the regions with the highest variety of products. In monetary terms only 6 products generate more than 85% of the regional agricultural produce[3] (MINAGRI, 2017; Gobierno Regional de San Martín 2008).

San Martin landscape has a diversity of land uses from primary rainforest to long term monoculture production, with various farming systems in the middle such

[3] Main crops regarding its contributions to gross value added (GVA) are rice (32%), coffee (22%), cacao (12%), plantain (9%), palm oil (6.5%) and hard maize (about 5%).

multiestrata agroforestry, permanent pastures and the traditional swidden agriculture, including various types of management, intensification levels and access to irrigation. The main crops are produced in very different agroecological contexts: Rice is produced in flats areas, with access to irrigation; while cacao and coffee perennial crops are planted in slopes.

Cacao and coffee are the most important crops in terms of number of households involved in the business and prices, other crops such as *sacha inchi (Plukenetia volubilis*), dry beans and grapes have also high prices. While maize, cassava and plantain count on significantly lower prices (MINAGRI, 2017). These are common cash crops among Kechua-Lamas communities, even in the case of the self-subsistence farmers who can set aside small amounts of their production to the market. So far, as aforementioned, permanent crops development is a strong trend, reflected already in Amazonian land use changes.

Perception of swidden agriculture

In Peru, including San Martin, the perception of swidden agriculture as the main driver of deforestation is very common among specialists, environmental and agrarian authorities (Gestion 2018; MINAM, 2019; UNODC, 2013), and it has been even official in the national climate change discourse for quite some time (Ravikumar et al. 2016; Sears et al, 2018). Though, how it has been pointed out by later studies, the data does not support this claim, because it is not based on field data or total area deforested, but in remote sensing interpretation of deforestation patch sizes and assumptions that all small patches are deforested by small-scale farmers that practice migratory agriculture (Robiglio, 2015; Sears et al, 2018; Ravikumar et al. 2016). Moreover, very different types of agricultural uses are mixed up (shifting agriculture practiced by indigenous groups, permanent forest clearing by migrants, among others for instance) under the term migratory or subsistence agriculture (ibid).

On the contrary, deforestation studies point out that medium size producers are statistically significant in relation to forest cover change. They are located in active deforestation zones and count with more resources for forest conversion to agricultural land or pastures (Robiglio, 2015). Escobal et al (2015) found that zones with predominately larger cultivated areas (more than 50 hectares) have a greater impact on deforestation. Also, for the specific 2005-2009 period in the *Selva Alta*, it was found that zones predominantly oriented to markets have 1.5% higher annual deforestation rate than areas where subsistence agriculture prevail.

Deforestation

Forest conversion in San Martin have resulted from a complex synergy of different factors, combined at different times over last decades and most of them are strongly related to strong state-led interventions for agricultural expansion and commodity-base economic booms (Figure 3).

The development of road network infrastructure, especially the *Marginal de la Selva* road (Belaunde Terry) had a great impact on the commercial and demographic dynamics in San Martin. As well as, long periods of massive migrations, particularly Andean, have caused major changes on agricultural dynamics that conflicted with traditional agriculture in the area (Velarde et al, 2010: World Bank, 2006; Rodriguez et al 2009; Marquardt, 2008). Therefore, deforestation is explained by various causes such as expansion of the agriculture, coca plantations and roads, forest resources and timber extraction, among others.

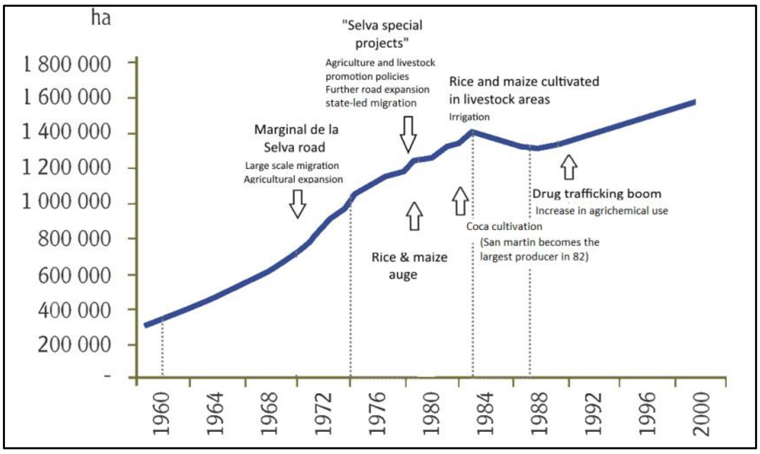

Figure 3: Total deforestation in San Martin for the period 1960-2000 (Adapted from Rodriguez 2009)

For the period 2000-2009, agricultural expansion was estimated to cause about 50% of forest lost in the entire Amazon. In the period 2001-2017 (figure 4), the average deforestation rate reached 24 thousand hectares/year, that resulted in 415 thousand hectares of tropical rainforest lost in San Martin. This accounts for 20% of the total forest clearing in the Amazon in this period (MINAM/MINAGRI, 2017). Some areas have been more affected than others, some districts deforestation can reach more than 90%, and provinces like *El Dorado* already have lost 70% of its forest area.

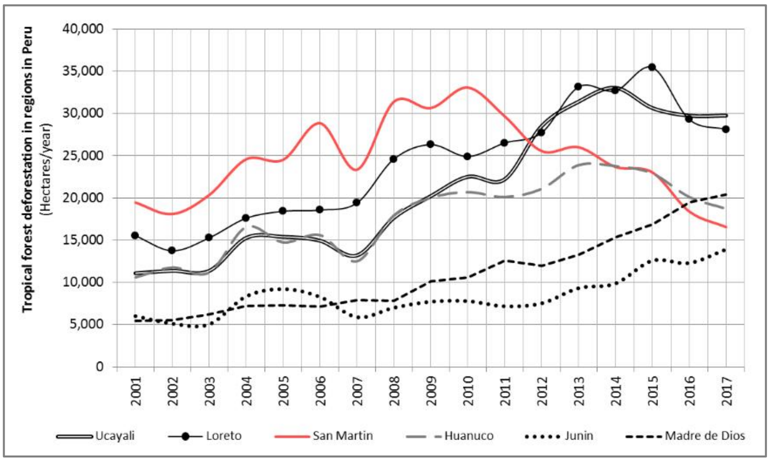

Figure 4: Total deforestation in the regions with the highest deforestation rates in the Peruvian Amazon for the period 2001-2017 (Source: MINAM/MINAGRI, 2017).

In the province of Lamas, deforestation compromises about 40% of their forest area (Gobierno Regional de San Martin, 2008; World Bank, 2006), three quarters of which was lost before 2000 (MINAM/MINAGRI, 2017). In Lamas district, deforestation have reached about 82% of the forest area, almost all of it lost before 2000 (figure 5).

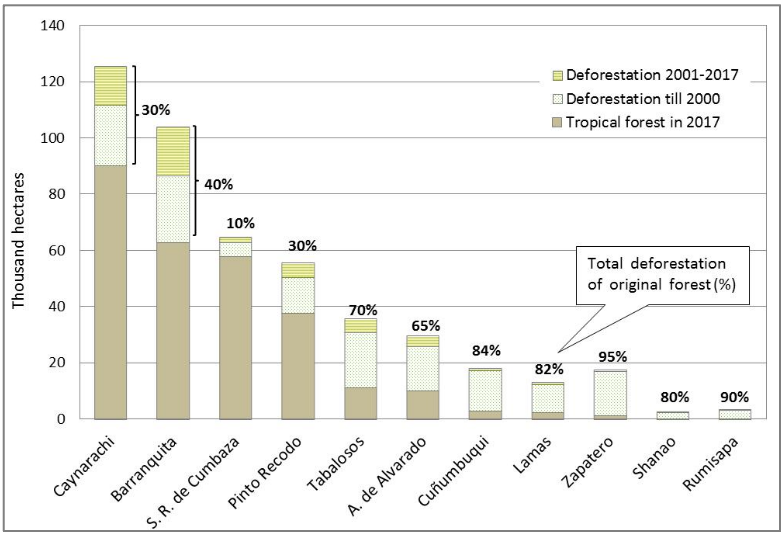

Figure 5: Total tropical forest deforestation per district in the province of Lamas (Source: MINAM/MINAGRI, 2017)

Initiatives for degraded areas recovery

Programs and projects are being developed to recover/restore degraded areas and ecosystems. Some at the national level, such as the National Program for Degraded Areas Recovery (PNRAD), Forest and Wild Ecosystems Restoration Guidelines and degraded areas identification and prioritization actions, as part of the Initiative 20x20[4]. In San Martin, 300 thousand hectares were identified as priority areas for restoration within this program (SERFOR, 2018). Additionally, within its conservation efforts the regional government have created the Ecosystem Conservation and Recovery (ZoCRES), a new land conservation modality, mostly oriented to secondary forest, in which the regional governments claim public land. However, ZoCRES are controversial because of overlapping with indigenous communities such as Kechwa-Lamas people. Also, they are not compatible with the new forestry law (Kowler et al, 2016).

Other initiatives, such as public private partnerships (Cordillera Azul National Park buffer zones), public investment projects (PIP by its initials in Spanish, for instance SNIP project 346491) and projects in alliances with NGOs are oriented to recovery and restoration, mostly through reforestation and agroforestry. Some of them include village and native communities.

[4] "It is a country-led initiative to bring 20 million hectares of land in Latin America and the Caribbean into restoration by 2020. The initiative—launched formally at COP 20 in Lima—supports the Bonn Challenge, a global commitment to bring 150 million hectares of the world's deforested and degraded land into restoration by 2020, and 350 million hectares by 2030, and the New York Declaration on Forests that seeks to restore 350 million hectares by 2030". Peru is member with the goal to restore 3.2 million degraded hectares at the country level (Initiative 20x20, 2018) http://initiative20x20.org/about

6 Results and discussion

6.1 What are the environmental impacts of agriculture in San Martin and how are they linked to ecosystem services?

Land cover changes, erosion and chemical use increase in San Martin evidence the environmental impact of agriculture as a whole. The wide diversity of agroecosystems and management practices do contribute differently to such impacts, therefore to the ecosystem services provision in the larger landscape.

6.1.1 Land cover change

In San Martin, the area of cultivated pastures and perennials like coffee and cacao has increased, while annuals area decreased, which resulted in a production decline of food crops like beans and fruits (BCRPa, 2017; MINAGRI, 2017). Crops such as plantain, coca, cassava and maize have reduced its relative importance for cultivation in about 13, 12, 10 and 6% since 1994, while rice has increased it in 19%[5] (Escobal et al, 2015). This and the concentration of economic value in fewer crops in San Martin (MINAGRI, 2017), are indications of a tendency towards monoculture and commodities production, greater areas of fewer crops are oriented to markets. In San Martin about 75% of the cultivated area is now cropped for markets (INEI, 2012b) which agrees with the sharp increase (from 55% to 75%[6]) of such area in the Selva region reported by Escobal et al (2015), who also points out that larger proportions of land in districts are used for main crops.

[5] For the Agrarian inter-census period (1994-2012)

Land cover change due to deforestation reached about 30% of the forest area in 2017[7], which has significantly modified the landscape in San Martin. Despite deforestation rate has been reduced to 2000s levels (less than 20 000 hectares/year (see figure 4), forest conversion to other uses, including agriculture, continues to be a strong trend in forest dynamics. For the period 2008 - 2017, agricultural activities caused 77% of forest deforested in San Martin (FCPF, 2019)). Perennials (mainly coffee, cacao and oil palm) rice and maize (Figure 6) have become the main crops expanded over forest (FIP, 2012). This expansion is consistent with multiples studies, especially for perennials (Escobal et al, 2015; Conservación Internacional, 2016; Robiglio, 2015; Suber et al, 2016). In the study area in Lamas district and among smallholders, cacao is a common crop.

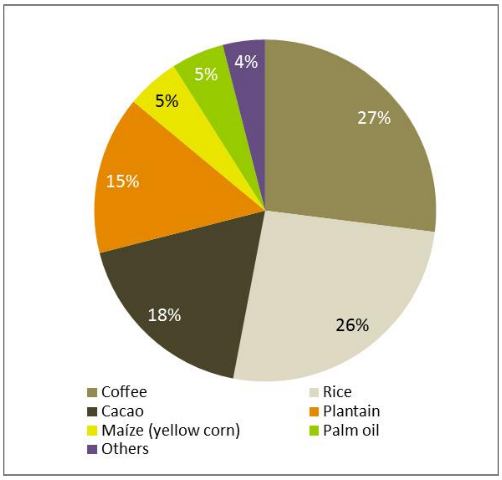

Figure 6: Relative importance of crops expansion over forest in San martin (FIP, 2012)

6.1.2 Erosion

Pluvial water erosion[8] is the main process of soil degradation in San Martin (Gobierno Regional de San Martin, 2016). Erosion increases with forest conversion to other uses, especially agriculture. The impact of agricultural management practices in the region is also reflected in erosion processes. In general, the erosion risk is increased with various unsuitable agricultural practices such as farming in slopes that are too steep, or cropping without rotation or fallow, improper use of fertilizers and organic manure, soil compaction due to heavy machinery, among others (Morgan, 2005).

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[7] The forest area calculated is about 4. 8 million hectares in total (see section 5.1.2) using offical data of MINAM/MINAGRI (2017). Other studies such as Layza et al (2018) and Rodriguez et al (2009) refer to higher levels of deforestation for 2000.

[8] "Soil erosion is a two-phase process consisting of the detachment of individual soil particles from the soil mass and their transport by erosive agents such as running water and wind" (Morgan, 2005)

According to the Ecological Economic Zoning (ZEE by its initials in Spanish) and the Forest Zoning proposal almost 20% of San Martin territory (about a million hectares) has been affected by degradation (Rodriguez et al, 2009, ANDINA, 2018). Some of these areas have lost the ecosystem services that allow agricultural production, erosion control and land-slides protection. The agricultural censuses reported that 0.4% of the area with no crops was not cultivated due to erosion in San Martin in 1994, this percentage increased to 2% (860 hectares) in 2012 (INEI, 2012a). Also, more than 6 thousand hectares were categorized as high-risk exposure in relation to floods events in the region (INEI, 2012a; Gobierno Regional de San Martin, 2016).

6.1.3 Chemical use

There are no official statistics of chemical use in terms of quantities per regions. Nevertheless, the number of farms that use fertilizers and other agrochemicals can be indicator of chemical use intensity. In two decades (1994-2012), the use of agrochemicals has increased for all four categories of chemicals in San Martin, especially of herbicides. The number and percentage of farms where these products are applied have almost doubled (figure 7). Agrochemical use is more common in commercial crops such as rice and oil palm. Even though, agrochemicals are not used traditionally in swidden agriculture, the Kechwa-Lamas perception that agrochemicals use has increased in some villages is consistent with grow in chemical use in San Martin.

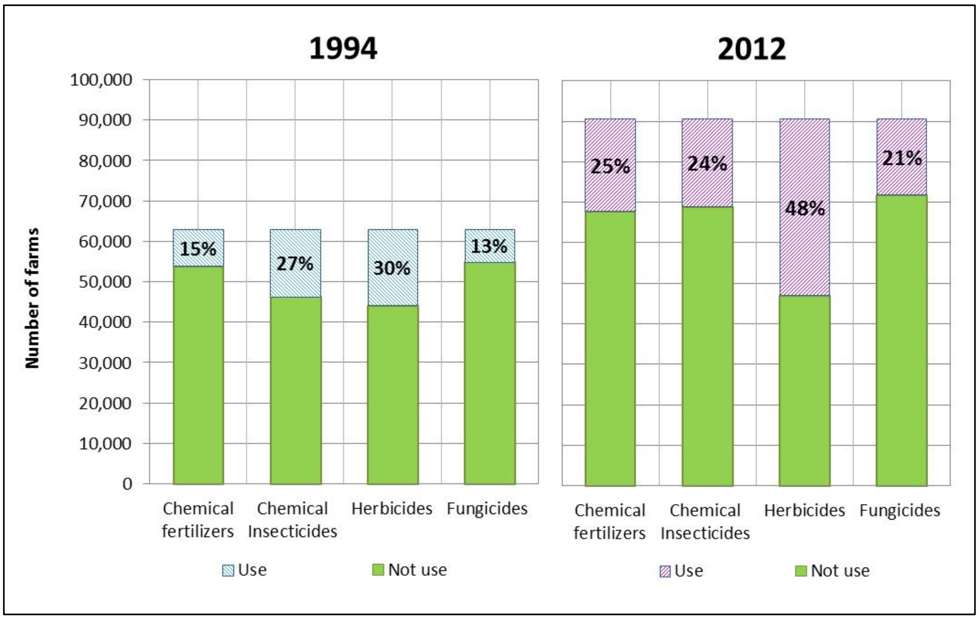

Figure 7: Number and proportion of farms that use chemical fertilizers and pesticides in San martin in1994 and 2012 (INEI, 2012b).

Even though there is an important proportion of farmers that don't make use of chemicals in their farming systems, only 6% (about 30 thousand hectares) of land in 2018 had organic certification[9], rain-fed production of coffee and cacao represent the majority of organic certifications in San Martin (interviews key informant, November, 2011; SENASA, 2019; INEI, 2012b).

6.2 What agro-ecological management practices that involve trees can be identified in traditional swidden system among Kechwa-Lamas farmers, with small landholdings and limited access to primary forest?

6.2.1 Agrobiodiversity as part of Kechwa-Lamas ecological identity

Despite of external influences and some degree of cultural erosion, the Kechwa-Lamas still maintain their own original knowledge of biodiversity and the farm, around which their vision of the world and nature is expressed. In their vision, humans are one of the three collectivities the natural world is formed of: "the gods", (*deidades*), "the humans" and "nature". They are all considered people and live in an environment of symbiosis and conversation; there are various rituals of conversation and communication in Kechwa–Lamas culture (Panduro, 1999). Therefore, the farm is not only the outcome of human activity, but it is the result of dialogue among different types of "knowledges" coming from humans, plants, animals, and spirits. In short, in Kechwa-Lamas world view everyone "nurtures".

Agrobiodiversity is the expression of Kechwa-Lamas identity which is essential in their agricultural management. The diversity of plants in the farm is supported by the local institution of "*mujeo*" (from the kechwa word for seed) that is a seed exchange system. Seeds are exchanged mainly by women of different families, and between communities. There is diversity as well, because plants appear "sown by" different animals such as *anuje* (*Dasyprocta fuliginosa*) bats, monkeys and parrots (evidence collected from farmers' interviews, Panduro, 1999). In contrast to the farmers in the riparian area, in high areas (mid watershed) with better soil fertility conditions and primary forest in the surroundings, the level of agrobiodiversity tends to be greater with more species that grow such as native potatoes[10].

6.2.2 Fallow importance and shortening

The fallow (*purma* in local terminology) stage is central for farmers to recover soil fertility in the swidden cycle, as well as, a source of fruits, materials like wood and

[9] In 2018, additional 17 000 hectares were transitioning to organic farming (SENASA, 2019)
[10] Interviews key informant, November 2011.

others. Fallow age and area in the farm positively relate to greater biomass production and species diversity, thus better soil restoration. However, the fallow is becoming shorter and smaller which may interfere with its role to recover soil fertility. This is happening because farms sizes have declined or simply the fallow is being replaced by single crops. Longer cropping phases of 6 or 7 years enhance the problem, because nutrients depletion is higher and might risk the soil capacity to recover in the fallow phase (Ribeiro et al, 2013). Some authors refer to this phenomenon as fallow shortening or fallow crisis (Kleinman et al, 1995; Richards, 1997 in Marquardt et al, 2010).

The greater difficulties to access land that many small-scale farmers are having are making their rotational agriculture significantly problematic. For the Kechwa-Lamas, this is a fact of life over past years, especially in the riparian zone.

In the riparian zone (Tinganillo, Alto Churuyaku and Alto Pucalpillo), 5 hectares were the average total area owned by the interviewed Kechwa-Lamas families[11]. They had from 1 to 4 hectares as actual cropping area. Most of the plots have been inherited after dividing up a bigger farm owned by a single farmer in the previous generation. Some farmers also had some plots in higher areas, where the sizes are bigger and there is still access to primary forest. Marquardt et al, (2010) reports that a family has a third of the area farmers used to have 30 years ago.

6.2.3 Swidden cycle in Lamas: Farm-forestry systems

¨*We say that the farm, the good farm, walks*¨ (Rafael Tapullima, Tingarillo)[12]

Swidden farming combine crops with trees, in a temporal sequence within a cycle that alternates crops stages with fallow periods. This combination takes place also in space, with trees scattered in the cropping areas (transitional stages) and with various areas in different phases of the cycle within the farm (Figure 8). Farmers obtain from their diverse system not only food, but also medicines, firewood, construction materials like timber and palm leaves for their roofs and others.

[11] Interviews key informants, November 2011 and 2018.
[12] Farmers interviews, October 2011.

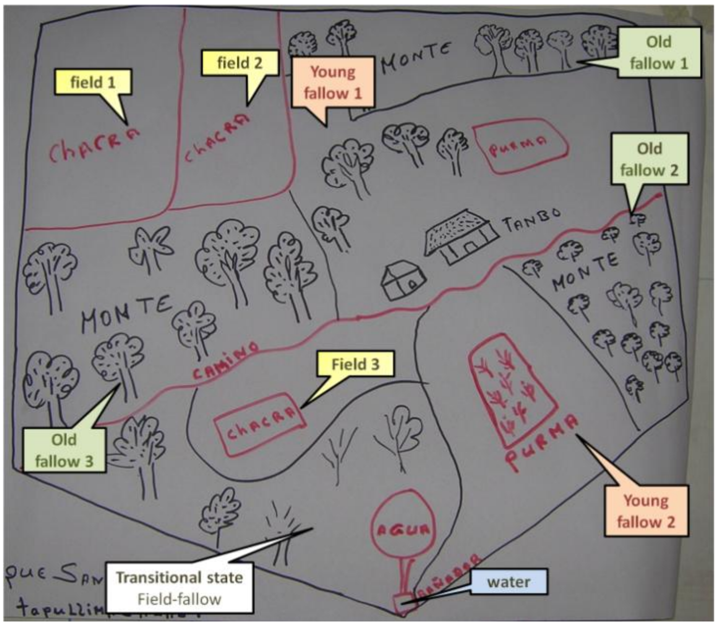

Figure 8: Farm map showing field, transitional stage, young and old fallow areas within a farm in Tingarillo community (Farmers interviews, October 2011)

As shown in this figure, different cropping fields and fallow of different "ages" are combined. In this farm there are: 3 cropping areas; one area in a transitional state; two young fallows (ages between 6 and 12 years) that look like a weak secondary forest, and three old fallows o *macchu purma*, old fallow number1 had more than 30 years in 2011, in 2018 most of it continues standing, except for a small fraction that became cropping field.

These farming systems are dynamic and are being constantly and gradually modified. As new conditions appear, such as reduced access to natural forests, smaller plot area that causes shorter fallows or very long cultivation periods, families adapt and take care of the practices that allow them to face these situations. In general, knowledge and practices in Kechwa-Lamas communities are very diverse. For instance, farmers are generally open to take part of NGOs projects and initiatives. They adapt, apply and try techniques in their fields, according to their own judgment[13].

Among the main variables in practices stand: the duration of fallow, fallow passive (natural regeneration) or active (farmers work to speed natural regeneration) management, the level of crops and species diversity, if it is a secondary forest cleared and/or if the degraded land is recovered. There is no primary forest in the field area, thus clearing primary forest is not an option.

[13] Farmers interviews, October 2011.

It is important to recognize the dynamics of the cycle and identify the elements that favour its sustainability, as well as, recognize those that diminish it. The following are the swidden agriculture cycle stages (See Figure 9):

1. Land preparation

The cycle begins with land preparation, clearing the fallow, locally called "*purma*" through different strategies, mainly different types of burning to be able to work the land and minimize nutrient losses, in this way farmers manage trade-offs in terms of nutrients. At this stage, some farmers rather incorporate degraded lands covered by herbs like *kashu uksha* (*imperata brasiliensis*) and *yaragua* (*Hyparrhenia rufa*), this carried out by planting crops and continuous weeding.

2. Cropping stage

Subsequently, the cultivation stage of the farm begins with annual cultivars interspersed with short duration perennial plants, intercropped in different ways. This stage lasts from 4 to 7 years for interviewed farmers. Thus, when the farm productivity lowers, for instance, plantain productivity is used as an indicator; the land is left to rest in order to recover fertility.

3. Young and old fallow stages

"We keep the purma in our farm because there is more fertilizer, then it [the land] can produce better, if it is left for longer time then it can yield better. …There is also a lot of firewood that is going to be mine [otherwise] I have to buy" (Raúl Tapullima Cachique, Alto Churuyaku)[14].

The fallow is central for the swidden cycle sustainability, biomass is produced and the soil is enriched with nutrients. The farmers state that the fallow is the way in which they can obtain a "good soil" with "fertilizer" or "vitamins" (they refer to the nutrients).

In most cases the land is left to rest in a transitional way "letting the *purma* appear" in cropping areas, which means that the forest vegetation is slowly developing, even before the cultivation stage ends, thus cropping fields and young fallows are combined in the space. Timber and various materials, including firewood are obtained by farmers from their own *purma*, which motivate them to maintain it.

The *purma* plays a role in family activities, the decision to cut down a *purma* is made in relation to family celebrations and events, and can be seen as a way of saving for some farmers. All interviewed farmers enrich and improve the quality of the fallow, sowing and transplanting species from the primary forest or other farms. Some authors call this practice "improved fallows", and it is not uncommon in the riparian area. In this stage, some trees that sprout naturally are planted and/or allowed to grow. The "*purma*" is maintained for a period of 6, 8, 12 years

[14] Farmers interviews, October, 2011

(stage 3: young fallow) or more than 15 years (stage 4: mature fallow or *machu purma*).

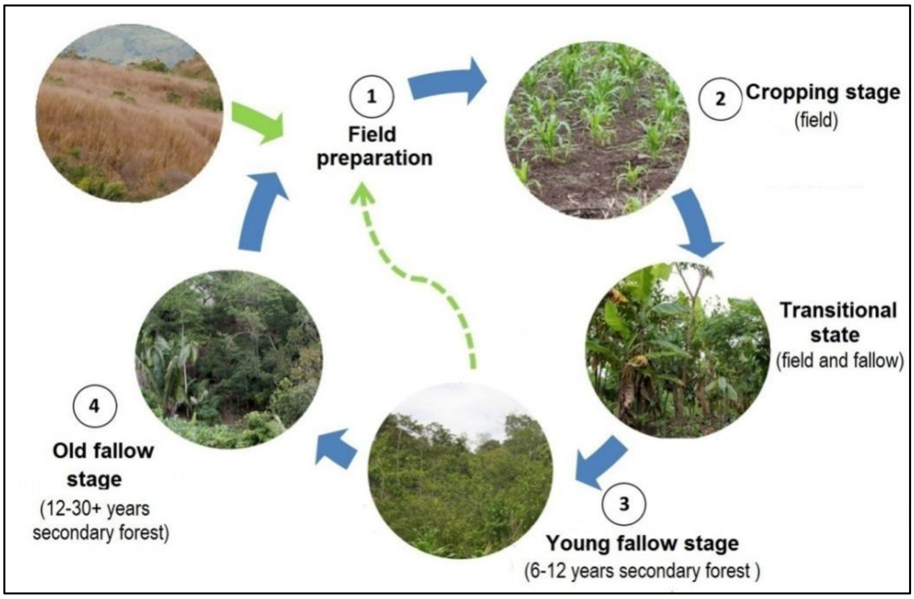

Figure 9: Swidden agriculture cycle in the riparian area in San Martin (Own elaboration).

6.2.4 Identified agro-ecological management practices

The Kechwa-Lamas cyclical system involves a traditional combined management of cropping areas and forest natural regeneration within the farm. Incorporation of various native crop and trees species within the system is very common, therefore high levels of tree diversity and agrobiodiversity are central, underpinning the various agricultural practices. This is true especially in the farm-forestry systems of the "curious" (innovative) Kechwa-Lamas farmers that were interviewed. The innovative farmers maintain and cultivate a great variety of species within their farms; they work on recovering degraded land and "improved fallows", performing practices such as planting various species to accelerate the process of building up fertility. These farmers' initiatives prove relevant to environmental conservation that should have impacts on the provision of Ecosystems Services.

Among the management actions identified, I highlight four groups of practices involving tree management and one group of other agricultural practices that are treated in less detail; the latter follow agro-ecological principles but not necessarily involve trees. The agroecological principles, to which these practices are contributing to be characterized as agroecological, are the following:

1. Enhance the **recycling of biomass**, with a focus in optimizing organic matter decomposition and nutrient cycling over time.
2. Strengthen the "immune system" of agricultural systems through **enhancement of functional biodiversity** – natural enemies, etc., by creating suitable habitats.

3. Provide the most **favourable soil conditions for plant growth**, particularly by managing organic matter and by enhancing soil biological activity.
4. **Minimize losses** of energy, water, nutrients and genetic resources by enhancing conservation and regeneration of soil, water resources and agrobiodiversity.
5. **Diversify** species and genetic resources in the agroecosystem over time and space at the field and landscape level.
6. **Enhance beneficial biological interactions** and synergies among agrobiodiversity components, thereby **promoting key ecological processes and services**.

As shown in table 3, most of the identified agricultural practices, explained in more detailed below, contribute to the six agroecological principles referred. Three of them are considered within the agroforestry category and the last three practices are included in the "other practices" group.

Table 3: Relative contribution of swidden agriculture management practices to agroecological principles (own elaboration Adapted from Nicholls et al 2017)

	Management practices*	Agroecological Principles					
		1	2	3	4	5	6
	Agroforestry	X	X	X	X	X	X
1	Fallows /improved fallows						
2	Degraded land recovery						
3a	Trees in cropping area						
3b	**Intercropping**	X	X	X	X	X	X
4	**Water conservation and harvesting**				X	X	
	Non-use of agrochemicals*				X		
5	Green manures as mulching*	X		X	X		
6	Living fences*		X	X		X	X

* Considered in the fifth group of other practices.

Kechwa-Lamas farmers acknowledge themselves that their agriculture differs considerably from conventional farming systems. They highlight the land set aside for fallows as the main feature that distinguish them from other types of agriculture in the area. Farmers also point out strategies as the maintenance old trees, ravines and "breed water species" in their streams as some of the most dissimilar aspects of their practice with other farming systems.

Figure 10 shows, within their corresponding stage in the swidden agricultural cycle, the four groups of management practices involving trees carried out by innovative farmers.

Figure 10: Swidden agriculture cycle in San Martin highlighting practices that favour its sustainability (Own elaboration).

Improved fallows accelerate the regeneration of the soil.

Unlike the fallow developed naturally, improved fallows allow access to a greater amount of nutrients, accelerating the new forest growth. Improved fallows are not practiced by all farmers in the area, because it requires higher ecological knowledge and labour.

Farmers actively work, planting and transplanting a high diversity of species from other farms, primary forest and other areas. They use palm species, fruit trees, timber trees and other perennial crops that together allow access to a greater amount of nutrients, even before the cropping stage ends. Among the most frequent species planted by farmers are *guava* (*Inga edulis*), *rujindi* (*Inga ruiziana*), and *atadijo* (*Trema micrantha*). Farmers use more than one technique for different species; for instance, *rujindi* and *atadijo* are also transplanted, germinating and/or growing naturally from shoots.

Farmers leave the shoots that naturally grow in the land after being transported by wind or "sown" by animals (They wait after one or two years of the cropping stage to leave them to grow). Among these species were *Shapaja* (*Attalea butyraceae*) *Poloponta* (*Elaeis oleifera*) and *Pashaca* (*Parkia sp)* the most common. For farmers in the area is usual to “help” the fallow keeping in the fields old trees that act as natural seed providers, looking for easy wind sowing, as well as, maintaining conditions to attract animals that help to sow, such as the *Añuje* (*Dasyprocta fuliginosa*), bats, monkeys and parrots.

Among the interviewed families, the "purma" area represented approx. 30% of small plots (3-4 ha), and more than 50% among farmers with larger plots (8-9 ha), this was a consistent result in 2011 and in the follow-up visit in 2018.

Incorporation of degraded land into the production cycle

Some families recover degraded land working in small areas (a quarter of a hectare), with intensive labour investment, intercropping, weeding and management that combine the other identified practices detailed in this section. So, they can reincorporate degraded land into the production cycle until it is transformed into an improved fallow.

Farmers state that it is common to begin the recovery process planting maize, because it can grow in very harsh conditions. This practice requires a high level of ecological knowledge and sustained work, and it is carried out only in the riparian areas, and not by all families, and those that carry out the land recovery process, do carefully assess their possibilities, otherwise the investment of time and labour may be in vain. Innovative farmers declared they felt motivated to recover degraded land to take part of their farms. One farmer stated that half of his farm was recovered, since the land was bought in such condition[15]. Some families estimated they have recovered one or two hectares in last few years (5 or 7 years).

> "This land was full of *kashu ukcha* (A weed related to impoverished soil), I've been planting corn little by little just to beat the *kashu ukcha*" (Raúl Tapullima Cachique, Alto Churuyaku)[16].

On-farm and off-farm water conservation

The effect of forest areas, particularly of mature *purma*, is recognized among farmers for improving water provision (more, clean and cold) within and off farms. The capacity of these areas to retain and regulate fresh water, increase soil moisture, lower fresh water temperature in springs and reduce soil erosion in very steep slopes is acknowledged and appreciated by farmers.

> "When one does not know how to take care of the water, the water leaves us, there are people who make their farms till the very edge of the ravine and the wells" (Waman Wasi, 2006).

Families relate some functional characteristics of specific plants and trees to the hydrological cycle. They sow and transplant from other places a wide variety of "breed water" species (Figure 11a and 11b), which are characterized by capturing more water around their root systems (Waman Wasi, 2006). Farmers are able to recognize them in early growing stages, name them and recommend their use. In

[15] Farmers interviews, November 2018.
[16] Farmers interviews, October 2011.

some very steep slopes, some farmers prefer not to clear the area because of the risk of land coming down, as well as, they sow "breed water" species for water conservation and reducing the degradation in very steep areas[17] (PRATEC, 2001). Kechwa-Lamas maintain and improve the forested areas near springs, streams and in slopes. Areas are maintained weekly to keep the streams of water running[18].

> "It is good to have our well surrounded by trees that "cry" water such as *Ceticos* (*Cecropia spp*), *aguajales* (*Mauritia flexuosa*), *Ishangas*, *witinos* (*Xanthosoma sagittifolium*, local tuber), *patquinas*, because the forest has water, then our well never dries" (Custodio Sangama from Congopera community in Waman Wasi, 2006)
>
> "Where there is a ravine, [the area and surrounded vegetation] is preserved, then we put even more [trees or plants]… also the forest with its leaves protects the humidity"[19].

Figure 11: "Breed water" Species that retain water in their roots (a) *Shapaja* (*Attalea moorei/Attalea butyracea*) in the farm of Andres (b) small *Ojé* (Ficus insipida)

The accessibility to water and taking care of water in the surrounding areas is particularly relevant to women, because they are in charge of bringing water to the house for different uses, including cooking. They also go to the sources of water to wash clothes. Many of these species are planted by animals (*Poloponta, shapaja, bombonaje*), or wind (*cetico, ishanga*), or both[20].

[17] Farmers interviews, November, 2011.
[18] Farmers Interviews, October, 2011
[19] Key informant intreviews, November, 2011
[20] Farmers interviews, October, 2011

"Me and my children take care of this little piece of land, we have a unique care of it, we are sowing trees that are not found around here at the moment, in order to have more water. In this place we sow and take after trees such as *aguaje (Mauritia flexuosa, poloponta (Elaeis oleifera), topa, situlli, bombonaje (Carludovica palmate), rujindi (Inga ruiziana), ishanao, huairuro, cetico (Cecropia spp), quillosisa, shape (Attalea butyracea), atadijo (Trema micrantha), fapina, pashaca* (o) (*Parkia spp*.) (Maria Belen Tapullima Salas from Alto churuyacu in Waman Wasi, 2006)

Intercropping including trees in the cropping fields

Intercropping and tree incorporation favours the complementarity of crops to improve productivity and optimize various ecological processes. Among Kechwa-Lamas it is common to associate annual crops (two or more crops grow together during all or part of the crop cycle) and short-lived perennials. Also, farmers plant or let grow trees and assess the right time to plant different crops to reduce competition over light and nutrients. For example, in the first years of the cultivation of cocoa, when the shade is low, banana is planted among the young cacao trees, these protects the soil from evaporation in periods of low precipitation and / or greater radiation.

Common intercropping is to sow maize, beans and cotton together with fewer plant of chili, pumpkin and some fruits specifies such as papaya and plantain. Other crops such as cassava, peanuts are also interspersed in different configurations. The calendar of intercropped species is showed in figure 12.

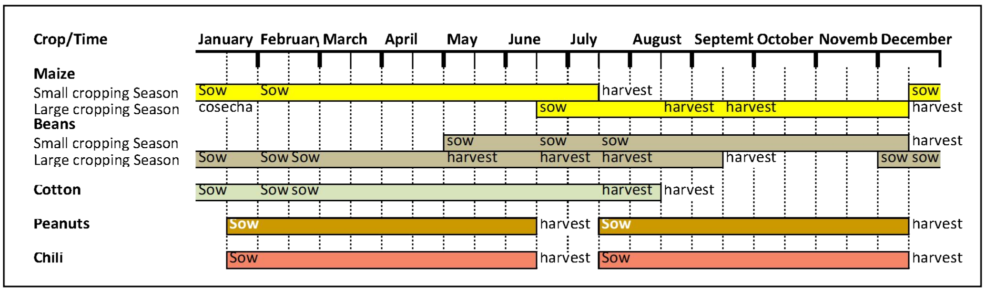

Figure 12: Calendar of main crops usually intercropped of Kechwa-Lamas (adapted from Waman Wasi calendar)

Other practices: Non-use of agrochemicals, green manures, weeds control.

In general, many of these techniques seek to accumulate soil nutrients or "vitamins" as referred by farmers. Some common actions identified during the cultivation phase are: the continuous manual weeding without using any pesticides; the use of the extracted weeds as green manure (plants used to fertilize the soil in piles or scattered like mulching); the use of living and dead barriers, for instance trees are planted or logs are left across the slopes to trap leaves, nutrient and sediments.

Some farmers indicate that he has learnt this practice from his parents and extensionists[21]. The interviewed farmers indicate that chemical fertilizers and pesticides are not commonly used in the fields, besides these are not easily accessible for a large majority and their use is explicitly related to declining quality of their water sources[22]. Though, Kechwa-Lamas perceive that agrochemicals use has gained ground among some farmers.

[21] Farmers Interviews, october, 2011.
[22] Farmers Interviews, october, 2011.

6.3 In what ways do Kechwa-Lamas swidden farming practices contribute to an increased maintenance/provision of ecosystem services in the larger landscape?

6.3.1 Ecosystem Services in Swidden agriculture

The cycle of agriculture carried out by Kechwa-Lamas families in their farm-forestry systems, encompasses a set of actions that regenerate and maintain the capacity of their agricultural systems to generate ecosystem services. In this section, the agroecological farming practices performed by innovative farmers are linked to the maintenance/ enhancement of specific ecosystem services provision.

The rotational nature of the Kechwa-Lamas system implies a dynamic provision of the different ES categories along the cycle (Figure 13). Since these agricultural practices are characterized by the use of a high diversity of species and varieties of plants/trees inside and outside their farms, it is worth to underscore that higher diversity levels managed by farmers should have a positive impact on ES provision.

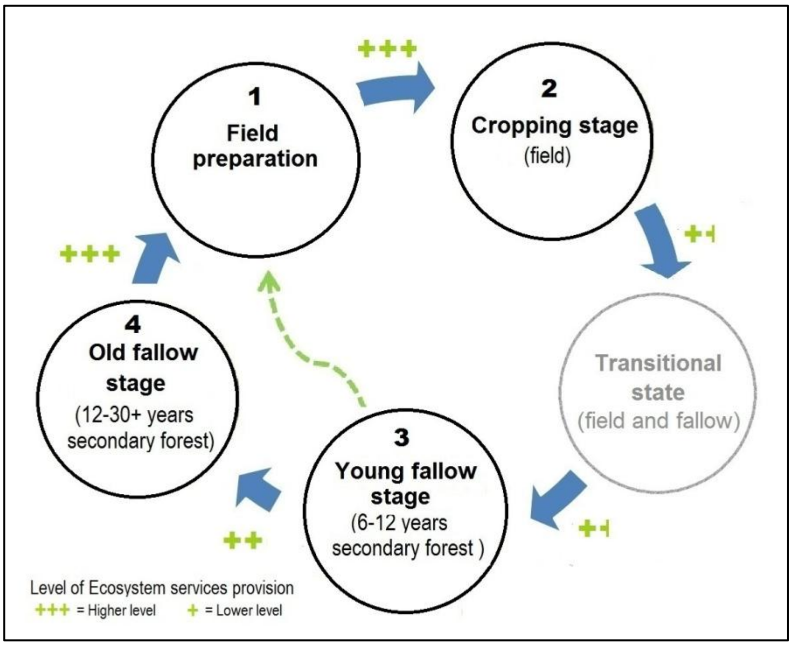

Figure 13: Referential level of ecosystem services provision in the different stages of swidden agriculture cycle (Own elaboration).

According to the collected evidence in this study, the ecosystem services that are maintained/ enhanced by the Kechwa-Lamas families are presented in table 4. The identified provisioning services are related to the variety of species grown and harvested in Kechwa-Lamas systems. While, cultural services are related to diversity as an essential element of their identity and heritage, as well as, to their ecological knowledge and understanding of the farm and forest as an integrated system. The Pollination and seed dispersal services (by wind and animals) are enhanced by farmers keeping old trees and conditions in their fields to attract animals. Apart from bees being recognized as main pollinators, many other animals such birds and bats provide pollination services as well (Nabhan and Buchmann, 1997 and Jaipal et al., 2005 in Garbach et al, 2014).

Regulating and supporting ES from 4 to 9 are grouped and developed in some more detail referring to the agroecological practices performed by innovative farmers, involving tree management. Soil Organic Matter (SOM)[23], strongly dependant on vegetative covers and soil biota, is central in provision of these services (Barrios et al, 2012; Kibblewhite et al, 2008; Smukler et al, 2012).

Table 4: Ecosystem services maintained/enhanced by Kechwa-Lamas farmers in their farm-forestry systems in the riparian area (own elaboration for Kechwa-Lamas farmers adapted from Shibu 2009)

#	Ecosystem services	ES category	Spatial scale		
			Farm/Local	Regional	Global
1	Food	P	X		
2	Firewood, timber, fibers, medicines and other materials	P	X		
3	Pollination and Seed dispersal	R	X		
4	Carbon sequestration and storage	R	X	X	X
5	Erosion control	R	X	X	
6	Hydrological services: water quantity & quality	R	X	X	
7	Soil fertility	R	X		
8	Nutrient cycling	S	X		
9	Maintenance of biodiversity/agrobiodiversity	S	X	X	X
10	Cultural identity, heritage	C	X	X	X

P: Provisioning R: Regulating S: Supporting C: Cultural services

6.3.1.1 Agrobiodiversity in-situ conservation

Farmers manage, use and have ecological knowledge of a high number of species, maintained through in-situ conservation in their farms. This diversity covers

[23] "Soil organic matter consists of living parts of plants (principally roots), dead forms of organic material (principally dead plant parts), and soil organisms (microorganisms and soil animals) in various stages of decomposition" (Bot & Benites, 2005:75)

different species from crops to native trees, palms and plants that not only implies aboveground biodiversity, but also belowground. With this ecological knowledge farmers can contribute to the understanding of biodiversity underpinning agroecosystem functioning, therefore to ecosystem services provision.

During quick transect walks across the farms in the riparian areas where conditions are harsher (less humid, no primary forest left, weeds cover some extensions of land), the number of crops ranged between 5 and 9 in the farming area that involves intercropping, with more than one variety within the species. Whereas, in the areas of *purma* and agroforest (intermediate stages between cropping phase and secondary forest), the number of species ranged between 12 and 27, including perennials such as cacao. In the follow-up visit, 7 years later these ranged between 28 and 39 species for 10-39 years *purmas*. For the region (surroundings to Lamas), the centre Waman Wasi indicates a total of 129 managed species among medicinal plants, fruits and trees that also include a great richness of varieties.

Farmers are well aware of the trade-offs between crop diversity and higher quantities of a single crop. Raúl Tapullima Cachique[24] (Alto Churuyaku) indicates for one of the lots he is recovering with maize cultivation, that it might yield about 2 tons when planted alone, but about 1.2 tons of maize when intercropped, however, the land also yields papaya, plantain and beans for instance.

Research in functional diversity indicates that this can be lost sooner than species richness (Smukler et al, 2012). High levels of biodiversity lower the risk of losing an entire functional group when faced with drastic change, so it is the supply of ecosystem services. The variety of reactions from different species in the same functional group adds to the resilience of the agroecosystem (Martin-Lopez et al, 2007).

6.3.1.2 Soil fertility and nutrients cycling

Soil related ecosystem services, such as nutrient cycling and soil fertility are optimized along the Kechwa-Lamas swidden cycle, in both, during the cropping stage as in the fallow period. Improved fallows where farmers "help" the secondary forest and intercropping including trees are central to boost these specific ES. These efforts are very relevant in the Amazon ecosystem, because most of the nutrients are found in the biomass; therefore, soil fertility depends on vegetative processes that renew it continuously (Marquardt et al, 2013).

Falling leaves and others biomass additions from vegetation provide a protection cover that directly nourishes the soil; fine roots, roots exudates are also inputs to the soil. When these materials decompose, they become humus which regulates the delivery of nutrients that can be absorbed and recycled by plants. Soil organic matter (SOM) and particularly humus are key for nutrients availability (Marquardt

[24] Farmers interview, october 2011

et al, 2013; Barrios et al, 2012). This is generally enough to cover crops requirements for most nutrients, usually with the exception of phosphorous (Barrios et al, 2012).

Farmers actively speed up natural regeneration in improved fallows, managing many species, including diversity of trees, especially those that produce greater amounts of biomass and larger quantity of falling leaves. Many of the tree-species planted and selected by farmers are fast growing N-fixing, for instance guaba (*Inga edulis*) is a leguminous tree very appreciated because it grows fast, provides, wood, shade, fruits and improves soil quality (Marquardt et al, 2013), which is related to their root nodule symbiosis with nitrogen-fixing bacteria.

Soil organic matter and biological activity are generally found to be **higher near trees**, along with nutrients availability that can be increased in its vicinity as well (Buresh and Tian, 1997; Barrios et al, 2012; Pardon et al, 2017). Trees can provide habitat conditions for soil biota, playing an important role in promoting biological activity, along above and belowground biodiversity. Several groups of soil organisms are more abundant in agricultural systems with trees than without trees. These differences are more evident when comparing agroforestry systems with continuous cropping with no trees (Barrios et al, 2012; Van Noordwijk et al 2015). In the Amazon, soil macrofauna is strongly associated with tree canopy closure, which also protects it from high temperature and drought stress (Barrios et al, 2012).

Integration of trees since the cropping stage brings various benefits and allows for a gradual transition to the fallow period. According to different features, trees can improve inputs, cycling, and efficiency of nutrients use (Barrios et al, 2012; Shibu, 2009). Trees capture nutrients before and after cropping season because their growing season is usually longer than most crops (Shibu, 2009).

> "We farm with trees because the trees let their leaves fall, and these leaves decay and feed the soil" (Luis Sangama Cachique from Churuyaku, October, 2011)

Trees' rooting systems can access nutrients that drain below the crops rooting zone and extract nutrients from deeper layers of the soil. For instance, deep-rooted trees have a better capacity to accumulate phosphorus (Barrios et al, 2012; Kleiman et al, 1995; Van Noordwijk et al, 2015). These properties can be boosted in association with mycorrhizal fungi (Barrios et al, 2012), which depending on the type, help to access organic or inorganic P, N and other pools of nutrients. Trees that share mycorrhiza with other plant species possibly transfer them nutrients and may play a role as inoculum reservoirs for annuals (Van Noordwijk et al, 2015).

Farmers intercrop various annual crops and short-lived perennials. Cereals like maize and legumes (beans and peanuts, among others) are often intercropped in the fields. In this way farmers improve environmental resources use, because intercropping can increase availability and absorption of limited resources such as water, light or nutrients, increasing efficiency of use by above and below ground complementary interactions among crops, as well as, plants and soil biota. Soil stability and structure are improved as well due to roots complementary (Wezel et al, 2014; Brooker et al, 2013).

Intercropping can result in fewer losses (less weed, pest and plant diseases), stabilized yields over years, and increased productivity compared to monocrops, especially in low-N inputs systems (Raseduzzaman & Jensen, 2017; Hauggaard-Nielsen et al 2008; Wezel et al, 2014; Brooker et al, 2013). Various studies report that these advantages of intercropping can be reduced with higher soil nitrogen available (Bedoussac et al, 2015).

Legumes and non-legumes intercrops commonly planted by Kechwa-Lamas farmers can use sources of nitrogen in a complementary way. Grain legumes supply atmospheric N and N-rich residues recycling (Hauggaard-Nielsen et al 2008). According to Brooker's review, legumes intercrops improve **nitrogen availability** due to legumes weaker competition for soil nitrogen, also because non-legumes obtain extra nitrogen freed by the legume in the soil or through mycorrhizal fungi in their roots (Brooker et al, 2013). In cereals and legumes intercrops, cereals are better at using soil inorganic nitrogen. Then, legumes are forced to cover a great part of its nitrogen requirements by fixating atmospheric N_2 in association with rizhobium (Jensen 1996). In Acidic soils, the roots of plants adapted to such conditions (peanuts, maize, beans, among others) release organic acids and phosphates which can improve phosphorous nutrition of associated crops and protect them from Aluminium toxicity (Brooker et al, 2013).

Other techniques used by Kechwa-lamas such as green manure, weed control, living and dead barriers, seek to accelerate the nutrients inputs or "vitamins" into the soil. According to Marquardt et al (2010) these techniques play various functions such as: to capture silting materials, to hold the soil through the roots or the planted trees, as well as, to distribute and concentrate nutrients, among other uses.

6.3.1.3 Hydrological services & erosion control

Water related ES motivate farmers to manage their tree-based systems and the forest areas outside their farms, especially, since there is an increasingly water shortage problem and Kechwa-Lamas depend on small streams and springs (pukios) for their water provision. Entire communities have learnt from experiencing decline of fresh water provision. Local government initiatives to bring water through pipes from other areas have in some cases disregarded natural local provision of fresh water. This was the case in the Morillo community, with a system fed with water from somewhere else, people dismissed the forested areas, then affecting considerably natural water supply. Eventually, attention was directed back to forested areas to secure water regulation, quality and supply.[25]

[25] Farmers interview. October, 2011.

Farmers perceive that forest areas provide fresh water better in quantity and quality (for longer, cleaner and colder), which relates to water supply, regulation and purification services. The protection role of these areas is also underscored by farmers and linked to erosion control. On the contrary, croplands with no trees are related by farmers to a significantly lower water provision; and agrochemicals use, atypical in Kechwa-Lamas systems, is associated to water quality decline.

> “If you are going to do *chakra* (cropping field) in the entire area of the farm, the wa-ter decreases, and dries out little by little because there is no longer forest. Even the roots “breed” water, and if you don’t believe me, you can chop the roots of *cetico* (*Cecropia spp*) and you will see how the water comes out and drips, and in the *aguaje (Mauritia flexuosa),* and *ishanga* as well¨. (Milton Sangama from Alto churuyacu in Waman Wasi, 2006)

Farmers’ perception is consistent with the influence that different ecosystems exert on the hydrological cycle, which governs the amount of water moving across the landscape. The water balance is significantly affected by forest and the plant community in general, therefore, the type of **vegetation as well as management play an important role in water quantity and quality** (Brauman et al., 2007; Mastrorilli et al, 2018).

Soil - plant interactions impact processes such as water evaporation, infiltration, soil storage capacity, rainfall impact on the soil, nutrients/pollutants uptake, and transformations that affect water availability and erosion (Mastrorilli et al, 2018). Farmers manage soil organic matter and the soil community as SOM living fraction through vegetation ground cover and organic inputs, impacting several of the aforementioned water-related processes.

Tree cover has generally great impacts on infiltration and water flow in the landscape (Boelee, 2011). In the agriculture-forest landscape of Lamas, where farmers recover degraded land, the enhancement of water supply and regulation services due to forest patches and scattered trees in the fields seem to have a positive impact on water availability. Newer tree cover theory suggests that intermediate tree densities can maximize groundwater recharge in degraded land, each new tree generates higher hydrologic gains than transpiration and interception losses. In denser tree cover, these losses surpass gains (see figure 14). Even if the stream flow effects of greater canopy covers could be slightly negative in the beginning, they can become neutral due to trees age or management (Ellison et al, 2017).

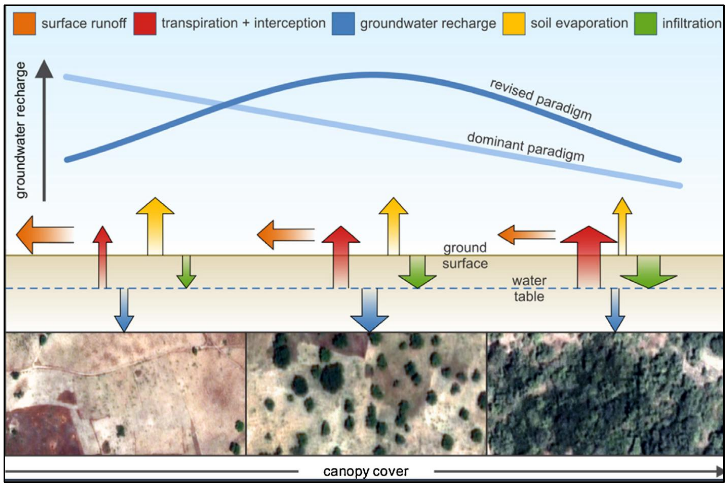

Figure 14: Infiltration and groundwater recharge relative to tree cover (Source: Ilste et al. 2016 in Ellison et al, 2017).

Trees have a strong effect in terms of water, some key features are: they transpire water, their leaves intercept rainfall, the canopy provide shade, deep rooting systems capture water and their falling leaves and branches cover the soil providing organic inputs. These features have an important effect on **temperature, moisture, soil biota and soil organic matter** (Barrios et al, 2012). While, t**ree in agricultural fields have cooling effects** which lessen evaporation losses and increase soil organism activity. Also, their roots can **redistribute water** in the soil, moving water upwards and downwards, rainwater can be stored where it is not evaporated and can be brought back to the topsoil by the roots. Tree-soil biota interactions promote macroporosity, soil aggregates formation and stability that improve soil water retention and help to endure rainfall events.

Tree-based is a central feature of Kechwa-Lamas systems that contributes to hydrological services provision, but it is not the only one when farmers employ techniques targeted at **increasing soil fertility, nutrient efficiency and** use of **diversity of species** specially in relation to water conservation, they also enhance hydrological services in their farms as well as at larger spatial scales.

In terms of water quantity, practices of Kechwa-Lamas farmers such as organic materials continual addition and minimal removal are particularly relevant. **Roots and soil covered with plant litter** such as leaves, branches among others, slow water flow which improves infiltration and reduces evaporation (Brauman et al, 2007; Bot & Benites, 2005). Soil water evaporation can be reduced by 30-50% because of mulching for instance (Garbach et al, 2014), **the organic materials** above and belowground that farmers leave in the fields (including roots, crop residues and others) improve the **organic matter content,** fostering soil organism activity that feed on plant residues, roots by-products and other organic materials (Bot & Benites, 2005).

Soil organic matter encourages biological activity and influences soil biota composition (Bot & Benites, 2005). SOM active fraction which is rapidly decomposed is the main food source for a major part of soil biodiversity, while humus, the more stable fraction of organic matter that has already undergone full decomposition, is very complex to be consumed by most organisms[26] and it is especially important to increase water infiltration and soil capacity to store water. Various organic matter sources, quantity and quality contribute differently to these properties. For instance, substances like polysaccharides that bind soil particles together into steady aggregates promote aggregation and structural stability (Bot & Benites, 2005).

Soil organic matter, including **tree/plants roots, in combination with soil organism activity maintains soil structure,** which underpins soil water availability (Kibblewhite et al, 2008, Bot & Benites, 2005**).** Direct seeding and avoidance of tillage by farmers cause little soil disturbance which is beneficial for soil biota, especially macrofauna. By ingestion, soil organisms break down organic materials, mixing them with soil minerals; bacteria, fungi and particularly worms are important because of their glue-like secretions that contribute to soil aggregation. Soil covered with residues prompts earthworms to the surface promoting porosity that favours infiltration. Burrowing and feeding activities of macrofauna help to create pathways for air and water (Bot & Benites, 2005; Power et al, 2010). Difference in porosity allows for a **balance between soil infiltration and water storage** (Ellison et al, 2017, Barrios et al, 2012).

Farmers' efforts to minimize soil exposure, nutrients and sediments loss are related to **water quality and purification services**. Right timing for sowing crops and intercropping variety of species, including tree rooting systems, aim at matching **nutrients availability and crop demand** which allows higher nutrient use efficiency (Barrios et al, 2012). While, the little soil removal (direct seedling, avoidance of tillage) minimizes leaching or losses to the atmosphere associated to faster organic matter decomposition and organic nitrogen conversion to mineral forms, which can surpass crop demand (Kibblewhite et al, 2008). Living and dead barriers used by farmers are considered buffers that promote sediment deposition and nutrients retention that also contribute to water quality (Shibu, 2009; Brauman et al., 2007).

Diversity can be beneficial in many respects to improve water conservation. Species use water in different ways; thus, species choices are important to balance water flows (Ellison et al, 2017). Farmers' knowledge is key, since they use diversity of crops, trees and "breed water" species, that translate in diversity above and belowground as well, with various leaves types, root to different depths, quality of organic matter and various soil biota interactions.

[26] Decomposition can be "rapid (sugars, starches and proteins), slow (cellulose, fats, waxes and resins) or very slow (lignin)" (Bot & Benites, 2005).

Some of the referred **“breed water” species** are palms, such as *aguaje* (*Mauritia flexuosa*) which is found in wetlands in the Amazon. These particular palms (see figure 15) have large roots that could represent yet more of the 40 % of the total biomass that serve to recharge aquifers and ravines (Freitas et al, 2006). According to Velasquez (2010) its deep and dense root system favours water retention in the soil profile.

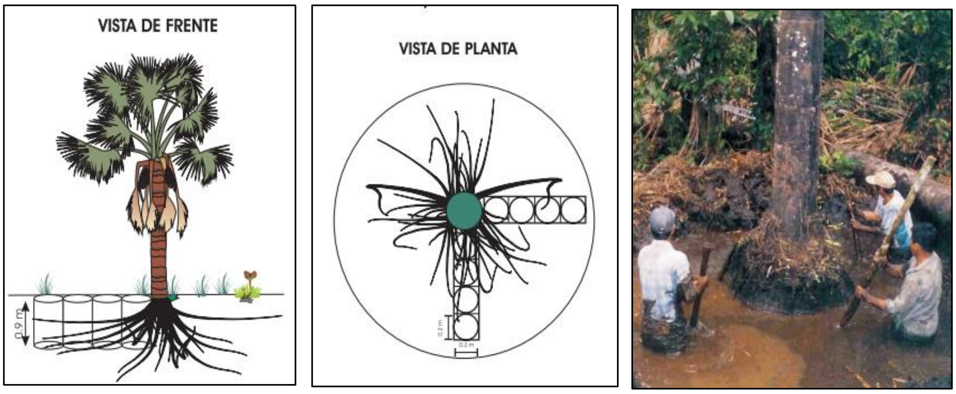

Figure 15: Mauritia flexuosa “breed water” species (a) Front view, (b) roots system, (c) Digging of main root of Mauritia flexuosa to measure biomass content.

> “I have planted more than 30 *aguajales (Mauritia flexuosa*), that is why there is water, they are there to take after the water, to maintain it” (PRATEC/ Asociacion Choba Choba, 2001)

These soil erosion and physical protection services are associated to conservation measures like partially decomposed organic materials on the ground and tree cover. The protection role of tree-based system relies in their property to reduce land-slides and soil erosion in the high season (rains). In riparian zones, the forest areas are recognized as **field natural protection** from the rivers, one of the reasons given by farmers is their role as physical barriers and the presence of many and deep roots.

Bruijnzeel et al, (2004) indicate that “reforestation and soil conservation measures are capable of reducing the enhanced peak flows and stormflows associated with soil degradation [and] in the case of a well-developed tree cover, [as well] shallow land sliding”. The various species intercropped by farmers like trees and short and leafy vegetation protect the ground surface and provide a constant cover to the soil. The amount of litter on the surface, the decomposition rate and plant architecture above and belowground are key factors to trap sediments and reduce erosion (Le Bissonnais et al. 2004 In Wezel 2014; Brauman et al., 2007; Power et al, 2010). Swift et al (2004) argues that the role of plant diversity on slopes is even greater, since “soil protection on slopes depends more on partially decomposed litter with good ground contact than on fresh leaves that can be easily washed away”.

Research carried out on soil erosion for swidden agriculture reports a wide variation, from negligible values to more than 100 mg /ha per year and even 350 mg/ha per year of soil lost for the most intensified systems that shortened fallows. Though, many of these values represent soil loss only for the cropping stage, reflecting strong differences in farming practices and climate, topography and soil conditions. When fallow periods are considered, the erosion rates decline significantly (Ziegler et al, 2009). Several studies indicate that surface soil loss during the fallow phase is similar to intact forest and considerably lower than palm oil for instance (Sidle et al. 2006, Bruijnzeel 2004, Ziegler et al. 2007, de Neergaard et al. 2008, Valentin et al. 2008 in Dressler et al, 2017).

6.3.1.4 Carbon Sequestration and storage

Kechwa-Lamas agriculture, as a tree-based agroecosystem with the fallow as essential part of the farming cycle, has a great capacity to store and sequester carbon, though, in a dynamic way.

Land uses show that some agroecosystems can provide food and marketable agricultural products such as various fruits, coffee and cacao, while maintaining about 25 to 50% of the carbon stocks. As shown in figure 16, for different land uses in Cameroon, Brazil and Indonesia, the larger capacity of carbon storage is in the vegetation aboveground, while soil carbon stock belowground in shifting agricultures is shown to be quite similar to forest and complex agroforest systems. BGC (Below ground carbon) in intensive tree-crops systems is shown to be lower (with exception of Cameroon) than other land uses including pastures and grasslands. Strong variations in BGC were reported in this study due to soil clay content and methods to measure large root biomass.

Fox et al (2011), indicates that BGC is mostly uncertain for most land cover in tropical regions, in the case of swidden fallows in Asia, they report that BGC values could be about $\leq$ 20% of the AGC (Above ground carbon). There are indications that soils with higher biological activity may have a stronger potential for carbon storage. Agricultural practices of Kechwa-Lamas can be linked to the promotion of biological activity, therefore may have a positive impact on carbon storage in soils. However, biotic and abiotic mechanisms are not fully understood in regard of C stabilization and carbon fluxes determined by practices, these appeared to be dependent on specific soil and climatic conditions (Dignac et al, 2017).

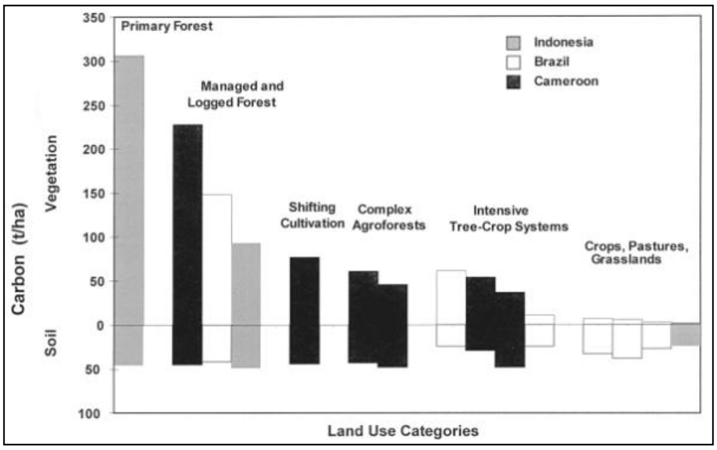

Figure 16: Aboveground and soil carbon storage across different land uses in Cameroon, Brasil and Indonesia (Palm et al, 2005).

Figures 16 and 17 show that shifting cultivation can store as much or more carbon than complex agroforest[27] or intensive tree-crop systems, like oil palm and cacao. The combination of crops with long fallow can store more carbon than intensive tree-crop systems; however, the economic returns are very low. It can be noted that the length of the fallow makes a significant difference in the carbon stock, while fruits sales do the same in the profitability of the system.

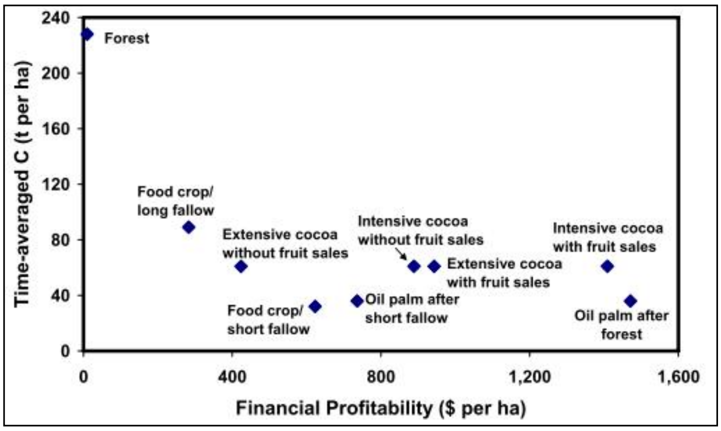

Figure 17: Comparison of financial profitability and carbon storage in different land uses in Cameroon (Tomich et al, 2005).

For the Peruvian Amazon (figure 18), the fallow also evidences a significant increase on the carbon stock of the farming system. Even short fallows have a considerably higher storage capacity than annual crops (maize, cassava rice). The carbon stock of a 15-year fallow is 6 and 10 times that of a 3-year fallow (White et al, 2005). This implies that improved fallows can accelerate the storage capacity of

[27] Defined in the study as: 2 yr of cropping followed by establishment of *Theobroma cacao* (jungle cacao) with a 25-yr establishment phase and 40-yr rotation/ or a permanent, nonrotational cacao system established through gap and understory plantings of cacao (Palm et al 2005, p. 44)

swidden systems. Swidden agriculture is a food system that can provide high level of carbon storage and sequestration, but profitability is very low in comparison to other systems.

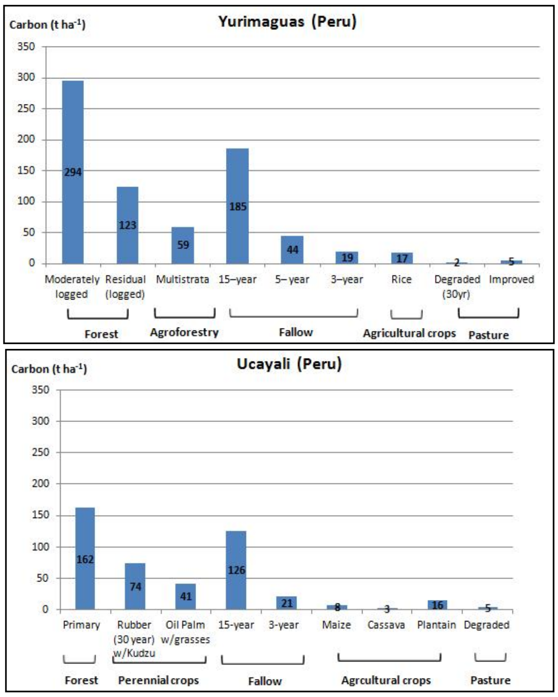

Figure 18: Carbon storage of different land uses in two locations in the Peruvian Amazon. San Martin and Ucayali (Own elaboration with data from White et al, 2005).

White et al. (2005) report that forest and tree-based systems are greenhouse sinks, in contrast to annual cropping, that exacerbates gases release with intensification. This, because annual systems capture little carbon (C), have higher emissions of nitrous oxide (N_2O) and a smaller consumption of methane (Ch_4) and in some cases even release methane. Though, the rate at which carbon is accumulated (about 3 Mg C ha-1 yr-1) can be quite similar for annual crops, tree plantations and forest, but the contrasting residence times of 1, 10 and 83 years respectively, account for the difference in the carbon stocks across these land categories (Hairiah et al, 2011).

Innovative farmers preserve higher levels of biodiversity in their cropping and fallow stages, which could have an additional positive impact in carbon storage. Mortimer et al (2017) study on cacao agroforestry systems report values of carbon storage between 57 -70 TC/ha, which are strongly dependant on the density and associated tree species, C stock can be as high as five-fold than cacao monoculture.

From a life cycle assessment, it is worth to underscore the overall lower greenhouse gases emissions related to the agroecological practices of shifting agriculture in Lamas, in contrast with more intensive systems. New adaptive practices such as improved fallows and recuperation of degraded land represent a potential to offset GHG (Greenhouse Gas) emissions. White et al (2005) point out that tree-based systems set up in the degraded lands of the tropics could even counteract to some extent past effects of deforestation. Preserving soil-related ecosystem services that build up fertility of soil in time, releases farmers from the greenhouse gas emission embedded in the production of chemical fertilizers. Similarly, using man power, farmers have lower dependence on fossil fuels doing without machinery, consequently reduceing greenhouse emissions from burning fossil fuels.

In general, high level of carbon storage and sequestration are ecosystem services that shifting agriculture in Lamas can still provide in comparison to more intense and conventional food production systems. Nevertheless, these services may be in decline, this due to a transition to other agricultural systems with lower carbon stocks and higher economic returns.

6.4 Interpretation and implementation of the results in a sustainability context

In this section, I discuss the sustainability of Kechwa-Lamas swidden cycle supported by the findings, as well as, the enhancement of specific ecosystem services provision in comparison to other agricultural systems, in the context of increasing environmental impacts of agriculture in San Martin.

6.4.1 Towards sustainable food and farming systems

Agricultural policies need to tackle principles and direct action for sustainable agriculture and food systems. Management decisions and practices in agroecosystems can influence directly impacts and ecosystem services delivery of agriculture (Power et al, 2010; Fremier et al, 2014; Tscharntke et al., 2005 in Garbatch et al, 2014).

A sustainable path in food systems embraces the principles of resilience, diversity and multi-functionality (IPES Food, 2015). Agroecological principles of minimizing losses, enhancement of biological interactions, diversity and recycling are articulated with the pillars (impacts minimization, conservation and use efficiency) of sustainable food and agriculture (see section 3). Efforts directed toward a transition to more sustainable farming need to achieve multiple objectives. Sustainable agriculture must maintain ecosystems functions to contribute to food security and support present and future generation's needs, and at the same time, protect and improve equity and rural livelihoods (FAO; 2014). A transition to sustainable agricultural production requires, not only, optimization of existing agricultural systems, but also different types of innovations and reconfiguration of farming, in which ecological intensification[28] plays a significant role (Tittonell, 2014). Current priorities and strategies, centred on monocultures and conventional intensification, are to be expanded to include a wider range of agricultural strategies and actors with different capacities and potentialities, more focused on socio-environmental dimensions of agricultural sustainability.

Agroecological cropping practices are central and have a strong potential for future sustainable production. The farming practices explored in this study are adaptations of traditional agroforestry management, intensified based in ecological processes. Many of these agroecological practices, such as trees scattered in the fields that bring biodiversity and water benefits, including enhancement of green and blue water[29], cereals with legumes intercrops that operate like "ecological precision farming" or agroforestry in general, are integrated to very low extent in today's agriculture in temperate regions (Wezel et al, 2014). Though, they are

[28] It is defined as "the means to make intensive and smart use of the natural functionalities of the ecosystem (support and regulation)", also it implies landscape scale approaches (Tittonell et al, 2014).

[29] "Green water refers to naturally infiltrated rain, attached to soil particles and accessible to roots. Blue water refers to liquid water in rivers and aquifers" (Rockström et al, 2009).

going to be very important elements in agricultural production in the future (Vandermeer, 2011; Jensen et al, 2015).

6.4.2 The good farm walks: Rotational agroforestry systems for food production

Rotational is a key characteristic of Kechwa-Lamas swidden agriculture that has to be emphasized, since there is a general confusion when this kind of agriculture is referred as "migratory", which also includes other types of agriculture and it infers that primary forest is continuously cleared and abandoned. Swidden farming is considered agroforestry because it is a tree-based system that involves dynamic forestry and agricultural management (Pfund et al, 2011; Cronkleton et al, 2014; Robiglio et al, 2015).

Kechwa-Lamas perspective of agricultural production is forest-focused and soil management is **conceptualized in terms of forest management as well** (Marquardt et al, 2008). Thus, t**rees, fallows** and h**igh levels of** agrobiodiversity are essential components of their management to sustain production based in ecological processes and entails sequential and simultaneous agroforestry.

6.4.2.1 Diversity and agroecological practices along the cycle.

Ribeiro et al (2013) argues that swidden positive effects in soil are sustainable because the fallow stage mimics forest ecological processes. According to Styger and Fernandes (2006), intensification in swidden systems is based on species diversity of both crops and fallows, taking advantage of their specific traits. For instance, some trees with particular root systems may be more competent for simultaneous agroforestry and others for sequential combinations of crops and trees (Van Noordwijk et al 2015). With a great agrobiodiversity, within and around the agroecosystem, farmers contribute to the flexibility of the farming system, increasing its capacity to recover from disturbances, consequently farmers contribute to more resilient agroecosystems. With a high number of species, is likely to have more than one species within a functional group, this means species that carry on the same function within an ecosystem.

Agroecological practices along the entire cycle prove crucial to assure the system sustainability. Farmers do strongly acknowledge that cropping stages and fallows are dependent on each other and for subsequent cycles. Practices such as improved fallows, water conservation and intercropping including trees let farmers access land farming sooner, especially innovative farmers. Their work all along the crop-fallow cycle optimizes resources use and services that allows intensification. This is very relevant for Kechwa-Lamas to face the problem of land accessibility, which force farmers to extend cropping periods and shorten fallows.

The cropping stage is pointed out to be as important as the fallow to maintain the fertility balance in the system. Wood et al (2017) argue that cropping practices have even a greater effect in soil fertility than fallows duration, which, implies that prolonged farming may erode soil fertility despite long fallows across multiples cycles. To secure sustainability in the long run, they advocate for local amendments and improved fallows over long fallows. Farmers' holistic approach along the entire cycle, rather than specific techniques only during fallows, might make a significant difference in soil fertility. Farmers that practice improved fallows also apply agroecological techniques during the cropping period.

6.4.2.2 Multifunctional farming systems

Kechwa-Lamas swidden agriculture is above all a food production system, and as such farmers bring food security for their households and to society as well. To society, not only because subsistence farmers set aside a proportion of their food crops to markets, but also, because most of their agroecosystems are multifunctional. Focusing on ecosystems services allows an assessment well beyond the economic dimension and market catering capacity of agriculture. This evidences the multifunctional nature of Kechwa-Lamas agroecosystems.

They produce a wide variety of provisioning services (firewood, timber, fibers, medicines and various materials), and enhance supporting and regulating ecosystem services (of which I draw the analysis to nutrient cycling, soil fertility, hydrological services, erosion control, carbon storage and sequestration), that even allow many of the farmers with high ecological knowledge recover degraded areas to put them back in production.

Ecosystem services in Kechwa–Lamas swidden agriculture in comparison to other agricultural systems

Kechwa–Lamas agricultural systems should be compared to other agricultural systems and not to primary forest. They cannot compete with natural forest ecosystem services provision. This agricultural management evidences significant differences with conventional farming from field to landscape scale. In contrast to conventional cropping centred in soil, Kechwa-Lamas farming systems, especially those of innovative farmers, are centred in trees (in fields, fallows and forests) and agrobiodiversity conserved in situ.

Kechwa-Lamas systems enhance supporting ecosystems like nutrient cycling and soil fertility through biological processes, by actively managing their fallows (about a third to half of the farm) and various techniques in the farming phase. For instance, with intercropping and N-fixing plants or trees in their fields, farmers increase nutrient inputs, recycling and efficiency, without using agrochemicals and minimizing with this, nitrate leaching to aquatic environments (Jensen et al, 2011; Jensen et al, 2020).

By contrast, most intensive farming systems maintain fertility and structure through tillage and inputs of organic and chemical fertilizers (Daily et al., 1997 in Garbach et al, 2014). In conventional cropping systems less than 50% of nitrogen and phosphorus is taken up by crops (Shibu, 2009). Fertilizer leaking rather increases water pollution, which can also occurre due to pesticides leaking. White et al (2005) found, in their research of different land uses in the Amazon, that in comparison with high-input cropping, swidden agriculture and other land uses present better soil physical and biological characteristics. High input farming has lower organic matter, lower microbial biomass and macrofauna diversity.

Kechwa-Lamas farmers influence in various ways the hydrologic cycle, therefore the amount of water moving through the landscape (Brauman et al., 2007). Intermediate tree densities like in the Kechwa-Lamas agriculture-forest landscape can maximize groundwater recharge, according to new tree cover theory (Ellison et al, 2017).

Water provision is optimized by maintaining fallows and trees, including a wide variety of native "breed water" species (*criadoras de agua*) which are also managed in ravines, slopes and villages surroundings**.** In this way, farmers improve infiltration and at the same time, maintain soil organic matter and structure to balance soil water availability (Barrios et al, 2012). Farmers can conserve water in their fields and simultaneously minimize erosion, by using various techniques (intercropping, green manure, leaves litter and keeping residues in the fields, living barriers etc.) that reduce soil exposure (Boelee, 2011; Brauman et al., 2007). Several studies point out a very low impact of swidden systems regarding surface erosion, which in the case of swidden is mostly related to the very beginning of the cropping phase (Sidle et al. 2006; Forsyth and Walker 2008, Valentin et al. 2008 in Ziegler et al, 2009).

Conventional management implies cropping the entire field without fallows or trees, increasing erosion and sediments movement. In cropland rainfall interception is smaller and root systems are shallow which limits water availability (Brauman et al., 2007; Foley et al., 2005). In upland agricultural landscapes, a decline of local hydrological services is reported where swidden agriculture has been replaced for more permanent or more intensive agricultural systems like monocultures and commercial agriculture (Van Vliet et al, Ziegler et al, 2009; Klemick, 2008).

Likewise, overall greenhouse gases emissions are lower in swidden cultivation in comparison to intensive farming. As tree-based systems, natural regeneration is speeded up, carbon storage and sequestration are greatly enhanced in swidden (Dressler et al, 2017). Though, the ability of swidden can vary significantly in its capacity to sequester carbon depending in various factors such as the length and area of the fallow, land-use history, among others (Fox et al, 2011).

Swidden carbon storage capacity in long fallows can be comparable or higher than complex agroforestry such as cacao and coffee, and greater than monocultures such as rubber and oil palm (White et al, 2005; Palm et al, 2005 Fox et al, 2011). In Indonesia, palm oil can only replace shrubs and grassland regarding carbon storage (Fox et al, 2011). No use of fertilizers and resources efficient use of nitrogen for instance, have an important impact on greenhouse gases emission. Though, this can also apply to efficient use of fertilizers in conventional systems and organic agriculture using conventional technics (for instance monoculture to produce organic rice).

6.4.3 Challenges for conservation and sustainable agriculture in San Martin

One of the main challenges in San Martin is to develop productive agrarian strategies that go beyond the historic extraction tendency of simply directing raw materials to other markets outside the region. Many researchers agree on this problem, arguing that there is a false perception of the Amazon as a great fertile land, with plenty of resources that are not being taken advantage from (Gobierno regional de San Martin, 2008; Rodriguez et al, 2009). So far, the reality of San Martin shows that the Amazon is a greatly culturally and ecologically diverse territory, facing strong environmental and socioeconomic challenges, which rather require differentiated and specific ways to be dealt with (Rodríguez et al, 2009).

6.4.3.1 Land sharing and land sparing approaches

In landscapes approaches to agriculture, swidden agricultural systems are examples of "land sharing" strategies (Padoch and Sunderland, 2013), as they integrate environmental and production functions, enhancing ecosystems services synergies and complementarities of different landscape components (Mastrangelo et al., 2014). Kechwa-Lamas farm-forest landscapes clearly represent "land sharing" strategies that enhance multiple ecosystem services.

Whereas, state policies are mostly oriented to a "land sparing" approach that separates intensified agricultural production and undisturbed natural habitats, it implies then that producing food in less land makes possible to spare area for nature (Mastrangelo et al., 2014; Huang et al, 2014). The "land sparing" approach is reflected on forestry and agricultural strategies aiming to reduce deforestation, importantly focused on promotion of single crops, productivity and zoning schemes that separate farming and forestry land uses.

The new forestry law (N° 29763) proposes an agroforestry legal definition with a concession mechanism that links agricultural production and forestry activities, which can favour an intermediate sharing-sparing approach to land use that can better integrate farm-forest landscapes like Kechwa-Lamas study area. Thus, diverse productive and conservation components can be supported

Nevertheless, in practice it is not certain that these changes will benefit smallholders such Kechwa-Lamas farmers, especially regarding effective land titling. Even less certain is that the mechanism can incentivise farmers to preserve and improve their agroecological practices in their rotational agroforestry systems.

6.4.3.2 Linking agriculture environmental impacts to ecosystem services in San Martin

The trend of forest conversion, increase in agrochemical use together with higher crop specialization and crop diversity decline, suggests a process of intensification and landscape simplification in San Martin. These trends can gradually compromise critical supporting and regulating ecosystem services (Kremen and Miles, 2012).

Already about a million hectares have been degraded, including agricultural land (Gobierno Regional de San Martin, 2016), which implies that ecosystems have significantly lost their functions and productivity. In degraded soil, ecosystem services losses are not limited to soil fertility, but also regional water productivity, water quality and even carbon cycle are affected by degradation. Organic materials and nutrient availability, and processes like soil structure and water retention capacity are strongly reduced in these areas (Vlek et al. 2010 in Boelee, 2011).

The increasing trend of agrochemicals use in San Martin could exacerbate biodiversity loss and erode ecosystem services such as hydrological services, pest regulation, nutrient cycling and pollination. The impacts relate to increased nutrients and pesticides residues in surface and groundwater; potential hazards to human and soil health from substitution of biological pest control and nutrient cycles; pesticides effects on non-target species, among others (Power et al, 2010; Tilman et al, 2002, EFSA, 2014 Kibblewhite et al 2008). All these impacts worsen with excessive application and use of non-authorized and unsafe agrochemicals reported in Peru (Delgado-Zegarra et al, 2018).

Land cover changes in San Martin show that forest is continuously decreasing, while pastures and cropping areas had increased, especially with rice and perennials. This have negatively impacted forest ecosystem services provision, with erosion control, nutrient retention (related to higher water quality) and local flooding risk, among the services provided by forests that would be most affected (White & Minang, 2011). Also, carbon sequestration is reduced in comparison to pastures and cropland. Biodiversity, that underpins ecosystem services provision, is impacted as well due to habitat loss and fragmentation. According to an ecosystem services accounting exercise in San Martin, biodiversity loss at the species level is 0.2% yearly on average, which, regarding invertebrates for instance, represents 1 to 20 species lost each year (Mahbubul et al, 2016).

Land use changes may also imply some transition from cropland to pastures and perennials in San Martin, which modifies provisioning services from food crops to meat, milk and in the case of perennials to commodities (cacao, coffee). According to Gaglio et al (2017), the conversion to pastures may exacerbate soil structure maintenance, key process to other ecosystem services such as water supply and quality. Pastures can be exposed to overgrazing that means even further erosion.

Perennials in turn can provide high levels of supporting and regulating services depending on the management and diversity level. Several authors report coffee and cacao agroforest systems can storage and sequester carbon, regulate water flows, cycle nutrients and conserve biodiversity to a significant extent (Mortimer et al, 2017; Cerda et al, 2017). However, in perennials monocultures services supply is more limited and environmental impacts related to chemical use could be even increased as it has been reported for oil palm for instance (Van Vliet et al, 2012; Dressler et al, 2017).

6.4.3.3 Prioritization of socio-environmental sustainability in agriculture

It is true that San Martin has used some of the available management tools for natural resource management and conservation. This especially in relation to forest conversion, acknowledged as an impact of agriculture in San Martin, for which some initiatives, novel to Peru, are being implemented in the region. For instance: payments for hydrological ecosystem services, degraded areas identification, agroforestry concessions, reforestation with native species, agricultural territorial and forestry zoning, etc. (Guivin, 2018; DRASAM, 2020; Vargas, 2020; Ballón & Glave, 2015; MINAM, 2010; ProAmbiente, 2014). Nevertheless, strategies from the regional government regarding sustainable agriculture are still limited to address its social and environmental dimensions. Without sustainability criteria for agricultural activities and adequate support for farmers that already pursue more sustainable management, provision of critical services and socio-environmental impacts are likely to increase leading to further degradation.

Agricultural strategy falls short to define sustainability criteria for farming activities and to deal with matters relevant for agriculture such as food security, indigenous people legal rights, loss of traditional ecological knowledge, loss of agro-biodiversity, excessive use of agrochemicals, among others. All of them, of major significance to climate change mitigation and adaptation in agriculture. Territorial and regional environmental policy (PTR and PAR by its initials in Spanish) is declarative in nature regarding most of these issues (when they are referred to)[30], as they are not integrated into planning and management tools (like concerted regional plan, annual strategic plans, operative plans, agricultural annual) to be consistently translated into implementing actions and activities.

Regional government has oriented strong efforts on zoning initiatives such ZEE, forest zoning (ZF by its initials in Spanish) and agroecological zoning (ZAE by its initials in Spanish, still in progress) [31]. These certainly can help advance land use planning and management, though, consensus with stakeholders must be reached, taking in consideration perspectives on forestry and agriculture in local management. Various concessions modalities (conservation, timber, etc.) and conservation categories like ZoCREs overlap with communal lands and smallholders' farms. Moreover, actions to reduce land trafficking are not properly

[30] Agrobiodiversity is only referred to in the biodiversity regional strategy.
[31] ZAE and FZ are finished and the ZAE still in preparation in 2020.

addressed (a problem at the national law level), which really need to be considered to make these zoning schemes to work (Shanee & Shanee, 2016).

San Martin has prioritized to strengthen value change of cash crops like coffee or cacao, which has helped to improve income generation for many small farmers (Pintado, 2018). However, opposed to diverse systems, vulnerability to market fluctuations and disestablishing effects related to high dependence of a single crop still do not assure economic sustainability, for instance in the face of events like "*La roya*" (*Hemileia vastatrix*) disease outbreaks. Moreover, in San Martin inequality levels were not reduced but rather increased till 2015 (Ballón & Glave, 2015; IEDEP, sf; BCRP, 2019).

Processes of agricultural intensification exacerbate the competing land use problem in San Martin, where smallholders (who farm traditional products and an important share of food crops), especially subsistence farmers, are least likely to benefit, when they play an important role in food production, degraded land recovery, local knowledge and ecosystem services provision and cultural identity. If more land is used for specific single crops and less land oriented to food crops, self-provisioning may be impaired, and local food production and food security could be compromised.

6.4.3.4 Better support agrobiodiverse traditional farm forest systems

In the context of high vulnerability of agriculture to climate change and increasing environmental degradation in San Martin, Kechwa-Lamas farmers' capacity to maintain agrobiodiverse tree-based systems that produce food, proves to be very pertinent. However, support and assistance to smallholders is limited to a productivity approach that does not support their capacity to be resilient, manage risk, preserve biodiversity or provide multiple ecosystem services. State interventions give greater importance to income-generating activities or marketable crops such as cacao, coffee and palm, and tend to favour farmers enrolled in technological modernization or specialization for commodity market production. (Robiglio et al, 2015).

Contradicting measures and perverse incentives in both forestry and agricultural sectors, discourage smallholders conservation and agroforestry activities and rather help forest conversion to so called improved uses of the land (agriculture, pasture, among others). Imbalances are evidenced in what it is considered forest. Vast areas of forest are cleared because forests are not considered as such, if the land is categorized as best suitable for agriculture according to the Best Land Use Classification (CUM by its initials in Spanish) system. If the land is categorized as forest, even if it is already cleared, is owned by the state and cannot be transferred, unless the use is changed. The Best Land Use Classification system can be in fact, interpreted in various ways and has no value in agronomic terms, most forest land can be cultivated anyway with different technologies, amendments, etc. (EIA, 2015, Dammert, 2014).

Even though, these regulations apply to all activities, agricultural large-scale farming is favoured, while, land use change use is almost impossible for smallholders on their own (Shanee & Shanee, 2016, Dammert, 2014). Moreover, monoculture plantations are recognized as reforestation for production, fallow management in rotation is not officially recognized as management because is based in natural regeneration and not in plantation practices (Robiglio et al, 2015; Sears et al, 2018). Thus, it doesn't matter if farmers carry on traditional agroforestry activities that allow them to recover degraded land, manage fallows and conserve trees in their fields. If the land is classified as forest, they cannot own it or are able to manage it, because they have to comply with bureaucratic procedures and specific required techniques that do not fit in their rotational agroforestry systems.

With the new forestry law, forest definition is clarified to consider land cover and introduces the agroforestry concession mechanism, which can help some farmers to gain legal recognition. However, procedures, costs and significantly different perceptions of good management might limit smallholders' adoption. Also, land use change is still allowed for agri-business without solving pending titling and zoning, these issues may limit importantly progress regarding smallholders (EIA, 2015).

Conservation efforts need to recognize that agricultural systems can serve biodiversity, food security, as well as, ecosystem services provision. Also, that management can make a difference for agriculture sustainability. Any intervention in San Martin has to take into account the strong link between agricultural and forestry activities in the local practice, acknowledging Kechwa-Lamas tree-based agriculture as an agrobiodiverse food agroforestry system that is sequential but also simultaneous.

High productivity does not have to be the main objective in all agricultural systems. Productivity increase regardless of socio environmental sustainability is a significant shortcoming in the current agricultural strategy to sustain agriculture. Kechwa-Lamas tree-based agricultural systems are currently conserving agrobiodiversity in-situ, as well as, providing regulating and supporting ecosystems services. And this current effort of farmers and their activities potential for conservation and food production has to be supported and promoted as an approach as well. At the same time eenvironmental criteria have to be demanded to improve conventional systems.

Supporting farmers' capacities and potentialities to enhance multiple ecosystem services, from provisioning to supporting and cultural services, is an imperative to sustain agriculture in their local context in the long term. Ecological intensification plays a growing role to overtake yield optimization and commodities focus approaches. For this, promotion focus must be extended from technological innovation to include farmers' traditional knowledge innovations. This is very relevant for agroforestry, and in general for ecological intensification, which requires “activating more knowledge and refocusing the importance of ecosystem services in agriculture” (Jensen et al, 2015).

Initiatives, strategies and specific programs, such as the Agroecological Zoning, Low Emissions rural agricultural development (both still on progress), reforestation or degraded land recovery programs need to target sustainability criteria for agriculture, including agrobiodiversity and ecosystem services provision paying particular attention to Kechwa-Lamas communities and smallholders to effectively help them to maintain and improve their traditional agroforestry.

Changing from command and control to an incentives approach with concrete measures targeted at smallholders can better support small-scale farming. Among them, actions such as: payments for ecosystem services/ degraded land recovery, agroforestry concessions schemes better fit for smallholders, research and assistance targeting at co-producing knowledge, improved services and infrastructure for stockpiles collection, explicit inclusion of agrobiodiverse produce in San Martin label (regional green label, that could target maize and food crops produced in land in recovery for instance).

7 Conclusion

Kechwa-Lamas farmers manage **multifunctional traditional agroforestry systems** that enhance provisioning, supporting and regulating services. These are critical in the face of rapid land use change and competition in San Martin, where environmental impact of agriculture is increasing. **In comparison to conventional systems**, Kechwa-Lamas farmers don't use agrochemicals, produce diverse food, medicinal plants and different materials, conserve agrobiodiversity and enhance a wider variety of regulating and supporting services. Among them, nutrient cycling and soil fertility, soil erosion, hydrological services and carbon sequestration and storage. Some farmers are even able to recover degraded land with native species. Supporting farmer's sustainable practices within their swidden agriculture cycle can reduce the negative effects of demographic and environmental pressures.

Tree-based and rotational are central features of Kechwa-Lamas swidden agriculture that have to be emphasized. Centred on innovative farmers with limited access to primary forest**, four main agroecological practices along the entire cycle** were identified. First, fallows active management that accelerates soil regeneration. Second, incorporation of degraded land into the swidden cycle, cropped with intense weeding until it becomes improved fallow. Followed by water conservation (on-farm and off-farm) and intercropping including trees in the farmland that mitigate depletion processes during the cropping stage. Agroecological practices, that enhance services during the farming stage just as in the fallow, prove crucial to assure the cycle sustainability.

Kechwa-Lamas farmers **play an active role to cope with climate change**, for both, for mitigation (emission reduction) through carbon sequestration and for adaptation through maintaining agrobiodiversity and their farming system adaptive capacity. The richness of **species and varieties preserved and selected in situ** for generation of farmers can help to maintain the resilience of the farming system. **Kechwa-Lamas swidden** farmers have, apply and try very specific and practical knowledge in theirs systems. Their a**gricultural and ecological knowledge** is very relevant to sequential and simultaneous agroforestry, as well to ecological intensification.

The trends in forest conversion to agriculture, increase in agrochemical use together with higher crop specialization and possibly a decline in crop diversity, suggest a process of agricultural intensification and landscape simplification in San Martin. This could compromise supporting and regulating ecosystem services and increase degradation processes. Land use change from cropland to pastures and perennials modifies provisioning services from food crops to meat, milk and commodities (cacao, coffee). If land oriented to food crops is used for specific single crops, especially if these are not essential for nutrition, local food security may be compromised.

Strategies from the regional government regarding sustainable agriculture are still limited to address socio-environmental dimensions. Sustainability criteria for agricultural activities and adequate support for farmers that already pursue more sustainable management, considering different capacities and potentialities, are critical. An **integral approach to agriculture,** aiming to support agriculture sustainability in the long term in San Martin, should include **smallholders' concerns, problems and contributions**. **Kechwa-Lamas** a**gricultural and ecological knowledge is** very relevant to the transition towards sustainable agriculture; and it should be taken in consideration to contribute to formal knowledge systems to confront environmental risk and climate change.

8 Critical Reflections

Following this research, and recognizing the limitations encountered, I believe that to value further the culture of Kechwa-Lamas farm-forest systems, and in general any other sustainable livelihood elements related to agroecosystems, it is necessary to progressively widen the scope of analysis and action towards radical interdisciplinarity and cooperation.

It looks crucial to me to explore the relations of agroecological dynamics with physical and biochemical data, for example at the crop, soil and organism biodiversity level. Also, material and socio-economic relations with household subsistence flows, market flows, and welfare changes are additional phenomena to look at. This certainly requires wide-crossing collaboration between researchers in different institutions and disciplines, diverse community members and other relevant actors (such as authorities, educators, entrepreneurs, etc,). Thus, it is necessary, in formal and stable platforms, to stablish creative and flexible institutional settings that recognize not only the power of knowledge and work but also identities, emotions, and intercultural communication; in other words, the complexity of inter-human relations for better human-nature interactions.

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Appendix 1
Farmers Interview Guide

Family farm situation

- How long do you live and farm here?
- What is your household composition? Do you have any children?, Are they going to school?
- How many family members are working in the farm?
- How did you obtain your farm land?
- What are the general characteristics and harvest orientation (market, consumption, etc.) of the different farms owned?
- What are the main crops you grow?
- What are your plans/objectives in the next years for your family and for your farms?

Agricultural practices (farm, *purma* and degraded land)

- What are the most important agricultural activities in this farm (visited farm)?
- How do you farm? What do you use/ need to farm (seeds, tools…)? Do you use any type of fertilizer or chemical product?
- Do you farm differently than before (in comparison to your parents/ and 15 years ago)? What are the main changes?
- How do you maintain the water/ humidity in soil in your field?
- How does the corn grow in your farm? Alone or associated with other crops?
- What crops do you like to plant together (associated crop)?
- What has stopped/started sowing in the last 5 years? What would you like to farm and cannot do? Why do you think this is?
- What do you plant in this farm (visited farm)?
- Have any crops increased the farming area in the last 5 years? Why?
- Are shoots let grow in the farming area? Do you let them grow from the beginning of the farming stage? When do you let them grow?
- What animals help to sow? How do you attract these animals?
- Have you increased or decreased your cultivated area (including farming area in relation to "*purma*")?
- Why do you grow a "*purma*"? What do you use the "*purma*" for?
- How do you grow a "*purma*"? What is your plan for your "*purmas*" in this farm?
- How do you recover degraded land? What has motivated you to recover land?
- How much (area in hectares) have you recovered in the last 15 years?, and in the last 5 years?

Productivity and sales

- Do you know the production of your crops per hectare (1 year)? Are there differences when planted alone or associated?
- Where or to whom do you sell your harvest?
- Do you sell, exchange and/or use the wood/ production of your "*purma*"? What are the more useful trees?
- Do you know your production of wood/firewood of your "*purma*"? What is your production estimation?

Community and water

- Do you participate in community activities? What activities?
- What are you doing in your community for water conservation?
- What are the "breed water" plants do you know? Are the species that are sown outside your property different from those sown within your land?
- Do you think that the use of fertilizers / chemicals has increased, decreased or remains the same in the community? How do you realize that?
- Why do you think there are "tired lands" (degraded land)? Do you consider there are more/ less /or the same "tired land" in the community)

Table A: Area, crops and age of farming areas in the visited farm

	Area (hectares)	**Main crops**	**Farming cycle** (years)
Farming area 1			
Farming area 2			
Farming area 3			

Table B: Area, crops and age of *purma* area in the visited farm

	Area (hectares)	**Main species**	**Recovery cycle – "*purma* age"** (years)
Purma 1			
Purma 2			
Purma 3			

Table C Tree species and planting methods identified in transect walks in "purmas"

#	Species name	Sowing	Seedling	Transplanting	Wind /animal
1	Anuna				
2	Añahu caspi				
3	Atadijo				
4	Bolaina				
5	Bombonaje				
6	Cacao				
7	Caimito				
8	Canna				
9	Cedro				
10	Casho				
11	Cetico				
12	Cereso				
13	Coco				
14	Cocoboso				
15	Cordoncillo				
16	Fapina				
17	Huapina				
18	Huava				
19	Ishanga				
20	Ingua				
21	Jagua				
22	Limon				
23	Mandarina				
24	Mango				
25	Naranja				
26	Ocuera				
27	Oje				
28	Palta				
29	Pashaca				
30	pinshino				
31	Pifayo				
32	Plátano				
33	Polponta				
34	Pucaquiro				
35	Quillusisa				
36	Rujindi				
37	Sapote				
38	Shapaja				
39	Tapirina				
40	Teca				
41	Topa				
42	Yawar				
43					
44					
45					

Appendix 2

Factsheet (Divulgatory version)

Article in LEISA revista de Agroecología. Agroforestería y agroecología: experiencias. Volumen 35 no 4. Diciembre de 2019. http://leisa-al.org/web/index.php/volumen-35-numero-4

Pequeño ojé (*Ficus insipida*), especie criadora de agua. Autora

Manejo agroecológico y servicios ecosistémicos en los **sistemas chacra-bosque de los kechua-lamas**

GEANNINE CHABANEIX P.

La agricultura migratoria enfrenta el estigma de ser considerada como negativa para el entorno cuando, en realidad, es lo contrario. Este artículo presenta el trabajo agrícola de comunidades kechua-lamas cuyas prácticas de agricultura en movimiento proveen servicios ecosistémicos fundamentales para la preservación de la biodiversidad, la seguridad alimentaria, el fortalecimiento de la cultura local y, en última instancia, para la supervivencia ante las amenazas del cambio climático.

La agricultura migratoria se define como un sistema de rotación que alterna periodos de cultivo con periodos de descanso o barbecho lo suficientemente largos para regenerar la fertilidad del suelo y recuperar la productividad de la tierra (Altieri, 1999).

Sin embargo, existe una percepción negativa y mucha confusión respecto a lo que el concepto de "agricultura migratoria" significa. La rotación es una característica clave de este tipo de agricultura que es necesario destacar. Algunos especialistas continúan asociándola solo de manera negativa a la pérdida de bosques, mientras se pasan por alto respuestas adaptativas de familias agricultoras que, por el contrario, responden a principios agroecológicos y representan en sí mismas alternativas realistas para abordar los complejos problemas de la deforestación y la pérdida de servicios ecosistémicos forestales.

> **Nosotros decimos pues que la chacra camina, la buena chacra.**
> Misael Cachique, Tinaganillo

En los Andes tropicales amazónicos estos servicios son centrales, en especial en escenarios extremos debidos al cambio climático. Las familias que practican agricultura son altamente dependientes de los servicios forestales, pero son vulnerables frente a la inseguridad y falta mecanismos legales que reconozcan tanto la propiedad como el manejo tradicional agroforestal que realizan en sus territorios, los cuales comprenden el manejo de la chacra y la regeneración natural de los recursos forestales.

> **Mantenemos la purma porque hay más fertilizante, entonces puede [la tierra] producir mejor, se deja por más tiempo y luego puede rendir mejor… Y allí también hay harta leña, de mí va a ser, [si no] tengo que comprar.**
> Pedro Cachique Tapullima, Alto Churuyaku
>
> **Esta tierra estaba llena de kashu ukcha. He estado sembrando maíz poco a poco solo para vencer al kashu ukcha.**
> Pedro Cachique Tapullima, Alto Churuyaku

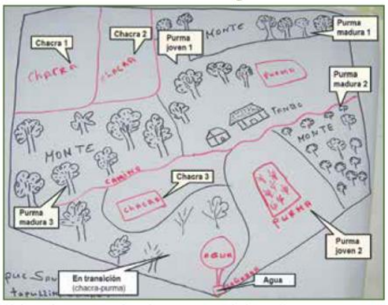
En este artículo se presentan las prácticas de tres comunidades kechua-lamistas (Tinganillo, Alto Churuyaku y Alto Pucalpillo) en la región San Martín en Perú, como ejemplos del aporte de la agricultura tradicional a la generación de servicios ecosistémicos. Se centra particularmente en las prácticas de familias de agricultores conocidos como "curiosos" que basan su sistema de producción en una cultura de diversidad y que realizan grandes esfuerzos de conservación y manejo activo de sus chacras. Estas unidades productivas, ubicadas entre los 250 y 600 m s. n. m. en la cuenca del río Mayo de la macrocuenca amazónica, pertenecen a un paisaje dominado por bosques secundarios, donde las familias han estado cultivando la misma tierra por más de dos generaciones.

El ciclo de la agricultura itinerante de los kechua-lamas: combinación de chacra y bosque

Esta agricultura se considera agroforestería porque combina cultivos con árboles en una secuencia temporal que alterna etapas de cultivos con periodos de descanso que regeneran el bosque secundario, llamado localmente *purma*. Esta combinación también tiene lugar en el espacio, con árboles dispersos en las chacras (especialmente en las áreas en transición) y con varias áreas en diferentes fases del ciclo (chacras, purmas) dentro de una parcela (figura 1). Estos sistemas son agrícolas y forestales a la vez, chacra y bosque se combinan temporal y espacialmente en un predio.

El ciclo (figura 2) comienza con la preparación del terreno y el despeje de bosque secundario mediante diferentes estrategias, principalmente con diferentes tipos de quema para minimizar la pérdida de nutrientes. En esta etapa algunos agricultores incorporan tierras degradadas cubiertas por hierbas

Figura 1. **Mapa de un predio mostrando las diferentes áreas en Tingarillo**



Elaborado por Misael Cachique y Natividad Tapullima.

como la *kashu uksha* (*Anacardia occidentaale*), la *imperata brasiliensis* y otras. Posteriormente realizan el cultivo de la chacra durante cuatro a seis años y, en algunos casos, hasta siete años, con cultivares anuales intercalados con plantas perennes de corta duración, asociadas de diferentes maneras. Al bajar la productividad, la tierra se deja descansar, en la mayoría de los casos de manera transicional, de modo que se va "dejando aparecer a la purma", incluso antes de que termine la etapa de cultivo. Algunas familias agricultoras mejoran la calidad de la purma sembrando y trasplantando especies desde el bosque primario, chacras u otros lugares. Algunos autores denominan esta práctica "barbechos mejorados". En esta etapa se plantan o se dejan crecer algunos árboles que brotan naturalmente. La purma se mantiene durante seis a ocho años o hasta por más de 15 años. Por ejemplo, la purma madura (figura 2) tenía más de 30 años en 2011, la mayor parte continúa en pie en 2018.

Estos sistemas de cultivo son dinámicos y se modifican gradual y continuamente. A medida que aparecen nuevas condiciones, como el menor acceso a bosques naturales, la reducción del área de las parcelas motiva barbechos más cortos o periodos de cultivo muy largos, pero las familias se adaptan y desarrollan nuevas prácticas que les permite hacer frente a estas situaciones, por ejemplo, el manejo activo del barbecho o barbecho mejorado (Marquardt y otros, 2012). En general la práctica es muy diversa. Entre las variables más importantes están la duración y el manejo pasivo o activo del barbecho, el nivel de diversidad de cultivos y si se despeja bosque secundario o si se recupera tierra degradada. Es por esto que es importante reconocer la dinámica del ciclo e identificar los elementos que favorecen su sostenibilidad.

Los servicios ecosistémicos en la crianza de la chacra y el bosque

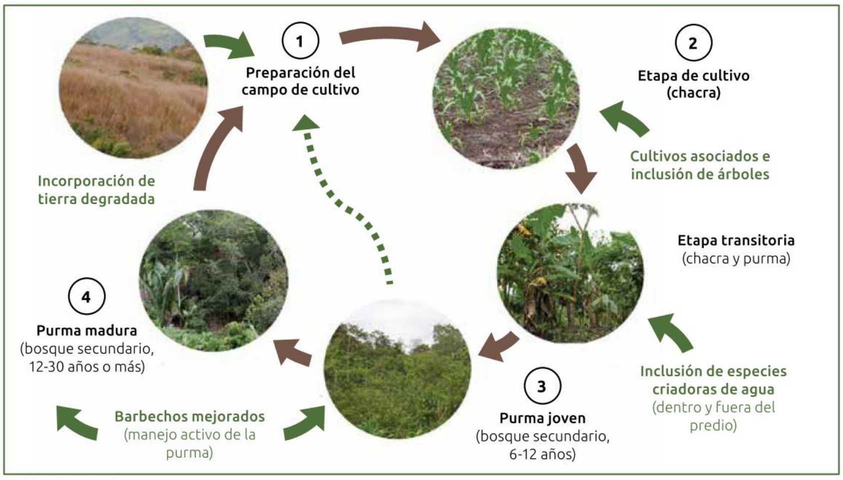
Los servicios ecosistémicos se entienden como los beneficios que se obtienen directa o indirectamente de los ecosistemas. Los sistemas agrícolas, como parte de los ecosistemas, reciben y consumen estos servicios, pero a la vez los brindan. La biodiversidad dentro y fuera del sistema agrícola es crucial en la generación de estos servicios. Los agricultores kechua-lamistas poseen importante conocimiento ecológico que aplican en el manejo de sus chacras para mantener y optimizar la provisión de servicios ecosistémicos. La conservación *in situ* de la agrobiodiversidad, que precisa la biodiversidad aplicada a la producción agrícola e involucra el factor humano y cultural (Altieri, 1999), es una primera forma en que las familias kechua-lamas contribuyen a ello.

A pesar de cierta erosión cultural, los kechua-lamas aún mantienen una riqueza de conocimientos tradicionales sobre agrobiodiversidad que, además, reconocen como una expresión de su identidad. En su visión consideran que la chacra-bosque no solo se debe a la actividad humana, sino al resultado de la conversación de diferentes tipos de "conocimientos" procedentes de humanos, plantas y animales. Según su cosmovisión "todos cultivan" (Arévalo Rivera y otros, 1999). El ciclo agrícola involucra una alta diversidad de especies de plantas y árboles dentro y fuera de sus predios. En los alrededores de Lamas, el centro Waman Wasi ha identificado el cultivo de un total de 129 especies entre plantas medicinales, frutales y otros árboles, sin contar las diferentes en variedades.

El ciclo de la agricultura en los sistemas chacra-bosque abarca un conjunto de acciones de manejo que son caracterizadas como agroecológicas. De acuerdo a la evidencia recopilada entre los agricultores innovadores kechua-lamas, estas prácticas regeneran y optimizan diferentes servicios ecosistémicos (tabla 1).

Entre estas prácticas, hemos podido identificar algunas que describimos a continuación:

Figura 2. **Ciclo de la agricultura de agricultores innovadores en Lamas (250 y 600 m s. n. m.), resaltando las practicas que favorecen su sostenibilidad**



Elaboración propia.

1. Barbechos mejorados que aceleran la regeneración del suelo

Cuando la tierra se deja descansar, el desarrollo del bosque secundario es la etapa más importante para la sostenibilidad del ciclo, ya que se produce biomasa y se enriquece el suelo con nutrientes. El barbecho mejorado acelera el crecimiento de un nuevo bosque y permite acceder a una mayor cantidad de nutrientes. Para ello se trabaja activamente plantando y trasplantando una alta diversidad de especies, incluso desde antes de culminar la fase de cultivo. De esta manera se potencian la fertilidad del suelo y el ciclo de nutrientes.

Entre las familias entrevistadas, el área de purma representó aproximadamente el 30% de las parcelas chicas (de 3 a 4 ha), y más del 50% entre los agricultores con parcelas con mayor área. Las especies plantadas comprenden especies maderables, frutales y palmeras. El rufindi (*Inga ruiziana*), la guava (*Inga edulis*) y el atadijo (*Trema micrantha*) están entre las más frecuentes. Además, de la diversidad de plantas "sembradas" por el viento o animales como el añuje (*Dasyprocta fuliginosa*), murciélagos, monos y loros.

Muchas especies son árboles fijadores de nitrógeno de rápido crecimiento que nutren directamente el suelo y cuyas hojas, al caer, retienen humedad y al descomponerse producen humus. Esto es importante tanto para la disponibilidad de nutrientes que son absorbidos y reciclados, como para la regulación y retención de agua en el suelo; capacidad favorecida también por la sombra que proporcionan los árboles (Marquardt y otros, 2012). Además, la mayor diversidad y cantidad de especies contribuye a la reducción de la erosión y al almacenamiento de carbono en la biomasa de los árboles y en el suelo.

2. Incorporación de tierra degradada al ciclo de producción

Las familias recuperan la tierra degradada trabajando en áreas pequeñas (0,25 ha). Con empleo intensivo de mano de obra, cultivos asociados, deshierbes y manejo ecológico logran la regeneración de los servicios ecosistémicos, reincorporándola al ciclo de producción hasta transformarla en barbecho mejorado. Esta práctica requiere de trabajo sostenido y un alto nivel de conocimiento ecológico, de otra manera la inversión en mano de obra puede ser inútil.

3. La cosecha de agua y el uso mínimo de fertilizantes o plaguicidas a nivel de paisaje

El rol de la purma madura es reconocido explícitamente en la provisión de servicios ecosistémicos vinculados al agua dentro y fuera de las chacras. La provisión y regulación de agua motiva a los kechua-lamas a mantener y mejorar las áreas boscosas cercanas a las quebradas y en zonas de pendiente. Ellos perciben el efecto de los sistemas forestales en la mayor humedad del suelo y mayor cantidad y mejor calidad del agua ("limpia y fría"). Asimismo, valoran sobre todo su capacidad de retención de agua, reducción de la erosión y del riesgo de aluviones.

Las familias relacionan algunas características funcionales específicas de ciertas especies de plantas y árboles con el ciclo hidrológico. Siembran y trasplantan una variedad de especies que "crían agua" (ver fotos), caracterizadas por capturar mayor cantidad de agua alrededor de sus sistemas radiculares (Waman Wasi, 2006). Los agricultores son capaces de reconocer estas especies en sus primeras etapas de desarrollo y las nombran y recomiendan su uso.

Adicionalmente, los fertilizantes químicos y plaguicidas no son de uso común en los campos, lo cual reduce significativamente los riesgos de contaminación de los cuerpos de agua.

4. La asociación de cultivos e inclusión de árboles en el sistema agrícola

La complementariedad de los cultivos mejora la productividad, estabiliza los rendimientos y optimiza diversos procesos ecológicos. Entre los kechua-lamas es común que se asocien cultivos anuales y plantas perennes con árboles (dos o más cultivos en simultáneo durante todo el año o en parte del ciclo del cultivo). Por ejemplo, en los primeros años del cultivo del cacao, cuando la sombra es poca, se siembra plátano entre los

Tabla 1. **Servicios ecosistémicos optimizados por agricultores innovadores kechua-lamas en sus sistemas chacra-bosque**

Servicios ecosistémicos	Categoría	Escala espacial		
		Predio/local	Regional	Global
1. Alimentos	Provisión	x		
2. Leña, madera, fibras, medicinas y otros materiales	Provisión	x		
3. Polinización y dispersión de semillas	Regulación	x		
4. Secuestro y almacenamiento de carbono	Regulación	x	x	x
5. Control de la erosión	Regulación	x	x	
6. Servicios hidrológicos: cantidad y calidad de agua	Regulación	x	x	
7. Fertilidad del suelo	Regulación	x		
8. Ciclo de nutrientes	Soporte	x		
9. Mantenimiento de la biodiversidad/agrobiodiversidad	Soporte	x	x	x
10. Identidad cultural, patrimonio	Servicios culturales	x	x	x

Elaboración propia.

Shapaja (*Attalea moorei, Attalea butyracea*), especie criadora de agua.
Autora

cacaoteros jóvenes, lo cual protege el suelo al mantener la humedad en periodos de baja precipitación o mayor radiación.

Diferentes cultivos como maíz, frijoles, algodón, ají, calabaza, yuca, maní y algunos árboles frutales como papaya y plátano se siembran intercalados en diversas configuraciones generando beneficios como una mayor eficiencia en el uso de los nutrientes y el agua, que se puede atribuir a la presencia de diferentes sistemas radiculares, además de la mejora de la fertilidad del suelo por una menor compactación. La inclusión de árboles aumenta la materia orgánica y la disponibilidad de nutrientes y promueve la actividad biológica. Aquellos árboles con raíces largas permiten extraer nutrientes y humedad de las capas más profundas del suelo y, al mismo tiempo, reducen la lixiviación (Kleinman y otros, 1995). Simultáneamente, el aumento de la cobertura del suelo previene la erosión.

Conclusión

Al vincular la agricultura itinerante de los kechua-lamas con la provisión de servicios ecosistémicos se evidencia que sus prácticas tradicionales, además de producir alimentos, optimizan el suministro de diferentes tipos de servicios ecosistémicos, particularmente aquellos de soporte y regulación que no tienen valor de mercado. En un paisaje agroforestal sin acceso al bosque primario, la provisión de servicios de los sistemas chacra-bosque es aún más relevante.

Las prácticas de las comunidades kechua-lamistas son una prueba de que la agroforestería tradicional, común en muchas de las comunidades a lo largo de la Amazonía peruana, brinda oportunidades valiosas en el desarrollo de estrategias hacia sistemas agroalimentarios social, cultural y ambientalmente más sostenibles. Por tanto, su reconocimiento y apoyo como una forma válida de relación humano-ambiente es importante para rescatar y replicar prácticas ancestrales y modernas que empaten la agricultura con la conservación y mantenimiento de servicios ecosistémicos.

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Appendix 3

Manuscripts for international Journal

Abstract

In the Amazon, life supporting services are essentially associated to forest areas. Nevertheless, the connection of ecosystem services (ES) to agricultural systems is also of great importance. Agricultural management can directly sustain either supporting or degradation processes, that impact on the larger landscape. This study focuses on understanding how Amazonian swidden agricultural knowledge and practices, from the Kechwa-Lamas in Peru, contribute to sustainability via ecosystem services. For this, agroecological practices of innovative farmers were identified and analysed in relation to ES provision. The study found that Kechwa-Lamas agricultural tradition, deeply embedded in their identities, stands as a resisting force that maintains multifunctional agricultural systems, which enhance on-farm and off-farm ES. Using centrally high levels of agrobiodiversity and trees, Kechwa-Lamas manage a traditional rotational agroforestry that combine farm and forest in the same field and allow a dynamic provision of ES. Improved fallows, intercropping, degraded land recovery and use of water conservation species are some of the strategies along the Kechwa-Lamas swidden cycle that enhance and regenerate ES. Some of which are adaptations of traditional swidden resulted from intensification of ecological processes. Farmers' agroecological management and ecological knowledge is very relevant to agriculture sustainability and to confront environmental risk and climate change.

Introduction

Worldwide, 60% of ecosystem services are in decline, many of which have been degraded as a result of pressure to increase food provision services (MEA, 2005). In the Amazon context, life supporting services are importantly associated to forest areas. Nevertheless, the expansion of the agricultural frontier, ranching and a long history of intensive natural resources extraction (Bunker 1984; UNEP-ACTO: 2009; Bennett et al. 2018) are direct causes of loss and degradation of the rainforest aquatic and terrestrial ecosystems. Thus, the capacity to provide critical ecosystem services is continuously undermined in many parts of the basin.

In the face of climate change and growing development of economic activities in the Amazon, there is increasing concern, from both the local and global communities, regarding interventions that can protect the remaining areas of forest, as well as, livelihood of people living in these areas (Betts et al, 2008; Nobre et al, 2016, Marquardt et al, 2018). In this scenario, it is of great importance what kind of agriculture is practiced. So far, conventional intensification of agriculture is the dominant approach in the Amazon, driven by a primary focus on the achievement of higher yields; while, local and traditional ways to work are overlooked (low inputs and high labour).

Swidden agriculture is an ancestral practice among farmers in the Amazon, which can be characterized as a traditional agroforestry system (Pfund et al, 2011; Cronkleton et al, 2014; Robiglio et al, 2015). It is a rotational farming system that combines field crops with tree species in the farm, alternating periods of farming with fallows phases long enough to regenerate soil fertility and subsequent land productivity (White et al, 2005, Altieri, 1999). Trees and agrobiodiversity are essential components of these systems. Scholars argue that traditional swidden systems have a key role to play to enable goals directed at both forest conservation and agricultural diversity, enhancing various types of ecosystem services (Fifanou et al, 2011; Padoch & Pinedo-Vasquez, 2010; Ziegler 2012; Sears et al, 2018). Though, swidden farming is often associated with environmental destructive practices such as deforestation, particularly in circumstances of high demographic and land use pressures, which is when the rotational system can become problematic (Kleinman et al, 1995). In Peru, this perception is very common, not only among specialists, but among many environmental and agrarian authorities working at different regional and national levels. Officially, in Peru swidden agriculture has been pointed out as the main driver of deforestation, though the deforestation data does not support this claim (Ravikumar et al. 2016). On the contrary, deforestation studies point out that medium size producers are statistically significant in relation to forest cover change. They are located in active deforestation zones and count with more resources for forest conversion to agricultural land or pastures (Robiglio, 2015).

Meanwhile, the ecological practices and adaptive responses to land use pressures of farmers carrying on swidden agriculture are ignored (Marquardt et al. 2013; Sears et al., 2018), and their locally developed alternatives to address deforestation and ecosystem services loss in the Amazon go unnoticed. In general, swidden farming is not taken into consideration in state initiatives and interventions as a farming system with potential to contribute to tackle today's highly complex land use situation in the Peruvian Amazon.

Tillman et al. (2002) argues that society in its way towards a more sustainable agriculture needs to recognize and support farmers appropriately to guarantee the provision of food and other ecosystem services. The capacity of agricultural systems to supply different types of ecosystem services, beside food, has been proven crucial to uphold the productivity of the farming system and the larger ecosystem. Especially, regarding the provision of supporting and regulating functions that are not easily visible and don't have market value i.e. soil formation, nutrients cycling, water purification, etc.

In this study I advocate that small-scale Kechwa-Lamas swidden farming system in San Martin already provides a diversity of functions (provision, regulating and supporting ecosystem services) to a wider landscape and that the initiatives and actions of these farmers should be supported and taken into account in the development of strategies towards more sustainable agriculture in the San Martin Amazonian landscape.

Methods

The fieldwork for the study was carried out in two parts. The major part was performed between October and November 2011 and it was complemented with a shorter intensive follow-up in November 2018. The use of different sources of evidence for data collection allowed to verify and strengthen the findings. I carried out interviews and employed secondary sources of evidence such as government official reports, non-governmental organization publications and other local grey literature. Field observation methods were also used, including direct observation and participant observation in communal activities and gatherings. These methods were particularly useful in the initial part of the fieldwork for testing interview questions and adapting the research design.

I carried out a total of 20 interviews to farmers and key informants. Fifteen non-structured farmers interviews in their fields which also allowed me to talk to family members that work in the farm, do with them the transect walks and observe their activities. These interviews were performed in more than one occasion, which according to Bryman (2012), allows for some insights and possibly for establishing more causal connections. Five semi-structure interviews were performed with key informants from non-governmental organizations members, government officials and other actors in the region, who could bring additional information and perspective to the research. Additionally, one focus group discussion was held with innovative farmers, using the farm mapping visualization technique.

The Kechwa-Lamas farmers participating in the study come from five Kechwa-Lamas villages; Alto Pucalpillo (part of which is now Bajo Pucallpa), Tinganillo, Alto Churuyaku, Naranjal and Morillo. They all practice swidden farming and were farmers that were considered innovative, locally known as "curious" by other community members, meaning they are considered to carry out more active management and conservation efforts in their farms. These farmers were the centre of this study. The study focuses on farmers living in the communities of Tinganillo, Alto Churuyaku and Alto Pucalpillo, where a wide variety of tree management practices were carried out in comparison to other communities. While the villages of Morillo and Naranjal were visited to have a more general idea of Kechwa-Lamas agricultural practices.

The premises of the civil society organization *Asociación Waman Wasi*, in the city of Lamas, capital of the Lamas district and province, were used as a coordination centre and to obtain additional qualitative data from participants and expert team members of the *Asociación Waman Wasi.* Desk work was carried out mostly in Lima. The assistance and discussions with members of *Waman Wasi*, many of whom were also Kechwa-Lamas, was central for participants selection, to get familiar with local customs and terminology and for the study internal reliability.

Study area

The study took place in Kechwa-Lamas territory in Lamas, one of the provinces of the San Martin region which is part of the tropical Andes biodiversity hotspot (CEPF, 2015). The area is located in the north-eastern part of the Peruvian Andes, in the Upper Amazon basin. The upper Amazon or “Rupa Rupa” is an intersection space between the high Andes and the Low Amazon or “Omagua” that mingles ecological features of both ecosystems, whose inhabitants themselves are an expression of both Amazonian and Andean Cultures (Arévalo, 1999). This area exhibits diverse altitudes, topographies and climatic conditions that vary widely seasonally and inter-seasonally, hosting a broad diversity of species and cultivars. Overall, the climate is warm and humid with one season of marked higher precipitation between December and April (Arévalo, 1999).

Lamas is predominantly a rural province. About 75% of the labour force is employed in agriculture and a third of the agricultural land is farmed by small scale farmers that access less than 10 hectares (INEI, 2012). Kechwa-Lamas are one of the ethnic groups in the heterogeneous upper Amazon and represent the largest population of indigenous people in San Martin. They inhabit small native communities spread in the region, near Lamas, the largest Kechwa-Lamas town of Wayku (Waman Wasi, 2006). Spanish and kechwa are still spoken, while other local languages were gradually lost (Panduro, 1999). Kechwa-Lamas are generally smallholders that make a living from swidden agriculture (PRATEC/Asociacion Choba Choba, 2001). Mestizo and Andean migrants are two other main groups of smallholders in San Martin.

Aggressive state policies between the 40s and 70s promoted the expansion of agriculture, and stimulated massive migration, mostly Andean to set up monoculture farming systems. These agricultural systems were not suited to the local agroecological conditions and contributed to the depredation of the tropical forest (Gobierno regional de San Martin, 2008; Velarde et al, 2010). Economic booms of specific agricultural products had usually caused instability among small-scale farmers like the Kechwa-Lamas. For instance, cotton promoted with promising high prices, sold in international markets, motivated farmers to change over to cotton farming, taking the land of a diversity of crops and even the primary forest (Rengifo et al, 2008).

San Martin landscape has a diversity of land uses from primary rainforest to long term monoculture production; with various farming systems such as multiestrata agroforestry, permanent pastures and the traditional swidden agriculture, including various types of management, intensification levels and access to irrigation. The main crops are produced in very different agroecological contexts: Rice is produced in flats areas, with access to irrigation; while cacao and coffee perennial crops are planted in slopes. These are the most important in terms of prices and number of households involved in the business (MINAGRI, 2017). In the study area in Lamas district and among smallholders, cacao is a common crop. Maize, cassava, and plantain, that count on significantly lower prices, are common cash crops among Kechua-Lamas communities, even in the case of the self-subsistence farmers who can set aside small amounts of their production to the market.

The five Kechwa-Lamas communities that were visited are located in two different ecological zones of the Mayo river watershed: The three communities that were the focus of the study (Tinganillo, Alto Churuyaku and Alto Pucalpillo) are located in the lower riparian zone at 250 - 600 m.a.s.l., where no primary forest is left, fallows are developing weak secondary forest and areas of degraded soil are part of the landscape (Waman Wasi, 2011); The two communities in the mid watershed (Naranjal, in the upper limit, and Morillo), at 600 to 800 m.a.s.l., are areas with more slopes, greater amount of rainfall and some primary forest cover. In the province of Lamas, deforestation compromises about 40% of their forest area (Gobierno Regional de San Martin, 2008; World Bank, 2006). In Lamas district, more than 80% of the forest are was lost before 2000 (MINAM/MINAGRI, 2017). Thus, two generations of Kechwa-Lamas families have been living in areas with mostly secondary forest. In the field area there is only secondary forest.

In San Martin, agricultural activities caused 77% of forest conversion in the period 2008 - 2017 (FCPF, 2019). Perennials (mainly coffee, cacao, and oil palm) rice and maize have become the main crops expanded over forest (FIP, 2012). The area of cultivated pastures and perennials has increased, while annuals area decreased. This resulted in a production decline of food crops like beans and fruits (BCRPa, 2017; MINAGRI, 2017). Higher social-environmental pressures such as, transition to cash crops, vulnerability to market fluctuations and population growth, including massive migration into the territory, have significantly increased the competition and conflict among different groups for land and resources (Egerlid et al, 2016; Marquardt et al, 2018). Many of the problems faced by small-scale farmers are derived from the agricultural intensification and disruption of the Swidden agriculture cycle (Marquardt et al., 2013).

Swidden cycle in Lamas riparian area: farm and forest

Swidden Agriculture is a traditional and ancestral practice in the Amazon, practiced as well in the upper Amazon of Lamas by Kechwa-Lamas farmers. This small-scale agriculture has taken place on the eastern watershed slopes (“laderas”) of the Andes and in small spaces with high plant density and diversity (Rengifo, 1999).

The swidden cycle (figure 1) begins with the **preparation of the terrain** (stage 1) and secondary forest clearing through different strategies, mainly with different types of burning to minimize nutrients loss. As aforementioned, there is only secondary forest in the area**, thus clearing primary forest is not an option**. At this stage, some farmers incorporate degraded land covered by herbs such as *kashu uksha* (*imperata brasiliensis*), *yaragua* (*Hyparrhenia rufa*) and others. Then, in **the cropping** (stage 2) the farmland is planted ("*chakra*") with annual cultivars interspersed with short-lived perennials, associated in different ways. This stage lasts for four to six years and, in some cases up to seven years, including a transitional state when the fallow, locally called "*purma",* is let to "appear" before the cropping phase ends, naturally growing trees are planted or allowed to grow. When productivity lowers, the land is left to **fallow to regenerate the secondary forest.** The fallow is kept for six to 12 (stage 3), 15 years, or up to more than 30 years (stage 4). Young fallows (ages between 6 and 12 years) look like weak secondary forest, while old fallows or "*macchu purma"* are mature fallows with more than 12 years. Farmers obtain timber and various materials, including firewood from their own *purma,* which motivate them to maintain it. The *purma* play a role in family activities, the decision to cut it down is made in relation to family celebrations and events and can be seen as a way of saving. Therefore, either young or old fallow can be cleared to start the cycle once again.

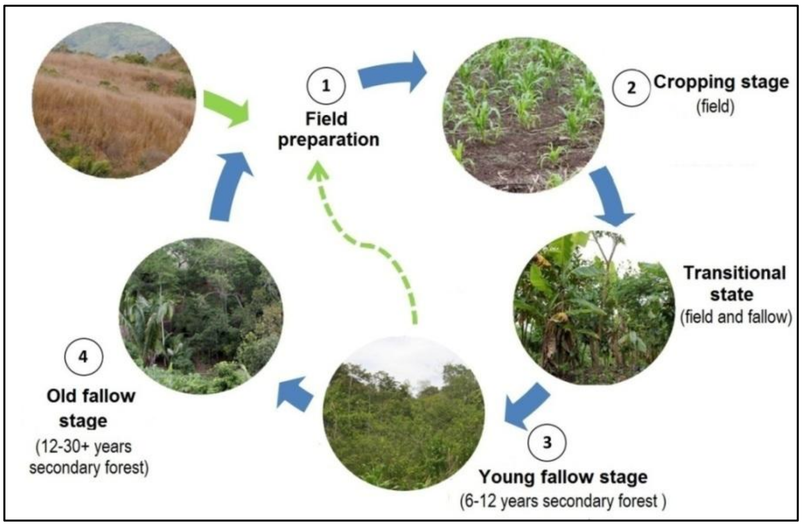

Figure 1: Swidden agriculture cycle in the riparian area in San Martin (Own elaboration).

Greater difficulties to access land that many small-scale farmers are having are making their rotational agriculture significantly problematic. For the Kechwa-Lamas, this is a fact of life over past years, especially in the riparian zone. Marquardt et al, (2010) reports that a family has a third of the area farmers used to have 30 years ago.

Results

The Kechwa-Lamas cyclical system involves a traditional management of cropping areas and forest natural regeneration. These are both agricultural and forestry systems, where field crops and trees are combined in a temporal sequence and in space, with trees scattered in the cropping areas (especially in the transition areas) and several areas in different phases of the cycle within the same plot (figure 2). Incorporation of various native crop and trees species within the system is very common.

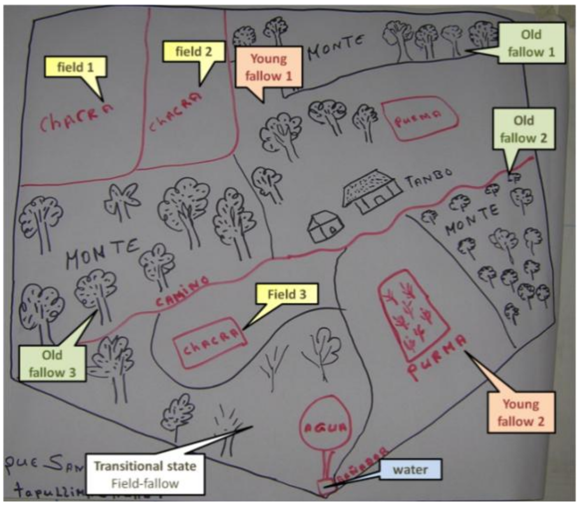

Figure 2 Farm map showing field, transitional stage (agroforest), young and old fallow areas within a farm in Tingarillo community (Mizael Cachique y Natividad Tapullima, October 2011)

These farming systems are dynamic and are continuously modified. As new conditions appear, families adapt and develop new practices that allow them to face such situations (Marquardt et al., 2012). In general, the practice is very diverse. Among the most important variables are the duration, the passive or active management of the fallow, the level of crop diversity, and whether secondary forest is cleared or degraded land is recovered.

Agro-ecological management practices

Kechwa-Lamas farmers acknowledge that their agriculture differs considerably from conventional farming systems. They highlight the land set aside for fallows as the main feature that distinguish them from other types of agriculture. Farmers also point out strategies as the maintenance old trees, ravines and "breed water species" in streams as some of the most dissimilar aspects of their practice. Kechwa-Lamas farm-forestry systems entail a set of management actions characterized as agroecological. High levels of agrobiodiversity, including tree diversity are central, underpinning agricultural practices. Among them, I highlight five groups of practices, four of them involving tree management. These are showed in figure 3, in the corresponding stage within the swidden cycle.

Figure 3: Swidden agriculture cycle in San Martin highlighting practices that favor its sustainability (Own elaboration).

Improved fallows accelerate the regeneration of the soil.

Unlike the fallow developed naturally, improved fallows allow access to a greater amount of nutrients, accelerating the new forest growth. Improved fallows are not practiced by all farmers because it requires higher ecological knowledge and labour. Innovative farmers speed up natural regeneration by actively planting and transplanting a high diversity of species from other farms, primary forest and other areas. They use palm species, fruit trees, timber trees and other perennial crops that together allow access to a greater amount of nutrients, even before the farming stage ends. Among the most frequent species planted by farmers are *guava* (*Inga edulis*), *rujindi* (*Inga ruiziana*), and *atadijo* (*Trema micrantha*).

> *"We keep the "purma" in our farm because there is more fertilizer, then it [the land] can produce better, if it is left for longer time then it can yield better. ...There is also a lot of firewood that is going to be mine* [otherwise] *I have to buy".* (Pedro Cachique Tapullima, Alto Churuyaku).

Farmers leave the shoots that naturally grow or when transported by wind or "sown" by animals (They wait after one or two years of the cropping stage to leave them to grow). Among these species *Shapaja* (*Attalea butyraceae*) *Poloponta* (*Elaeis oleifera*) and *Pashaca* (*Parkia sp*) were the most common. For farmers is usual to "help" the fallow keeping in the fields old trees that act as natural seed providers, looking for easy wind sowing, as well as, maintaining conditions to attract animals that help to sow, such as the *Añuje* (*Dasyprocta fuliginosa*), bats, monkeys, and parrots. Among the interviewed families, the "*purma*" area represented approximately 30% of small plots (3-4 ha), and more than 50% among farmers with larger plots (8-9 ha), this was a consistent result in 2011 and in the follow-up visit in 2018.

Incorporation of degraded land into the production cycle

Some families recover degraded land working in small areas (a quarter of a hectare). Farmers state that it is common to begin the recovery process planting maize, because it can grow in very harsh conditions. For this, intensive labour investment is required for weeding and management that combine the practices identified. So, they can reincorporate degraded land into the production cycle until it is transformed into an improved fallow.

> *"This land was full of kashu ukcha (A weed related to impoverished soil), I've been planting corn little by little just to beat the kashu ukcha". (*Pedro Cachique Tapullima of Alto Churuyaku, October 2011).

This practice requires a high level of ecological knowledge and sustained work. It is carried out only in the riparian areas and not by all families. Those that carry out the land recovery process do carefully assess their possibilities, otherwise the investment of time and labour may be in vain. Innovative farmers declared they felt motivated to recover degraded land to increase their farms productive area. One interviewed farmer stated that half of his farm was recovered since the land was bought in such condition. Some families estimated they have recovered one or two hectares in last 7 - 15 years.

On-farm and off-farm water conservation

The effect of forest areas, particularly of mature *purma*, is recognized among farmers for increasing soil moisture as well as for improving water quantity and quality (more, provided for longer, cleaner and colder). The capacity of areas covered by forest to retain and regulate water, avoid soil erosion and lower temperature of fresh water is appreciated by farmers.

> *¨If you are going to do "chakra" (cropping field) in the entire area of the farm, the water decreases, and dries out little by little because there is no longer forest. Even the roots "breed" water, and if you don't believe me, you can chop the roots of cetico (Cecropia spp) and you will see how the water comes out and drips, and in the aguaje (Mauritia flexuosa), and ishanga as well¨.* (Milton Sangama from Alto churuyacu in Waman Wasi, 2006).

Families relate some functional characteristics of specific plants and trees to the hydrological cycle. They sow and transplant from other places a wide variety of species, referred as "breed water" species which are characterized by capturing more water around their root systems (Waman Wasi, 2006). Farmers are able to recognize and name them in early growing stages and recommend their use. In some very steep slopes, some farmers prefer not to clear the area because of the risk of land coming down. They rather sow "breed water" species for water conservation and reducing degradation (PRATEC, 2001). Many of these species are planted by animals (*Poloponta, shapaja, bombonaje*) or wind (*cetico, ishanga*) or both. Kechwa-Lamas maintain and improve forest cover near springs, streams and in slopes. These areas are maintained in the community with weekly collective work, thus streams of water keep running.

> *¨It is good to have our well, surrounded by trees that ¨cry¨ water such as Ceticos (Cecropia spp), aguajales (Mauritia flexuosa), Ishangas), witinos (Xanthosoma sagittifolium, local tuber), patquinas, because the forest has water, then our well never dries¨* (Custodio Sangama from Congopera community in Waman Wasi, 2006).

Figure 4: “Breed water” Species that retain water in their roots (a) Shapaja (Attalea moorei/Attalea butyracea) in the farm of Andres (b) small Oje (Ficus insipida)

Intercropping including trees in the cropping fields

> *“We farm with trees because the trees let their leaves fall, and these leaves decay and feed the soil” (*Miguel Cachique Sangama from Churuyaku, October, 2011)

Among the Kechwa-Lamas it is common to associate short-lived perennials and annual crops (two or more crops simultaneously during all or part of the crop cycle). The integration of trees since the cropping phase allows for a gradual transition to the fallow period. Also, farmers assess the right time to plant different crops to reduce competition over light and nutrients. For example, in the first years of the cultivation of cocoa, when the shade is low, banana is planted among the young cacao trees, these protects the soil from evaporation in periods of low precipitation and/or greater radiation. Common intercropping is sowing maize, beans and cotton together with plant of chili, pumpkin and some fruits such as papaya and plantain. Other crops such as cassava, peanuts are also interspersed in different configurations. Farmers are well aware of the trade-offs between crop diversity and higher quantities of a single crop. For instance, in the lots recovered with maize, it was point out that maize might yield about 2 tons when planted alone, but about 1.2 tons when intercropped[32], though, papaya, plantain and beans for instance are also harvested.

Other practices: Non-use of agrochemicals, green manures, weeds control.

In general, many techniques seek to accumulate soil nutrients or "vitamins" as referred by farmers. Some common actions identified during the cultivation phase are: the continuous manual weeding without using any pesticides; the use of the extracted weeds as green manure (plants used to fertilize the soil in piles or scattered like mulching); the use of living and dead barriers, for instance trees are planted or logs are left across the slopes to trap leaves, nutrient and sediments. For example, a farmer indicates that he has learnt this practice from his parents and extensionists[33]. Interviewed farmers state that chemical fertilizers and pesticides are not commonly used in the fields, besides these are not easily accessible for a large majority. They explicitly relate their use to declining quality of water sources, though; perceive that agrochemicals use has gained ground among some farmers.

[32] Farmers interviews, Pedro Sangama Tapullima (Alto Churuyaku), November 2011

[33] Key informant interviews, November 2011.

Ecosystem Services in Kechwa-Lamas farm and forestry

The rotational nature of the Kechwa-Lamas systems implies a dynamic provision of different ES categories along the cycle (Figure 5). Since the agricultural management is characterized by the use of a high diversity of species and varieties of plants/trees inside and outside their farms, it is worth to underscore that higher diversity levels should have a positive impact on ES provision. The highest level in the cycle would be reached during the old fallow stage, especially of regulating and supporting ES.

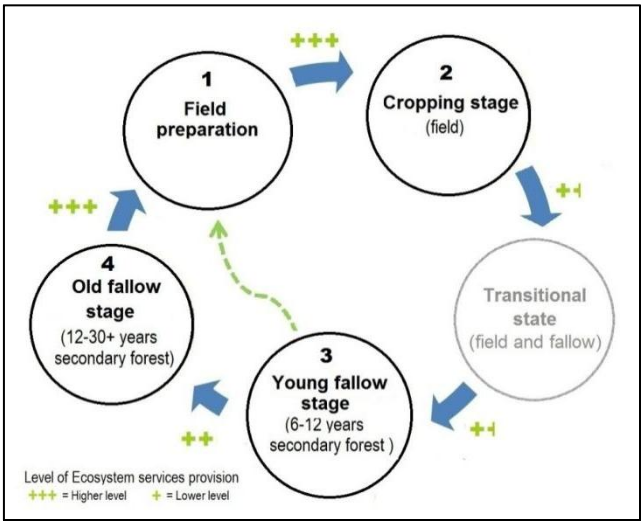

Figure 5: Referential level of ecosystem services provision in the different stages of swidden agriculture cycle (Own elaboration).

Based on the evidence collected among innovative Kechua-Lamas farmers and ES literature, the identified agroecological practices in this study are linked to the optimization and regeneration of the ecosystem services presented in Table 1.

Table 1: Ecosystem services maintained/enhanced by Kechwa-Lamas farmers in their farm-forestry systems in the riparian area (own elaboration for Kechwa-Lamas farmers adapted from Shibu 2009)

#	Ecosystem services	ES category	Spatial scale		
			Farm/Local	Regional	Global
1	Food	P	X		
2	Firewood, timber, fibers, medicines and other materials.	P	X		
3	Pollination and Seed dispersal	R	X		
4	Carbon sequestration and storage	R	X	X	X
5	Erosion control	R	X	X	
6	Hydrological services: water quantity & quality	R	X	X	
7	Soil fertility	R	X		
8	Nutrient cycling	S	X		
9	Maintenance of biodiversity/agrobiodiversity	S	X	X	X
10	Cultural identity, heritage	C	X	X	X

P: Provisioning R: Regulating S: Supporting C: Cultural services

Provisioning services are related to the variety of species grown and harvested, while cultural services are linked to diversity as an essential element of Kechwa-Lamas identity and heritage as well as their understanding of the farm and forest as an integrated system. Pollination and seed dispersal services are enhanced by farmers keeping old trees and conditions in their fields to attract animals. Apart from bees being recognized as main pollinators, many other animals such birds, and bats provide pollination services as well (Garbach et al, 2014). Regulating and supporting ES from 4 to 9 are developed in more detail. Soil Organic Matter (SOM)[34] and soil biota, strongly dependent on vegetative cover, soil, and climatic characteristics, are central in the provision of these services (Barrios et al, 2012; Kibblewhite et al, 2008; Smukler et al, 2012; Dignac et al, 2017).

Agrobiodiversity in situ conservation
Despite some cultural erosion, the Kechua-Lamas still maintain a wealth of traditional knowledge on agrobiodiversity that they recognize as expression of their identity. In their vision they consider that the farm-forest is not only due to human activity, but also the result of the conversation of different types of "knowledge" from humans, plants, and animals. According to their worldview, everyone “nurtures" (Arévalo Rivera et al., 1999).

Farmers manage and have ecological knowledge of a high number of species maintained through in-situ conservation in their farms. This diversity covers different species from crops to native trees, palms and plants that not only implies aboveground biodiversity, but also belowground, with different leaf types and root depth, organic matter quality and various soil biota interactions. In the riparian areas, where conditions are harsher the number of crops ranged between 5 and 9 in the farming area, with more than one variety within the species. Whereas, in the areas of *purma* and agroforest (intermediate stages between cropping phase and secondary forest), the number of species range between 12 and 27, including perennials such as cacao. In the follow-up visit, 7 years later the number of species in 10-39 years *purma* ranged between 28 and 39.

For the region (surroundings to Lamas), the centre *Waman Wasi* indicates a total of 129 managed species among medicinal plants, fruits and trees that also include a great richness of varieties[35]. For instance, for the case of banana, maize, and cassava, more than ten varieties can be found in farms fields (Waman Wasi, 2011). Research in functional diversity indicates that this can be lost sooner than species richness (Smukler et al, 2012). Thus, high levels of biodiversity lower the risk of losing an entire functional group when faced with drastic change, so it is for the supply of ecosystem services.

Soil fertility and nutrients cycling
These services are optimized in both, during the cropping stage and in the fallow. Farmers actively speed up natural regeneration in their improved fallows, managing variety of vegetation, including trees, especially those that produce greater amounts of biomass and larger quantity of falling leaves. Many of the tree-species planted and selected by farmers are fast growing N-fixing (Marquardt et al, 2013).

Tree integration improves efficiency use, nutrients availability and recycling. Trees capture nutrients before and after cropping season because their growing season is usually longer than most crops (Shibu, 2009). Their rooting systems can access nutrients that drain below the crops rooting zone and extract nutrients from soil deeper layers. For instance, deep-rooted trees have a better capacity to accumulate phosphorus (Barrios et al, 2012;

[34] Soil organic matter consists of living parts of plants (principally roots), dead forms of organic material (principally dead plant parts), and soil organisms (micro-organisms and soil animals) in various stages of decomposition (Bot & Benites, 2005)

[35] Key Informant, Luis Romero, October 2011.

Kleiman et al, 1995; Van Noordwijk et al, 2015). Trees that share mycorrhiza with other plant species possibly transfer them nutrients and may play a role as inoculum reservoirs for annuals. Trees can provide habitat conditions for soil biota, playing an important role in promoting biological activity (Van Noordwijk et al 2015; Barrios et al, 2012). This and soil organic matter which contribute to soil structure are generally found to be higher near trees (Buresh and Tian, 1997; Pardon et al, 2017). In the Amazon, soil macrofauna is strongly associated with tree canopy (Barrios et al, 2012).

The **various intercrops** during the farming phase improve environmental resources use. Intercropping can result in fewer losses (less weed, less pest and plant diseases), more stable yields over years compared to monocrops (Raseduzzaman & Jensen, 2017; Hauggaard-Nielsen et al 2008; Wezel et al, 2014), increased limited resources availability and efficiency use by above and below ground complementary interactions among different crops, plants/trees and soil biota. Soil stability and structure are improved as well due to roots complementary (Wezel et al, 2014; Brooker et al, 2013). Legume and non-legumes can use resources in a complementary way. The cultivation of cereals like maize with grain legumes (beans, peanuts, among others), common in Kechwa-Lamas fields, improve nitrogen availability because cereals are better at using soil inorganic nitrogen and legumes are forced to cover a great part of their requirements by fixating atmospheric N_2 (Jensen 1996). In acidic soils, plants roots adapted to such conditions (peanuts, maize, beans, among others) release organic acids and phosphates which can improve phosphorous nutrition of associated crops and protect them from aluminum toxicity (Brooker et al, 2013).

Techniques such as green manure, weed control, living and dead barriers accelerate nutrients inputs or ¨vitamins¨ into the soil. Falling leaves and others biomass additions from vegetation provide a protection cover that directly nourishes the soil, fine roots, roots exudates are also soil inputs. When these materials decomposed become humus which regulates the delivery of nutrients that can be absorbed and recycled by plants. Soil organic matter (SOM) and particularly humus are central for nutrients availability (Marquardt et al, 2013; Barrios et al, 2012).

Protection & erosion control

Soil erosion and physical protection services are associated to conservation measures like minimizing soil exposure, partially decomposed organic materials on the ground and tree cover. The protection role of tree-based system relies in their property to reduce landslides and soil erosion in the high season (rains). In the riparian zone, the forest areas are recognized as field natural protection from the rivers, one of the reasons given by farmers is their role as physical barriers and the presence of many and deep roots.

Bruijnzeel et al, (2004) indicates that reforestation and soil conservation can reduce peak flows and prevent shallow landslides. The various species intercropped by farmers, like trees, short and leafy vegetation, protect the ground surface. Living and dead barriers are considered buffers that promote sediment deposition and nutrients retention (Shibu, 2009; Brauman et al., 2007). The amount of litter on the surface, the decomposition rate and plant architecture above and belowground are key factors to trap sediments and reduce erosion (Le Bissonnais et al. 2004 In Wezel 2014; Brauman et al., 2007; Power et al 2010). Swift et al (2004) states that plant diversity role on slopes is even greater, since "slopes soil protection depends more on partially decomposed litter with good ground contact than on fresh leaves that can be easily washed away".

Research carried out on soil erosion for swidden agriculture report a wide variation, from negligible values to more than 100 mg /ha and 350 mg/ha per year of soil lost for the most intensified systems (shortened fallows). Though, many of these values represent soil loss only for the cropping stage, reflecting strong differences in farming practices and climate, topography, and soil conditions. When fallow periods are considered in calculations, the erosion rates decline significantly (Ziegler et al, 2009). Several studies indicate that surface soil loss during the fallow phase is similar to intact forest and considerably lower than palm oil for instance (Sidle et al. 2006, Bruijnzeel 2004, Ziegler et al. 2007, de Neergaard et al. 2008, Valentin et al. 2008 in Dressler et al, 2017).

Hydrological services

Water related ES motivate farmers to manage their tree-based systems and forest areas outside their farms, especially, since there is an increasingly water shortage problem and Kechwa-Lamas depend on small streams and springs (*pukios*) for their water provision. Farmers relate forested areas to water supply, regulation, and purification services. On the contrary, croplands with no trees are associated to lower water provision, and agrochemicals use, atypical in Kechwa-Lamas systems, related to water quality decline.

These perceptions are consistent with the influence that different ecosystems exert on the amount of water moving across the landscape. Soil - plant interactions impact processes such as water evaporation, infiltration, soil storage capacity, rainfall impact or nutrients/pollutants uptake and transformation which affect water quantity, quality, and erosion (Brauman et al., 2007; Mastrorilli et al, 2018). Through ground cover and vegetation organic inputs, farmers manage soil organic matter and the soil community (SOM living fraction) impacting several of the aforementioned water-related processes.

Tree cover has generally great impacts on infiltration and water flow in the landscape (Boelee, 2011). In the agriculture-forest landscape of Lamas, where farmers recover degraded land, the enhancement of water related services due to forest patches and scattered trees in the fields can have a greater positive impact on water availability than previously thought. Newer tree cover theory suggests that intermediate tree densities can maximize groundwater recharge in degraded land (**Figure 6**), each new tree generate higher hydrologic gains than transpiration and interception losses (Ellison et al, 2017).

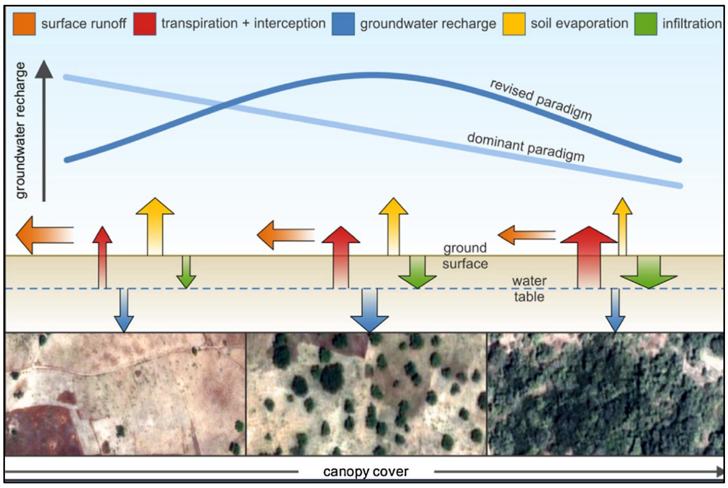

Figure 6: Infiltration and groundwater recharge relative to tree cover (Source: Ilste et al. 2016 in Ellison et al, 2017).

Trees have a strong effect in terms of water, some key features are: they transpire water, their leaves intercept rainfall and the canopy provide shade, deep rooting systems capture water and their falling leaves and branches cover the soil providing organic inputs. All of which has an important effect on temperature, moisture, soil biota and soil organic matter. **Trees in agricultural fields have cooling effects** which lessen evaporation losses and increase soil organism activity; canopy closure protects from high temperature and drought stress (Barrios et al, 2012). Also, their roots can **redistribute water**, moving water upwards and downwards, rainwater can be stored where it is not evaporated and brought back to the topsoil by roots.

Tree-based is a central feature of Kechwa-Lamas systems that contribute to hydrological services, though, when farmers employ techniques targeted at increasing soil fertility, nutrient efficiency and use of diverse species, especially in relation to water conservation, they enhance hydrological services in their farms as well as at larger spatial scales.

In terms of water quantity, practices such as organic materials continual addition and minimal removal are particularly relevant. **Roots and soil covered with plant litter** such as leaves, branches, among others, slow water flow which improves infiltration and reduces evaporation (Brauman et al, 2007; Bot& Benites, 2005). Soil water evaporation can be reduced by 30-50% because of mulching (Garbach et al, 2014). Above and belowground o**rganic materials** that Kechwa-Lamas leave in the fields improve the **organic matter content** that influence soil biota composition, fostering the activity of soil organisms that feed on plant residues, roots by-products and others. Humus that has already undergone full decomposition is especially important to increase water infiltration and soil capacity to store water. Soil organic matter (including roots) and soil organism activity maintain soil structure, which underpins soil water availability (Kibblewhite et al, 2008, Bot& Benites, 2005).

Direct seeding and avoidance of tillage cause little soil disturbance, which is beneficial for soil biota, especially macrofauna. By ingestion, soil organisms break down organic materials, mixing them with soil minerals. Bacteria, fungi and particularly worms are important because of their glue-like secretions that contribute to soil aggregation. Macrofauna Burrowing and feeding activities help to create pathways for air and water. Soil covered with residues prompt earthworms to the surface promoting porosity that favours infiltration (Bot& Benites, 2005; Power et al, 2010). Difference in porosity allows for a balance between soil infiltration and water storage (Ellison et al, 2017, Barrios et al, 2012).

Efforts to minimize soil exposure, nutrients and sediments loss are related as well to water quality and purification services. Dead and living barriers that reduce erosion are also related to water quality.Right timing for sowing crops and intercropping variety of species, including trees, aim at matching nutrients availability and crop demand which allows higher nutrient use efficiency (Barrios et al, 2012). Little soil removal minimizes leaching or losses to the atmosphere associated to tillage. These losses are related to faster organic matter decomposition and organic nitrogen conversion to mineral forms that surpass crop nutrient demand (Kibblewhite et al, 2008).

Diversity can be beneficial in many respects to improve water conservation. Species uses water in different ways, thus species choices are relevant to balance water flows (Ellison et al, 2017). Farmers' knowledge is key, since they use high diversity of crops, trees and "breed water" species. Some of these **"breed water" species** are palms, such as *aguaje* (*Mauritia flexuosa*) which is found in wetlands in the Amazon. These particular palms (**see**

figure 7) have large roots that could represent yet more of the 40 % of the total biomass that serve to recharge aquifers and ravines (Freitas et al, 2006). According to Velasquez (2010) its deep and dense root system favours water retention in the soil profile.

> ¨I have planted more than 30 *aguajales* (Mauritia flexuosa), that is why there is water, they are there to take after the water, to maintain it¨ (PRATEC/ Asociacion Choba Choba, 2001)

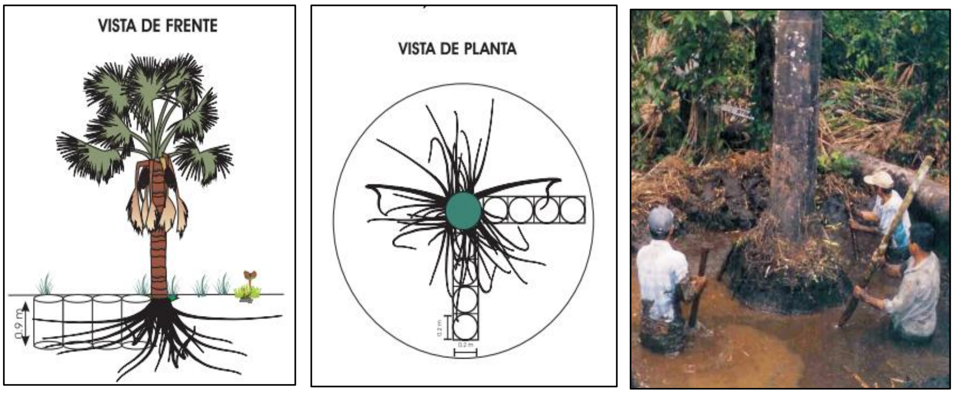

Figure 7: Mauritia flexuosa "breed water" species (a) Front view, (b) roots system, (c) Digging of main root of Mauritia flexuosa to measure biomass content.

Carbon sequestration and storage

As a tree-based agroecosystem with the fallow as essential part of the farming cycle, Kechwa-Lamas agriculture has a great capacity to store and sequester carbon in a dynamic way. Swidden can store as much or more carbon than complex agroforest[36] or intensive tree-crop systems, like oil palm and cacao (Palm et al, 2005). The combination of crops with long fallow can store more carbon than intensive tree-crop systems; however, the economic returns are very low. For different land uses, it was found that the length of the fallow makes a significant difference in the carbon stock, while fruits sales do the same in the profitability of the system (Tomich et al, 2005).

For the Peruvian Amazon (**figure 8**), the fallow length also evidences a significant increase on the farming system carbon stocks. Even short fallows have a considerably higher storage capacity than annual crops (maize, cassava rice). The carbon stock of a 15-year fallow is 6 and 10 times of a 3-year fallow (White et al, 2005). This implies that improved fallows can accelerate the storage capacity of swidden systems.

[36] Defined in the study as: 2 yr of cropping followed by establishment of *Theobroma cacao* (jungle cacao) with a 25-yr establishment phase and 40-yr rotation/ or a permanent, nonrotational cacao system established through gap and understory plantings of cacao (Palm et al 2005, p. 44)

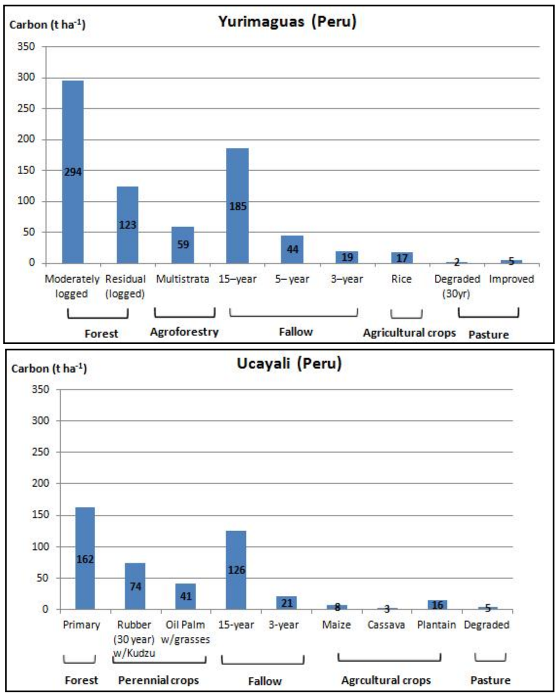

Figure 8: Carbon storage of different land uses in two locations in the Peruvian Amazon. San Martin and Ucayali (Own elaboration based on data from White et al, 2005).

White et al. (2005) report that forest and tree-based systems are greenhouse sinks, in contrast to annual cropping that exacerbates gases release with intensification. This, because annual systems accumulate little carbon (C), have higher emissions of nitrous oxide (N_2O) and a smaller consumption of methane (Ch_4) and in some cases even release methane. Though, the rate at which carbon is accumulated (about 3 Mg C ha-1 yr-1) can be quite similar for annual crops, tree plantations and forest, but the contrasting residence times of 1, 10 and 83 years respectively, account for the difference in the carbon stocks across these land categories (Hairiah et al, 2011).

The larger carbon storage capacity is in aboveground vegetation. Fox et al (2011) indicate that BGC (Below ground carbon) is mostly uncertain for most land cover in tropical regions. In the case of swidden fallows in Asia, BGC values could be about ≤ 20% of the AGC (Above ground carbon). There are indications that soils with higher biological activity may have a stronger potential for carbon storage. Agricultural practices of Kechwa-Lamas can be linked to the biological activity promotion, which may have a positive impact on carbon storage in soils. However, biotic and abiotic mechanisms are not fully understood in regard of C stabilization and carbon fluxes determined by practices, which appeared to be dependent as well on specific soil and climatic conditions (Dignac et al, 2017). Innovative farmers preserve higher level of biodiversity in their cropping and fallow stages, which could have an additional positive impact in carbon storage. Mortimer et al (2017) study on cacao agroforestry systems report values of carbon storage between 57 -70 TC/ha, which are strongly dependant on the density and associated tree species, C stock can be as high as five-fold than cacao monoculture.

From a life cycle assessment, it is worth to underscore the overall lower greenhouse gases emissions related to swidden agroecological practices in Lamas, in contrast with more intensive systems. New adaptive practices such as improved fallows and recuperation of degraded land represent a potential to offset GHG (Greenhouse Gas) emissions. White et al (2005) point out that tree-based systems set up in the degraded lands of the tropics could even counteract to some extend past effects of deforestation. Preserving soil-related ecosystem services that build up fertility of soil in time, releases farmers from the greenhouse gas emission embedded in the chemical fertilizers use. Similarly, using manpower, farmers have lower dependence on fossil fuels doing without machinery, consequently reduced GHG from burning fossil fuels.

In general, high level of carbon storage and sequestration are ecosystem services that swidden agriculture in Lamas can still provide in comparison to more intense and conventional systems. Nevertheless, these services may be in decline due to a transition to other agricultural systems with lower carbon stocks but higher economic returns.

Discussion

1. The good farm walks: Rotational agroforestry systems for food production

Rotational is a key characteristic of Kechwa-Lamas swidden agriculture that has to be emphasized, since there is a general confusion when is referred as "migratory", which is associated to other agricultural systems and infers that primary forest is continuously cleared and abandoned. Conversely, Kechwa-Lamas systems entail sequential and simultaneous agroforestry. Kechwa-Lamas perspective of agricultural production is forest-focused and soil management is conceptualized in terms of forest management as well (Marquardt et al, 2008). Trees, fallows, and high levels of agrobiodiversity are essential components of this management based in ecological processes to sustain production.

a. Diversity and agroecological practices along the cycle.

Ribeiro et al (2013) argues that swidden positive effects in soil are sustainable because the fallow stages mimics forest ecological processes. According to Styger and Fernandes (2006), intensification in swidden systems is based on species diversity of both crops and fallows, taking advantage of their specific traits. For instance, some trees with particular root systems may be more competent for simultaneous agroforestry and other for sequential combinations of crops and trees (Van Noordwijk et al 2015). With a great agrobiodiversity, within and around the agroecosystem farmers contribute to the flexibility of the agroecosystem, increasing its capacity to recover from disturbances, consequently to their resilience.

Agroecological practices along the entire cycle prove crucial to assure the system sustainability. Farmers strongly acknowledge that cropping stages and fallows are dependent on each other and for subsequent cycles. Practices such as improved fallows, water conservation and intercropping including trees let farmers to access land farming sooner. The work all along the crop-fallow cycle optimizes resources use and services that allows intensification. This is very relevant for Kechwa-Lamas to face the problem of land accessibility, which force farmers to extend cropping periods and shorten fallows.

The cropping stage is appointed out to be as important as the fallow to maintain the fertility balance in the system. Wood et al (2017) states that cropping practices have even a greater effect in soil fertility than fallows duration, which implies that prolonged farming may erode soil fertility despite long fallows across multiples cycles. To secure sustainability, they advocate for local amendments and improved fallows. Farmers that practice improved fallows also apply agroecological techniques during the cropping period.

This holistic approach, rather than specific techniques only during fallows, might make a significant difference in soil fertility.

b. Multifunctionality of Kechwa–Lamas farming systems

Focusing on ecosystems services allows an assessment well beyond the economic dimension and market catering capacity of agriculture. This type of agriculture is above all a food production system, and as such, farmers provide food security for their households and to society. This because subsistence farmers set aside a proportion of their food crops to markets and manage multifunctional agroecosystems. These systems produce a wide variety of provisioning services (firewood, timber, fibers, medicines and various materials) and enhance supporting and regulating services that even allow many of the farmers, with high ecological knowledge, recover degraded areas for production.

Ecosystem services provision in comparison to other agricultural systems

Kechwa–Lamas systems should be compared to other agricultural systems and not to the primary forest. This management evidences significant differences with conventional farming from field to landscape scale, though it cannot compete with natural forest ecosystem services provision. In contrast to conventional cropping centred in soil, Kechwa-Lamas farming systems are centred in trees (in fields, fallows, and forests) and agrobiodiversity conserved in situ.

These systems enhance supporting ecosystems through biological processes in the cropping phase and by actively managing their fallows. By contrast, most intensive farming systems maintain fertility and structure through tillage and inputs of organic and chemical fertilizers (Daily et al., 1997 in Garbach et al, 2014). In conventional cropping systems less than 50% of nitrogen and phosphorus is taken up by crops (Shibu, 2009). This rather increases water pollution which is intensified with the use of other agrochemicals. White et al (2005) found in the Peruvian Amazon that land uses, including swidden, present better soil physical and biological characteristics than high-input cropping. High-input farming has lower organic matter, lower microbial biomass and lower macrofauna diversity.

Kechwa-Lamas farmers influence in various ways the hydrologic cycle managing vegetation, including trees, fallows and a wide variety of native "breed water" (criadoras de agua) species. They improve infiltration, maintain soil organic matter and structure to balance soil water availability (Barrios et al, 2012), and at the same time minimize erosion. Several studies point out a very low impact of swidden systems regarding surface erosion, which is mostly related to the very beginning of the cropping phase (Sidle et al. 2006; Forsyth and Walker 2008, Valentin et al. 2008 in Ziegler et al, 2009). Local hydrological services are reported to decline in upland agricultural landscapes, where swidden agriculture has been replaced for more permanent or more intensive agricultural systems like monocultures and commercial agriculture (Van Vliet et al, Ziegler et al, 2009; Klemick, 2008). Conventional management implies cropping the entire field without fallows or trees, increasing erosion and sediments movement.

Likewise, overall greenhouse gases emissions are lower in swidden in comparison to intensive farming. As natural regeneration is speeded up, carbon storage and sequestration can be greatly enhanced in swidden (Dressler et al, 2017). Though, this capacity can vary significantly depending in various factors such as the fallow length and area, land-use history, among others (Fox et al, 2011). Carbon storage capacity in long fallows can be comparable or higher than complex agroforestry such as cacao and coffee, and greater than monoculture such as rubber and oil palm (White et al, 2005; Palm et al, 2005 Fox et al, 2011). No use of fertilizers and resources efficient use of nitrogen for instance, have an important impact on greenhouse gases emission. Though, this can also apply to efficient use of fertilizers in conventional systems and organic agriculture using conventional technics (for instance monoculture to produce organic rice).

2. Challenges for conservation and sustainable agriculture in San Martin

One of the main challenges in San Martin is to develop productive agrarian strategies that go beyond the historic extraction tendency of simply directing raw materials to other markets outside the region. Many researchers agree on this problem, arguing that there is a false perception of the Amazon as a great fertile land, plenty of resources that are not being taken advantage from (Gobierno regional de San Martin, 2008; Rodriguez et al, 2009).

A process of intensification and landscape simplification in San Martin is suggested by patterns of forest conversion, higher crop specialization, crop diversity decline and increase in agrochemical use, worsen by excessive application and use of non-authorized unsafe agrochemicals (Delgado-Zegarra et al, 2018). These processes can gradually compromise critical supporting and regulating ecosystem services (Kremen and Miles, 2012). Land use changes imply some transition from cropland to pastures and perennials in San Martin, which modifies provisioning services from food crops to meat, milk and in the case of perennials to commodities (cacao, coffee).

Though, perennials can provide high levels of supporting and regulating services, this is dependent on management and diversity level. Several authors report coffee and cacao agroforest systems can storage and sequester carbon, regulate water flows, cycle nutrients and conserve biodiversity to a significant extent (Mortimer et al, 2017; Cerda et al, 2017). Conversely, perennial monoculture services supply is more limited, and environmental impacts related to chemical use could be increased, as it has been reported for oil palm for instance (Van Vliet et al, 2012; Dressler et al, 2017).

Land sharing and land sparing approaches

Kechwa-Lamas farm-forest landscapes clearly represent “land sharing” strategies, as they integrate environmental and production functions that enhance multiple ecosystem services. Whereas state policies are mostly oriented to a “land sparing” approach that separates intensified agricultural production and undisturbed natural habitats, it implies then that producing food in less land makes possible to spare area for nature (Mastrangelo et al., 2014; Huang et al, 2014). This approach is reflected on forestry and agricultural strategies aiming to reduce deforestation, importantly focused on single crops promotion, productivity and zoning schemes that separates farming and forestry land uses.

Regional government has oriented strong efforts on zoning initiatives such ZEE, forest zoning (ZF by its initials in Spanish) and agroecological zoning (ZAE by its initials in Spanish). These certainly can help advance land use planning and management, though, consensus with stakeholders must be reached, taking in consideration perspectives on forestry and agriculture in local management. Various concessions modalities (conservation, timber, etc.) and conservation categories like ZoCREs overlap with communal lands and smallholders farms with different formality levels.

The new forestry law (N° 29763) proposes an agroforestry legal definition with a concession mechanism that links agricultural production and forestry activities, which can favour an intermediate sharing-sparing approach to land use that can better integrate farm-forest landscapes like the study area. Nevertheless, in practice it is not certain that these changes will benefit smallholders such Kechwa-Lamas farmers. Even less certain that this mechanism can incentive farmers to preserve and improve their agroecological practices.

Agricultural strategy falls short to define sustainability criteria for farming activities and to deal with matters relevant for agriculture such as food security, indigenous people legal rights, loss of traditional ecological knowledge, agrobiodiversity loss and agrochemicals excessive use, among others. All of them, of major significance to climate change mitigation and adaptation in agriculture. Territorial and regional environmental policy (PTR and PAR by its initials in Spanish) is declarative in nature regarding most of these issues (when they are referred to), as they are not integrated into planning and management tools (like concerted regional plan, annual strategic plans, operative plans) to be consistently translated into implementing actions and activities.

Better support agrobiodiverse traditional farm forest systems

In the context of high vulnerability of agriculture to climate change and increasing environmental degradation in San Martin, Kechwa-Lamas farmers' capacity to maintain food agrobiodiverse tree-based systems prove to be very pertinent. However, support and assistance to smallholders is limited to a productivity approach that does not support their capacity to be resilient, manage risk, preserve biodiversity or provide multiple ecosystem services (Robiglio et al, 2015). Management can make a difference for agriculture sustainability. Any intervention in San Martin has to take into account the strong link between agricultural and forestry activities in the local practice.

Imbalances are evidenced in what it is considered agricultural land or forest. Monoculture plantations are recognized as reforestation for production, fallow management in rotation is not officially consider as management because is based in natural regeneration and not in plantation practices (Robiglio et al, 2015; Sears et al, 2018). Vast forest areas are cleared because are not considered as such, if the land is categorized as best suitable for agriculture according to the Best Land Use Classification (CUM by its initials in Spanish) system. When land is categorized as forest, even if it is already cleared, is owned by the state and cannot be transferred, unless the use is changed (EIA, 2015, Dammert, 2014). Even though these regulations apply to all activities, agricultural large-scale farming are favoured, while land use change is almost impossible for smallholders on their own (Shanee & Shanee, 2016, Dammert, 2014).

With the new forestry law, forest definition is clarified to consider land cover and agroforestry concessions is introduced as a mechanism, which can help some farmers to gain legal recognition. However, procedures, costs and significantly different perceptions of good management might limit smallholders' adoption. Also, land use changes still allowed for agri-business without solving pending titling and zoning issues may limit importantly progress regarding smallholders (EIA, 2015).

High productivity does not have to be the main objective in all agricultural systems. Moreover, productivity increase regardless of socio environmental sustainability is a significant shortcoming to sustain agriculture in the current agricultural strategy. Environmental criteria have to be demanded to improve conventional systems, whereas farmers efforts that already enhance ES must be supported and promoted. Kechwa-Lamas management need to be recognized as an approach as well as its potential for conservation and food production.

An incentive approach with concrete measures targeted at smallholders can better support small-scale farming, actions such as: payments for ecosystem services/ degraded land recovery, agroforestry concessions schemes better fit for smallholders, research and assistance targeting at co-producing knowledge, improved services and infrastructure for stockpiles collection, explicit inclusion of agrobiodiverse produce in San Martin label (regional green label, it could target maize and food crops produced in land in recovery for instance), among others.

Ecological intensification plays a growing role to overtake yield optimization and commodities focus approach. For this, promotion focus must be extended from technological innovation to include farmers' traditional knowledge innovations. This is very relevant for simultaneous and sequential agroforestry, and in general for ecological intensification, which requires "activating more knowledge and refocusing the importance of ecosystem services in agriculture" (Jensen et al, 2015).

3. Towards sustainable food and farming systems

A sustainable path in food system embraces principle of resilience, diversity, and multi-functionality (IPES Food, 2015). Agroecological principles of minimizing losses, enhancement of biological interactions, diversity and recycling are articulated with the pillars of impacts minimization, conservation and use efficiency of sustainable food and agriculture. A transition to sustainable agricultural production requires, not only, optimization of existing agricultural systems, but also different types of innovations and reconfiguration of farming, in which ecological intensification plays a significant role (Tittonell, 2014). Current priorities and strategies, centred on monocultures and conventional intensification, are to be expanded to include a wider range of agricultural strategies and actors with different capacities and potentialities, more focused on socio-environmental dimensions of agricultural sustainability.

Agroecological cropping practices are central and have a strong potential for future sustainable production. The farming practices explored in this study are adaptations of traditional agroforestry management intensified based in ecological processes. Many of these agroecological practices, such as trees scattered in the fields that bring water and biodiversity benefits, cereals with legumes intercrops that operate like "ecological precision farming" or agroforestry in general, are integrated to very low extent in today's agriculture in temperate regions (Wezel et al, 2014). Though, they are going to be very important elements in agricultural production in the future (Vandermeer, 2011; Jensen et al, 2015).

Conclusions

Kechwa-Lamas farmers manage **multifunctional traditional agroforestry systems** that enhance provisioning, supporting and regulating services. These are critical in the face of rapid land use change and competition in San Martin, where environmental impact of agriculture is increasing. **In comparison to conventional systems**, Kechwa-Lamas farmers don't use agrochemicals, produce diverse food, medicinal plants and different materials, conserve agrobiodiversity and enhance regulating and supporting services. Some farmers even recover degraded land. Supporting farmer's sustainable practices within their swidden agriculture cycle can reduce the negative effects of demographic and environmental pressures.

Tree-based and rotational are central features of Kechwa-Lamas swidden agriculture that have to be emphasized. A**groecological practices of** innovative farmers with limited access to primary forest enhance services during the farming stage just as in the fallow, which prove crucial to assure the cycle sustainability. **Kechwa-Lamas swidden** farmers have, apply and try specific and practical knowledge in their systems. Their a**gricultural and ecological knowledge** is very relevant to sequential and simultaneous agroforestry, as well to ecological intensification. Thus, farmers should be taken in consideration to contribute to formal knowledge systems to confront environmental risk and climate change. Kechwa-Lamas farmers **play an active role to cope with climate change**, for both, for mitigation (emission reduction) through carbon sequestration and for adaptation through maintaining agrobiodiversity and their farming system adaptive capacity. The richness of **species and varieties preserved and selected in situ** for generation of farmers, can help to maintain the resilience of the farming system.

An **integral approach to agriculture,** aiming to support agriculture sustainability in the long term in San Martin, should include **smallholders' concerns, problems and contributions**. Strategies from the regional government regarding sustainable agriculture are still limited to address socio-environmental dimensions. Sustainability criteria for agricultural activities and adequate support for farmers that already pursue more sustainable management, considering different capacities and potentialities, are critical.

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