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Local Perspectives on Ecosystem Service Trade-Offs in a Forest Frontier Landscape in Myanmar

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Received: 5 February 2019; Accepted: 8 March 2019; Published: 12 March 2019

Abstract: Extensive land use changes in forest frontier landscapes are leading to trade-offs in the supply of ecosystem services (ES) with, in many cases, as yet unknown effects on human well-being. In the Tanintharyi Region of Myanmar, a forest frontier landscape facing oil palm and rubber expansion, little is known about local perspectives on ES and the direct impact of trade-offs from land use change. This study assessed the trade-offs experienced with respect to 10 locally important ES from land user perspectives using social valuation techniques. The results show that while intact forests provide the most highly valued ES bundle, the conversion to rubber plantations entails fewer negative trade-offs than that to oil palm. Rubber plantations offer income, fuelwood, a good microclimate, and even new cultural identities. By contrast, oil palm concessions have caused environmental pollution, and, most decisively, have restricted local people's access to the respective lands. The ES water flow regulation is seen as the most critical if more forest is converted; other ES, such as non-timber forest products, can be more easily substituted. We conclude that, from local perspectives, the impact of ES trade-offs highly depends on access to land and opportunities to adapt to change.

Keywords: ecosystem service; trade-offs; adaptation; social valuation; frontier landscape; Myanmar

1. Introduction

The benefit of a landscape is more than the sum of its products. Particularly in rural areas of the tropics, the services provided by land—such as soil conservation, an agreeable microclimate, or spiritual values—are integral to local people's well-being. The concept of ecosystem services (ES), defined as the benefits people obtain from nature [1], has gained attention in research since the Millennium Ecosystem Assessment [2]. It is based on the idea that each ecosystem or habitat provides a certain set of supporting, provisioning, regulating, and cultural services for human well-being [2]. More recent concepts refrain from using supporting services as a separate type and rather see them as underlying functions for the supply of final ES [3,4]. A set refers to a 'bundle' of ES that 'repeatedly appear together across space or time' [5]. Land use is a potential spatial reference for such ES bundles.

Regulating and provisioning ES in particular have been studied more extensively in land use research [6]. Comprehensive assessments that include all three or even four service types (as e.g., [7]) are lacking, since cultural ES are often left out or studied separately. Moreover, studies often do not consider the changes in ES over time. It has been suggested that ES assessments consider temporal dynamics in addition to spatial patterns [8] and distinguish between supply and demand, among other factors [9]. Even when local people manage to adapt their use to a lower ES supply, their demand may remain.

It is crucial to take into account different stakeholders, as changes in the provision of ES occurring as a result of changes in land use or land management practices are closely linked to governance. As such, ES trade-offs often take place in situations where there are competing claims and interests of stakeholders [6]. They are mostly found among provisioning and regulating services and less so with cultural services [10]. However, it is still difficult to find studies on linkages between trade-offs and their ultimate impact on human well-being [6].

The social, or socio-cultural, approach was originally used for cultural services only but is now gaining attention in research [11] for the comparison of different types of services [12] or the assessment of ES bundles and has been increasingly used (e.g., [13,14]). In terms of ES, socio-cultural values are defined as 'the importance people, as individuals or as a group, assign to [. . .] ES' [15]; they express both material and non-material well-being. Thus, ES are determined by people's preferences according to the cultural and institutional context they live in Ref. [16]. These perspectives of local stakeholders assessed with social valuation techniques bring together cultural, economic, and ecological considerations in ES assessments. Qualitative and deliberative research methods have gained importance in developing countries [17] and countries with limited data availability [18].

ES trade-offs are particularly obvious in landscapes experiencing large-scale land acquisitions and fast land use changes, as is the case in many tropical countries with formerly large forest tracts. In these areas, so-called forest frontier [19] or agricultural frontier [20] landscapes, forests are increasingly being threatened by cash crop expansion [19] and the traditional livelihoods of people living within and near their borders are at stake. Forest-dependent communities, including shifting cultivators, can lose their natural assets and be forced to find alternative livelihoods. Furthermore, the loss of ES, such as climate and water regulation, can disturb further aspects of their lives. As agricultural expansion into forest frontiers is not only driven by a growing population but also by changing consumption patterns and international markets [19,21], ES trade-offs often have negative consequences for local stakeholders [6].

In Southeast Asia, two dominant patterns of land acquisition in forest frontier landscapes have been identified as large forestry-related acquisitions and smaller agriculture-related acquisitions [22], with the former often occurring under the pretext of agricultural or industrial development [23]. One of Myanmar's few remaining forest frontiers, Tanintharyi Region, is affected by both [24]. Before 2010, the country had undergone 50 years of military regime and civil war, and forests in border areas, such as Tanintharyi, had been a refuge as well as a source of livelihood (in addition to a few mixed plantations with betelnut and cashew) for the local people. However, in the past 20 years, the area has increasingly become a hotspot for large-scale land acquisitions for oil palm or rubber on the one hand and conservation activities on the other, frequently hand-in-hand [21]. In addition to a major deforestation period between 1997 and 2004 [25], a government-supported rubber boom that began in 2007 has been motivating private investors and smallholder farmers to grow rubber plantations on former forest and mixed plantation land [26]. Outdated and incoherent land classification systems fail to account for the customary land use rights of local communities [27]. The current land law from 2012 gives farmers the opportunity to apply for official land titles if their land is classified as agricultural land [27]; however, these use rights are usually restricted to a few selected commercial crops. This is one of the reasons why shifting cultivation has mostly stopped and traditional mixed plantations are now only present in small areas. By 2013, more than one-third of Tanintharyi's land surface had been allocated for agribusiness concessions intended for oil palm [27]. Concessionaires often do not respect traditional land rights or boundaries of permanent forest estates [27]. Consequently, local communities have little say in the use of land, even though they suffer the most from the dwindling ability of the landscape to provide ES. However, no comprehensive ES assessments covering several land uses and services have been carried out in Myanmar.

This study aims to identify local people's perspectives on the values of a variety of ES [12] provided by different land uses within the landscape. It tries to complement existing research by concentrating on land use ([28] or [29]) and by analysing bundles of ES instead of separate services [3]. Rural households often find ways to cope with changes in the supply of natural resources and associated services [30]. We aim to show by means of a case study not only the impacts of land use change and ES trade-offs, but also the adaptation measures that local communities adopt to enhance their livelihoods and well-being. The study was guided by the following research questions: (a) How are ES perceived and what do people consider the attributes of ES in a forest frontier context? (b) To what extent are bundles of ES provided by each land use? (c) What are the ES trade-offs deriving from land use change from forest to rubber and oil palm? (d) How do local people adapt to these trade-offs?

2. Materials and Methods

2.1. Theoretical Framework

This study is embedded in land system science, which addresses transformations in landscapes with a combined perspective of environmental and social systems thinking and aims at producing knowledge for sustainable development [31]. The ES concept presents implicit links to sustainability [32]. It is also a means to explore the relations between nature and humans. Hence, we are using the ES framework as a conceptual lens to investigate the benefits people obtain from nature. The Intergovernmental Platform on Biodiversity and Ecosystem Services emphasizes the need for normative frameworks in ES research [16]. This study's theoretical framework builds on the cascade model [33], which is widely used in ES research [3] and distinguishes between the ecological (supply) and socio-economic (demand) side [11]. As such, it connects biophysical structures and functions to human well-being (Figure 1). We adapted the model to focus the biophysical lens on land use (in the way that mapping approaches often do [34]), and the socio-economic and cultural lenses on human well-being.

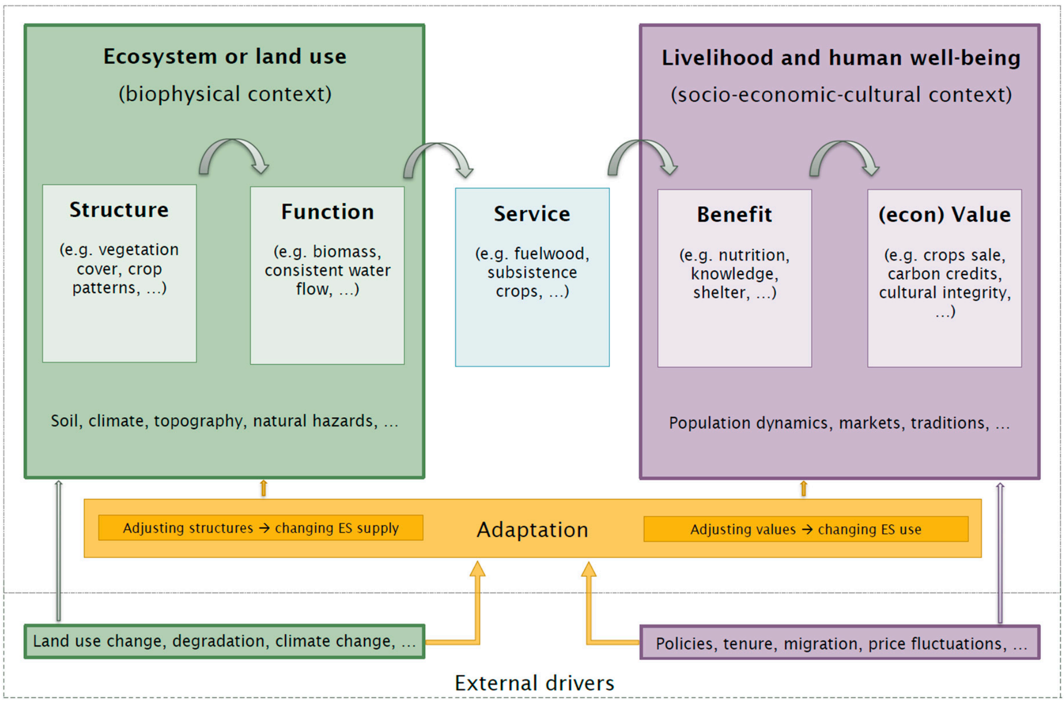

Figure 1. The cascade model for ecosystem services and adaptation (adapted from [33]).

The adapted framework further includes the aspect of adaptation to external drivers, which influence the biophysical or socio-economic system and thus the final services. This reflects the fact that people also react to a changing ES supply, either by adjusting land use or land use practices or by substituting products to satisfy demands. The framework highlights the dynamic nature of ES supply and demand.

2.2. Study Area

We selected the Tanintharyi Region of Myanmar as a study site due to its exemplary but under-researched characteristics as a forest frontier landscape. Myanmar is among the top three countries with the greatest annual net forest loss since 2010 [35]. We chose three villages in the northern part of Tanintharyi for their vicinity to the Tanintharyi Nature Reserve and their experience with conversion to both oil palm and rubber (Figure 2).

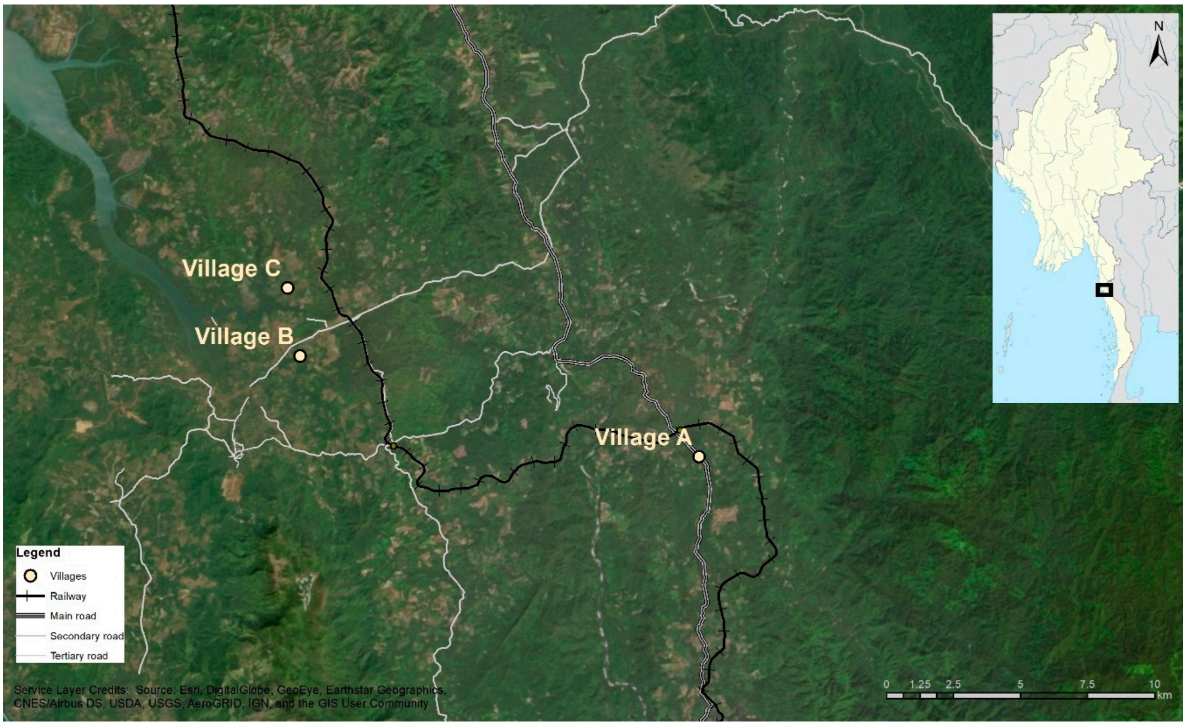

Figure 2. A map of the study villages in Yebyu Township, Tanintharyi Region, Myanmar (sources: ESRI [36], MIMU [37,38]).

Village A has over 200 households and is situated next to the main road, on land classified as agricultural. This land classification means that many farmers were able to acquire land titles and often invest in private rubber plantations. Village A also has a community forest. Villages B and C are situated on land classified as a forest reserve [27], which means they cannot obtain land titles. They have been heavily affected by oil palm concessions. Village B has around 40 households and Village C, the most remote of the three, has only 20 households. Most of the research was carried out in the three villages, with some additional expert interviews conducted in the wider study area.

2.3. Ecosystem Services Classification

The study differentiated between three ES types: provisioning, regulating, and cultural [3]. Supporting services were not considered as individual types, but rather seen as functions within the cascade (Figure 1). We used an original list of 22 ES, based on the Common International Classification of Ecosystem Services (CICES, [4]) and adapted to the local context using information from the literature and prior knowledge. While some of these ES are already used, others may take on greater relevance in an uncertain future. To ensure that the spectrum of ES types was represented, several cultural services were included in the analysis although they were challenging to attribute to specific land use categories.

2.4. Social Valuation

Interpretive methods are effective in uncovering the reasons behind the valuation of certain ES by land users [39]. This is particularly important for ES that are perceived differently by land users or other stakeholders. With our focus on local land users' perspectives, we decided to use social valuation techniques for ES [40]. Such techniques have been found to be the most suitable way to value a wide range of ES [12] in line with the cascade model (Figure 1). The social valuation approach is based on societal values for ES, in contrast to the ecological approach, which measures ecosystem functions, and the economic approach, which assigns monetary values to the benefits from ecosystems [40]. There are two steps in social valuation: First, the identification of valuable ES to stakeholders and second, the ranking of these stakeholders' preferences or values according to a scoring system [40].

2.5. Data Collection

The research was guided by an explorative study design [41]. Data collection took place over five weeks using a participatory research approach. The methodology consisted of a total of four transect walks, 16 focus group discussions (FGDs), and 27 semi-structured key informant interviews, which ensured triangulation. This is depicted in Table 1. For the interviews, a purposive sampling design [42,43]—i.e., a selective sampling by the researcher's judgement and substantive criteria, in this case according to a participant's knowledge on specific land uses—was applied to develop a typology of land user cases in the villages and agricultural specialists at the regional and national level.

Table 1. An overview of methods per village and topic.

Place	Transect Walks	Focus Groups	Key Informant Interviews					
			Forest	Rubber	Mixed	Oil Palm	Rice	Lime
Village A	2	5	2	1	1	-	1	1
Village B	1	5	1	1	1	1	1	-
Village C	1	6	1	1	2	1	2	-
Regional	-	-	2	-	-	1	-	-
National	-	-	-	1	1	1	2	1
Total	**4**	**16**	**6**	**4**	**5**	**4**	**6**	**2**

In each village, data collection started with one general FGD on land use and land use change, followed by a transect walk with some of the participants, including the village head. We then carried out the rest of the FGDs on specific land uses and land use practices, followed by the key informant interviews. Each FGD was held at the village level and involved around 10 people. Diverse participants were selected according to the following criteria: main livelihood activity, wealth, gender, and age. Topics focused on land use, land management practices for each land use, and land use change, and served to understand the activities of ES beneficiaries [15]. We held key informant interviews on the existing land uses and their supply of ES, focusing on one land use in each interview. This was repeated in all villages where the respective land use is present and with other relevant key informants at the regional (plantation managers) and national (researchers) level. To assess the importance of a specific land use for the supply of ES, we gave interviewees a list of 10 ES and asked, "How important is land use A for the supply of ecosystem services 1–10 at the landscape level, ranging from not important to very important, and how do you use it?". Follow-up questions then revealed how certain services were understood and valued, and how demand and actual use are related to supply. For example, for fuelwood from mixed plantations, the follow-up questions were: "How much fuelwood do you get from mixed plantations? Is it enough to cover your needs? How is the quality of the fuelwood? Do you prefer fuelwood from betelnut or cashew trees?". In total, the interviews included six on forests, four on rubber, five on mixed plantations, four on oil palm, six on rice, and two on lime. Taking extensive field notes was indispensable during all interviews.

2.6. Data Analysis

After all data were collected, we transcribed field notes from transect walks and texts from focus groups and interviews and applied a thematic coding system [41] based on land uses and ecosystem services. Following an explorative approach, we developed further codes on drivers of change after reading through the transcripts. A structured content analysis [41] followed. The qualitative content analysis built the foundation for the ES scoring process [44]. Additionally, we carried out a coding query using all transcripts to find links between ES and drivers of change, interpreting more than two overlaps as a rather strong link.

2.7. Scoring System

In order to systematically analyze and compare data, we carried out a scoring process based on a qualitative content analysis [41]. We assigned each ES a supply score from 0 to 3 depending on the quantity and quality supplied by respective land uses building on the criteria outlined below. For the analysis of trade-offs, we continued with the 10 most highly valued ES based on the following determinants: supply and demand scores, adherence to specific land uses, data availability from interviews, and a balance of representative ES for all ES types. Table 2 describes the supply scoring criteria for these 10 ES in detail.

Table 2. The ecosystem service (ES) supply scoring criteria for the 10 selected ES.

ES		Description	Scoring Criteria for ES Supply
Provisioning	Subsistence crops	Crops for subsistence include mainly rice, vegetables, and fruit.	0 = no subsistence crops planted 1 = some subsistence crops planted intermittently 2 = some subsistence crops planted continuously 3 = subsistence crops dominate land use (LU)
	Commercial crops	Commercial crops are sold raw or after primary processing.	0 = no commercial crops planted 1 = some commercial crops planted 2 = medium-income commercial crops dominate 3 = high-income commercial crops dominate LU
	Livestock	Livestock products include meat, eggs, leather, and manure.	0 = no livestock present 1 = sometimes livestock present (mostly chicken) 2 = livestock present (chicken or cattle) 3 = livestock dominant (cattle)
	Wild plants	Wild plants are for nutrition or medicine. No plant materials are discussed.	0 = no wild plants 1 = few wild plants present 2 = wild plants present, but low diversity 3 = abundant and highly diverse wild plants
	Fuelwood	Fuelwood includes small trees and branches used for cooking.	0 = no material for fuelwood present 1 = some low-quality fuelwood present 2 = much fuelwood present with different qualities 3 = abundant fuelwood of high quality
Regulating	Water flow	Water is used locally (regulation of below-surface water flows).	0 = no contribution or disturbance to water flow 1 = limited contribution to water flow 2 = improved water flow 3 = high contribution to water flow and quality
	Biodiversity	Biodiversity refers to the maintenance of nursery populations and habitats for domestic and wild species.	0 = destruction of biodiversity (pollution) 1 = low biodiversity 2 = good agrobiodiversity 3 = high biodiversity overall
	Microclimate	Regulation and improvement of the microclimate (air flow, temperature).	0 = disturbance of a healthy microclimate 1 = common microclimate 2 = agreeable microclimate 3 = very agreeable microclimate and high C-seq.

Table 2. *Cont.*

ES		Description	Scoring Criteria for ES Supply
Cultural	Education	Education is the land use contribution to the knowledge base of children and adults.	0 = not important for education 1 = part of education (parent to child) 2 = important for education and training 3 = many opportunities for continued education
	Cultural identity	Embedment in local culture includes traditions, religion, spiritual value, and connectivity.	0 = no cultural value, no cultural products 1 = some products used traditionally 2 = LU and products important to cultural identity 3 = LU strongly embedded in culture

LU, land use; C-seq, carbon sequestration.

The aim of the social valuation was to obtain, for each ES, six supply scores (one for each land use) and one demand score. It is understood that ES demand is influenced by the landscape and ES availability but does not change between land uses. This allows for a direct comparison between ES supply and the contribution to local demand for each land use. Demand is defined as "the amount of a service required or desired by society" [45], whereby the rural poor in developing countries are usually more reliant on the use of local ES [46]. Thus, demand is reflected in direct use, indirect use, potential benefit, and the intrinsic value that people attribute to a service [47]. Accordingly, the scores for ES demand are based on the qualitative content analysis according to the following criteria:

0 = people do not use this ES directly and do not see a benefit or value
1 = people see a benefit or value but do not use it directly
2 = people use it directly or indirectly
3 = ES is essential for livelihoods and human well-being [46]

During the interviews, villagers also explained about past, current, and sometimes even future demand, which allowed us to detect trends.

3. Results

3.1. The Tanintharyi Landscape and Local Perspectives on Ecosystem Services

In Tanintharyi Region, most land used to be covered with natural forests. Local communities remember that they derived various regulating and cultural services from their environment at the time. However, they also actively used forest lands for shifting cultivation for subsistence as well as livestock herding, benefiting from an immense variety of provisioning services. Later, with the introduction of mixed plantations of cashew, betelnut, and minor crops, farmers felt they could still benefit from many ES, including additional commercial crops. However, they were not able to benefit from ES in the early 1990s, a time during the country's long-running civil war in which the local communities were often hindered from accessing their fields. Today, many of the interplanted annual crops, such as vegetables or herbs, are still used for subsistence or semi-subsistence. Intercropping is done both in traditional mixed plantations as well as in new rubber plantations during the first years before the canopy closes.

The impact of losing certain ES became evident to the local people with the allocation of oil palm concessions in the study area. They observed soil compaction and water pollution, and, being banned from areas designated for oil palm, experienced a loss of provisioning and cultural services. Cattle herders had to make sure that no cattle entered those areas, an additional risk that made them decide either to reduce the number of cattle or to stop herding altogether; today, the ES 'livestock' mainly refers to small livestock, such as pigs, chicken, and ducks. The view of globally highly significant ES—such as carbon sequestration or biodiversity—has increased locally since the arrival of different organizations trying to raise awareness and press for forest conservation. Nonetheless, these ES do not have the same priority for the local population as those that directly contribute to their livelihoods and well-being, such as 'water flow' and 'microclimate', two regulating services that are perceived as very important. Most villagers derive their drinking and non-drinking water from pipes connected to the water catchment area in the mountains, while others rely on small wells or fetch water from the stream. Of these options, the mountain water is valued most highly. Microclimate, too, is directly felt by the villagers: with the loss of forests, they are experiencing increased heat during the dry season. Farmers also believe that changes in the microclimate and seasonal water availability could be affecting productivity of their cashew and betelnut plantations. In terms of education, local people perceive some land uses to be more valuable because they provide the opportunity for training. This is the case for rubber, where companies provide farmers with specific technical training, and for community forests, where the user groups are trained in sustainable forest management and use by non-governmental organizations. Other land uses, particularly those with cultural importance, such as forests or rice production, are an integral part of parental teaching and therefore offer educational benefits to children.

3.2. Bundles of Ecosystem Services for Each Land Use

Each of the land uses in the study area delivers a certain bundle of ES, including provisioning, regulating, and cultural services. The scores according to Table 2 illustrate to what extent a certain land use provides bundles of 10 selected ES according to local perspectives (Figure 3).

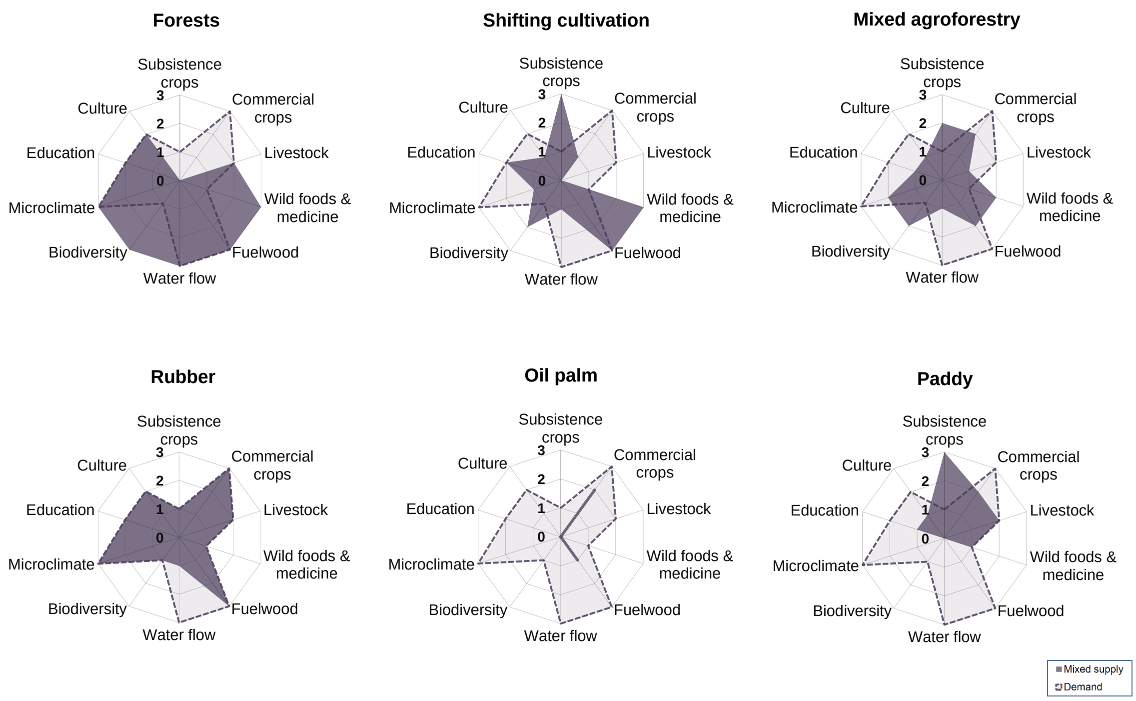

Figure 3. Local perspectives on ecosystem service bundles provided by different land uses in a forest frontier landscape in Tanintharyi, Myanmar.

Intact forests provide many regulating ES as well as non-timber forest products. Cultural services are tied to the forest ecosystem, which explains the strong connection with nature that has been observed with people living in the Tanintharyi forest frontier. However, forests that are not used for shifting cultivation lack opportunities for subsistence and especially commercial crops, which are highly favored by local communities. This seems to be one of the reasons why rubber plantations have become very popular even for smallholders in the recent past. In fact, rubber plantations seem to fulfil local ES demand almost entirely. Compared with other land uses, rubber is the main source of income for smallholders (as owners and/or tappers) and also provides fuelwood for household use. One reason is that farmers obtain tenure rights and have access to the benefits. Furthermore, rubber is also often associated with poultry production. Unlike other tree crops, the roots of rubber are not damaged by chickens, and rubber tappers living within plantations appreciate the additional income opportunity. Interestingly, these good financial opportunities mean that local people are beginning to assign important cultural values to rubber plantations. This indicates that cultural services, but also other ES, can change quite rapidly over time and are adapted to the context. People also recognize that rubber cultivation—requiring specific new production skills—brings opportunities for training and education. Capacity-building related to rubber cultivation and primary processing is supported by the government and private companies.

Mixed plantations are recognized by land users to provide a balanced bundle of ES, but important services, such as commercial crops or fuelwood, are supplied less than in other land uses (Figure 3). This is reflected in many farmers' decisions to convert them to rubber. Most farmers keep a few low-input traditional mixed plantations with cashew and/or betelnut while concurrently investing in rubber since 2007. Oil palm plantations on the other hand, mainly owned by investors, are experienced by local communities as having detrimental effects on the supply of ES in the study region. From their perspectives, oil palm plantations provide limited ES because benefits are not accessible to them. While they do provide potential benefits in the form of commercial palm nuts, these go only to the companies. Further, several people stated that the companies' dominating practices lead to disservices for the entire landscape, such as water contamination, air pollution, and a loss of biodiversity. Lastly, paddy rice cultivation, limited to a few flat areas, provides a fairly different set of ES compared to the other land uses. Paddy fields are the main providers of the region's staple food (previously, shifting cultivation too). While upland rice could produce enough for household consumption, paddy fields often yield a surplus for the market. However, considering that the total rice production area is limited in Tanintharyi Region, much of the rice consumed is produced in other regions of Myanmar. Paddy fields can also be important for grazing livestock, especially cattle and buffalo, during the dry season.

The findings reveal that one service—the regulation of water flows—can only be provided fully if forests are intact. This is a major concern throughout the study area. With the water catchment area in the mountains as the primary source of water, these forested lands have ensured an intact hydrological cycle in the past. Local people feel that none of the current land uses are able to maintain water flows to the same effect (Figure 3).

3.3. Ecosystem Service Trade-Offs from the Main Land Use Changes

In terms of land area, the most relevant land use changes in the forest frontier landscape of Tanintharyi Region are the conversion from forests to mixed plantations (in the distant past), oil palm (20 years ago), and rubber (since 2007). The resulting trade-offs (Figure 4) are especially felt for locally used ES.

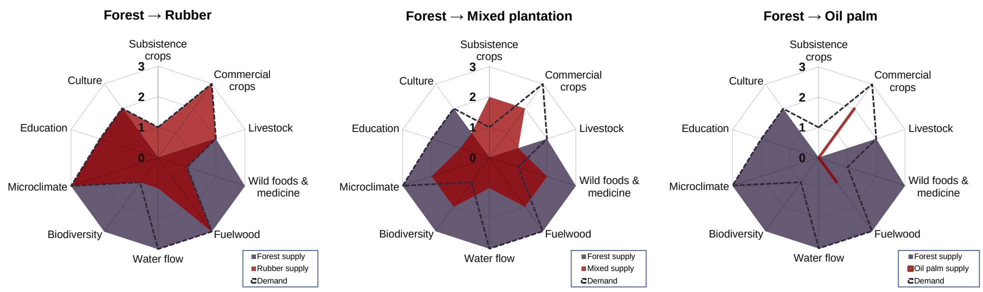

Figure 4. The ecosystem service trade-offs in a forest frontier landscape in Tanintharyi, Myanmar.

We found obvious trade-offs between regulating ES and provisioning ES for income generation (i.e., commercial crops) when forests are converted to any form of agriculture. Comparing the three main types of land use change from forest, however, there are vast differences in the trade-offs. First, oil palm. In terms of the total supply of ES, conversion to oil palm has been experienced most negatively.

We found a decline in all ES apart from an increase in commercial crops, which benefits only a small set of stakeholders. This is especially alarming for locally important services, such as the regulation of water flows or microclimate. Second, mixed plantations. The conversion to mixed plantations has had both positive and negative effects on the provided ES bundle. The big difference compared to oil palm is that no ES was lost completely for the local population. Instead, almost the same bundle of ES is supplied, but to a lesser extent. Third, rubber. In terms of serving local people's needs, the trade-offs are lowest when forests are converted into rubber plantations (Figure 4). There is a continued supply of fuelwood, for example, that rubber farmers can use themselves or sell to other villagers. Rubber plantations also cover almost all needs for regulating and cultural services.

While the study area has seen no oil palm expansion in the last two decades, forests and mixed plantations are still being converted into rubber plantations. This is causing a strong decrease in the supply of water flow regulation, microclimate, and biodiversity services: developments that local land users fear will have a negative impact on their future well-being. In our study, they assigned high demand to the ES of water flow and microclimate and expressed concern about the overall loss of intact forests. On the other hand, the financial opportunities for farmers gained by converting forests into rubber plantations cannot be underestimated. Increased income can have multiple positive effects on local communities' livelihoods and well-being. However, the results clearly show that there is one unresolved issue connected with the trade-offs: the regulation of water flows. Each of the three most prominent land use changes leads to a significant decline in this ES. Local communities feel that only intact forest ecosystems are fully able to maintain a healthy water flow (Figure 4). However, they fear that because of their limited land use decision-making power, more forests in the upland water catchment area could be converted in the future. An additional concern is that interruptions to the hydrological cycle are usually not recognized straight away but only become evident over a longer period.

3.4. Changing Demand

The study showed that both the use of and the demand for ES are not constant over time. During focus group discussions and key informant interviews, people compared past with current use and even mentioned potential future benefits and their expected value. Thus, people seem to adapt not only their direct use but also their overall demand depending on availability in the landscape and other factors, such as tenure and access, markets, knowledge, and emotional patterns. Furthermore, in- and out-migration, which is widespread in Tanintharyi, potentially influences the overall demand for ES. However, our data do not provide enough evidence linking migration with specific ES. Table 3 shows demand trends and the links between drivers and ES demand according to how often they were specifically mentioned and found relevant (if mentioned 1–2 times → +, if mentioned 3 or more times → ++).

Along with supply trade-offs between subsistence and commercial crops, the demand for subsistence crops as an ES has also decreased. For one, people can buy food for their household at affordable prices on local markets. (While a few people expressed worries about food shortages, they had not yet experienced these. Although people expect the demand for subsistence crops to remain low, this could change rapidly in the case of a sudden escalation of conflict or limited market access.) For another, the enhanced cultivation of commercial crops (rubber but also minor crops, such as lime or cocoa) has been accompanied by improved infrastructure and market access. The demand for wild foods and medicine depends on availability of commercial substitute products. A decline in direct use is leading to a loss of knowledge on which wild plants are edible or have medicinal properties; this is also further affecting overall demand. Nonetheless, several land users explained that they want to keep wild plants in their plantations because of potential future benefits.

Table 3. The change and drivers of change for the ecosystem service demand in Tanintharyi, Myanmar.

	Past Demand	Current Demand	Future Demand	Drivers of a Changing ES Demand			
				Tenure	Market	Knowledge	Emotion
Subsistence crops	High	Low	Low	-	++	-	+
Commercial crops	Medium	High	High	++	++	+	+
Livestock	High	Medium	Medium	+	++	+	++
Wild foods and medicine	High	Medium	Medium	-	++	+	-
Fuelwood	High	High	High	-	-	-	-
Water flow	Medium	High	High	-	-	+	-
Biodiversity	Low	Low	Medium	+	+	++	+
Education	Medium	Medium	Medium	-	+	++	-
Cultural identity	Medium	Medium	Low	-	+	-	++

- = no link; + = rather weak link; ++ = rather strong link.

We found that the need for water flow maintenance is consistently high and that the effects of a disturbed hydrological cycle may become even more evident in time. For local land users, it is difficult to place a value on biodiversity as a service because often it holds many indirect or potential benefits that are not yet recognized. Benefits are also linked to other ES and could include insects for pollination for agricultural production, plants with medicinal traits, or drought-resistant crop varieties, to name but a few. So, in local perspectives, the value of the ES biodiversity includes many potential uses. As knowledge on biodiversity increases, biodiversity is likely to be more appreciated, both at the local and the global level. If eco-tourism develops in the region, which is an option favored by most of the interviewed villagers, the accompanying financial opportunities would cause biodiversity as a service to be valued much more highly.

Education and cultural identity services are difficult to assign to specific land uses, although some land uses offer additional educational benefits; access to these ES is more specifically linked to physical (i.e., distance to school) and financial (i.e., ability to pay school fees) factors within the area than to the supply from elements of the landscape. Accordingly, the link to land use should not be taken as given, as cultural values assigned to specific land uses were found to also change over time but need to be assessed in their actual context. This is one way for local communities to adapt to the trade-offs they face (Figure 1).

3.5. Local Adaptation Processes

In Tanintharyi, people had to adapt to different environments and living situations several times during and after the civil war, which was most acute in the early 1990s. They also adapted to changes in the availability of land area and the expansion of oil palm plantations by intensifying their mixed cultivation plots, giving up cattle, and seizing opportunities from external initiatives to establish community forestry (e.g., village A) or to attend training sessions and receive seedlings for new crops (e.g., lime, cocoa, elephant foot yam). Changing ES use is another way of adapting to trade-offs in ES supply. This is possible for all services that can be exchanged with commercial goods. Accordingly, subsistence crops are substituted with food bought on the market, and medicinal plants can be replaced by pharmaceutical pills and visits to formal clinics. Nonetheless, local people believe in the value of wild plants and potential medicinal uses, so they let them grow on their land to avoid future vulnerability.

We found that livestock as an ES has changed in form since local people had to give up their cattle 20 years ago due to a lack of grazing land and the ban on entering oil palm concession areas. Cattle are less important today because of their incompatibility with current land uses and land tenure, even though people still have a strong emotional connection to livestock herding (Table 3). In contrast, there is a growing local market for poultry products, mainly for eggs. Even new opportunities to use chicken manure as a fertilizer in rubber plantations are evolving, and people are adapting to this by keeping chicken and pigs. They provide similar benefits, including income generation, risk aversion and stability, and manure. While they may not provide mechanical labor, as was usually the main value of cattle, farmers no longer need this as there are fewer paddy fields within the landscape.

Adaptation can also entail people changing their land use or land use practices. One example in the study area is village B. The land users reacted to a loss of forests and shifting cultivation, diversifying their mixed plantations to balance out the supply of ES. The villagers tend to manage their farms to resemble natural forest ecosystems: the farms provide the same benefits, such as biodiversity, microclimate, and factors for forming cultural identity, while at the same time supplying more provisioning ES, such as subsistence and commercial crops or fuelwood.

4. Discussion

4.1. The Ecosystem Services Framework in Practice

Using the cascade model [33] as a framework proved useful for analyzing all aspects of an ES, although the distinction between functions and services was sometimes challenging. Nevertheless, the cascade helped us to consider the relationships between the supply and the demand side of ES [3]. In addition, looking at ES along the cascade with local communities improved communication between land users and researchers and supported the inclusion of both ecological and socio-economic and cultural aspects in the discussion [3]. Even though the CICES framework was useful for obtaining a well-structured and comparable list of ES, several adjustments had to be made for it to fit the local context. This highlights how important it is to consider local settings and understandings of ES before starting an assessment [48]. The early separation between subsistence and commercial crops was essential, especially as it is a major reason for land use changes and one of the main trade-offs for local land users in the study area. This suggests that differentiating between subsistence and commercial crops adds an important aspect to ES research.

Social valuation as a method has proven to be well-suited for comparing bundles of different types of ES across land uses and could be further promoted [6,9]. Having more studies with a similarly comprehensive list of ES would support the out-scaling of the results. Recognizing that social valuation was an important first step in assessing ES trade-offs at the local scale, we propose ensuing studies that quantify and map ES at a larger scale to address policy-makers and achieve an impact on landscape planning [15,49]. The promoted value pluralism approaches hereby promise holistic assessments for a sustainable development [16,50,51].

Adaptation processes have gained attention mainly in relation to climate change research. However, they are also relevant where other factors influence socio-ecological systems or landscapes, as this study has shown. Adding adaptation to the framework allows researchers to illustrate the dynamics of ES supply and demand, to confirm that ES are not static in time and space, and to discuss the role of humans in ecosystem processes. This study demonstrates that not all declines in ES supply necessarily have a negative impact on livelihoods and well-being. On the contrary, land use change and ES trade-offs often bring new opportunities. This has been illustrated by the new cultural value assigned to rubber plantations or the emergence of chicken farms on small patches of land. As seen in this research, both physical characteristics of the landscape and people's valuations change in time. Thus, including changing demands and adaptation processes in ES assessments can move ES research forward.

4.2. Ecosystem Service Trade-Offs in a Forest Frontier Landscape

We found a distinct shift from subsistence crops and wild foods towards commercial crops. The conversion in Tanintharyi from forest and shifting cultivation to commercial crops is frequent in other forest frontiers that had previously been used for shifting cultivation. Such landscapes are often subject to large-scale conversions of forests for the cultivation of commercial crops [21,52] and sometimes driven by interests in timber [22]. In Southeast Asia, the major commodities are rubber and palm oil, and similar ES trade-offs can be expected in other forest frontiers. Our findings supplement a review [53] that found that rubber expansion in the Mekong Region negatively affects the supply of water and climate regulation services. Further, it states that rubber as a single crop poses high risks to the livelihoods of local farmers. On the other hand, small-scale farmers often opt for diversification strategies [54] and their land use decisions are based not only on economic considerations but also on the environmental, cultural, and political context [55,56]. This has also been observed in our study area. Rubber cultivation in Tanintharyi started only recently, even though it had been cultivated in the neighboring Mon State for nearly a century [26], and there were no farmers in our study area who depended solely on rubber. Nevertheless, rubber plantations do pose a potential threat for local agricultural systems and human well-being where their expansion advances into intact forest landscapes and crucial water flows are interrupted. A biophysical mapping of the landscape and hydrological processes will thus be highly useful to assess these risks in more detail. Impacts of oil palm expansion have been described mostly for Indonesia and Malaysia and include the positive potential as commercial crops and the negative effects on subsistence crops, wild foods, water quality and quantity, climate regulation, biodiversity, and cultural services [57]. The results are mostly in line with our findings. However, the commercial potential is not accessible to local farmers. Even for the private sector, financial gains from palm oil are limited because of low productivity in Myanmar [58]. Due to this, only 19% of the allocated concession areas have been planted [27] and investors are sometimes planting rubber as the more profitable crop instead [56]. According to a study [59], forest conversions to oil palm have negative effects on remaining forests because they increase pressure on them (displacement of fuelwood collection, timber harvesting, etc.). This was not observed in the case study site but may well be an important issue in other forest frontier landscapes. There are multiple possibilities as to why it did not occur in the study area: The opportunity to collect fuelwood from rubber plantations, the conservation status of the remaining forest, and the community forestry initiatives, which promote a sustainable protection and use of forested lands.

Our results also indicate that the extent to which ES trade-offs occur and affect local people's well-being highly depends on the inclusion of the local population in the land use development process, their rights and access to resources, and common regulations for managing ES at the landscape level. It appears that the current legal framework on land governance does not adequately consider the needs of local land users, as many are struggling to obtain tenure rights for their customary lands. A large part of the negative trade-offs from oil palm conversion is thus because local people are prevented from entering the lands and using it for multiple purposes, such as growing subsistence crops or rearing livestock. Several studies proposed that negative trade-offs can be mitigated if forest-dependent communities participate in decisions and are actively engaged in land management [60], if people's access to ES is ensured [61], if forest land regulations are simplified [62], if land management rules are negotiated with all stakeholders [63], and if strategies and policies are directed towards a minimization of ES trade-offs in the landscape [64].

4.3. Outlook for Tanintharyi Region

In the forest frontier landscape of Tanintharyi Region, our findings suggest that local people prefer having diverse land uses, as this allows for a balanced ES supply.

On the one hand, forest conservation is necessary in the water catchment area. Uncontrolled expansion of rubber has proved to endanger long-term water supply in other areas of the Mekong Region [53], and signs that this could also occur in the study area are already being observed by the local communities. A close monitoring of this development and the implementation of forest conservation measures thus seems necessary, especially where water sources are threatened. However, one might question whether a state-protected area and the strong land-sparing approach is the right pathway in terms of maintaining ES bundles. Community forestry schemes coupled with management plans for a sustainable use of resources arguably contribute more to conservation [65–67] and the provision of a holistic bundle of ES. Studies have even shown that community forests in Myanmar can also reduce disparities by contributing to the livelihoods of different subgroups within a community [68]. Inclusion of local people's perspectives is a major advantage and prerequisite for community forests.

On the other hand, agricultural land uses, especially rubber and mixed plantations, are crucial for local livelihoods. The main importance of mixed plantations seems to be the aspect of diversification and risk minimization for resilience, particularly for smallholder farmers. A study in China found that land use choices and agrobiodiversity depend on ethnicity, wealth, land tenure, and rubber farming experience, among others [54], and similar patterns have been observed in our study area. As yet, Myanmar's land governance system and limited tenure rights for farmers in classified reserved forest areas [56] do not allow for adequate local land use decisions. However, with the expansion of commercial plantations leading to improved infrastructure and markets, these developments may improve local people's well-being in several dimensions. Nonetheless, while the farmers' interest to grow commercial crops is expected to remain high, a distinction between different types of crops should be made. Generally, an exaggerated dependency on one crop alone is a high risk [54]. Furthermore, in Myanmar, the land registration process to obtain formal land tenure requires farmers to stipulate the intended land use, which influences farmers' land use decision. For officially recognized commercial crops, such as rubber, this is much easier.

This study confirmed that a landscape with a variety of land uses can provide a more balanced bundle of ES, whereas concentration on one land use always entails major trade-offs. Maintaining heterogeneity and connectivity in the landscapes is important to provide a larger portfolio of ES [3]. We therefore opt for a combination of land-sparing and land-sharing approaches in the given landscape [69,70]. To balance ES supply and demand in the studied forest frontier landscape, several options for improving existing land uses could be developed, including integrated animal husbandry with poultry, optimized agroforestry combinations [71,72], sustainable oil palm cultivation [73,74] with an outgrower scheme, or increased use of bamboo. Further investigations of these options could add to a sustainable landscape management strategy and enhanced human well-being.

5. Conclusions

This study documented the perspectives of local land users on ecosystem service trade-offs in a Myanmar forest frontier landscape with significant expansion of commercial plantation crops. We found that the regulation of water flow is experienced as the main challenge and that this ES is strongly associated with intact forest lands. For areas with important hydrological functions, adequate forest management planning and the prevention of conversion to other land uses are thus vital. More studies are needed to assess water flows at the regional level. Nevertheless, local land users in the study area still benefit to a certain extent from many of the regulating and provisioning services, even when areas are converted from forests to rubber or mixed plantations of cashew and betelnut. Benefits include the supply of wild foods, medicinal plants, and fuelwood, and the regulation of microclimate and biodiversity. While forests are important for local cultural identities and support water flows, biodiversity, and various timber and non-timber forest products, rubber plantations offer income and provide ES such as fuelwood, an agreeable microclimate, and even new cultural values. Mixed plantations are appreciated for their balanced ES bundles and low-risk cultivation. On the other hand, trade-offs are experienced most negatively in local communities where forests are converted into oil palm plantations. These are associated with disservices to water flows and other regulatory functions by reportedly polluting nearby rivers with agricultural chemicals. Local people's restricted access to these lands further exacerbates their perspectives on trade-offs.

To enhance local benefits from ES, we argue that it would be crucial to revise the legal framework of land governance, to grant enhanced land rights to local people, and ensure their participation in land deal processes. We found that the people adapt their use of ES according to landscape transitions and other factors, such as changing markets, knowledge, or tenure rights. Improved infrastructure, which goes along with agricultural investment in forest frontier landscapes, not only brought better opportunities for selling commercial crops but also substituted certain ES, such as subsistence crops, wild foods, and medicinal plants. Local adaptation processes can in turn also influence the landscape (through changing land use or land management practices) as well as the demand for formerly important services, such as wild plants for food and medicine.

In terms of ES research, we have demonstrated that social valuation is well-suited for assessing local stakeholders' perspectives and for comparing bundles of different ES types across land uses in a region with limited prior data availability. Our results provide a good basis for further research to quantify and map ES on a larger scale in Tanintharyi Region. More generally, this study also contributes to the understanding of ES trade-offs in tropical forest frontier landscapes and the potential impact of these trade-offs on local livelihoods and human well-being. It has shown that even though bundles of ES are linked to specific land uses, they are not necessarily lost when land uses change. Our findings highlight the need to include local stakeholders in land governance and in the optimization of land management practices in forest frontiers. Holistic ES assessments such as this with more in-depth qualitative and additional quantitative studies can contribute to formulating sustainable land management strategies for functioning ecosystems and human well-being; as such, they are crucial instruments for policy-makers to assess the impact of land use changes and the resulting trade-offs for the local population.

Author Contributions: Conceptualization, M.F., J.G.Z., and F.S.; methodology, M.F., J.G.Z., and C.J.; validation, M.F.; formal analysis, M.F.; investigation, M.F.; resources, J.G.Z., F.S., C.J., and W.M.; data curation, M.F.; writing (original draft preparation), M.F.; writing (review and editing), M.F., A.H., J.G.Z., C.J., F.S., and W.M.; visualization, M.F.; supervision, J.G.Z. and F.S.; project administration, J.G.Z. and W.M.; funding acquisition, M.F., J.G.Z., and F.S.

Funding: This research was carried out within the project "Managing telecoupled landscapes for the sustainable provision of ecosystem services and poverty alleviation", funded by the Swiss National Science Foundation SNSF and the Swiss Agency for Development and Cooperation SDC in the frame of the r4d programme [400440 152167].

Acknowledgments: The authors are grateful for the technical exchange with all researchers of the project "Managing telecoupled landscapes for the sustainable provision of ecosystem services and poverty alleviation" and the OneMap Myanmar project, and especially for Cing Don Nuam for her precise translations and support during data collection. We appreciate the attentive editing work of Tina Hirschbuehl and the constructive comments of the three reviewers. We thank the local authorities, who supported the work, and the village leaders, who facilitated the process of data collection. Most importantly, we want to express our gratitude to the community members of our study villages for their time and their interest.

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

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