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RESEARCH



The cash crop boom in southern Myanmar: tracing land use regime shifts through participatory mapping

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ABSTRACT

Tropical forest landscapes are undergoing vast transformations. Myanmar was long an exception to this trend – until recent policy reforms put economic development at the forefront. Under ambiguous land rights, commercial agriculture has spread rapidly, causing an unprecedented loss of biodiversity-rich forest. In south-eastern Myanmar, where land tenure is highly contested due to several decades of conflict, scientific evidence on these complex social-ecological processes is lacking. In the absence of past satellite data, we applied a participatory mapping approach and co-produced annual land use information with local land users between 1990 and 2017 for two case study landscapes. Results show that both landscapes have undergone a land use regime shift from small-scale farmers' shifting cultivation to plantations of rubber, betel nut, cashew, and oil palm. These changes are likely to have long-term impacts on land users' livelihoods and the environment. We call for a reconsideration of land governance arrangements and concerted land use planning that respects the rights of local land users and strengthens their role as environmental stewards. Applied with careful facilitation, participatory mapping could be an important tool to engage communities in the highly challenging process of transforming land governance to achieve more sustainable outcomes in this post-conflict context.

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1. Introduction

Many forest frontier landscapes in the tropics have recently undergone wide-ranging transformations from subsistence farming to cash crop production (Curtis et al. 2018). Local land use changes are increasingly being triggered by the demands and strategies of actors at multiple levels of governance – a phenomenon that land system scientists termed 'telecoupling' (Liu et al. 2013; Eakin et al. 2014). This is particularly the case in South-East Asia, where the main driver of deforestation has shifted from expansion of agricultural land by smallholders through shifting cultivation to the establishment of large-scale commercial plantations of rubber, oil palm, and other commodity crops (Rudel et al. 2009; Sayer et al. 2012; Fox and Castella 2013). These landscape transformations are deeply affecting the local social-ecological systems, with manifold impacts on people's well-being and the environment. If they are not addressed through transformative strategies and actions towards sustainable development, they might increase social disparities and environmental degradation (Zaehring et al. 2019).

For a long time, deforestation advanced more slowly in Myanmar than in other South-East Asian countries, as the military government in place between 1962 and 2011 reduced foreign influence to

a minimum. Today, Myanmar hosts some of the largest remaining intact forest areas in South-East Asia (Schmidt 2012). However, unprecedented political and economic reforms have put economic development at the forefront, resulting in increasing pressure on these biodiversity-rich forests (Webb et al. 2012). Cropland expansion models under scenarios of increasing agricultural value and political stability forecast large areas of forested land yet to be converted into cropland in Myanmar's border provinces, particularly in the east (Zhang et al. 2018). Commercial logging and the establishment of large-scale commercial crop plantations have come to be the main drivers of deforestation in Myanmar (Rao et al. 2013). Reforms in the forest sector have so far focused mainly on managed timber estates under government control in central Myanmar, while the remaining forests in states inhabited by ethnic minorities have been left outside of effective regulations and management (Woods 2015). Under the military regime, the government strategically allocated large-scale agricultural concessions to businessmen with close ties to military leaders in contested territories, arguably to assure the state's control over these territories (Woods 2011; Gum Ja Htung 2018). Many of the (sometimes very large) oil palm concession areas

are not yet fully planted (Woods 2015). In spite of this, local land users are not allowed to use the land and are often punished for trespassing. They demand that the government return unused concession land to its customary users, and in the case of Tanintharyi Region in south-eastern Myanmar, the regional government agreed to do so. However, this has not happened to date, and local land users fear that they will irrevocably lose the legal rights to this land under the guise of recent land reforms, particularly the 2012 ‘Vacant, Fallow, and Virgin Land Management Law’ (Thein et al. 2018).

Tanintharyi Region in south-eastern Myanmar is one of the country’s contested territories where state control was long limited due to conflict – in this case, a civil war between the Karen National Union and the Myanmar government’s military (Lundsgaard-Hansen et al. 2018). Many agribusinesses have been granted concessions in the region, mainly for the production of palm oil and rubber. This has increased pressure on the region’s forests, which are among South-East Asia’s last remaining high conservation value forests (Donald et al. 2015). The ongoing abandonment of shifting cultivation by smallholder farmers for subsistence rice production constitutes an additional threat to biodiversity, as fallows are being transformed into monoculture tree crop plantations in many places (Prescott et al. 2017). The Myanmar government has explicitly fostered this expansion of commercial agriculture at the expense of other land uses to boost national economic development (Fujita and Okamoto 2006; Woods 2015). The impacts of this widespread landscape transformation on local land users’ livelihoods and their vulnerability to external climatic or market shocks have not yet been explored in the context of Myanmar.

The ongoing transformation of Myanmar’s biodiversity-rich landscapes needs to be monitored in detail to understand how it is linked to the underlying decision-making processes. These, too, must be thoroughly understood to devise timely and well-targeted interventions towards greater sustainability. In land system science, such wide-ranging and likely irreversible landscape changes that entail a transformation of people’s livelihoods from subsistence farming to commercial agriculture, along with institutional changes, are understood as regime shifts (Müller et al. 2014; Ramankutty and Coomes 2016). Land use regime shifts in a landscape can entail several parallel sequences of changes from one land use to another, also called land use change trajectories. Land use regime shifts can happen abruptly, for example as a result of political or economic shocks, or gradually over several decades, for example after the introduction of new policies (Jepsen et al. 2015). Lack of land use data at sufficient spatial and temporal resolution hampers the assessment of land use regime shifts. In the often cloud-covered humid tropics, multi-temporal

satellite imagery of the past is scarce and only available at medium to low spatial resolution. A land cover change analysis based on data from only a few points in time over a longer period will not tell us whether a land use regime shift happened abruptly or gradually. An additional methodological challenge lies in the fact that land use, as opposed to land cover, cannot be directly inferred from satellite imagery (Verburg et al. 2009). To monitor the progress of land system regime shifts and identify specific political, economic, climatic, or other events that influenced the land use history, we need to analyse the different land change trajectories occurring in a landscape. This requires annual land use (as opposed to land cover) information that is hard to come by in data-poor contexts like Myanmar.

Participatory mapping of land use changes based on local knowledge offers a potential solution for producing land use information at high spatial and temporal resolution that can complement remotely sensed information (Zaehringer et al. 2018). Participatory mapping of spatial information has been widely applied to include local land users in the process of co-producing legitimate maps of their experienced surroundings (Rambaldi et al. 2006). Purposes of its application include (but are not limited to) delineating current natural resource uses (e.g. Kalibo and Medley 2007; Bernard et al. 2011; Nackoney et al. 2013), mapping people’s landscape values (Bourgoin et al. 2012; Fagerholm et al. 2012), and supporting efforts to gain legal recognition of customary land and resource rights (e.g. Wainwright and Bryan 2009; Bryan 2011). Participatory mapping has also been used to validate remotely sensed land use and land cover change data (e.g. Hoover et al. 2017). However, it has rarely been applied to reconstruct dense land use change histories. Co-production of land use information together with local land users has the potential to foster social learning processes and empower marginalized land users (McCall and Minang 2005; Schneider et al. 2017). Accordingly, participatory mapping can serve as both a scientific and a political tool and is well suited to support integrative and engaged science (Ernoul et al. 2018). In Myanmar, due to the country’s long authoritarian history, participatory research approaches have only recently gained momentum. Nevertheless, participatory mapping holds promise for supporting the transformation, envisaged in Myanmar’s 2030 sustainable development plan (The Government of the Republic of the Union of Myanmar 2018), of land governance towards greater sustainability.

To shed light on land use regime shifts in the context of rapidly advancing social-ecological transformations in Myanmar, we applied a participatory mapping approach and established annual land use change histories for two case study landscapes in Tanintharyi Region, where land tenure is highly contested. In this paper, we describe how the different land use categories

evolved between 1990 and 2017 and assess whether a land use regime shift has taken place in the study landscapes. We frame our findings in the context of political and institutional changes in the country. In the discussion, on the one hand, we reflect on our methods and highlight lessons learned from implementing a participatory mapping approach in a post-conflict context. On the other hand, we reflect on our empirical findings, which contribute to the literature of land use regime shifts in former shifting cultivation areas, and focus on their potential implications for sustainable development in Myanmar.

2. Methods

2.1. Case study landscapes

For this study, we selected two case study landscapes in the forest-frontier context of Yebyu Township, Tanintharyi Region, in south-eastern Myanmar (see Figure 1). The two landscapes are representative of the more widespread land uses in Tanintharyi Region, including forest, subsistence rice cultivation, rubber, oil palm, betel nut, cashew, and other cash crop plantations (De Alban et al. 2019). As we planned to use participatory mapping to document annual land use change histories, we chose the village scale for our assessment. Tanintharyi Region is characterized by a humid tropical climate, with one main rainy season

from May to October. The region has about 1.2 million inhabitants, of which the large majority are Buddhist (MIMU 2018). It has experienced major improvements in terms of security since 2012, when ceasefire agreements and political dialogues ended a decades-long civil war between the Karen National Union and the Myanmar government. Nevertheless, safety considerations also played an important role in selecting the case study landscapes, as there is still a lot of tension between the two parties in many areas of Tanintharyi region.

Each case study landscape consists of one village and the land that is, or was, customarily used by its inhabitants. The two villages differ in terms of official land zoning regulations, ethnicity, and accessibility. The village of Ein Da Rar Zar is located in an area officially classified as Reserved Forest, which is administered by the central government's Department of Forestry (World Resources Institute 2016) and where any agricultural activities undertaken without the Department's authorization are formally illegal. The population mainly consists of members of the Karen ethnic minority, and the village is difficult to access, as it is reachable only via secondary roads. The village of Hein Ze lies in a zone designated for agricultural purposes, and its population is mainly Burmese. It is easily accessible, as it is located on the main road from Kaleinaung to Dawei. Hein Ze lies close to the Tanintharyi Nature Reserve (TNR), a protected area established in 2005.

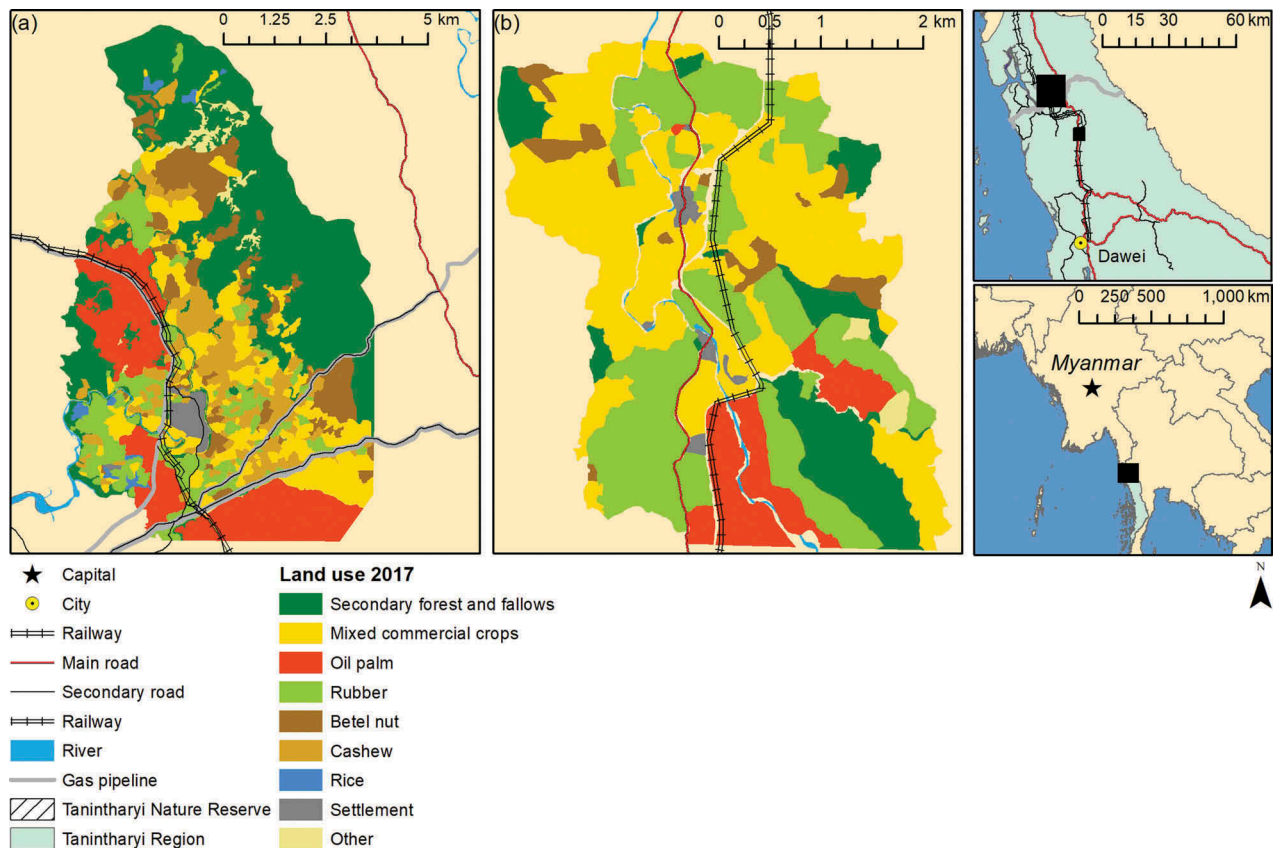


Figure 1. Overview of case study landscapes in Tanintharyi Region, Myanmar.

2.2. Remote sensing and participatory mapping

At the outset of this study, in March 2017, we conducted exploratory focus group discussions in each of the study villages ($n = 11$ to 28 participants) to discuss the main land use changes, their drivers, and their impacts on the environment and human well-being with local land users. We asked the village chief to invite as many interested village inhabitants as possible, ideally representing the overall village population in terms of livelihoods, wealth level, and gender. Myanmar researchers facilitated the focus groups in Myanmar language (Burmese) in the local village hall. Participants were asked to list all past land use changes they could remember and then rank them based on how positively or negatively they affected their well-being using coloured stickers. Each land use change was then discussed in more detail regarding who benefitted and who was negatively affected, in what way. Further, participants discussed the impact of each land use change on the environment. Based on these discussions, we decided to take 1990 as the starting point for the empirical investigation of land use changes in our case study landscapes, as land users had said that the main land use changes had occurred after this date. To map land use in the two case study landscapes for every year since 1990, we combined remote sensing with participatory mapping. This novel approach has been described in detail by Zaehring et al. (2018); here, we only provide details regarding its implementation in the selected case study landscapes in Myanmar.

Based on the focus group discussions, we developed a land use categorization system. Next, we conducted a participatory mapping workshop on two consecutive days in each of the two study villages. The main goals of these workshops were: (1) to identify and label the main geographical features of the case study landscapes, (2) to delineate the borders of current plots with distinct land uses and assign the plots to the different land use categories based on very high-resolution satellite imagery; and (3) to document the spatially explicit land use change trajectory of each delineated plot. For these mapping workshops, our aim was to work with local experts on land use change – that is, those land users most knowledgeable about land use change in their village.

We therefore asked the village chief to invite around 10 participants that had been using land over a longer period of time (ideally since 1990) in different parts of the village and that would have knowledge about the different types of crops planted in the village. While five land users contributed to the participatory mapping workshop in Hein Ze, the one in Ein Da Rar Zar involved 14 land users. However, some of these did not stay for the whole workshop but rather helped to map only those parts of the village that they were most familiar with. The participants were generally better educated than the average village inhabitant and included, for example, the village chief and the person responsible for forest in the village. The participatory mapping workshops were conducted in Myanmar language (Burmese) and facilitated by the third author of this paper, a Myanmar researcher specializing in spatial analysis and knowledgeable about the local context in Tanintharyi Region. In the beginning of each workshop, the facilitator explained the workshop objectives and highlighted that the aim was to map land use (i.e. what type of crops were produced on what land or how forested areas were used) and not individual land tenure. This distinction was important, given the history of conflicts related to land tenure in the case study areas. Trust between the workshop participants and the researchers had been established over the course of the previous 18 months, during which the researchers had repeatedly been present in the villages for other project activities. Before starting their research activities in the villages, the research team including both Myanmar and international researchers completed a detailed risk assessment to make sure that none of the participants in any of the research activities would be put in danger or suffer any repercussions.

As a current reference point and basis for establishing the land use change history, we commissioned very high-resolution Pléiades satellite images of the case study landscapes of Hein Ze and Ein Da Rar Zar in November 2016 and February 2017, respectively (Table 1). To use the satellite images in the participatory mapping workshops, we printed them in colour and with a metric grid onto A0-format paper. We selected a scale of 1:10,000 to enable a detailed view of the imagery's features.

Table 1. Details of participatory mapping conducted in the two case study landscapes.

	Ein Da Rar Zar	Hein Ze
Satellite imagery acquisition date	Pléiades, 25 February 2017	Pléiades, 11 November 2016
Number of mapping workshop participants	14	5
Field walks/motorbike rides [km]	142	17
Number of polygons	620	155
Average size of polygons [ha]	11.38	9.43
Total mapped area [km ²]	70.54	14.62

The images were covered with transparent plastic sheets, on which the workshop facilitator wrote the names of distinctive natural (e.g. rivers, mountains) and infrastructural (e.g. roads, railways) features. At the beginning of each workshop, the participants took quite a long time to become acquainted with interpreting the satellite images, and these features helped with orientation. Finding a common understanding of the proposed land use categories was another challenge that took up a significant amount of time. As the workshop participants had difficulties separating the categories of secondary forest (i.e. forest regrowth that is no longer part of a shifting cultivation system), shifting cultivation fallows, and shifting cultivation rice fields for the past, we had to merge them into a single land use category, which we called ‘Secondary forest and fallows’.

With the help of the participants, the facilitator then delineated the borders of current plots with distinct land uses, drawing polygons on the transparent sheets. To label the land use categories for the different plots in different years as explained by the workshop participants, the facilitator used sticky notes in different colours. Within each workshop, a smaller subgroup of participants was especially engaged with the mapping process and seemed to take it as a matter of personal interest to come up with the most exact representation of the land use history, while others were more passively involved. In the beginning of the workshop, the facilitator made it clear that participants could leave whenever they felt tired or felt that they could not provide any more information.

To complete the land use history for those polygons for which the workshop participants were unable to provide detailed information, the third author of this paper conducted field walks together with other land users from the study villages who were knowledgeable about the land use history of those specific areas. During these field walks, the researcher took GPS points for the land uses encountered along the way and asked the land users since when the specific land use had been in place, and what the previous land use had been, and the one before that, and so on, until they had traced the land use history back to 1990. In the case of Ein Da Rar Zar, the field team used a motorbike to move around the case study landscape, which was much larger than the one in Hein Ze. When the team arrived back in the village, the researcher added the land use information to the map from the workshop.

In a last step, the polygons were spatialized in eCognition Developer software (Trimble 2013) by means of object-based segmentation and manual modification. The annual land use information collected during the participatory mapping workshops and field walks was then attributed to each polygon’s attribute table in ArcGIS (ESRI 2016). We refrained from verifying land users’ recall of past land use, as only one other

very high-resolution satellite image would have been available for the past. To visualize the land use change trajectories, we produced spatially explicit annual land use maps in ArcGIS and stacked area charts in the R statistical software (R Core Team 2015). The interpretation of mapping results was supported with information from stakeholder interviews for which detailed information is provided in Lundsgaard-Hansen et al. (2018). These interviews were conducted with representatives of the village administration, land users, regional entrepreneurs, a private agribusiness, a military agro-industrial company with a concession for oil palm cultivation, landless migrant workers, the Tanintharyi Nature Reserve Project, and an international NGO that supports community forestry. In total, the second and fifth author of this paper together conducted 31 semi-standardized interviews on these stakeholders’ activities, strategies, and resources. They analysed the data using thematic coding and comparative content analysis.

3. Results

3.1. Overall land use changes in the Ein Da Rar Zar and Hein Ze case study landscapes

In this section, we present our findings regarding the evolution of the six main land uses in the Ein Da Rar Zar and Hein Ze case study landscapes between 1990 and 2017 (Figure 2, Table 2) and interpret them using information from the stakeholder interviews. The spatially explicit land use changes from year to year in the two case study landscapes may be viewed in online visualizations (<https://datablog.cde.unibe.ch/wp-content/uploads/figure3.html>).

The first finding concerns the dominant land use in both case study landscapes at the beginning of our study period in 1990 – a mix of secondary forest and shifting cultivation fallows (Figure 2, Table 2). This land use shrank tremendously over time and in 2017 covered as little as 36% of the area in Ein Da Rar Zar and 13% in Hein Ze in 2017. Results from the stakeholder interviews showed that the massive decline in shifting cultivation in the case study landscapes over the last 27 years is explained by a combination of different factors. These include new opportunities for generating income, especially from rubber (*Hevea brasiliensis*) and betel nut (*Areca catechu*), which encouraged people to transform their shifting cultivation systems into permanent tree crop plantations. The entry into force of the Farmland Law in 2012 (The Republic Union of Myanmar 2012), which requires land to be under permanent cultivation in order for users to obtain a land use certificate, was another important reason for land users in Hein Ze to abandon shifting cultivation. But even in Ein Da Rar Zar, where the law does not apply, land users

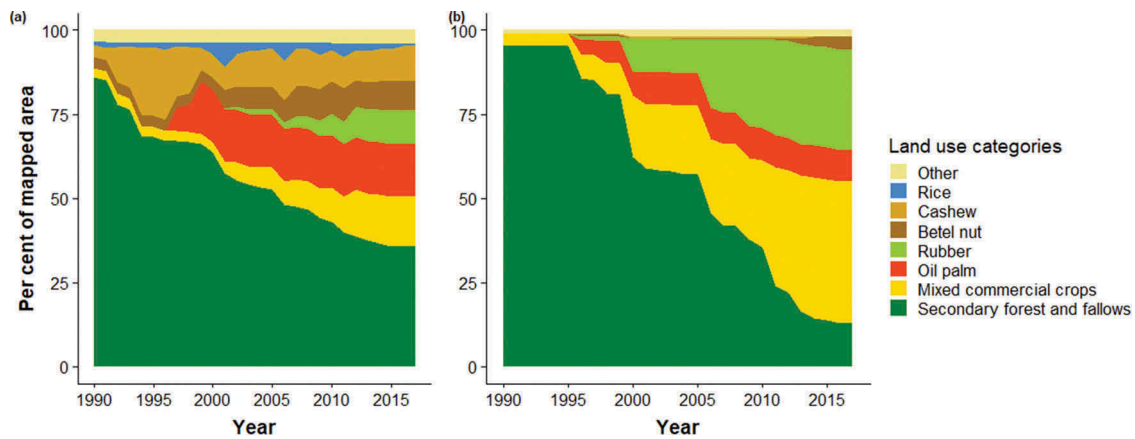


Figure 2. Land use change between 1990 and 2017 in per cent of the total mapped area, in the case study landscapes of (a) Ein Da Rar Zar and (b) Hein Ze, both in Tanintharyi Region, Myanmar.

Table 2. Shares of land use categories (as percentage of total analysed area) and net area of change (as percentage of total analysed area) for the years 1990 and 2017 in Ein Da Rar Zar and Hein Ze.

Land use category	Ein Da Rar Zar			Hein Ze		
	% area 1990	% area 2017	Net area of change (%)	% area 1990	% area 2017	Net area of change (%)
Secondary forest and fallows	86	36	−50	95	13	−82
Mixed commercial crops	3	15	12	3	42	39
Oil palm	0	16	16	0	9	9
Rubber	0	10	10	0	30	30
Betel nut	3	9	6	0	4	4
Cashew	4	11	7	0	0	0
Rice	1	1	0	0	0	0
Other	4	4	0	2	2	0

planted permanent crops to manifest their use of the land, as they feared the land might be acquired by external investors and companies. Other factors include the increased availability of affordable rice on local markets, which allowed local land users to abandon rice cultivation for subsistence, as well as improved security, which enabled them to stay in their villages and take care of permanent plantations. Furthermore, with more and more land being occupied by external actors, local land users increasingly face difficulties accessing land for cropland expansion; this, too, might have led to agricultural intensification in the case study landscapes.

Second, monoculture rubber plantations were less important in Ein Da Rar Zar than in Hein Ze (Table 2). In Ein Da Rar Zar, they were introduced in 2000 and covered only 10% of the landscape in 2017. In Hein Ze, by contrast, we observed a large expansion of monoculture rubber plantations over the study period. The first ones were established by smallholder farmers in 1996. A marked increase occurred from 2000 to 2015, with monoculture rubber plantations covering 30% of the case study landscape since. According to land users interviewed in Hein Ze, local authorities informed them around 2006–2007 that each household would have to grow at least five rubber trees. This likely happened in the context of the Myanmar government's plan to expand

the rubber market, and it might explain the marked expansion of rubber between 2005 and 2007 in Hein Ze (Figure 2). However, the expansion was not exclusively driven by local land users; the apparently high availability of land in Hein Ze attracted outside investors who also established rubber plantations.

Third, oil palm (*Elaeis guineensis*) plantations were established in 1997 in Ein Da Rar Zar and in 1996 in Hein Ze, after which they remained stable in both case study landscapes (Figure 2). Today, they cover 16% of the area in Ein Da Rar Zar and 9% in Hein Ze (Table 2). Stakeholder interviews revealed in both cases that the plantations had been established by actors from outside the case study landscapes who aimed to produce palm oil to meet the national demand for edible oil, soap, and other products. In the case of Ein Da Rar Zar, a military-owned company planted oil palms on 1,102 ha (although the concession covered a larger area). In Hein Ze, it was mainly private agribusiness companies who acquired a total of 138 ha of land for oil palm plantations.

Fourth, the land use category of mixed commercial crops consists mainly of rubber plantations mixed with other tree crops such as betel nut or cashew. In both case study landscapes, this land use category was almost inexistent in 1990 and developed in the course of the study period (Figure 2, Table 2). In 2017, mixed

commercial crops covered 15% of the landscape in Ein Da Rar Zar. In Hein Ze, they expanded more significantly, covering about 42% of the area in 2017.

Fifth, with monoculture cashew (*Anacardium occidentale*) plantations it is much the other way round: Ein Da Rar Zar experienced a steady increase in monoculture cashew plantations between 1992 and 1997, when some land users started to mix cashew with betel nut and/or rubber; whereas in Hein Ze, we found no monoculture cashew plantations at all (Figure 2, Table 2).

Rice (*Oryza sativa*) fields, finally, covered a very small percentage of Ein Da Rar Zar's landscape in 1990, and that percentage remained almost stable over time (Figure 2, Table 2). In Hein Ze, land users grew rice exclusively through shifting cultivation during our study period; accordingly, rice cultivation is hidden in the secondary forest and fallow category of land use.

3.2. Land use change trajectories

In addition to showing how specific land uses evolved over time, the annual land use information allows us to take a closer look at the sequence of multiple land use changes on a given plot, or the plot's land use change trajectory, over the study period (Figure 3).

In Ein Da Rar Zar, the most frequent land use change trajectories since 1990, which together covered about 50% of the total area assessed, all started with secondary forest and fallows being converted to cash crops (Table 3). The most important trajectory by area, covering 15.6% of the case study landscape, is from secondary forest and fallows first to cashew and later to oil palm. This trajectory evolved mainly on three large plots that all belong to a military-owned

company today (Figure 3). The next most common trajectories were from secondary forest and fallows to cashew, and from secondary forest and fallows to monoculture rubber plantations (Table 3). In most cases, these two trajectories also included one year of rice cultivation immediately after the secondary forest and fallows were cut. The conversion from secondary forest and fallows to mixed commercial tree crop plantations with or without rubber, containing mainly betel nut, cashew, lime, and other tree species, was widespread as well, and a similar percentage of the overall landscape was converted from secondary forest and fallows to monoculture betel nut plantations (Table 3).

The only land use change trajectory that did not start with secondary forest and fallows in 1990 and which concerned more than 1% of the assessed area was the conversion from cashew to rubber plantations (Table 3). By far the most important land use category that did not experience any change between 1990 and 2017 was secondary forest and fallows. It accounted for 36 of the 46 per cent of stable area in Ein Da Rar Zar.

Hein Ze presented a similar picture, with secondary forest and fallows being the main land use converted to mixed commercial crops and monoculture rubber plantations (Table 3). About 10% of the area was converted from secondary forest and fallows to oil palm, and 3.7% was converted from secondary forest and fallows to betel nut. In contrast to Ein Da Rar Zar, Hein Ze does not have any monoculture cashew plantations. Together, the changes covered more than 80% of the Hein Ze case study landscape. Only 13% of the area was still covered with secondary forest and fallows in 2017. This accounted for the largest part of stable areas between 1990 and 2017.

Table 3. Land use change trajectories and areas that remained stable between 1990 and 2017 in the case study landscapes of Ein Da Rar Zar and Hein Ze. Only trajectories covering more than 1% of the total assessed area are presented; the remaining change trajectories are aggregated under 'other changes'.

	Land use change trajectory	Area [ha]	% total area	
Ein Da Rar Zar	Change	3,784.9	53.7	
	Secondary forest and fallows to cashew to oil palm	1,101.6	15.6	
	Secondary forest and fallows (to rice) to cashew	600.2	8.5	
	Secondary forest and fallows (to rice) to rubber	497.6	7.1	
	Secondary forest and fallows to mixed commercial crops	406.6	5.8	
	Secondary forest and fallows to betel nut	404.5	5.7	
	Secondary forest and fallows to betel nut to mixed commercial crops	204.0	2.9	
	Secondary forest and fallows to cashew to mixed commercial crops	199.0	2.8	
	Cashew to rubber	92.1	1.3	
	Secondary forest and fallows to cashew to rubber	70.9	1.0	
	Other changes	208.2	3.0	
		Stable categories	3,268.7	46.3
	Hein Ze	Change	1,205.8	82.5
Secondary forest and fallows to mixed commercial crops		556.8	38.1	
Secondary forest and fallows to rubber		432.5	29.6	
Secondary forest and fallows to oil palm		138.8	9.5	
Secondary forest and fallows to betel nut		54.4	3.7	
Other changes		23.24	1.6	
		Stable categories	256.2	17.5

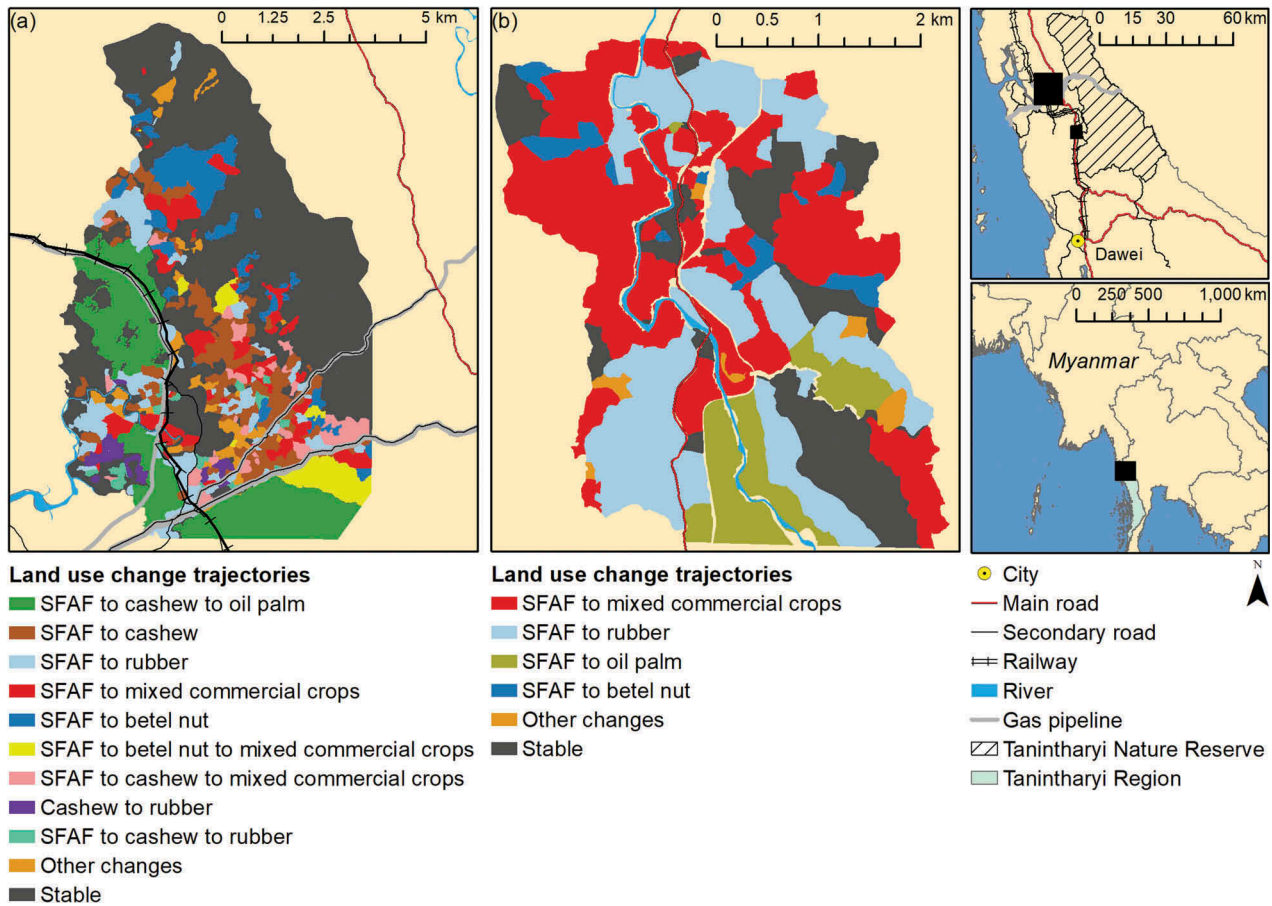


Figure 3. Map of land use change trajectories between 1990 and 2017 in the case study landscapes of (a) Ein Da Rar Zar and (b) Hein Ze, both in Tanintharyi Region, Myanmar. (SFAF = Secondary forest and fallows).

4. Discussion

4.1. Land use regime shifts from subsistence to cash crop farming

In our study in a humid tropical forest-frontier context, participatory mapping proved a powerful approach to tackling the methodological challenge presented by the lack of very high-resolution satellite imagery for assessing past land use changes. The annual land use information obtained through participatory mapping workshops and field walks enabled us to shed light on the developments that led to an extensive loss of secondary forest and a steep decline in shifting cultivation in two case study landscapes. These insights would not have been possible without the annual information. For example, had we only considered land use at the beginning and at the end of our study period (i.e. in 1990 and 2017), the largest share of deforestation and abandonment of shifting cultivation in Ein Da Rar Zar would have appeared to have been caused by the expansion of oil palm plantations. The case study landscape's detailed land use history, however, reveals that secondary forest and fallows were first converted to cashew plantations by small-scale land users before a military-owned external agribusiness acquired the land and established oil palm

plantations on it. This is an important nuance in the debate about the role of oil palm expansion in the deforestation of high conservation value forests in Myanmar (Woods 2015). Cashews are produced for domestic and international markets and generate income for small-scale land users. With the conversion of cashew to oil palm plantations, many local land users lost access to this land and the opportunity to profit financially. Another large part of the secondary forest and fallows in Ein Da Rar Zar – and the entire area converted from this land use in Hein Ze – was converted into mixed or monoculture cashew, betel nut, and rubber plantations by small-scale farmers as well as external private investors. In Ein Da Rar Zar, some land users converted secondary forest and fallows first to monoculture plantations of either betel nut or cashew, and later diversified them by mixing in the other of these two crops or rubber.

The mapping of land use change trajectories over almost 30 years revealed that our two case study landscapes have undergone land use regime shifts (Müller et al. 2014) from small-scale land users' farming systems for subsistence production to local land users', external private investors', and agribusinesses' farming systems for cash crop production. Due to the large labour and financial investments involved, the transformation of

landscapes dominated by secondary forest and fallows into different cash crop cultivation systems focusing on rubber, oil palm, betel nut, and cashew likely presents a permanent land use change – or, in other words, a land use regime shift. In theory, this shift is not necessarily irreversible, as modelling studies predict land abandonment even for intensively cultivated areas in certain world regions (Price et al. 2015). It is unlikely to be reversed, however, given the ongoing population growth and people's high dependence on land for their livelihoods in Tanintharyi Region (Department of Population, Ministry of Immigration and Population 2015). Accordingly, this shift is likely to have long-lasting and multifaceted implications for local livelihoods and the environment.

A large share of the land users in our case study landscapes have abandoned subsistence rice production through shifting cultivation and permanent rice cultivation. Instead, they now rely on income from the sale of rubber, betel nuts, and cashews for their livelihood. Such social-ecological changes towards greater market dependency have been documented all over South-East Asia (e.g. Huijun et al. 2002; Thongmanivong and Fujita 2006; Setboonsarng et al. 2008; Rigg 2014; Friis et al. 2016), and there is concern that they might increase the vulnerability to external shocks of the poorest households relying on shifting cultivation (Castella et al. 2012). In our case, households generated income from a diversity of sources, and it remains unclear whether their increased reliance on monetary income presents a substantial risk to their food security. Oil palm plantations, however, were mainly controlled by private and military-owned agribusinesses. This contributed to an increasing shortage of land among small-scale farmers, thereby possibly indirectly incentivizing them to intensify production on their own land. Although the agribusinesses appeared to have offered local land users some casual wage labour opportunities, the latter did not seem to be interested, as they disagreed with the occupation of their land by external investors in the first place. Despite increasing land shortage, overall, many of the small-scale farmers in our case study landscapes seemed to be in a more favourable position economically in 2017 than they had been in 1990 (Nydegger 2018). It is probably the environmental dimension of sustainability that is impacted most severely by the land use regime shifts in our case study landscapes, although we have not studied this in detail. The new land uses that replaced secondary forest and fallows most likely provide different bundles of ecosystem services to local land users, with various implications on the well-being of different people (Raudsepp-Hearne et al. 2010; Feurer et al. 2019). However, as Rasmussen et al. (2018) have shown, agricultural intensification can lead to positive well-being outcomes despite environmental degradation, at least in the short term. Future research in Myanmar therefore needs to look deeper into these complex social-ecological pathways associated with

smallholders' transition from subsistence to commercial farming in order to fully understand the implications that such a land use regime shift has for sustainable development.

Based on our findings, we would like to make three key management and policy recommendations:

(1) Land use planning is key. Until now, land users have continuously adapted their land uses in response to various political and economic signals. To preserve the diversity of land uses and their different social and ecological functions in the future, this adaptation must happen in a more concerted manner. This would require ensuring that village authorities as well as individual land users have access to information, for example on government strategies targeting land use, on expected trends in cash crop prices, or on scientific knowledge about the capacity of different land uses to provide various ecosystem services in their current state and under future land use change scenarios. Capacity building, preferably through experts from Myanmar, will be crucial in developing the collective and individual skills needed to interpret and integrate different types of information and knowledge into land use decision-making. Moreover, since sustainable development is a highly normative issue, it is important to consider all the different stakeholders' claims on land and to enable processes through which trade-offs between different sustainable development goals can be negotiated. As sustainable development is a highly dynamic and complex process, such negotiations should not aim at reaching a final state in the form of 'a sustainable landscape'. Instead, ensuring that different voices are heard and considered, and that those who lose out in the process are compensated in one way or another, might help build up legitimacy of external interventions from governmental and other stakeholders, and thus reduce the potential for land use conflicts in Tanintharyi Region.

(2) In line with this, the contribution of current land governance arrangements to sustainable development needs to be carefully reconsidered and local land users' land rights strengthened. Although the 2012 Farmland Law has enabled land users in certain land zones to obtain a so-called 'Form Seven' land use certificate, the overall legal framework continues to contain a lot of ambiguity that needs to be resolved (Mark 2016).

(3) Finally, to protect the unique biodiversity of Tanintharyi Region, local land users – who probably have the strongest values with respect to forests (Feurer et al. 2019) – must be supported in taking on the role of environmental stewards. They already have the possibility to apply for community forestry certificates, but most of them are unaware of this opportunity (Lundsgaard-Hansen et al. 2018).

4.2. Co-production of knowledge through participatory mapping in a post-conflict context

Myanmar poses several challenges to researchers, due to the many years of political and economic isolation and civil war. First, there is a general lack of accessible data on land use and land tenure, with a few exceptions, such as the Myanmar Information Management Unit platform, which maintains a repository of data from all sectors (MIMU 2019). Second, most local land users have never been exposed to foreigners, let alone international researchers, as foreigners need a special permit to visit villages in highly contested, post-conflict rural areas like Tanintharyi Region. Our participatory mapping approach allowed us to address both challenges in an integrative way, by co-producing scientific knowledge together with local land users, and it yielded important benefits.

(1) The co-production of land use change information in the under-researched context of Tanintharyi Region constituted an important contribution to scientific knowledge production. It addressed the systemic perspective of land system science research, which is indispensable in knowledge production for sustainable development (Zaehringer et al. 2019). Furthermore, engaging local land users in knowledge production helped to make the research process more accessible to them. This is particularly important in this post-conflict context, where the various local stakeholders follow all interventions by outsiders with scrutiny, and uncertainty about the processes and purpose of research can easily lead to rumours and false expectations.

(2) The participatory mapping exercise served as a social learning tool (Schneider et al. 2009; Reed et al. 2010), initiating a learning process among workshop participants through interaction with others in a safe space. The participatory mapping workshops attracted participants, some of them illiterate, who were interested and curious to engage with the researchers, receive intellectual stimulation, and learn about their own surroundings. At first, participants had difficulties orienting themselves on the printed satellite imagery. Through careful facilitation by the third author (a Myanmar national), they learned how to identify important spatial references and to relate the imagery to their real surroundings. The bird's-eye view of the satellite imagery provided them with a new perspective on their villages and the surrounding land. Asking the participants to contribute their knowledge on historical land use changes to the imagery rendered their local knowledge explicit. Discussions about land use changes on different plots enabled the participants to reflect more deeply on the causes of these changes and their impacts on local people's well-being and the environment, in

continuation of the work that had taken place in the focus groups. This is crucial in the context of rapidly progressing deforestation and environmental degradation, which may have far-reaching impacts on the well-being and land use options of future generations.

(3) At the same time, participatory mapping can serve as a way of bringing to the fore the voices of local land users, who are often marginalized by external investors or government actors who have substantially more resources for defending their claims (Lundsgaard-Hansen et al. 2018). Some participants in the village of Ein Da Rar Zar appreciated the participatory mapping process especially because it confirmed, in a spatially explicit way, that the military-owned oil palm company had occupied land that had previously been used by local farmers.

Our approach could also be useful in other contexts and projects that aim at jointly producing information about land use and the environment. However, there are some limitations that researchers and practitioners need to consider. First, mapping land use changes plot by plot in a workshop setting is very time-consuming, and therefore only suitable for fairly small areas (i.e. village level). Second, issues of land tenure and land ownership are highly sensitive in a post-conflict context such as the one we encountered in Tanintharyi Region. Maps are a powerful tool in such a contested environment, and different stakeholders might try to influence mapping outcomes for their benefit, depending on their power and their interest in influencing the mapping process (Kyem 2006). Our stance as researchers for sustainable development applying a transdisciplinary research process is that we explicitly consider ourselves stakeholders in the process rather than objective observers. This means that we are aware that our own norms influence the process and outcomes (Nielsen et al. 2019). While it was not our intention to directly challenge power dynamics through the mapping endeavour – which is the purpose of critical cartography (Kim 2015) – the choices we took with respect to the selection of participants and what to map do have power implications. We therefore need to reflect on 'who gains and who loses' (Chambers 2006) from our intervention. For example, by selecting participants from village inhabitants who have lived in the area for a long time, we excluded investors more recent to the area. Although we refrained from mapping land tenure, land use change maps may likewise highlight conflictive issues such as the establishment of oil palm plantations run by military-owned and private agribusinesses. The village inhabitants now have maps at their disposal that show what land areas and land uses were lost to oil palm plantations. This might lead to claims for compensation. However, they are still in a weaker position than the oil palm investors, who have connections to the government and are much better endowed with

resources. Therefore, while the participants in the mapping exercise might have gained from the process, it is safe to assume that the oil palm investors did not, and will not, lose anything. Mapping of historical land use change has fewer implications for various stakeholders' attempts at territorialization than mapping of future land use with a focus on use rights. Nevertheless, any participatory mapping endeavour requires very careful facilitation, cautious communication of mapping results with regard to their validity, and a clear data management plan, especially in a conflict or post-war setting.

For the future, we see important opportunities for participatory mapping as well as the co-production of scientific knowledge in Myanmar, as the Myanmar government has recently published its Sustainable Development Plan for 2018–2030. According to this plan, to increase the ability of all people to engage with the government is part of the government's strategy (The Government of the Republic of the Union of Myanmar 2018). However, the government's interactions with civil society in Tanintharyi Region have been rather unfruitful so far. In this context, a participatory approach holds potential to support the transformation towards more sustainable land governance. The co-production and visualization of spatially explicit local knowledge helps to promote local peoples' concerns vis-à-vis higher-level authorities or external actors (Rambaldi et al. 2006). In order to advance sustainable development in Myanmar in a process that includes the voices of local communities, local land users first need to define the problems and challenges of sustainable development from their perspective. Applied with careful consideration and reflexion, participatory mapping could be an important tool to engage local communities in the highly challenging and complex process of transforming land use and land governance towards more sustainable outcomes in Myanmar.

5. Conclusion

Land use in Myanmar is changing at unprecedented temporal and spatial scales. Applying a combination of remote sensing and participatory mapping in two case study landscapes in Tanintharyi Region, our study found that both case study landscapes have undergone a land use regime shift between 1990 and 2017. The majority of land formerly used by small-scale land users for shifting cultivation for subsistence rice production, as well as secondary forest patches, have been converted into new and more intensive land use systems. The most prominent new land use categories are mixed and monoculture tree crop production systems for commercialization by small-scale land users and external private investors, consisting mainly of rubber, betel nut, and cashew, as well as commercial oil palm plantations run by military-owned and private

agribusinesses. These changes are likely irreversible due to the high monetary and labour investments involved in the land conversion. The loss of secondary forest and fallow vegetation might affect ecosystem service supply to local land users as well as to stakeholders at other levels. Further research is needed to gain a detailed understanding of how these land use changes affect the provision of ecosystem service benefits to socially disaggregated types of land users, and how peoples' relations with their environment have changed over time. Our participatory mapping approach enabled foreign and Myanmar researchers to co-produce scientific knowledge together with land users at the village level. It has potentially contributed to social learning among participants, offering them a new perspective on their environment and triggering reflection on the implications of these land use changes for their current and future well-being. Such a transdisciplinary approach is highly suited to support the generation of knowledge for sustainable development, which includes lasting peace and environmental integrity, in a highly contested and biodiversity-rich environment like Tanintharyi Region in southern Myanmar.

Author Contributions

J.G.Z. designed the study, analysed the data, and wrote and revised the manuscript. T.T.T. and F.S. conducted the participatory mapping workshops and field walks and contributed to writing the manuscript. J.C.L. contributed to conceptualizing and designing the participatory mapping approach and to revising the manuscript. L.L.-H., N.N.T., and W.M. conducted stakeholder interviews and focus group discussions in the case study landscapes and contributed to writing the manuscript.

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