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Wild food collection and nutrition under commercial agriculture expansion in agriculture-forest landscapes

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ABSTRACT

Wild food constitutes a substantial part of household food consumption around the world, but rapid land use changes influence the availability of wild foods, which has implications for smallholders' food and nutrient intake. With increasing commercial agriculture and biodiversity conservation efforts in forested tropical regions, many shifting cultivation systems are being intensified and their extent restricted. Studies examining the consequences of such pressures commonly overlook the diminishing role of wild food. Using a combination of collection diaries, participant observation, remote sensing, and interviews, we examined the role of agriculture-forest landscapes in the provision of wild food in rapidly transforming shifting cultivation communities in northern Laos. We found that wild food contributed less to human diets in areas where pressure on land from commercial agriculture and conservation efforts was more intense. Our results demonstrate that increasing pressure on land creates changes in the shifting cultivation landscape and people's use thereof with negative effects on the quality of nutrition, including protein deficiency, especially in communities adjacent to core conservation areas. Our study shows the importance of adopting a more nutrition-sensitive approach to the linkages between commercial agriculture and biodiversity conservation (and the policies that promote them), wild food provisioning, and food security.

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1. Introduction

Nutritional outcomes for rural inhabitants are determined not simply by food production in a landscape or even household incomes, but are highly influenced by access to and control over the resources which make up a person's diet (Sen, 1983). Rapid change is occurring across rural landscapes in the world's developing countries in terms of both land use and governance. Commercial agriculture is rapidly increasing in forested tropical regions, thereby transforming many subsistence-oriented shifting cultivation systems towards more commercial agriculture, often in accordance with national policies aiming at economic growth (Hall, 2011; Hall et al., 2011; van Vliet et al., 2012). These land use changes not only influence local people's income levels and possibly the amount of food purchased, but also affect the availability of wild food as forests, fallows, and agricultural fields are converted

to more intensive agriculture (Padoch and Sunderland, 2013). Ickowitz et al. (2014) find a positive relationship between forest cover and dietary diversity in a multi-nation African study. Ironically, however, conserving forests does not guarantee wild food availability. Global efforts to reduce deforestation and increase the proportion of terrestrial land in protected areas, for example through Reduced Emissions from Deforestation and Forest Degradation (REDD+) schemes and Aichi Target 11 of the United Nations Convention on Biological Diversity, often result in a recentralising of control and reduced access to these resources for local populations (Ribot et al., 2006; Sandbrook et al., 2010; West et al., 2006).

Limited attention has been devoted to understanding this intersection between land use change, forest governance, wild food availability, and nutrition (Foran et al., 2014; Sibathu et al., 2015; Vira et al., 2015). The lack of attention to this complex intersection between land use change and adequate nutrition is problematic as it remains unknown how cash crop expansion and conservation efforts change local people's collection of wild foods and what the implications are for diet quality. The consequences may be severe in contexts where subsistence agriculture and food collection are prevalent and where purchase of varied

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food items is limited (Shackleton and Pandey, 2014). Despite many scholarly efforts to assess the role of ‘bush meat’ in rural diets (e.g. Sarti et al., 2015; van Vliet et al., 2015), the need for research on the intersection between land use change and nutrition has only gained attention recently. Further, it has been stressed that such research must take contributions from the entire landscape into account (Padoch and Sunderland, 2013; Sayer et al., 2013; Sibathu et al., 2015; Global Nutrition Report, 2014). Advances have been made with regards to the nutritional contribution of forest foods (e.g. Ickowitz et al., 2014; Rowland et al., 2016); we contribute by also including wild foods from non-forest habitats in our analysis, in part inspired by Powell et al. (2013).

The core of the problem is that increasing incomes from intensified agriculture alone will not necessarily lead to reduced hunger or improved nutrition because many people, particularly those with limited land, capital, and food market-access, may be unable to shift to reliance on markets for suitable and affordable food, and instead continue to rely on access to a diversity of local resources (Pinstrup-Andersen, 2009; Ickowitz et al., 2014; Powell et al., 2015). This means that large proportions of rural populations, despite widespread modernisation of farming practices, continue to rely on forests and other habitats in addition to the agricultural crops to secure adequate food and nutritionally balanced diets for their families. The diverse contribution of wild foods from forest-agriculture landscapes to local diets has been demonstrated by many studies (for example Angelsen et al., 2014; Christensen, 2002; Ickowitz et al., 2016; Lykke et al., 2002; Paumgarten and Shackleton, 2011; Wunder et al., 2014), but it is often overlooked in development efforts, particularly when the contribution is diminishing in the face of widespread, rapid land-use changes and associated alterations in the access and control over food resources (Shackleton et al., 2015; Vira et al., 2015). Wild food, especially meat and fish, has been shown to be important in terms of dietary diversity, even if consumption frequency may be low (Golden et al., 2011; Sarti et al., 2015; Shackleton et al., 2015; van Vliet et al., 2015). Several studies highlight the important contribution of wild food to dietary diversity that risks being lost in a ‘nutritional transition’ away from locally produced and collected food to purchased food because of modernization and globalization (Piperata et al., 2011; Remis and Jost Robinson, 2014; Sarti et al., 2015; van Vliet et al., 2015). The contribution of forests to income and diet is better thought of as “the supermarket of the wild” rather than as gap-filling (Wunder et al., 2014: S39), and loss and degradation of forest areas can therefore be expected to exacerbate food insecurity and nutrition (Krahn, 2003, 2005; Krahn and Johnson, 2007; Van Noordwijk et al., 2014). In addition, the poor rely heavily on wild food harvested from natural areas other than forests (Angelsen et al., 2014; Mertz et al., 2001). A recent study from Tanzania found that wild foods from agricultural land made a larger dietary contribution than wild foods from forests (Powell et al., 2013).

Achieving all the components of food security is thus highly complex and while economic growth can be shown to reduce food insecurity and improve the average nutritional status of populations (FAO, 2015; WFP, 2007), inclusive growth and attention to local needs and context are fundamental for guaranteeing food and nutrition improvements (FAO, 2015; Dawson et al., 2016). The focus of food security studies has changed from a primary preoccupation with the sufficiency of staple grains and calories, towards the importance of a balanced and safe diet that includes protein, vitamins, and other micronutrients (Ickowitz et al., 2014; Pingali, 2015), with micronutrient deficiency or inadequate nutrition being referred to as the “hidden hunger” (e.g. Ickowitz et al., 2014, p. 287). This is especially relevant for the poorest part of the world’s population (FAO, 2015) and Powell et al. (2015) conclude that for developing countries “diversity within rural and agricultural landscapes may be an important part of a food environment that supports healthy dietary choices” (p. 535). They call for more research on how local communities manage their landscapes for supporting healthy diets, or what the Global Nutrition Report (2014) refer to as

“nutrition-sensitive landscapes”. Analogously, Sayer et al. (2013) highlight food security aspects as an important outcome of integrative landscape and land use planning.

In this paper, we take up this challenge with specific attention to the shifting cultivation systems of Southeast Asia. Northern Laos was selected as our study site as it provides a pertinent experimental area to examine how cash crop expansion and increased conservation efforts change people’s use of landscape for food provisioning. These landscapes traditionally delivered a broad variety of wild foods, which formed local populations’ subsistence. However, over the past 5–10 years landscapes have experienced rapid land use changes from subsistence-oriented upland rice cultivation towards commercial based maize cultivation happening at a very large scale (as documented by Castella et al., 2013; Lestrelin et al., 2013; Hall, 2011; Schönweger et al., 2012; Vongvisouk et al., 2014). Similarly, the shifting cultivation landscape has been influenced by conservation efforts (Moore et al., 2012). The introduction of cash cropping alongside policies seeking to increase forest cover in Laos have been shown to have had some negative impacts on rural inhabitants’ livelihoods and ability to cope with shocks (Castella et al., 2013). Here we examine these political and landscape changes (i.e. the combined influence of biodiversity conservation and cash cropping), with regards to diet and nutrition.

We pose two questions in the article: 1) how does increased pressure on land through conservation efforts and cash crop expansion change local people’s use of shifting cultivation landscapes for wild food provisioning? And 2) how is diet quality influenced by changes in the collection of wild food resulting from land pressures? Our main argument is that increased pressures on land through commercial agriculture expansion and conservation efforts reduce the quality of nutrition when local people rely less on wild food derived from the terrestrial landscape without having market-access to diverse, nutritious food. We take a special look at protein, as protein deficient diets have been identified as one of the main risks for rural Laotian communities (Krahn, 2003, 2005).

2. Nutrient sensitive landscapes: The intersection between land use change, wild food collection and nutrition in Laos

The number of undernourished people in Southeast Asia has been more than halved between 1990 and 2015 and this is largely attributed to economic growth (FAO, 2015). The trend is similar for Laos and a study by the World Food Program (WFP) (2007) finds a strong, positive effect of household wealth assets on food security. Many governments place economic growth high on their agenda, and the Government of Laos is no exception. It is firmly committed to lifting Laos out of the ranks of the Least Developed Countries by 2020 and halving the levels of extreme poverty (World Bank, 2014). But the vision of economic growth in Southeast Asia is heavily embedded in large-scale land use changes promoting cash crop production. The Government of Laos, like many other governments of developing countries, actively promotes the expansion of cash crop production (Castella et al., 2013; Vongvisouk et al., 2016), with the general expectation that modernization and intensification of agriculture should transform the lives of smallholders through a green revolution. Such transformations of livelihoods are purported to happen through increasing productivity and incomes, thereby benefitting livelihoods and increasing the consumption of marketed foods and other goods. The dependence on the immediate surroundings for subsistence livelihoods is thereby assumed to decline, and perhaps eventually leading to a shift away from farming. Such large-scale land use changes have been well documented (Castella et al., 2013; Dwyer, 2011; Hall, 2011; Lestrelin et al., 2013; Schönweger et al., 2012). Yet, several studies have also identified negative livelihood impacts that land use changes have had for much of the upland population such as decreased livelihood- and biodiversity which limits the capacity to cope with unexpected events (among them Castella et al.,

2013; Ducourtieux et al., 2005; Kenney-Lazar, 2012; Suhardiman et al., 2015).

In Laos, the number and size of protected areas have expanded since the establishment of 18 National Protected Areas (NPA) in 1993 and now covers >12% of the national territory (GoL, 2005; Moore et al., 2012). While these NPAs are sometimes presented as areas that preserve biodiversity and thus help secure livelihood of nearby villages, many villages have experienced restrictions and prohibitions on their historical uses of the flora and fauna in the areas that were converted into protected areas (Johnson et al., 2010; Moore et al., 2012).

The establishment of protected areas and other land use regulations further intensifies the demand for land and increases (formal) restrictions on the use of many parts of the landscape, whether for food provisioning or for other livelihood activities (Broegaard et al., 2017; Castella et al., 2013; see also Vedeld et al. (2012) for a study of livelihood impacts of a protected area in Tanzania). A “comprehensive food security and vulnerability analysis” of Laos by WFP (2007) commented that the pressure to change from more subsistence-oriented shifting cultivation to commercial farming, together with the large-scale establishment of plantations and contract farming, influence cropping area and biodiversity, and reduce the contribution of food from the landscape, which has traditionally been important (Krahn and Johnson, 2007). Likewise, the WFP's Laos Country Strategy 2011–2015 (WFP, 2010:14) quotes a study showing that economic growth in Laos has *not* led to a significant reduction in child malnutrition despite the downward trend in undernourishment in Southeast Asia in general, as well as in Laos, over the past decades. Similarly, a UN report on Millennium Development Goal Progress in Laos finds that hunger at household-level has increased since 2002 (<http://la.one.un.org/millennium-development-goals/mdg-progress-in-lao-pdr>).

Although rice sufficiency is both a national and local concern in Laos, the main political focus is on increased economic growth to which the agricultural sector is expected to contribute significantly, not leaving much attention to the importance of diverse and balanced diets (e.g. World Bank, 2015). This lack of attention to diet quality issues is problematic for several reasons. Multiple studies have shown how wild food – especially wild animals (Scoones et al., 1992) – constitutes a substantial part of household food consumption in shifting cultivation systems (Christensen, 2002; Cruz Garcia and Price, 2012; Fiedler, 1994). Krahn (2003) pinpoints that “many wild plant and animal species provide foods with greater nutrient densities than are present in alternative foods imported through market networks in remote mountain areas” (p. 6) (for studies of nutrition and dietary diversity in the Amazon region see also Piperata et al., 2011; van Vliet et al., 2015 and Sarti et al., 2015; for Madagascar see Golden et al., 2011; for a multi-country study in Africa see Ickowitz et al., 2014; and for Indonesia see Ickowitz et al., 2016). According to Krahn (2003) the traditional diet rich in meat, vegetables, and fruit appears to be nutritionally adequate, and she identifies the increased rice consumption and reduced intake of meat as the greatest nutritional challenge for the Lao upland population (Krahn, 2003; see also Krahn and Johnson, 2007). Similarly, Powell et al. (2015) call for more attention to wild food contribution to overall diets and several studies in Laos have attempted to map the composition of wild food in overall diets (Clendon, 2001; Foppes and Ketphanh, 2004; Johnson et al., 2010; Kenichiro et al., 2004; Krahn, 2005). The comprehensive food security and vulnerability analysis in Laos by WFP (2007) concludes that

“wild meat and aquatic resources [...] are the biggest sources of animal protein in rural Lao PDR. Consumption of domesticated animals cannot currently compensate for a potential loss of access to and availability of wildlife” (p.1).

The World Food Program (2007) also asserts that animal protein differentiates households with acceptable food consumption from households with poor or borderline consumption. If the ongoing land use

changes cause declining collection of wild animals and other wild foods, protein deficiencies and reduced quality of diet are a likely outcome and they may outweigh beneficial impacts of increased purchasing power gained through expanding cash crop production.

3. Study area and methodology

3.1. Study area

The study took place in three villages (Fig. 1), all located in northern Laos in Huaphan Province and bordering the Nam Et-Phou Louey National Protected Area (NEPL-NPA). Huaphan Province represents a particularly interesting province, reportedly having one of the highest rates of households engaged in the collection of non-timber forest products in Laos (WFP, 2007). At the same time, 21% of the households in the province were characterized in 2007 as having either poor (2%), or borderline (19%) food consumption patterns (WFP, 2007).

The NEPL-NPA was created in 1993, but until 2000 it remained more a less a ‘paper park’ with little impact on villages in the area. However, active NPA management began in 2000 with funding and technical support from international environmental NGOs (Moore et al., 2012). The park's boundaries were redefined and expanded in 2010. The establishment and expansion of boundaries has created ‘enclosed’ communities inside the park (adjacent to core areas of the NPA), as well as increased pressure on land for those villages situated outside of the NPA area, but having lost land to the NPA. Although agricultural production is the main source of sustenance for the population in the area, the promotion of contract farming – initiated by foreign investors from China and Vietnam whose main interest is maize production – has also had profound impacts across the region (Broegaard et al., 2017; Castella et al., 2013; Messerli et al., 2009; Vongvisouk et al., 2014; Vongvisouk et al., 2016).

The three villages (Khorn Ngua, Son Koua, and Phon Song) were chosen to represent different degrees of proximity to the NPA as well as represent different positions in a transition process from traditional shifting cultivation systems towards more continuous cultivation and cash crop production. These sampling criteria were chosen in order to yield insight on the cumulative influence of cash crop production and conservation on wild food collection and nutrition. Due to lack of longitudinal data, we focus on differences between the villages as we argue that they represent different degrees of influence of cash crop production (Rasmussen et al., 2016b). There has been an increase in commercial production in all three study villages since maize was introduced in 2010, although the increase in production has taken place in very different ways. While wild food collection in principle can take place throughout the landscape, we distinguish between the collections according to the habitat type where it took place, as we show in the results section.

Khorn Ngua is situated outside of the NPA, has 60 households, and is the village where the land use system has changed the least. It is still predominantly traditional shifting cultivation, with most cultivation concentrated on steep slopes. Farmers' main crop is rice, grown in the uplands for 1 to 2 years, after which the fields are left fallow. The cultivated rice fields are the mainstay of the human diet, albeit wild animals and plants also are considered important sources of food. Main trapping and catching techniques for rodents include snares, single-capture traps, and pitfall traps. All members of the household are involved in wild food gathering, while able-bodied adults contribute to the cultivation. No commercially produced fertilizers or pesticides are applied, and maize is being more or less integrated in the shifting cultivation system, but with shorter rotation than shifting cultivation for upland rice.

Son Koua is the largest of the three villages, with 178 households. Analogous to Khorn Ngua, the expansion of commercial maize production has occurred in Son Koua through integrating maize into the rotational agricultural system. However, the village is located close to a paved road (Fig. 2) implying that the community has better market

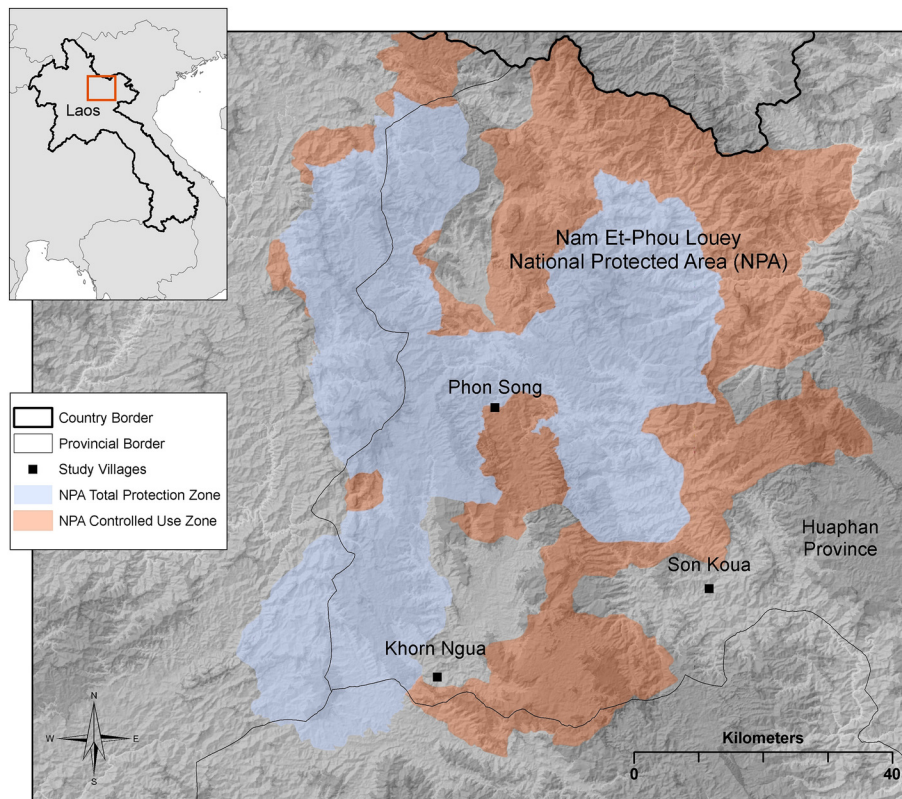


Fig. 1. Map of the study sites, northern Laos. Landsat imagery (RGB = 3–2–1) from January 2015 was used as the base layer.

access and is more integrated in a larger economic system. For example, the village has been widely promoted as a site for ecotourism.

Phon Song is located within the NPA and in this village the expanding cash crop production has in contrast to Khorn Ngua and Son Koua occurred through a land use change from shifting cultivation of rice to continuously cultivated maize. Part of the reason for the continuous cropping is that the NEPL-NPA surrounds Phon Song, whether as Controlled Use Zone or as Total Protection Zone (Fig. 2), thereby limiting access to arable land, and not allowing the increase in land under agriculture identified in other villages through interviews. Yet, with the fallow period being omitted in the maize systems of Phon Song, it is uncertain how long the continuous maize cultivation system can be sustained without causing land degradation. In Phon Song, the cultivation involves commercial fertilizers and pesticides. The village has 50 households.

3.2. Data collection

Three complementary methods - collection diaries, semi-structured interviews and participant observation - were employed to examine how the collection of wild food contributed to the diet. A spatial analysis of land cover changes was made for the delimited village lands between 2006 and 2015, based on remotely sensed satellite imagery.

3.2.1. Collection diaries

Collection diaries were used to estimate the amount and variety of wild animals and plants collected by households from terrestrial and aquatic habitats. The diaries did not include cultivated food (for example from vegetable gardens and domestic animals) as they were designed with a specific focus on wild food. We specifically targeted 33 households (11 from each of the three selected villages). A stratified sample of households was selected to ensure representation of households with fields located at short, medium and long distances from the village, as previous studies suggest that distance influences collection

decisions (Delang, 2006). Data were collected in each village during four periods, corresponding to each of the four sub-periods of 1) slashing and burning; 2) planting; 3) weeding; and 4) harvesting, in order to ensure data-collection during different seasons. Each data collection period lasted for one week per village. We differentiated between collection from fields, fallows, and forest areas for terrestrial habitats. Diaries were chosen as a methodology, given that prior studies had shown their usefulness and high level of detail to explore household consumption of wild vegetables and other plants (Christensen, 1997; Lykke et al., 2002; Mertz et al., 2001; Rasmussen et al., 2016a). A research assistant visited all eleven participating households every evening in each of the villages during the recording weeks, and together they recorded the products collected, the quantity taken, the location of collection, and the final use of the product. Records were kept on a daily basis for one week in each of the four sub-periods, amounting to a total of 924 household-days of recordings for all three villages. To account for intra-household variations in collection patterns, all household members were invited to participate in the evening sessions. If some members were not available, they were asked to tell the participating members prior to the session about their collection for that day.

Daily, rather than weekly recordings were chosen in order to minimize a memory lapse and to account for daily variation and capture infrequently collected items. Daily visits turned out to prompt a great level of detail, as the products that had been collected during the day often were shown and discussed with the research assistant. All hunted animals were identified by research assistants to taxonomic group, rather than at the species level.

3.2.2. Semi-structured interviews

During the first sample weeks of diary recordings (the slashing period), semi-structured interviews were conducted with the same 33 households who took part in the diary recordings in the three villages. These interviews served to yield insight on cultivation practices and

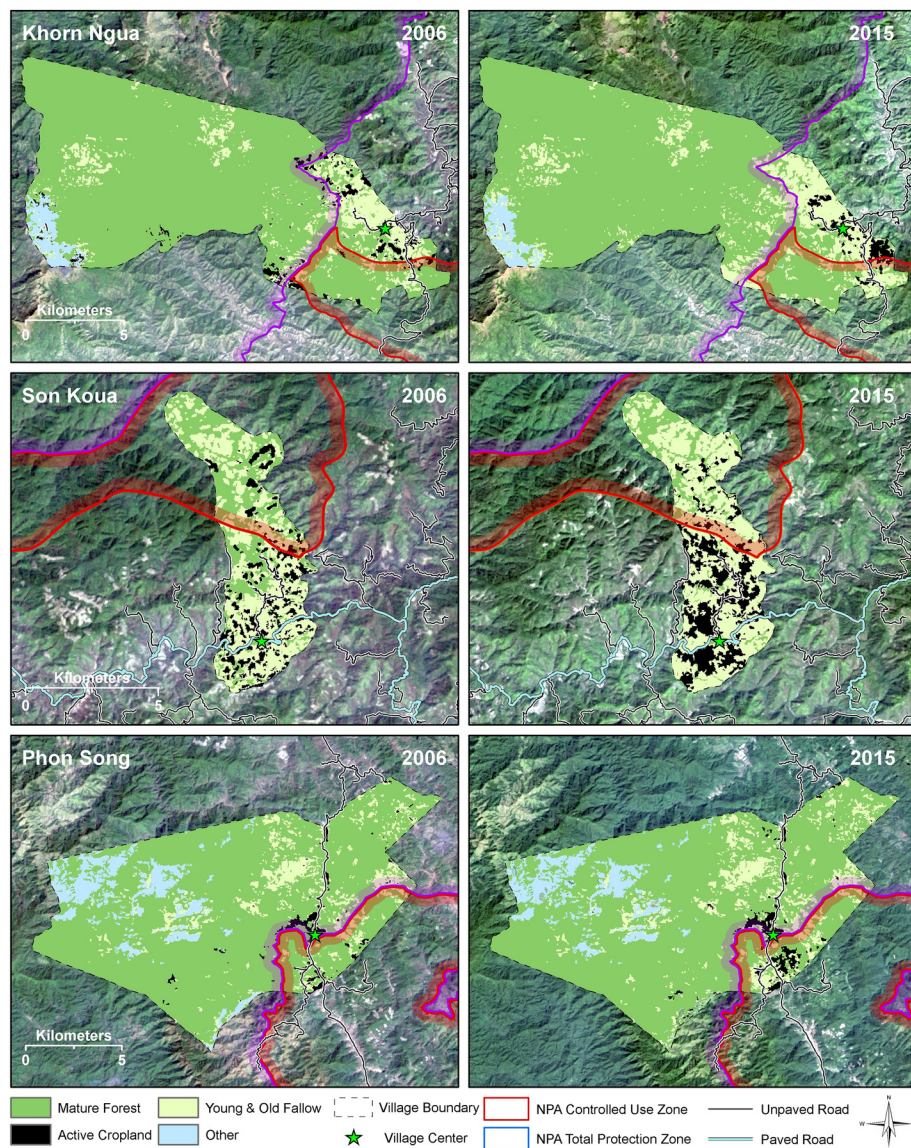


Fig. 2. Land cover maps for 2006–2015 within the village boundaries of Khorn Ngua, Son Koua and Phon Song, based on Land Use Planning Reports 2012. Maps are based on classification and time series analysis of Landsat imagery. Landsat Imagery (RGB = 3–2–1) from 2006 to 2015 is used as a background base layer.

the general collection of various items from various habitats. Additionally, these households were interviewed a second time after the harvest was completed in order to gather information on the agricultural production, hunting (in the primary forest areas) and to validate the patterns emerging from the collection diaries. To understand socio-economic aspects of the agricultural production, we also interviewed a bigger sample of households across the three villages ($n = 100$). This sample included the 33 households from the diary recordings and included questions regarding all possible contributions to diet, including wild food, grown food, reared livestock and purchased food.

3.2.3. Participant observation

In order to get a better understanding of the products households gathered on their way to and back from the fields, we accompanied each of the 33 households on these walks. This was done four times evenly distributed over the agricultural season, thereby providing a concrete vantage point from which the respondent could describe the products he or she collected. Although the methods outlined above are well suited to assess people's collection of wild foods, we note that participants may have (intentionally) failed to record, describe or showcase all collected products, especially regarding illegal products.

3.3. Data analysis

In order to estimate protein gaps, the quantities of collected rats (in grams) were used to estimate the percentage of required protein intake that was satisfied by the wild food collection from the landscape under the different agricultural systems present in the three study sites. The calculations were based on the following assumptions: (1) the per capita protein requirement is approximately 50 g per day (<http://iom.nationalacademies.org/Activities/Nutrition/SummaryDRIs>), and (2) protein levels of 7% and 18% in rice and rats, respectively.

For the spatial analysis our aim was to map changes in land cover/use for each of the three villages over a 10-year period from 2006 to 2015. For a detailed description of the data and methodology used, see Appendix A. For mapping, we used the rich archive of Landsat satellite imagery freely available from the United States Geological Survey. We targeted four land cover/use categories: mature forest, forest fallow, active cropland and other land. Of these classes forest fallow is by far the most difficult class to map with Landsat because after 3–4 years of regrowth it becomes difficult to distinguish it from more mature forest (Hett et al., 2012). To reliably map the fallow system, a dense time series change detection algorithm was developed. This allowed the forest-

cropland-regrowth patterns to be sufficiently identified. We first used a Random Forests classifier (Breiman, 2001) to classify a cloud free Landsat image for the chosen base year 2005 into 3 classes: forest, active cropland and other land. To map forest fallow for the base year 2005 we analyzed annual time series of Landsat imagery from 1989 to 2005. This analysis revealed forest that had been previously cleared for agriculture and regrown. We then continued the time series analysis from 2006 to 2015 to track how the fallow system and active cropland developed in the three villages. Manual corrections were made to the maps to remove any obvious errors introduced by the automated mapping procedure. For accuracy assessment, we used a stratified random validation sample of 120 points. Overall accuracy of the maps was 89% for 2006 and 91% for 2015.

4. Results

Comparison of the land cover maps for 2006 and 2015 for each village (Fig. 2) shows that the area of active agricultural fields in Khorn Ngua in 2015 is estimated to be smaller (280 ha) than in 2006 (400 ha). Yet, when comparing spatial data for each year (Appendix A), we see fluctuations in the yearly cleared area with peaks around 2010–2014. Yet, in Son Koua the land cover maps show a marked increase in active agricultural land, from approximately 420 ha in 2006 to 670 ha in 2015 (also with a peak in 2010 of approx. 890 ha).¹ The active agricultural area has been more stable in Phon Song, both with regards to extent (from 250 to 320 ha between 2006 and 2015, with no marked peaks) and location. For maize-production to be economically viable, good road infrastructure is a must, favouring this activity in Son Koua over Khorn Ngua. Meanwhile, the agricultural area is limited by the NPA regulations in the total protection zone surrounding Phon Song. The impact of the NPA regulations, although not entirely successful, can also be seen in the other two villages, where agricultural activities are increasingly relocated to areas outside of the two NPA management zones. The land cover map also shows an increase in fallow areas especially in Son Koua.

4.1. Wild animal gathering from the terrestrial landscape

Based on the household collection diaries, we found that rats, grasshoppers, bamboo weevils, squirrels, and bamboo rats were the five most frequently gathered animals from the terrestrial landscape, accounting for 77% of 336 reported collection events (Fig. 3).²

A rather limited and irregular collection of other wild animals was observed across all villages, representing from 18% of all collection events in Khorn Ngua to 38% in Phon Song. Interviews confirmed this contribution of other wild animals to household food consumption, although no longer a major component. Some hunting took place in all three villages, and consisted primarily of legal hunting of birds and small mammals in forest areas within the village lands. One in four interviewees reported that members of their household continued to hunt larger animals, particularly wild pigs and deer despite the regulations of the NPA,³ though they were caught only a few times per year and represented a limited contribution to contemporary diets. In Son Koua, the hunting of other wild animals was also limited because collection from forest areas was considered burdensome due to the longer

¹ The marked increase in active agricultural area in 2010 in Khorn Ngua and Son Koua collided in time with maize traders investing heavily in the area.

² A collection event yields typically more than one individual of the smaller animals. Average yield per collection event was 2.6 for grasshoppers, 6.4 for bamboo weevils, 2.2 for bamboo rats and 1.3 for squirrels. For larger animals, one collection event typically yields only one animal.

³ While some smaller animals were permitted objects for hunting, the NPA regulations made hunting of most larger mammals illegal. While previous large fines given for illegal hunting were reported to reduce hunting activity, this is probably also subject to some under-reporting. However, data from interviews fit quite well with what was observed during prolonged and repeated stays in the three villages.

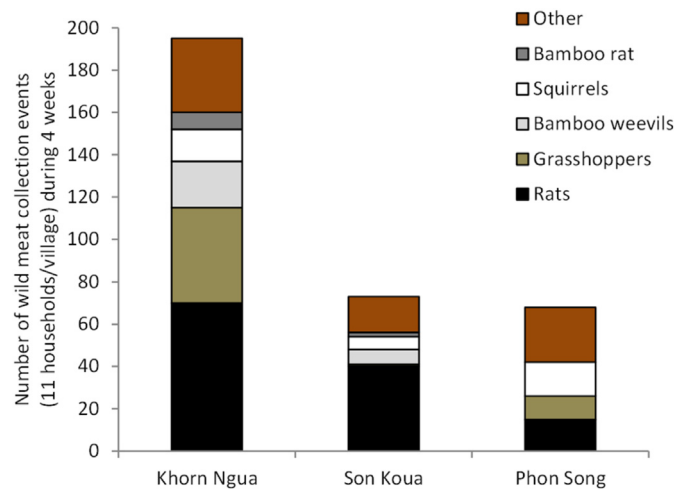


Fig. 3. Contribution of shifting cultivation landscape habitats to local people's collection of wild meat in three villages, Northern Laos. $N = 924$ household days and 258 collection events for the five most frequently collected wild meats.

distances to these areas. However, it should be noted that households in all three villages hunted to some degree.

Rats were by far the most frequently gathered animal, accounting for 125 out of the 336 collection events registered across the three villages. However, hunting of rats was much less common in Phon Song (22% of all collection events) than in Khorn Ngua (36% of all collection events). Across the three villages, households did also engage frequently in squirrel hunting (Fig. 3). Squirrels were primarily caught in the primary forest, but the majority of collection events yielded only one squirrel, meaning that the meat intake per person was rather limited.

In Khorn Ngua, there were 70 rat collection events over four weeks, equivalent to 1.6 events per household per week (Fig. 4a). In Phon Song, only 14 events were observed over the four weeks, equivalent to 0.3 events per household per week. The gathering of rats across all villages took primarily place in the agricultural fields, which accounted for 90% of all recorded rat collection events ($n = 125$ events) in Khorn Ngua and 60% in both Son Koua and Phon Song (Fig. 4a). The same pattern was observed for the contribution of agricultural fields towards the total number of rats collected ($n = 336$ rats) with 92%, 50%, and 65% in Khorn Ngua, Son Koua, and Phon Song, respectively (Fig. 4b). A one-way ANOVA revealed a statistically significant difference ($F(2121) = 4.6, p < 0.05$) between the villages as to the number of rats collected per collection event with a fairly limited number in Phon Song ($M = 1.9, SD = 1.2$) as compared to Khorn Ngua ($M = 2.6, SD = 1.4$) and Son Koua ($M = 3.3, SD = 2.0$). A post hoc Tukey test showed that Phon Song differed significantly at $p < 0.05$ from the other villages. Focusing on rats as the main wild animal collected, and considering that these are primarily collected from the active fields (Fig. 4b), we contribute this difference mainly to the different degree to which the agricultural system has changed in the villages, as a response to external pressures and opportunities.

While all households who participated in the diaries hunted rats in Khorn Ngua, only 8 and 5 of the eleven participating households engaged in rat hunting in Son Koua and Phon Song, respectively. A one-way ANOVA showed a statistically significant difference ($F(230) = 3.6, p < 0.05$) between the villages as to the number of rats collected per household with the lowest collection in Phon Song ($M = 2.4, SD = 3.7$) as compared to Son Koua ($M = 11.9, SD = 18.8$) and Khorn Ngua ($M = 16.5, SD = 10.6$). A post hoc Tukey test showed that Phon Song differed significantly at $p < 0.05$ from the other villages.

The findings suggest that not only may the land use have changed the landscape and thereby affected the availability of wild foods, the different land use practices and related tasks may also have changed people's time allocated to wild food collection. Another way that the

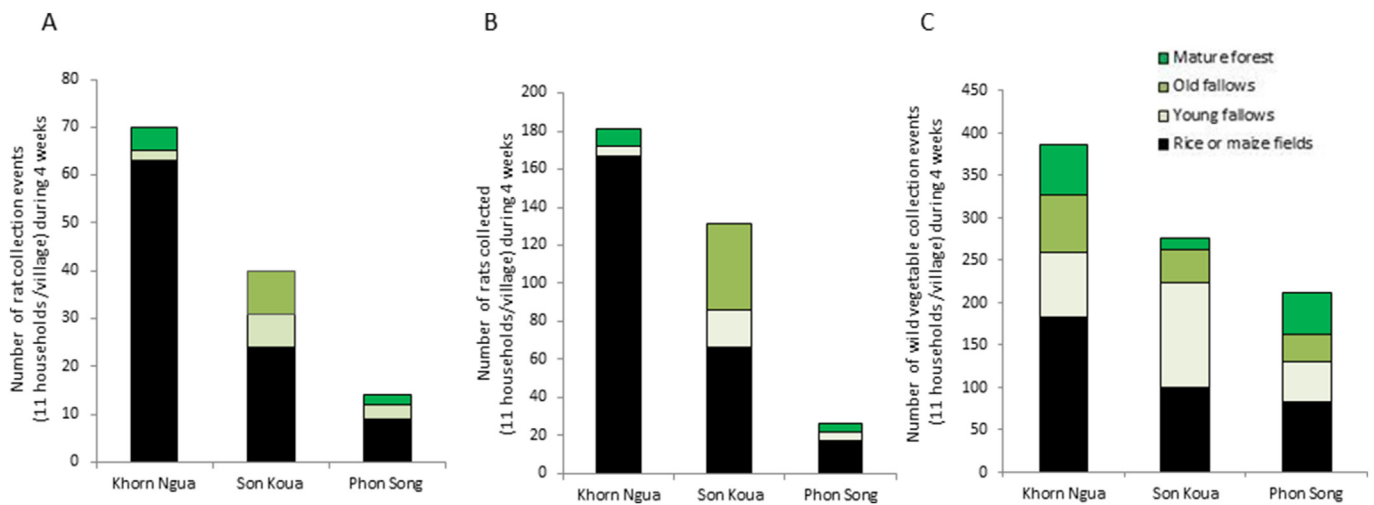


Fig. 4. Contribution of shifting cultivation landscape habitats to local people's collection of rats and wild vegetables in three villages, Northern Laos. $N = 924$ household days, 125 rat collection events (A), 336 rats (B), and 874 wild vegetables collection events (C).

changed land use may have influenced both the number of rats collected and the frequency of rat collection events was through the introduction and use of rodenticides, which made the traditional rat collection unattractive due to fear of poisoning. Rodenticides were introduced in Phon Song, but not in the other two villages, and according to interviews, the rodenticides and other pesticides were introduced by cash crop investors.

4.2. Wild plants gathered from the terrestrial landscape

Analogous to our findings on wild animal collection, the frequency of wild plant collection events was lowest in Phon Song and highest in Khorn Ngua. Households collected wild plants for consumption almost twice as frequently in Khorn Ngua ($n = 387$ events) as in Phon Song ($n = 211$ events) (Fig. 4c). The agricultural fields accounted for a substantial proportion (47% in Khorn Ngua, 36% in Son Koua, and 39% in Phon Song), but with similar quantity estimates per collection from the different habitats.⁴

With regards to wild plants, our data from the collection diaries revealed that households in Khorn Ngua on average collected wild plants four times a week from the agricultural fields. The lowest collection frequency from the agricultural fields was observed in Phon Song (1.9 times per week per household). Based on the number of collection events observed, our findings indicated that the wild plants contributed much more to a diverse diet in the villages with more traditional shifting cultivation agricultural systems, and much less in the village dominated by cash crop production.

4.3. Protein-intake

A one-way ANOVA was conducted to compare the three villages in terms of additional protein requirements after considering the two main protein sources – rice and rats (Table 1). We found a statistically significant difference ($F(230) = 3.4, p < 0.05$) with the lowest additional requirements in Khorn Ngua ($M = 14.6\%$, $SD = 12.6$) as compared to Phon Song ($M = 35.8$, $SD = 10.9$). A post hoc Tukey test showed that Phon Song differed significantly at $p < 0.05$ from the other villages.

As to the question of whether households in Phon Song fulfilled the protein need by relying on other sources, we found that this was not the case. Five points derived from the interview and collection diary data substantiate this conclusion. Firstly, interviews on the reasons for

having livestock and their contribution to diets showed that people commonly did not seek to eat them. Rather, the purpose of keeping livestock in these villages was to meet living costs as they arose and pay for weddings etc., while domestic animals were primarily consumed at festivals. Other studies have likewise shown that livestock provide an important, although limited contribution to the diet (Clendon, 2001; Krahn, 2005; WFP, 2007). Secondly, there was limited hunting of large wild animals, mainly due to the NPA regulations.⁵ Thirdly, the intuitively appealing assumption that increased income would be translated into improved food sufficiency and improved nutritional status makes it relevant to ask whether the identified 'protein-gap' was actually fulfilled by purchase of other sources of protein. Our interviews showed that while people were starting to consume more livestock and purchase a little more meat in Son Koua and Khorn Ngua, it was not widespread, as it was primarily the wealthier households who could afford to do so. In Phon Song, which had the lowest rice sufficiency, highest protein gap, lowest collection of greens, and most difficult road access, meat purchase was almost non-existent. In general, there was limited food purchase in all three villages. Our interviews⁶ revealed that the household's agricultural activities in Khorn Ngua and Son Koua totaled a considerable higher value (reported in Million Kip ($M = 8.81$, $SD = 4.41$ and $M = 8.76$, $SD = 5.68$, respectively), than in Phon Song ($M = 5.63$, $SD = 6.79$). However, in all three villages, household rice sufficiency for all twelve months of the year, whether through own production or through income and purchase, had decreased between 2004 and 2014, in Khorn Ngua from 93% to 73%, in Son Koua from 92% to 88%, and worst in Phon Song, where it had decreased from 83% to only 57% of households.

Fourth, attention had to be devoted to the protein derived from aquatic habitats, since fish generally are an important source of protein in Laos. Based on the collection diaries, we found that households in Khorn Ngua and Son Koua on average had a fishing frequency of 2.5 and 1.8 times per week, respectively, over a year. Similar to our findings on rat collection events, the frequency was lowest in Phon Song: Households' fishing efforts were restricted to once a week. The lower frequency in Phon Song was not outweighed by the amount of fish caught. On the contrary, the amounts caught in Khorn Ngua (820 g per fishing event) and Son Koua (780 g per fishing event) were almost twice the

⁵ Restrictions were especially strongly enforced in Phon Song, but also felt in the other two communities.

⁶ Interviews were carried out with 30 households in Phon Song, 30 in Khorn Ngua and 40 in Son Koua. However, we exclude data on agricultural income from 6 households in Son Koua who did not cultivate land, as they held professional offices.

⁴ Most often one collection event would yield a handful or approximately 30 g.

Table 1
Protein derived from rice and rats in the terrestrial ecosystems of three villages, northern Laos.

Terrestrial protein sources	Khorn Ngua	Son Koua	Phon Song
Rice ^a protein intake (g) per household per day	161 (SD = 22)	158 (SD = 21)	152 (SD = 18)
Rat ^b protein intake (g) per household per day	53 (SD = 34)	38 (SD = 61)	8 (SD = 12)
Protein need (%) after rice and rat meat intake	15 (SD = 13)	22 (SD = 28)	36 (SD = 11)

n = 924 household-days and 336 rats.

^a Based on a protein content of 7%.

^b Based on a protein content of 18%.

amount caught in Phon Song (441 g per fishing event). When these aquatic protein sources were added to the terrestrially derived protein, we found that the protein intake in Khorn Ngua with the more traditional shifting cultivation system actually matched the protein need (Table 2). In Son Koua, the need was reduced to <15% (which for the wealthiest households was probably offset by meat purchase), but in the village of the Phon Song, a substantial protein need was still observed - on the order of 22–36%, and as mentioned above, was not offset by purchase of food.

Finally, one could argue that protein derived from beans and wild plants should be accounted for. Since our interviews did not yield reliable estimates on the amount of beans consumed (as these are grown in vegetable gardens, rather than collected, and therefore not included in our diaries), we had to rely on a study from another community in the NEPL-NPA (Johnson et al., 2010) which found that families had an intake of 32 g of beans per person per day. Using this figure and a protein content of approximately 3%, we found that a need for protein remained in Son Koua (0–13%) and Phon Song (20–34%). Since we identified >120 different plant species and a collection event most often entailed collection of a handful of different leaves, it was inherently difficult to translate those wild plants into their respective protein contribution. However, it is well established that plants contribute an important source of vitamins and micro-nutrients, in addition to some protein (see studies in Powell et al., 2015), and our findings (Fig. 4c) indicated that the contribution by wild plants, especially from the active upland fields, to a diverse diet, was much more pronounced in the villages with more traditional shifting cultivation agricultural systems, and much less in the village dominated by continuous cash crop production. Interviews showed that practically no purchase of vegetables and other plants took place in any of the three villages, as there were no local markets for these.

5. Discussion and concluding remarks

Our empirical focus on shifting cultivation systems in Laos has shown that the studied villages have significantly different levels of dietary diversity, both with regards to protein and vegetable intake from wild sources. Based on interviews as well as land cover change analysis we explain the observed difference in wild food collection between the villages with the degree to which they have undergone recent land use changes related to cash crop expansion as well as conservation initiatives. These changes are in parts driven by agricultural policies that pursue land sparing rather than land sharing, although they may obtain neither (Vongvisouk et al., 2016), yet may affect local peoples' nutrition negatively. As our interviews and observations show a situation where

Table 2
Protein derived through fish from aquatic ecosystems in three villages, northern Laos.

Aquatic protein sources	Khorn Ngua	Son Koua	Phon Song
Fish ^a protein intake (g) per capita per day	10	6.8	2.5
Protein need after rice, rat meat, and fish intake	0–3%	1–15%	22–36%

n = 924 household-days and 240 fishing events.

^a Based on a fish intake of 59, 40, and 15 g per capita per day for each of the three study sites, respectively, and an estimated protein content of 17% in fish.

protein-rich foods and vegetables are rarely bought, partly as there is no easy access to a market, we conclude that even the increasing income reported in interviews obtained from cash crop production does not offset the decrease in collection of wild food. Our empirical findings are supported by Krahn (2005) who also found a food consumption pattern in rural Laos that is changing rapidly towards an almost exclusive rice diet, partly due to the change in access to and use of natural resources. Our findings are likewise in line with studies of the 'nutritional transition' from other parts of the world (Sarti et al., 2015; van Vliet et al., 2015). These studies have found that the most 'modern' populations and villages in rural settings are those with the most inadequate nutrition. Increasing commercialization of agriculture causing large-scale and rapid landscape and land use changes in the tropics, often in interaction with conservation efforts, may thus have severe impacts on dietary outcomes. Yet, dietary outcomes of these changes have received little attention. In addition to the lack of local diversified food markets, possible explanations for the missing relation between rising income and improved diets include that cash income from maize production mainly are spent on household assets such as scooters, tractors and telephones in addition to being invested in children's education and, for the wealthier households, placed as savings on bank accounts (Vongvisouk et al., 2016).

Dietary outcomes are strongly linked to the nature of agricultural development, conservation of forests, and the availability of and access to wild food and our study advances existing knowledge by showing the important contribution made from active agricultural fields in this traditionally shifting cultivation system, undergoing change. We find that the collection of wild food represents an important source of protein and other nutrients in more traditional shifting cultivation villages. However, the wild food provision from the shifting cultivation landscape appears to be diminishing with increasing pressures on land, whether from the NPA or the expanding cash crop production. Change from shifting cultivation to more continuous maize cultivation limits the amount of wild food that local people collect from the agricultural fields which represent by far the most important place of collection in our study area. Further, if households do not replace the wild food with other protein sources, which is the situation in the villages furthest away from good roads and markets, it may result in a lack of protein. Thus, we also show how the conversion towards more intensive agriculture has different outcomes in different types of villages. Those villages with more agricultural land and less pressure from conservation initiatives may benefit from increasing incomes from commercial farming and still be able to maintain, and possibly even enhance diets whilst continuing to access a range of wild foods. In contrast, villages with limited agricultural land and restrictive rules on cultivation and foraging may experience income increases happening in concert with a radically declining availability of wild food. However, it is important to remember that households differ within villages and while some may have income and be somewhat resilient to the dietary effects, the poorest and those with access to the least land, are likely to suffer far more.

Getting sufficient animal protein is a general challenge in many rural areas and in particular in rural Laos (Johnson et al., 2010; Krahn and Johnson, 2007; Krahn, 2003, 2005) even though fish and other animals from aquatic habitats provide an important source of protein. Thus, our study aims to improve the understanding of how changes in agricultural production system (from more subsistence-oriented shifting cultivation

to a system with considerable production of cash crops for regional or foreign markets) affect the collection of protein-rich foods. Furthermore, we have demonstrated that collection of wild plants also diminishes with increasing pressures on land and a reduction of the shifting cultivation landscape. As no purchase of vegetables and other plants takes place, the reduced collection translates directly into a lower diet quality. Our findings thus question the commonly assumed link between cash income and dietary diversity, although it may hold for household food sufficiency. Failing to pay attention to the 'hidden hunger' as mentioned in the introduction may overlook potential protein and nutrient deficiencies caused by the declining collection of wild food and the very limited food purchase in many rural villages.

In the presented study, we have taken a landscape approach to analyse changes in collection of wild foods in that we distinguish between what is collected from different habitat categories throughout the landscape. We found that rats were the most frequently collected source of protein and these were primarily hunted in the *agricultural fields*. This finding is in line with recent findings of the importance of wild food from agricultural areas by Powell et al. (2013) and underscores the importance of taking into consideration the changes in production on those fields, or the use of different inputs on these fields, in order to understand the implications of land use changes for the provisioning services from terrestrial ecosystems with regards to wild food. We therefore propose that future studies dealing with the intersection between land use changes, nutrition, and food security devote specific attention to the contribution of wild food from agricultural fields and threats to this contribution. Increased use of agro-chemicals (pesticides, herbicides and rodenticides) has clearly limited the collection of, for example, animals for consumption. We expect the use of agro-chemicals to increase further, with greater contact to traders/investors who promote cash crop production. This would be an important element to monitor in future research on nutrition-sensitive landscapes, i.e. the impact of the changing land use systems on food security and nutrition. Here, the impact of increased use of agro-chemicals on the aquatic environment and its food provision has to be taken into account as well.

At a more general level, we call for attention to the concept of *nutrition-sensitive landscapes* (Global Nutrition Report, 2014) for two purposes: First, to acknowledge the intersection between nutrient and diet studies and land use studies, and secondly, to provide a basis for updating theories of changes about the linkages between land use changes on the one hand, and food sufficiency and possible nutrient deficiencies on the other. This has implications for the SDGs and their attempt to integrate the previously distinct aspects of landscapes, conservation and poverty, which should receive much greater focus as part of the SDG development agenda (Messerli et al., 2015). Our study supports findings that dietary outcomes are strongly linked to the nature of agricultural development, conservation of forests, and the access to wild foods, especially where road access is limited. In line with Shackleton and Pandey (2014), we argue that the role of wild foods must be integrated into poverty alleviation programmes as well as taken into account in protected area management. Our study contributes to Sibathu et al. (2015)'s call for research that helps provide a better understanding of how agriculture and food systems can be made more nutrition-sensitive in particular situations – in the particular situation of shifting cultivation systems under increasing pressures from different land uses, including conservation and expanding cash crop production. The policy implications of our findings are that conservation and development policies need to devote attention to the linked sectors of health, poverty, and agriculture, and address how these linkages play out in the face of large-scale land use changes such as concessions and contract-farming schemes. Similar calls for integration of sectorial policies are made by Sarti et al. (2015); Shackleton et al. (2015) and van Vliet et al. (2015), among others. In Laos, the government's Land Use Plans are a major implementation tool for governing land use at a landscape level, and our study clearly shows the need for the above mentioned

cross-sectoral analysis, as outcomes pursued in land use planning may have unintended consequences on other aspects of rural livelihoods.

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Appendix A. Supplementary data

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