Ecosystem Services 17 (2016) 75–86

Contents lists available at ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser

A combination of methods needed to assess the actual use of provisioning ecosystem services

Laura Vang Rasmussen [a,b,*], Ole Mertz [a], Andreas E. Christensen [a], Finn Danielsen [c], Neil Dawson [d], Pheang Xaydongvanh [e]

[a] Department of Geosciences and Natural Resource Management, University of Copenhagen, Øster Voldgade 10, DK-1350 Copenhagen K, Denmark
[b] International Forestry Resources and Institutions (IFRI), School of Natural Resources & Environment, University of Michigan, United States
[c] Nordic Agency for Development and Ecology (NORDECO), Skindergade 23, DK-1159 Copenhagen K, Denmark
[d] School of International Development, University of East Anglia, Norwich, UK
[e] Faculty of Forestry, National University of Laos, Vientiane, Laos

ARTICLE INFO

Article history:
Received 19 February 2015
Received in revised form
28 October 2015
Accepted 10 November 2015

Keywords:
Ecosystem service availability
Southeast Asia
Shifting cultivation systems
The hidden harvest

ABSTRACT

Failure to recognize that potential provisioning ecosystem services are not necessarily collected and used by people may have important consequences for management of land and resources. Accounting for people's actual use of ecosystem services in decision making processes requires a robust methodological approach that goes beyond mapping the presence of ecosystem services. But no such universally accepted method exists, and there are several shortcomings of existing methods such as the application of land use/cover as a proxy for provisioning ecosystem service availability and surveys based on respondents' recall to assess people's collection of e.g. wild food. By combining four complementary methods and applying these to the shifting cultivation systems of Laos, we show how people's actual use of ecosystem services from agricultural fields differs from ecosystem service availability. Our study is the first in Southeast Asia to combine plot monitoring, collection diaries, repeat interviews, and participant observation. By applying these multiple methods borrowed from anthropology and botany among other research domains, the study illustrates that no single method is sufficient on its own. It is of key importance for scientists to adopt methods that can account for both availability of various services and actual use of those services.

1. Introduction

The importance of the concept 'ecosystem services' was elevated by the publication of the Millennium Ecosystem Assessment (MA) in 2005, a work involving over 1300 scientists. One of the outcomes of the MA was a call for research on measuring, modeling and mapping ecosystem services, and assessing changes in their delivery with respect to human wellbeing (Carpenter et al., 2006; Millennium Ecosystem Assessment, 2005; Sachs and Reid, 2006). Yet, the MA did not prescribe *how* to use the concept of ecosystem services (Seppelt et al., 2011). Since the completion of the MA, the number of scientific articles addressing ecosystems services has augmented exponentially (Fisher et al., 2009), and this ongoing research has revealed new challenges in the basic science needed to assess ecosystem services (Carpenter et al., 2009). The lack of consensus on methods that can be consistently applied makes it difficult for scientists to assist policy makers with robust recommendations on ecosystem service governance. Action is therefore needed to develop rigorous and practical approaches.

A wide spectrum of methods has been proposed to assess the availability and use of provisioning ecosystem services. These include site-scale and landscape-scale modeling, biophysical observations and economic studies (see Bagstad et al., 2013a for a review of 17 ecosystem service tools). But there are challenges to such studies. Too often, ecological and economic studies have been carried out separately from each other (Carpenter et al., 2006) and this has led to results that are difficult or impossible to use for decision-makers. Another challenge in existing approaches is that ecosystem services can be difficult to measure directly. The application of land cover/land use as a proxy for ecosystem service availability has accordingly been widespread (Bennett et al., 2009; Naidoo et al., 2008). Yet, the relationship between land use/land cover, ecosystem service availability and people's actual use of

* Corresponding author at: Department of Geosciences and Natural Resource Management, University of Copenhagen, Øster Voldgade 10, DK-1350 Copenhagen K, Denmark.
E-mail address: lrasmuss@umich.edu (L.V. Rasmussen).

http://dx.doi.org/10.1016/j.ecoser.2015.11.005

services remains untested in many regions of the world (Nelson et al., 2009). As the land use/land cover does not necessarily reveal which specific ecosystem services the landscape provides and whether people actually use those services, simple land use/land cover proxies might not adequately capture crucial information needed (Bennett et al., 2009). Rather, we need integrated social-ecological approaches that can differentiate between ecosystem conditions, availability of ecosystem services, and people's actual use of ecosystem services (Guerry et al., 2015).

In the present paper, we show how people's actual use of provisioning ecosystem services can be systematically examined through complementary methods that take both social and ecological factors into account. We focus on provisioning ecosystem services in shifting cultivation systems, and we pay special attention to people's use of services from agricultural fields. Such focus is particularly important as previous research on agricultural fields as sources of ecosystem services other than the main food crops has been limited (Schulp et al., 2014). This is remarkable as Scoones et al. (1992) already two decades ago called for a focus on the 'hidden harvest' from agricultural fields, especially wild food sources including both plants and animals. The concept of a hidden harvest refers to the fact that along with the major crops planted by the farmer, a range of plant material and animals can be found in agricultural fields that represent important sources of potential food, and in Borneo agricultural communities consume as many as 700 different wild and semi-wild plan species of which many come from fields and fallows (Christensen, 2002). In addition to being food sources, many wild plants also have medicinal and animal feed purposes (Cruz Garcia and Price, 2012). Some animals present in the arable lands are likewise essential food sources, especially with regards to proteins (Fiedler, 1994) although they often are deemed pests. Despite the obvious importance of these wild food sources, decades of official food security policies worldwide have tended to overlook their importance. The underestimation results from the lack of monetization of wild food as well as the lack of formal markets, and hence they are not captured in national level accounting (Dovie et al., 2007).

By contrast, a large body of prior research has focused on forest areas as providers of ecosystem services such as wild food, pharmaceuticals and a range of other non-timber forest products (NTFPs) (de Groot et al., 2010; Delang, 2006b; Heubach et al., 2011). A recent special issue of *World Development* included both global-comparative studies and case studies that assessed the environmental incomes local people gain from forest also referred to as forest-extractive incomes (Wunder et al., 2014). The popularization of the concept of ecosystem services has widened the attention of research to include land use types other than those deemed most important for the conservation of biodiversity, to consider the landscape scale and include a greater diversity of land use types including agricultural fields (de Groot et al., 2010; O'Farrell and Anderson, 2010). Failure to fully recognize the importance of agricultural fields in assessments of people's use of ecosystem services has potentially important consequences for management of land and resources. While recent studies have focused on the change towards more intensive collection among local people of the fewer species of economic value (Belcher et al., 2005; Kusters et al., 2006; Nanthavong et al., 2011), we concentrate on methods to assess the broad range of provisioning ecosystem services local people utilize from the agricultural fields. Our attention is devoted to four categories of provisioning ecosystem services: wild vegetables, wild meat, fodder, and medicinal plants.

The shifting cultivation systems of Southeast Asia provide a unique experimental area to test methods for assessing how people derive provisioning services from the fields. These landscapes deliver a broad variety of ecosystem services of which many have been exploited by local people to gain part of their subsistence. But current land use transitions from subsistence to commercial agriculture are likely to have profound impacts. As our attention is devoted to local people's use of services at the village level, ecosystems and their 'beneficiaries' are co-located. We define 'shifting cultivation' in line with Mertz et al. (2009): "*a land use system that employs a natural or improved fallow phase, which is longer than the cultivation phase of annual crops, sufficiently long to be dominated by woody vegetation, and cleared by means of fire*". We note that fallows should not be considered abandoned (Brookfield and Padoch, 1994; Mertz et al., 2009) as farmers will return not only for later cultivation, but also use the area to collect numerous provisioning ecosystem services such as wild food (Fox et al., 2000).

By using three villages in Laos as case studies, the paper illustrates advantages as well as pitfalls of four different methods. The selected complementary methods are (1) Monitoring of agricultural field plots to identify which provisioning services people derive from their fields during a growing season from field preparation to harvest, (2) Collection diaries used to estimate the amount and variety of provisioning services households collect from various land use types, (3) Semi-structured interviews with selected household members to validate and provide additional information on the observed collection of provisioning ecosystem services, and (4) Participant observation to witness the collection. We show that if the methods are applied on their own, they fall short of estimating local people's actual use of the ecosystem services. In contrast, when the methods are used in concert, they provide attractive means for scientists for obtaining a robust understanding of, not only, the presence and availability of ecosystem services, but also whether these services are used as goods. The findings illustrate the inadequacies of using land use/land cover as a proxy for ecosystem service use. When the methods are used in concert, the results can inform decision makers about which ecosystem services are deemed important and actually used by local people.

2. Literature review on common methodologies to assess actual use of provisioning ecosystem services in Southeast Asia

As there is no single methodology recommended to assess people's use of provisioning ecosystem services, we look into methods applied within the field of ethnoecology, which describes local people's interaction with the natural environment, including both plants and animals. Ethnoecology operates at the interface of several disciplines and methods are mainly drawn from anthropology, botany, ecology, and environmental economics. These methods include: (1) ecological surveys such as plot monitoring to understand the diversity and occurrence of various plants and animals as well as the harvesting quantities, (2) quantitative methods such as questionnaires or collection diaries to obtain data on e.g. people's actual use of various plants and animals, (3) qualitative methods such as semi-structured interviews or group interviews to acquire an in-depth understanding of human behavior related to the use of resources, and (4) participant observation such as landscape walks conducted in the research area (Albuquerque et al., 2014; Martin, 1995).

Since research on availability and use of provisioning ecosystem services in many ways resemble ethnoecological work, we propose that ecosystem service assessments would benefit from drawing on ethnoecological methodologies. Yet, a main argument brought forward already in the mid-1990s was that ethnoecologists should combine different methods and techniques borrowed from the various disciplines included in ethnoecology in order to

obtain a complete understanding of the human use of plants and animals (Martin, 1995). This argument still persists and in their recently published book, Albuquerque et al. (2014) call for multi-method approaches. To unravel whether ethnoecological and ecosystem service studies on availability and use indeed have adopted multi-method approaches, we reviewed how different methods have been applied by scholars to assess people's use of wild food, fodder, and medicinal plants. Our review was based on publications found through an ISI Web of Knowledge search of articles up to 2014 with the search terms "non-timber forest products", NTFP, "wild food", NWFP (non-wood tree products) or "provisioning ecosystem services". We restricted the search to Southeast Asia to obtain a manageable data set and because our empirical work was based in this region. The mentioned search terms were therefore combined with: Vietnam, Philippines, Laos, Cambodia, Thailand, Burma, Myanmar, Malaysia, Indonesia, East

Table 1
Outcome of an ISI Web of Knowledge search of methods used in studies of local people's collection of various products from the surrounding environment in Southeast Asia, 1990–2014.

	Collection diaries	*Food diaries*	*Group interviews*	*Interviews repeated during the season*	*Participant observation of the collection*	*Plots*	*Survey based on respondent's recall*
Boissiere et al. (2014)	x		x	x			x
Cruz-Garcia and Price (2014a)				x			x
Cruz-Garcia and Price (2014b)			x	x			
He et al. (2014)							x
Kang et al. (2014)			x	x	x		
Luskin et al. (2014)							x
Nuwer and Bell (2014)							x
da Costa et al. (2013)							x
Ju et al. (2013)			x		x		x
Kang et al. (2013)			x	x	x		
Kosaka et al. (2013)				x		x	
Cabuy et al. (2012)					x		x
Cruz Garcia and Price (2012)			x				x
Ghorbani et al. (2012)				x	x		
Rist et al. (2012)			x				x
Souphonphacdy et al. (2012)							x
Kang et al. (2012)			x	x	x		
Motzke et al. (2012)							x
Pangau-Adam et al. (2012)							x
Allebone-Webb et al. (2011)				x			
Boissiere et al. (2011)			x			x	x
Cruz-Garcia and Price (2011)			x	x	x		
Ghorbani et al. (2011)				x	x		
He et al. (2011)			x			x	x
Sopsop and Buot (2011)							x
He (2010)				x			
Huber et al. (2010)							x
Howell et al. (2010)				x			
Jensen and Meilby (2010)							x
McElwee (2010)							x
Rao et al. (2010)					x	x	x
Camacho et al. (2009)							x
He et al. (2009)			x				
Jensen (2009)							x
McElwee (2009)							x
Arora (2008)				x			
Jensen and Meilby (2008)							x
Kim et al. (2008)							x
McElwee (2008)							x
Huang and Long (2007)			x				x
Melick et al. (2007)						x	x
Delang (2006a)							x
Delang (2006b)							x
Ducourtieux et al. (2006)							x
Kabir and Webb (2006)			x			x	x
Salam et al. (2006)			x				
Wattanaratchakit and Srikosamatara (2006)						x	x
Rao et al. (2005)						x	x
Salick et al. (2005)			x				x
Lacuna-Richman (2004)							x
Long and Li (2004)			x	x	x		
Christensen (2002)			x	x	x		x
Tungittiplakorn and Dearden (2002)				x	x		
Ogle et al. (2001)				x			x
Somnasang and Moreno-Black (2000)							x
Somnasang et al. (1998)			x		x		x
Price (1997)	x		x		x		
Endicott and Bellwood (1991)	x	x		x	x		

Timor, Brunei or Yunnan. Moreover a second search was carried out using the terms meat and forest in combination with the listed country and region names. This was done in order to account for an increasing scientific focus on the contribution of wild meat to local people's diet (see e.g. Pangau-Adam et al., 2012; van Vliet and Nasi, 2008).

While the first search resulted in 120 publications, the second provided 43 results. Since the objective was to identify the methodologies used in published case studies on people's collection of various products or services derived from ecosystems, we omitted discussion papers as well as studies on one single product such as cardamom. We selected case studies specifically describing people's collection and use of various products from their surrounding environment, while we did not include publications that analyzed only the presence of various products. In total, 58 articles were considered relevant all published from 1990 to 2014 (Table 1). It should be noted that only one publication did actually refer to the collected products as provisioning ecosystem services, while the remaining studies primarily used the terms 'wild food' and 'NTFPs'. This final sample of 58 studies allowed us to draw conclusions on the common methods used by scholars to assess local people's use of various products in Southeast Asia.

As seen from Table 1, the most common method used was a survey based on people's recall. This method was applied in 69% of the identified studies ($n=58$). In these surveys, respondents were typically asked to list the species and amount they had collected on a yearly, seasonal or weekly basis. In 19% of the studies, a survey was used in combination with group discussions, while it was combined with participant observation in just 9% of the studies. Most of the studies that employed surveys based on recall were characterized by a relatively short fieldwork period (two to four weeks).

Studies with a longer duration of fieldwork would by contrast allow the researchers to carry out repeat interviews during the season. Repeat interviews were carried out in 33% of the 58 studies, and the majority of these studies combined the interviews with either group interviews or participant observation. Other methods that require a longer period in the field include plot monitoring and collection diaries. However, these methods were applied in very few studies (14% and 5% respectively; $n=58$), and no studies combined the two.

Although a complete literature review of whether scholars adopt a multi-method approach is beyond the scope of this paper, it is evident from the reviewed studies that the repeated calls for combined methods not have been heeded in studies of people's use of wild food, fodder, and medicinal plants. Rather, there is a methodological bias toward surveys based on respondents' recall. The review thereby illustrates the timely need to encourage and improve future applications of multi-method approaches. In the following sections, we demonstrate how such research can be carried out in the shifting cultivation systems of Southeast Asia.

Fig. 1. Location of the three study villages in Laos, the Nam-Et Phou Louey National Protected Area, and roads.

3. The study area

The study was carried out in three villages in Northern Laos: Phon Song in the Xon District, Khorn Ngua in the Hiam District, and Son Koua in the Houamuang district (Fig. 1). All villages were located in Huaphan Province. The region is characterized by a predominance of shifting cultivation, and the three study villages border the Nam-Et Phou Louey National Protected Area, the second largest national park in the country. The park was established in 1993, and its boundaries were expanded in 2009 (Castella et al., 2013). Areas of the park are designated as 'Total Protection Zone' or 'Controlled Used Zone', and there are rules for uses of these areas including hunting and NTFP collection. However, the formal rules do not necessarily reflect the reality of forest governance. But due to the inherently illegal nature of some of the household activities, households were assumed to be reluctant to exposing exactly where they hunted and collected various products. This hinders any analysis of exactly which part of the landscape is utilized, but we do not expect it to influence the study of availability and use of services from existing – and legally used-agricultural land. It should be noted that the landscapes also consist of forest which can be legally used, rivers and riparian habitats-all providing numerous and likely complementary services to local inhabitants.

Most shifting cultivation is concentrated on slopes with altitudes ranging from 200 to 1000 m above sea level, and slope gradients range from 0 to 130%. Rice and maize are the main crops, grown for 1–2 years before fallowing. The agricultural season can be divided into four sub-periods: the slash and burn period lasting from February to April (with a few households burning in May), the planting period from April to May, the weeding from late May to late August, and the harvesting occurring from September to October/November. Fields relatively close to the villages tend to have a shorter fallow period (3–4 years) than the fields located more than one hour walk from the villages where fallow length can be up to 18 years. However, the fallow period has in general been declining rapidly in recent years due to government interventions to protect forests (Bourgoin et al., 2013), and contract farming with a main focus on maize has been promoted as a way of turning traditional shifting cultivators into farm entrepreneurs (Castella et al., 2013; Vongvisouk et al., 2014). Especially in one of the villages (Phon Song), the impacts are profound as most maize cultivation has been continuous rather than rotational since its introduction. Across the villages, many households manage also paddy rice fields in the valley bottoms.

Although most foods are derived from the cultivated rice fields and domesticated animals, a recent study from Northern Laos has shown that a substantial part of the human diet comes from wild plants and animals (Castella et al., 2013). Moreover, other categories of provisioning ecosystem services such as fodder and natural medicine are assumed to play an essential role in these systems (Pfund et al., 2011). While part of these provisioning ecosystem services are likely to be collected daily by households for own consumption, others may be collected on a more seasonal basis for other purposes such as sale (Castella et al., 2013).

4. Methodology

The fieldwork in Laos was conducted over a 10 month period from February to November 2014. The first stage entailed introductions that served to legitimate the study ethically. In each of the villages, the village head was visited to seek authorization for the research and a community meeting was held to present the research and seek informed consent before the start of the study. At this meeting, the degree of participation that would be required was explained. In total 33 households, 11 in each village, were selected based on the principles of representativeness of (1) different fallow ages that would be cleared for cultivation; (2) fallow areas at short, medium and far away distances from the village.

Reasons for selecting monitoring of agricultural plots, collection diaries, semi-structured interviews, and participant observation as the four methods relate to the findings from the literature review showing that plots and diaries have, to our knowledge, not previously been combined. Interviews and participant observation were chosen as additional methods which could logistically be conducted alongside plots and diaries while the researcher was present in the village. Method selection was therefore also influenced by practical considerations of trying to keep the data collection somewhat cost-effective.

4.1. Method 1: agricultural plot monitoring

Areas of fallow vegetation which were due to be slashed in preparation for cultivation in the following months were identified and visited. In each of these areas, three permanent plots of 10×10 m^2 were randomly distributed and established by marking each plot corner (SE, NE, SW, and NW). In total, this amounted to 99 plots (three plots per household and 33 plots in each village). The established plots covered fallow periods ranging from 0 to 18 years. A fallow period of 0 years referred to the fact that two households were planning to re-crop existing rice fields, while 11 households re-cropped existing maize fields, primarily due to land shortages.

Observations taken from the areas that were going to be cultivated included slope gradient, fallow period, land use history, and a list of all tree and plant species in the plot. While establishing the plots, we explained to participants the importance of maintaining their normal cultivation practices and not change behavior due to selection of the plots as this would compromise the research design.

Each plot was accordingly re-visited and monitored four times during the cultivation season: during slashing, planting, weeding and harvest. The plots were visited together with a member from the household that cultivated the plot, and a detailed inventory was conducted on each sampling plot. The following observations were made for each plot: recording of dominant weed species and a visual estimation of the coverage; wildlife crop-damage monitoring designed to provide descriptive assessments of wildlife species that had caused the damage and a visual estimation of the area damaged; and household collection of certain resources measured as frequency and quantity. These resources were: wild food including vegetables and meat, medicinal plants, and fodder. With regards to the category of wild meat, animal taxa were used for the sake of brevity, rather than each species individually. For the remaining categories, the collected plants could be stored, and the individual species identified by the research assistant.

4.2. Method 2: collection diaries

In collaboration with research assistants, the 33 households recorded their collection of various products on a daily basis, for a period of one week during slashing, planting, weeding, and harvesting. This amounted to a cumulative census effort of 924 days of collection recordings.

Details about the products collected, the quantity taken, the household member collecting it, the location of collection, and the final use (consumed or traded), were all recorded. The collection diary method was inspired by studies carried out in Burkina Faso and Borneo where food diaries were used to assess the consumption of wild vegetables (Christensen, 1997; Lykke et al., 2002; Mertz et al., 2001). In these studies, the participating households (14) kept diaries of food ingredients consumed for all meals, and

whether these products were cultivated, collected in the wild, or purchased.

In the present study, the 33 participating households were visited by research assistants every evening during the four weeks of recordings. It was decided to collect dairies on a daily rather than weekly basis in order to minimize memory lapse. The daily visits to the households prompted a great level of detail as the products that had been collected during the day were often shown and discussed with the research assistant. When the households were visited, the research assistant helped with the recordings as a large percentage of the households were illiterate and independent recording would be very difficult. Although these very frequent visits were extremely labor intensive, they were considered a necessity. For example, when a few households were missed some evenings due to other obligations, they were accordingly asked to recall the collection for the previous day (s) which turned out to be more difficult than anticipated. It is acknowledged that this method might lack in precision as the most accurate method would be to ask people to weight or measure the collected items every day. However, if this was to be combined with research assistants helping with the recordings, it would be even more labor intensive. Thus, the chosen design is based on the fact that most prior research has had point of departure in people's recall of extracted products (Table 1), and a method based on daily recordings of the approximate amount collected has therefore been called for (Delang, 2006b).

The choice of conducting daily rather than weekly visits implied that diaries were kept in sample weeks instead of during the whole year as this would be too costly, especially in terms of the household response burden. As the sample weeks were spread evenly over the agricultural season, it was possible to get an average collection of the various products over the season, but also the seasonality patterns in the collection.

Further, households were asked to register where the collection of each product took place. The diaries thereby also allowed an overview of the relative importance of agricultural fields as providers of various products as compared to other land use types such as the primary forest.

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 specific day.

4.3. Method 3: repeat semi-structured interviews

During the beginning of the agricultural season and after the harvest, semi-structured interviews were conducted with members of the participating households to validate and provide additional information about the patterns emerging from the diary and plot data. For example, reasons for seasonal variation in the collection of specific products were discussed in detail with the households. Another theme of discussion was the travel time for resource extraction. Households were, for example, asked to explain how the travel time to their plots, fallow or forest influenced collection of various products. The choice of using interviews as a follow-up method rather than as a primary data collection method was made as we aimed for a high level of detail in collection patterns which may be difficult to capture with interviews. This is for example evident in prior interview-based research on the collection of wild vegetables (see e.g. High and Shackleton, 2000). In such interviews, individual species are often pooled and seasonal collection variations may be overlooked as the frequency of harvest is used to construct an estimate of the total production. Unless the interviews are repeated many times over the agricultural season, they may insufficiently grasp seasonal patterns.

4.4. Method 4: participant observation through landscape walks

As people usually collect various items on the way back from the field or the river (where they go fishing and washing), each of the 33 households were accompanied on these walks during the agricultural season. The aim was to get an overview of what people gathered and where rather than to get exact estimates of the extraction. During the walks the products obtained from the different land use types were discussed.

4.5. Possible combinations of the four methods

What then is the way to combine the four methods? Since the data collection efforts must strike a balance between rigor and feasibility, using all four methods in conjunction will often be too expensive. In the empirical study presented in the following sections, we outline how the methods can be combined and which type of information those combinations provide (Table 2). Depending on which question one seeks to answer, we propose combinations of the methods that would appear well suited to address that question. The empirical study will then allow us to point to pitfalls and opportunities related to commonly employed methods and their usefulness for assessing the actual use of ecosystem services.

5. Results

5.1. Types of uses: combining diaries and plots to identify main uses of ecosystem services

To assess which types of provisioning ecosystem services local people actually derive from the agricultural fields, we combined collection diaries and plot monitoring. We found that the two methods yielded the same results for the ranking of most frequently collected products used as wild meat and fodder (Table 3). For the wild vegetables, the collection diaries and the plot monitoring produced minor discrepancies in the ranking. As for the use of natural medicines, both methods revealed very limited collection from fields during the agricultural season.

5.2. Variations over time: combining diaries and plots to assess seasonal variations in ecosystem service use

With regard to potential seasonal variations in local people's use of ecosystem services, we found the same pattern for collection peak and low periods during the agricultural season when we compared our data derived from collection diaries and plot monitoring. The hunting and trapping of rats substantiate this point. Rat meat was amongst the preferred meat eaten, and the data from the diaries showed that both the frequency of rat-trapping-events and the number of rats collected increased from the slashing to the weeding period and then declined to the harvest period ($n=250$ rats) (Fig. 2). The same pattern of change was observed in rat collection from the plots ($n=76$ rats). The diary data displayed, however, a greater number of rats collected.

5.3. Variations between areas: combining diaries and interviews to estimate the importance of agricultural fields as compared to other land use types

Our comparison of key collection locations by estimates from the diary data and by semi-structured interviews revealed large differences (Table 4). Wild vegetables and wild meat were used as illustrative cases. Our diary data showed that agricultural fields were of greatest importance for the collection, far more important

Table 2
Possible combinations of four generic methods to examine mismatches between (1) the availability, and (2) local people's actual use of ecosystem services from agricultural fields. The type of information that can be obtained from each combination of methods is outlined.

	Plot monitoring	Collection diaries	Repeat semi-structured interviews	Participant observation
Plot monitoring		• Types of uses • Seasonal variations • Availability vs. use	• Types of uses • Household rationales	• Types of uses (primarily from plots)
Collection diaries			• Types of uses • Seasonal variations • Variations between collection areas • Household rationales	• Types of uses • Seasonal variations • Variations between collection areas
Repeat semi-structured interviews				• Household rationales • Qualitative descriptions of perceived use patterns
Participant observation				

than the primary forest. During the interviews most households emphasized by contrary the importance of old fallow areas and primary forest. They stressed that these areas were very productive sources of the desired species and products. When interviewees were confronted with the higher collection frequency of especially wild vegetables and meat from agricultural fields, they explained this by the proximity of these areas to the village and by the fact that products from the fields could be collected or trapped as part of the normal farming activity. The households did not perceive it as 'collection' as such as this kind of collection did not require an extra labor input. Therefore, they did not mention it at first during the interviews. In contrast, in the diaries they were asked specifically to list all the products they had put in their basket or bags during the day and that included several items taken from the fields.

5.4. Combining methods to assess a possible mismatch between presence and use of services

Our findings derived from the diary data and the plot data showed that people's actual collection of products from agricultural fields mainly entailed vegetables and meat, while the collection of fodder and medicinal plants was more infrequent. The question is whether these services (fodder and medicinal plants) were not available in the agricultural fields, or if some provisioning ecosystem services went unused? In order to explore this, we mapped the provisioning ecosystem services present in agricultural fields.

Table 3
Diary data and plot data: most frequently collected provisioning ecosystem services from agricultural fields in and adjacent to the Nam-Et Phou Louey National Protected Area, Northern Laos. Diary data consisted of 28 days of recording for 33 households (n=924 household-days). Plot data included 99 plots.

Potential use	Data on most frequently collected products derived from:	
	Collection diaries	Plot monitoring
Wild vegetables	1. Bamboo shoots (*G. albociliata*) 2. Phak tumtaeng (*S. americanum*) 3. Fern *(L. salicifolium)*	1. Fern *(L salicifolium)* 2. Bamboo shoots (*G. albociliata*) 3. Thickhead (*C. crepidioides*)
Wild meat	1. Rat (*Rattus* sp.) 2. Grasshopper (*Caelifera* sp.) 3. Bamboo weevil (*Cyrtotrachelus longimanus)*	1. Rat (*Rattus* sp.) 2. Grasshopper (*Caelifera* sp.) 3. Bamboo weevil (*Cyrtotrachelus longimanus)*
Fodder	1. Air potato (*D. bulbifera*) 2. Thickhead (*C. crepidioides*) 3. Forest banana (*Musa* spp.)	1. Air potato (*D. bulbifera*) 2. Forest banana (*Musa* spp.) 3. Thickhead (*C. crepidioides*)
Natural medicines	Very limited collection	Very limited collection

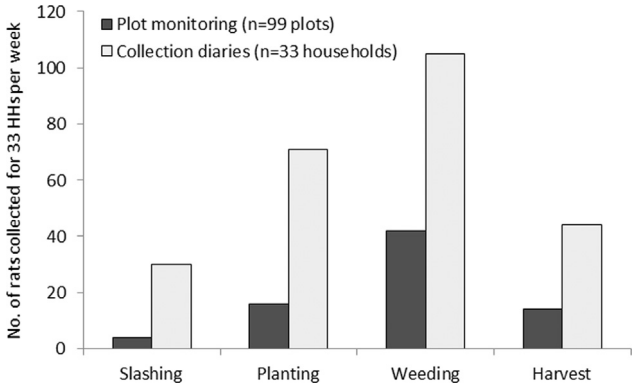

Fig. 2. Diary data and plot data: seasonal variation in households' collection of rats from agricultural fields in and adjacent to the Nam-Et Phou Louey National Protected Area, Northern Laos. Diary data consisted of 28 days of recording for 33 households (n=924 household-days and 250 rats) and plot data included 99 plots (n=76 rats). HH=household.

Based on the plot data, we found a clear mismatch between the presence of four plant species (*L. salicifolium, C. crepidioides, Eleusine indica, and C. odorate*) and people's actual utilization of the same species (Table 5). These species were all widely available in the plots and at the same time they had potential uses such as food, fodder and medicine purposes. Our data showed that most of these species went unused, except for the fern (*L. salicifolium)* which was utilized as a vegetable – but this was only from 38% of those plots in which it was present.

The interviews revealed that the main reason for people's inclination to harvest and utilize those plant species for medicine purposes was the construction of health centers. Products from these centers had substituted the use of medicinal plants implying that the use of medicinal plants had somewhat been decoupled of their presence in the fields.

6. Discussion

Existing studies of people's use of provisioning ecosystem services rely on a wide spectrum of methods, and there is no consensus on one adequate method to capture the possible mismatch between ecosystem service availability and actual use of those services. What we have tried to point out above, with an empirical focus on shifting cultivation systems in Laos and special attention given to the agricultural fields, is that if scientists are to more fully understand people's use of provisioning ecosystem services, a

Table 4
Diary data and interview data: Main locations of the collection of wild vegetables and bushmeat in and adjacent to the Nam-Et Phou Louey National Protected Area, Northern Laos. Diary data consisted of 28 days of recording for 33 households (n=924 household-days). Interviews were carried out with the same households.

Potential use	Data derived from:		
	Collection diaries		Repeat semi-structured interviews
	Top 3 collection locations in terms of frequency of collection-days	*Collection frequency pr. week and pr. household*	*Main collection location as perceived by households*
Wild vegetables	1. Fields	~3 times	Primary forest and old fallow
	2. Young fallow	~2 times	
	3. Old fallow	~1 time	
Wild meat	1. Fields	~2 times	Primary forest and old fallow
	2. Primary forest	<1 time	
	3. Young fallow	<1 time	

combination of methods is needed. Depending on how emphasis is being placed on the range of different use aspects, certain combinations of methods would appear to be more logical choices. For instance, it will matter for the selection of methods whether attention is devoted to the different types of uses, variations over time, or variations between use areas. As we will argue below, all the suggested methods have pitfalls if applied on their own, but if they are applied in concert they can reveal not only which ecosystem services the agricultural fields provide but also, critically, whether local people actually use those services (Table 6).

6.1. Potential limitations in suggested combinations of methods

What then are the pitfalls related to various combinations of methods? Firstly, if emphasis is being placed on identifying the broad range of provisioning services that local people derive from the fields, the similarity between the results derived from plot monitoring and collection diaries suggests that both methods are equally suitable. It may even be argued that each method can be applied on its own, and plots have in fact been promoted as a promising avenue for assessing the 'hidden harvest' from agricultural fields (Kosaka et al., 2013). But an approach based solely on plots has some pitfalls. For example, the plot data did not reveal whether people had collected additional services from other fields than their own. Moreover, even with carefully selected plots it remains a challenge to establish a sufficient number of representative plots in very diverse landscapes. If the methods are to stand alone, the diaries therefore appear more rigorous.

Secondly, if attention is devoted to seasonal variations in people's collection patterns, the results likewise indicated that plot monitoring and diaries are equally valid methods. Yet, the plot data allowed us to estimate the collection quantity from the plots, and not from all the agricultural fields. Since households hunted rats from a great number of agricultural fields, not only from the fields in which we had plots laid out, the plots did not give a comprehensive picture of the amount of rats derived from all fields. This also explained the significantly higher estimate obtained from the diaries (Fig. 2). The plot data did, however, provide an overview of the relative importance of each period from slashing to harvest. One might then be tempted to think that collection diaries could be applied on their own, especially since they can utilize daily data. Indeed, collection diaries can improve on our descriptive analysis by incorporating the diversity of products collected (such as the type of meat), the frequency of collection, and thereby detailed seasonality patterns for different products (for example, the peak period for specific types of vegetables). Yet, we doubt that collection diaries can be used on their own since the diaries crucially relied on very specific time periods. This meant that the collection of some products with a peak period in the dry season was not included in the data sets. However, as the main focus of the presented study was the agricultural season, this was not considered a major concern, but studies aiming to assess use of ecosystem services over a whole year should account for such issues. Moreover, diaries cannot reveal whether people actually are so dependent on food collection that they react sharply to relatively minor decreases in the availability of ecosystem services. Interviews could be conducted to unravel seasonal patterns in the collection of main food products like vegetables and meat (e.g. Jones et al., 2008).

Thirdly, if the aim is to estimate what role agricultural fields play as compared to other land use types, caution must be warranted about semi-structured interviews if they are to be applied on their own. The discrepancy between people's perceptions of most important areas for collection and the results from the diaries indicated that the interviews would fall short in relation to obtaining an understanding of the actual use of ecosystem services from agricultural fields. Even though primary forest areas – in theory-may be better for the collection of various products and therefore were deemed most important in local people's self-evaluations of collection patterns, the diary data revealed how primary forest was not the main harvesting source of any categories of provisioning services. This finding is interesting as it also contradicts the pattern seen when land use/land cover data are used as a proxy to quantify use of ecosystem services (Bennett et al., 2009). Forest areas are here highlighted as a landscape type with a high capacity of provisioning ecosystem services such as wild food and

Table 5
Diary data, interview data, and plot data: the linkages between availability and use of four plant species in and adjacent to the Nam-Et Phou Louey National Protected Area, Northern Laos. Diary data consisted of 28 days of recording for 33 households (n=924 household-days). Interviews were carried out with the same households. Plot data included 99 agricultural plots.

		Data derived from:		
Potential use	**Species**	**Collection diaries**	**Repeat semi-structured interviews**	**Plot monitoring**
Wild vegetables, fodder and natural medicines	*Lygodium salicifolium*	Unused by 42% of households	Gathered and used when needed	Present in 48% of plots Unused in 62% of those plots in which it is present
	Crassocephalum crepidioides	Unused by 42% of households	Gathered and used when needed	Present in 48% of plots Unused in 83% of those plots in which it is present
	Eleusine indica	Unused by all households, except for one	The use as a medicine plant has been substituted by products from a health center	Present in 19% of plots Unused in all plots in which it is present
Natural medicines	*Chromolaena odorate*	Unused by all households, except for one	The use as a medicine plant has been substituted by products from a health center	Present in 59% of plots Unused in all plots in which it is present except for one

Table 6
Possible combinations of four generic methods to examine mismatches between (1) the availability, and (2) local people's actual use of ecosystem services from agricultural fields. Pros and cons for each combination are outlined.

	Plot monitoring	Collection diaries	Repeat semi-structured interviews	Participant observation
Plot monitoring		**Pros** • Allow detailed descriptions of types of uses • Provide quantitative estimates of seasonal variations • Indicate potential mismatches between availability and use **Cons** • Require researcher presence throughout an agricultural season • Lack attention to household collection rationales	**Pros** • Allow descriptions of types of uses from plots • Provides insight on household rationales **Cons** • Require researcher presence throughout an agricultural season • Do not allow quantitative estimates of seasonal variations • Do not allow quantitative estimates of variations between different collection areas	**Pros** • Allow descriptions of types of uses from plots **Cons** • Require researcher presence throughout an agricultural season • Lack attention to household collection rationales • Do not allow quantitative estimates of variations between different collection areas
Collection diaries			**Pros** • Allow detailed descriptions of types of uses • Provide quantitative estimates of seasonal variations • Provide quantitative estimates of variations between different collection areas • Provide insight on household rationales **Cons** • Require researcher presence throughout an agricultural season • Lack attention to possible mismatches between availability and use	**Pros** • Allow detailed descriptions of types of uses • Provide quantitative estimates of seasonal variations • Provide quantitative estimates of variations between different collection areas **Cons** • Require researcher presence throughout an agricultural season • Lack attention to possible mismatches between availability and use
Repeat semi-structured interviews				**Pros** • Provide insight on household rationales **Cons** • Do not allow quantitative estimates of seasonal variations • Do not allow quantitative estimates of variations between different collection areas • Lack attention to potential mismatches between availability and use
Participant observation				

medicinal plants (Burkhard et al., 2009). In fact, primary forests are often assumed to be an exceptionally important source of edible plants and animals, ranging from bush meat to vegetables (de Groot et al., 2002; Lele et al., 2013). Based on our observations from the collection diaries, we caution against assumptions that local people are by default exploiting these services as factors such as proximity to forest areas may decide whether or not the services are actually collected and used by people. In line with these observations, a recent study from Rwanda revealed that local people primarily acquired provisioning ecosystem services from habitats outside of native forest, and that the use of services from native forests was mediated by the availability of substitutes (Dawson and Martin, 2015). However, it should be noted that collection diaries as well have some limitations as participants may fail to record all collected products whereas others may exaggerate, especially regarding socially desirable activities (Menton et al., 2009). Our study was undertaken across villages that (1) are located in and adjacent to a National Protected Area and (2) constitute various degrees of marketization, and we believe our findings are representative of the ecological and socioeconomic contexts in shifting cultivation systems of Southeast Asia.

6.2. *Implications for future design of studies to assess use of provisioning ecosystem services*

Our findings suggest that change is needed in the way scientists assess people's actual use of provisioning ecosystem services, not only when focus is on the agricultural fields in shifting cultivation systems but also when comparisons are made between the ability of different land use types to provide services to their inhabitants. The current methodological bias among scholars toward surveys based on respondents' recall (Table 1) is worrying as our empirical findings suggest that people's self-evaluations may not capture a number of important facets of the collection patterns. Unless surveys or interviews are carried out many times over the agricultural season, memory lapse must, for example, be considered a substantial shortcoming (Jones et al., 2008).

In our study, the possible memory lapse became especially apparent during interviews conducted after the harvesting season, when households were asked to describe the collection of e.g. wild meat. The clear seasonal pattern showed in Fig. 2 was not described by any of the 33 households, and in general it seemed difficult for households to provide exact amounts of rats collected during different periods of the agricultural. Moreover, local people collected products such as vegetables several times a day, and the interviews appeared to fall short on including a sufficient level of detail for aggregate data to be correct. The shortcomings of interviews to assess this level of detail have also been demonstrated by a prior study that employed interviews and food diaries, and it was shown how interviews may not be sufficient to analyze the importance of individual plant species (Mertz et al., 2001). Given these deficiencies of interviews based on respondents' recall, it is problematic that most studies focusing on NTFPs have been based on fieldwork carried out some weeks or even months after the respondents' collection of certain products. In sum, we are skeptical of the value of recall interviews by scientists if the purpose of the study is a detailed mapping of collection patterns. However, in a recent study on wild resource use (Gray et al., 2015), repeated household surveys were found especially useful to provide region-wide quantitative estimates of resource use practices although it was suggested that a desirable extension of the approach would be to include biological sampling. Our interviews provided valuable insight about the households' motivations and rationales for collecting various ecosystem services as well as on the factors that influenced the observed collection patterns: insight pertinent to understand the possible mismatches between ecosystem availability and use.

Our findings have demonstrated the need for a multi-method approach and for all the combinations outlined, participant observation through landscape walks proved valuable to grasp more detail on the apparent mismatch between ecosystem service availability and people's actual utilization of those services. The products collected by households during the walks sparked conversations about associated products available and their use. Starting with a single product collected during a landscape walk, allowed interviews to be focused on the range of associated products available and the use of certain products over others.

Finally, it should be noted that when selecting methods the time effort and data-density must be considered. As estimated by Christensen (1997) only after 10–12 weeks of walks with different informants in Borneo did the number of new recordings of useful species level off. For the four methods we propose to apply at the village scale, the data collection requires presence in the village in at least four weeks evenly distributed over the agricultural season plus time for introduction and training of field assistants. The methods are, however, not particular time consuming on their own implying that all four methods can be embraced within the time period the researcher is in the field – of course depending on the sample size. As each method has a bias, we argue that using several methods and making sure that those methods do not have the same bias provides for a better understanding of the potential mismatch between ecosystem service availability and use. It is pertinent to develop common methods that can capture when an ecosystem is actually delivering benefits to people. Only by doing so can we derive the knowledge needed to create a sound basis for planning interventions or policies intended to either minimize loss of certain services or enhancing the use of other services (Bagstad et al., 2013b). When beneficiaries and ecosystems are not co-located, it becomes even more pertinent to map and understand which services are actually used by people-for example in cases where different beneficiary groups compete for the same ecosystem services.

7. Conclusion

Most existing studies of local people's use of provisioning ecosystem services are based on the implicit assumption that ecosystem services provided from specific habitats will be collected and used by people. What we have tried to point out above, with an empirical focus on the agricultural fields in the shifting cultivation systems of Laos, is that ecosystem service availability does not necessarily imply use of those services. Rather, many services go unused. But what are then the methods that can capture this apparent mismatch between ecosystem service availability and people's actual use of services?

The present case study is, to our knowledge, the first to combine monitoring of agricultural plots, collection diaries, repeat interviews and participant observation in a Southeast Asian context. By doing so, the apparent mismatch between ecosystem service availability and people's actual utilization of those services becomes remarkably clear. These findings could not have been obtained based on one single method. Specific cases substantiate this point. For example, interviews based on re-call, self-evaluations, and perceptions of collection patterns turned out to yield rather different results than the diaries and plot monitoring which were based on observations of actual collection. Caution should therefore be warranted about interviews as a stand-alone method although it proved very valuable to identify possible causes of the observed mismatch between presence and people's actual use of certain services. At the empirical level, the discrepancy between people's perceptions of most important areas for collection and the results from the diaries offers another important area for

further investigation.

In sum, our empirical findings show how four different methods can complement each other and that different methods are indeed needed to challenge the common simplified assumption that ecosystem services provided from specific habitats will be collected and used by people. This reiterates the need to find a common way of combining methods borrowed from e.g. ecology and anthropology which is still lacking despite repeated calls for multi-method approaches. Rather, most case studies rely on a single method such as surveys that do not fully elucidate the diversity, extent, and seasonal variability in people's use of provisioning ecosystem services. The purpose of applying four different methods has been to select complementary methods, and to demonstrate the value of this complementarity, rather than to identify the single best method for assessing use of ecosystem services. By doing so, we have illustrated specific combinations of methods that would appear logical depending on how emphasis is being placed when scientists assess people's use of provisioning ecosystem services. At the methodological level, the findings illustrate how scholars need to integrate different methods more insistently with substantive concerns about the shortcomings of interviews. At the empirical level, the results serve to inform decision makers about which ecosystem services are deemed important and actually used by local people. Moreover, the findings demonstrate the importance of the hidden harvest from agricultural fields which both local people and policy makers tend to forget due to the lack of monetization of wild food.

Acknowledgments

This paper has been developed as part of the project 'Ecosystem Services, Wellbeing and Justice: Developing Tools for Research and Development Practice' (Grant no. NE/L001411/1), funded with support from the Ecosystem Services for Poverty Alleviation (ESPA) programme. The ESPA programme is funded by the Department for International Development (DFID), the Economic and Social Research Council (ESRC) and the Natural Environment Research Council (NERC). -See more at: http://www.espa.ac.uk

We have benefited from discussions with the PI Thomas Sikor, Sithong Thongmanivong, and other team members of the project, and these discussions are gratefully acknowledged. This research contributes to the Global Land Project. We thank two anonymous reviewers for helpful comments.

References

Albuquerque, U.P., Ramos, M.A., de Lucena, R.F.P., Alencar, N.L., 2014. Methods and techniques used to collect ethnobiological data. In: Albuquerque, U.P., Cruz da Cunha, L.V.F., de Lucena, R.F.P., Alves., R.R.N. (Eds.), Methods and Techniques in Ethnobiology and Ethnoecology. Springer, New York.

Allebone-Webb, S., Kuempel., N., Rist, J., Cowlishaw, G., Rowcliffe, J., Milner-Gulland, E., 2011. Use of market data to assess bush meat hunting sustainability in equatorial guinea. Conserv. Biol. 25, 597–606.

Arora, D., 2008. The houses that matsutake built. Econ. Bot. 62, 278–290.

Bagstad, K.J., Semmens, D.J., Waage, S., Winthrop, R., 2013a. A comparative assessment of decision-support tools for ecosystem services quantification and valuation. Ecosyst. Serv. 5, 27–39.

Bagstad, K.J., Johnson, G.W., Voigt, B., Villa, F., 2013b. Spatial dynamics of ecosystem service flows: a comprehensive approach to quantifying actual services. Ecosyst. Serv. 4, 117–125.

Belcher, B., Ruiz-Perez, M., Achdiawa, R., 2005. Global patterns and trends in the use and management of commercial NTFPs: Implications for livelihoods and conservation. World Dev. 33, 1435–1452.

Bennett, E.M., Peterson, G.D., Gordon, L.J., 2009. Understanding relationships among multiple ecosystem services. Ecol. Lett. 12, 1394–1404.

Boissiere, M., Bastide, F., Basuki, I., Pfund, J., Boucard, A., 2014. Can we make participatory NTFP monitoring work? Lessons learnt from the development of a multi-stakeholder system in Northern Laos. Biodivers. Conserv. 23, 149–170.

Boissiere, M., Sheil, D., Basuki, I., 2011. A booming trade? How collection of war residues affects livelihoods and forest in Vietnam. Int. For. Rev. 13, 404–415.

Bourgoin, J., Castella, J.C., Hett, C., Lestrelin, G., Heinimann, A., 2013. Engaging local communities in low emissions land-use planning: a case study from Laos. Ecol. Soc. 18, 9.

Brookfield, H., Padoch, C., 1994. Appreciating agrodiversity: a look at the dynamism and diversity of indigenous farming practices. Environ.: Sci. Policy Sustain. Dev. 36, 6–45.

Burkhard, B., Kroll, F., Müller, F., Windhorst, W., 2009. Landscapes' capacities to provide ecosystem services-a concept for land-cover based assessments. Landsc. Online 15, 1–22.

Cabuy, R.L., Marwa, J., Manusawai, J., Rahawarin, Y.Y., 2012. Non-woody plant species of Papuan Island forests, a sustainable source of food for the local communities. Indian J. Tradit. Knowl. 11, 586–592.

Camacho, L.D., Camacho, S.C., Yeo-Chang, Y., 2009. Values of forest products in the Makiling Forest Reserve (MFR), Philippines. For. Sci. Technol. 5, 35–44.

Carpenter, S.R., Mooney, H.A., Agard, J., Capistrano, D., Defries, R.S., Diaz, S., Dietz, T., Duraiappah, A.K., Oteng-Yeboah, A., Pereira, H.M., Perrings, C., Reid, W.W., Sarukhan, J., Scholes, R.J., Whyte, A., 2009. Science for managing ecosystem services: beyond the Millennium Ecosystem assessment. Proc. Natl. Acad. Sci. USA 106, 1305–1312.

Carpenter, S.R., DeFries, R., Dietz, T., Mooney, H.A., Polasky, S., Reid, W.W., Scholes, R.J., 2006. Millennium ecosystem assessment: research needs. Science 314, 257–258.

Castella, J.C., Lestrelin, G., Hett, C., Bourgoin, J., Fitriana, Y., Heinimann, A., Pfund, J.L., 2013. Effects of landscape segregation on livelihood vulnerability: moving from extensive shifting cultivation to rotational agriculture and natural forests in Northern Laos. Hum. Ecol. 41, 63–76.

Christensen, H., 1997. Uses of plants in two indigenous communities in Sarawak, Malaysia (Ph.D. thesis). Department of Systematic Botany, Institute of Biological Sciences, University of Aarhus, Denmark.

Christensen, H., 2002. Ethnobotany of the Iban and the Kelabit. Kuching and Aarhus, Forest Department, Sarawak; NEPCon and University of Aarhus.

Cruz Garcia, G.S., Price, L.L., 2012. Weeds as important vegetables for farmers. Acta Soc. Bot. Pol. 81, 397–403.

Cruz-Garcia, G.S., Price, L.L., 2011. Ethnobotanical investigation of'wild' food plants used by rice farmers in Kalasin, Northeast Thailand. J. Ethnobiol. Ethnomed. 7, 33.

Cruz-Garcia, G.S., Price, L.L., 2014a. Gathering of wild food plants in anthropogenic environments across the seasons: implications for poor and vulnerable farm households. Ecol. Food Nutr. 53, 363–389.

Cruz-Garcia, G.S., Price, L.L., 2014b. Human-induced movement of wild food plant biodiversity across farming systems is essential to ensure their availability. J. Ethnobiol. 34, 68–83.

da Costa, M.D., Lopes, M., Ximenes, A., Ferreira, Ad.R., Spyckerelle, L., Williams, R., Nesbitt, H., Erskine, W., 2013. Household food insecurity in Timor-Leste. Food Secur. 5, 83–94.

Dawson, N., Martin, A., 2015. Assessing the contribution of ecosystem services to human wellbeing: a disaggregated study in western Rwanda. Ecol. Econ. 117, 62–72.

de Groot, R.S., Alkemade, R., Braat, L., Hein, L., Willemen, L., 2010. Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecol. Complex. 7, 260–272.

de Groot, R.S., Wilson, M.A., Boumans, R.M.J., 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecol. Econ. 41, 393–408.

Delang, C.O., 2006a. Indigenous systems of forest classification: Understanding land use patterns and the role of NTFPs in shifting cultivators' subsistence economies. Environ. Manag. 37, 470–486.

Delang, C.O., 2006b. Not just minor forest products: the economic rationale for the consumption of wild food plants by subsistence farmers. Ecol. Econ. 59, 64–73.

Dovie, D.B.K., Shackleton, C.M., Witkowski, E.T.F., 2007. Conceptualizing the human use of wild edible herbs for conservation in South African communal areas. J. Environ. Manag. 84, 146–156.

Ducourtieux, O., Visonnavong, P., Rossard, J., 2006. Introducing cash crops in shifting cultivation regions-the experience with cardamom in Laos. Agrofor. Syst. 66, 65–76.

Endicott, K., Bellwood, P., 1991. The possibility of independent foraging in the rainforest of Peninsular Malaysia. Hum. Ecol. 19, 151–185.

Fiedler, L.A., 1994. Rodent Pest Management in Eastern Africa. FAO, Rome.

Fisher, B., Turner, R.K., Morling, P., 2009. Defining and classifying ecosystem services for decision making. Ecol. Econ. 68, 643–653.

Fox, J., Truong, D.M., Rambo, A.T., Tuyen, N.P., Cuc, L.T., Leisz, S., 2000. Shifting cultivation: a new old paradigm for managing tropical forests. BioScience 50, 521–528.

Ghorbani, A., Langenberger, G., Feng, L., Sauerborn, J., 2011. Ethnobotanical study of medicinal plants utilised by Hani ethnicity in Naban River Watershed National Nature Reserve, Yunnan, China. J. Ethnopharmacol. 134, 651–667.

Ghorbani, A., Langenberger, G., Sauerborn, J., 2012. A comparison of the wild food plant use knowledge of ethnic minorities in Naban River Watershed National Nature Reserve, Yunnan, SW, China. J. Ethnobiol. Ethnomed. 8, 17.

Gray, C.L., Bozigar, M., Bilsborrow, R.E., 2015. Declining use of wild resources by indigenous peoples of the Ecuadorian Amazon. Biol. Conserv. 182, 270–277.

Guerry, A.D., Polasky, S., Lubchenco, J., et al., 2015. Natural capital and ecosystem services informing decisions: from promise to practice. Proc. Natl. Acad. Sci. 112 (24), 7348–7355.

He, J., 2010. Globalised forest-products: commodification of the matsutake

mushroom in Tibetan villages, Yunnan, Southwest China. Int. For. Rev. 12, 27–37.
He, J., Dong, M., Stark, M., 2014. Small mushrooms for big business? Gaps in the sustainable management of non-timber forest products in Southwest China. Sustainability 6, 6847–6861.
He, J., Zhou, Z., Weyerhaeuser, H., Xu, J., 2009. Participatory technology development for incorporating non-timber forest products into forest restoration in Yunnan, Southwest China. Ecol. Manag. 257, 2010–2016.
He, J., Zhou, Z., Yang, H., Xu, J., 2011. Integrative management of commercialized wild mushroom: a case study of thelephora ganbajun in Yunnan, Southwest China. Environ. Manag. 48, 98–108.
Heubach, K., Wittig, R., Nuppenau, E.A., Hahn, K., 2011. The economic importance of non-timber forest products (NTFPs) for livelihood maintenance of rural west African communities: a case study from northern Benin. Ecol. Econ. 70, 1991–2001.
High, C., Shackleton, C.M., 2000. The comparative value of wild and domestic plants in home gardens of a South African rural village. Agrofor. Syst. 48, 141–156.
Howell, C.J., Schwabe, K.A., Abu Samah, A.H., 2010. Non-timber forest product dependence among the Jah Hut subgroup of Peninsular Malaysia's Orang Asli. Environ. Dev. Sustain. 12, 1–18.
Huang, J., Long, C., 2007. Coptis teeta-based agroforestry system and its conservation potential: a case study from northwest Yunnan. AMBIO 36, 343–349.
Huber, F.K., Ineichen, R., Yang, Y., Weckerle, C.S., 2010. Livelihood and conservation aspects of non-wood forest product collection in the Shaxi Valley, Southwest China. Econ. Bot. 64, 189–204.
Jensen, A., 2009. Valuation of non-timber forest products value chains. For. Policy Econ. 11, 34–41.
Jensen, A., Meilby, H., 2008. Does commercialization of a non-timber forest product reduce ecological impact? A case study of the Critically Endangered Aquilaria crassna in Lao PDR. Oryx 42, 214–221.
Jensen, A., Meilby, H., 2010. Returns from harvesting a commercial non-timber forest product and particular characteristics of harvesters and their strategies: aquilaria crassna and agarwood in Lao PDR. Econ. Bot. 64, 34–45.
Jones, J.P.G., Andriamarovololona, M.M., Hockley, N., Gibbons, J.M., Milner-Gulland, E.J., 2008. Testing the use of interviews as a tool for monitoring trends in the harvesting of wild species. J. Appl. Ecol. 45, 1205–1212.
Ju, Y., Zhuo, J., Liu, B., Long, C., 2013. Eating from the wild: diversity of wild edible plants used by Tibetans in Shangri-la region, Yunnan, China. J. Ethnobiol. Ethnomed. 9, 28.
Kabir, M., Webb, E.L., 2006. Saving a forest: the composition and structure of a deciduous forest under community management in Northeast Thailand. Nat. Hist. Bull. Siam Soc. 54, 239–260.
Kang, Y., Luczaj, L., Kang, J., Wang, F., Hou, J., Guo, Q., 2014. Wild food plants used by the Tibetans of Gongba Valley (Zhouqu county, Gansu, China). J. Ethnobiol. Ethnomed. 10, 20.
Kang, Y., Luczaj, L., Kang, J., Zhang, S., 2013. Wild food plants and wild edible fungi in two valleys of the Qinling Mountains (Shaanxi, central, China). J. Ethnobiol. Ethnomed. 9, 26.
Kang, Y., Luczaj, L., Ye, S., Zhang, S., Kang, J., 2012. Wild food plants and wild edible fungi of Heihe valley (Qinling Mountains, Shaanxi, central China): herbophilia and indifference to fruits and mushrooms. Acta Soc. Bot. Pol. 81, 405–413.
Kim, S., Sasaki, N., Koike, M., 2008. Assessment of non-timber forest products in Phnom Kok community forest, Cambodia. Asia Eur. J. 6, 345–354.
Kosaka, Y., Xayvongsa, L., Vilayphone, A., Chanthavong, H., Takeda, S., Kato, M., 2013. Wild edible herbs in paddy fields and their sale in a mixture in houaphan province, the Lao people's democratic republic. Econ. Bot. 67, 335–349.
Kusters, K., Achdiawan, R., Belcher, B., Ruiz Perez, M., 2006. Balancing development and conservation? An assessment of livelihood and environmental outcomes of nontimber forest product trade in Asia, Africa, and Latin America. Ecol. Soc. 11.
Lacuna-Richman, C., 2004. Using suitable projects in adding value to nonwood forest products in the Philippines: the copal (Agathis philippinensis) trade in Palawan. Econ. Bot. 58, 476–485.
Lele, S., Springate-Baginski, O., Lakerveld, R., Deb, D., Dash, P., 2013. Ecosystem services: origins, contributions, pitfalls, and alternatives. Conserv. Soc. 11, 343–358.
Long, C.L., Li, R., 2004. Ethnobotanical studies on medicinal plants used by the Red-headed Yao People in Jinping, Yunnan Province, China. J. Ethnopharmacol. 90, 389–395.
Luskin, M., Christina, E., Kelley, L., Potts, M., 2014. Modern hunting practices and wild meat trade in the oil palm plantation-dominated landscapes of Sumatra, Indonesia. Hum. Ecol. 42, 35–45.
Lykke, A.M., Mertz, O., Ganaba, S., 2002. Food consumption in rural Burkina Faso. Ecol. Food Nutr. 41, 119–153.
Martin, G.J., 1995. Ethnobotany: A Methods Manual. Chapman and Hall, London.
McElwee, P., 2009. Reforesting "Bare Hills" in Vietnam: social and environmental consequences of the 5 million hectare reforestation program. AMBIO 38, 325–333.
McElwee, P.D., 2008. Forest environmental income in Vietnam: household socio-economic factors influencing forest use. Environ. Conserv. 35, 147–159.
McElwee, P.D., 2010. Resource use among rural agricultural households near protected areas in vietnam: the social costs of conservation and implications for enforcement. Environ. Manag. 45, 113–131.
Melick, D., Yang, X., Xu, J., 2007. Seeing the wood for the trees: how conservation policies can place greater pressure on village forests in southwest China. Biodivers. Conserv. 16, 1959–1971.
Menton, M.C.S., Merry, F.D., Lawrence, A., Brown, N., 2009. Company-community logging contracts in amazonian settlements: impacts on livelihoods and NTFP harvests. Ecol. Soc., 14.
Mertz, O., Padoch, C., Fox, J., Cramb, R.A., Leisz, S., Lam, N.T., Vien, T.D., 2009. Swidden change in Southeast Asia: understanding causes and consequences. Hum. Ecol. 37, 259–264.
Mertz, O., Lykke, A.M., Reenberg, A., 2001. Importance and seasonality of vegetable consumption and marketing in Burkina Faso. Econ. Bot. 55, 276–289.
Millennium Ecosystem Assessment, 2005. Ecosystems & human well-being: synthesis report, Island Press.
Motzke, I., Wanger, T.C., Zanre, E., Tscharntke, T., Barkmann, J., 2012. Socio-economic context of forest biodiversity use along a town-forest gradient in Cambodia. Raffles Bull. Zool. 60, 37–53.
Naidoo, R., Balmford, A., Costanza, R., Fisher, B., Green, R.E., Lehner, B., Malcolm, T. R., Ricketts, T.H., 2008. Global mapping of ecosystem services and conservation priorities. Proc. Natl. Acad. Sci. 105, 9495–9500.
Nanthavong, K., Cherief, M., Keophosay, A., Castella, J.C., 2011. Management of Non Timber Forest Products (NTFPs) across the Nam Khan Watershed. Lao J. Agric. For. 23, 109–125.
Nelson, E., Mendoza, G., Regetz, J., Polasky, S., Tallis, H., Cameron, D.R., Chan, K.M., Daily, G.C., Goldstein, J., Kareiva, P.M., Lonsdorf, E., Naidoo, R., Ricketts, T.H., Shaw, M.R., 2009. Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales. Front. Ecol. Environ. 7, 4–11.
Nuwer, R., Bell, D., 2014. Identifying and quantifying the threats to biodiversity in the U Minh peat swamp forests of the Mekong Delta, Vietnam. Oryx 48, 88–94.
O'Farrell, P.J., Anderson, P.M., 2010. Sustainable multifunctional landscapes: a review to implementation. Curr. Opin. Environ. Sustain. 2, 59–65.
Ogle, B.M., Dung, N.N.X., Do, T.T., Hambraeus, L., 2001. The contribution of wild vegetables to micronutrient intakes among women: An example from the Mekong Delta, Vietnam. Ecol. Food Nutr. 40, 159–184.
Pangau-Adam, M., Noske, R., Muehlenberg, M., 2012. Wildmeat or bushmeat? Subsistence hunting and commercial harvesting in Papua (West New Guinea), Indonesia. Hum. Ecol. 40, 611–621.
Pfund, J.L., Watts, J., Boissiere, M., Boucard, A., Bullock, R., Ekadinata, A., Dewi, S., Feintrenie, L., Levang, P., Rantala, S., Sheil, D., Sunderland, T., Urech, Z., 2011. Understanding and integrating local perceptions of trees and forests into incentives for sustainable landscape management. Environ. Manag. 48, 334–349.
Price, L.L., 1997. Wild plant food in agricultural environments: a study of occurrence, management, and gathering rights in Northeast Thailand. Hum. Organ. 56, 209–221.
Rao, M.H., Myint, T., Zaw, T., Htun, S., 2005. Hunting patterns in tropical forests adjoining the Hkakaborazi National Park, north Myanmar. Oryx 39, 292–300.
Rao, M., Htun, S., Zaw, T., Myint, T., 2010. Hunting, livelihoods and declining wildlife in the Hponkanrazi Wildlife Sanctuary, North Myanmar. Environ. Manag. 46, 143–153.
Rist, L., Shanley, P., Sunderland, T., Sheil, D., Ndoye, O., Liswanti, N., Tieguhong, J., 2012. The impacts of selective logging on non-timber forest products of livelihood importance. Ecol. Manag. 268, 57–69.
Sachs, J.D., Reid, W.V., 2006. Investments toward sustainable development. Science 312, 1002.
Salam, M.A., Noguchi, T., Pothitan, R., 2006. Community forest management in Thailand: current situation and dynamics in the context of sustainable development. New For. 31, 273–291.
Salick, J., Yang, Y.P., Amend, A., 2005. Tibetan land use and change near Khawa Karpo, Eastern Himalayas. Econ. Bot. 59, 312–325.
Schulp, C.J.E., Thuiller, W., Verburg, P.H., 2014. Wild food in Europe: a synthesis of knowledge and data of terrestrial wild food as an ecosystem service. Ecol. Econ. 105, 292–305.
Scoones, I., Melnyk, M., Pretty, J.N., 1992. The Hidden Harvest: Wild Foods and Agricultural Systems. A Literature Review and Annotated Bibliography. International Institute for Environment and Development, London.
Seppelt, R., Dormann, C.F., Eppink, F.V., Lautenbach, S., Schmidt, S., 2011. A quantitative review of ecosystem service studies: approaches, shortcomings and the road ahead. J. Appl. Ecol. 48, 630–636.
Somnasang, P., Moreno, G., Chusil, K., 1998. Indigenous knowledge of wild food hunting and gathering in north-east Thailand. Food Nutr. Bull. 19, 359–365.
Somnasang, P., Moreno-Black, G., 2000. Knowing, gathering and eating: knowledge and attitudes about wild food in an Isan village in Northeastern Thailand. J. Ethnobiol. 20, 197–216.
Sopsop, L.B., Buot, I.E., 2011. The importance of non-wood forest products in the household economy of the direct users of Aborlan Guba system, Palawan Island, Philippines. J. Environ. Sci. Manag. 14, 51–59.
Souphonphacdy, D., Yabe, M., Sato, G., 2012. Impact of rubber concession on rural livelihood in Champasack Province, Lao PDR. J. Fac. Agric. Kyushu Univ. 57, 339–344.
Tungittiplakorn, W., Dearden, P., 2002. Biodiversity conservation and cash crop development in northern Thailand. Biodivers. Conserv. 11, 2007–2025.
van Vliet, N., Nasi, R., 2008. Hunting for livelihood in northeast gabon: patterns, evolution, and sustainability. Ecol. Soc. 13, 33.
Vongvisouk, T., Mertz, O., Thongmanivong, S., Heinimann, A., Phanvilay, K., 2014. Shifting cultivation stability and change: contrasting pathways of land use and livelihood change in Laos. Appl. Geogr. 46, 1–10.
Wattanaratchakit, N., Srikosamatara, S., 2006. Small mammals around a karen village in northern mae hong son province, Thailand: abundance, distribution and human consumption. Nat. Hist. Bull. Siam Soc. 54; , pp. 195–207.
Wunder, S., Angelsen, A., Belcher, B., 2014. Forests, livelihoods, and conservation: broadening the empirical base. World Dev. 64, 1–11.