Journal of Agricultural Science; Vol. 6, No. 9; 2014
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

The Impact of Agricultural Expansion on Forest Cover in Ratanakiri Province, Cambodia

Sanara Hor[1], Izuru Saizen[1], Narumasa Tsutsumida[1], Tsugihiro Watanabe[1] & Shintaro Kobayashi[2]

[1] Graduate School of Global Environmental Studies, Kyoto University, Kyoto, Japan

[2] Tottori University of Environmental Studies, Tottori, Japan

Correspondence: Sanara Hor, Graduate School of Environmental Studies, Kyoto University, Kyoto, Yoshida Hommachi, Sakyo-ku, Kyoto 606-8501, Japan. Tel: 81-80-4491-5499. E-mail: hor.sanara.24s@st.kyoto-u.ac.jp

Received: April 24, 2014 Accepted: June 26, 2014 Online Published: August 15, 2014

doi:10.5539/jas.v6n9p46 URL: http://dx.doi.org/10.5539/jas.v6n9p46

Abstract

In the northeastern Cambodian province of Ratanakiri, agricultural expansion has been a significant factor in the decline of forest coverage. As forests are essential for rural populations' livelihoods and a healthy environment, this study presents the dynamics of this transformed forest landscape resulting from changes in farming, land accessibility and policy changes. A multitemporal dataset consisting of two ALOS/AVNIR-2 images in 2007 and 2011 were used to compare changes in land cover, and the panchromatic image of 2012 Worldview-1 acquired at 100 km^2 was used to access specific land-use patterns. Qualitative research methods ranging from an ethnographic method to qualitative data analysis were performed for gathering in-situ information to understand human-induced changes in land use. The results illustrate three triggers found at the local level, actively changing the forest landscape: (1) indigenous people transforming the swidden farming system to the mono-cropping system without external support and agricultural market information, (2) chaotic property market resulting from migrants purchasing existing farms or forest lands from indigenous people via land brokers, and (3) the introduction of land concessions by government via the 2001 Land Law, which allows agricultural cooperation to develop plantations.

Keywords: agricultural expansion, forest cover change, land resource accessibility, swidden change, Ratanakiri

1. Introduction

The decline of forests and woodlands in most developing countries has occurred primarily as a result of converting the land for crop production (Food and Agriculture Organization [FAO], 1997). Cambodia is no exception, reporting large forest losses over the last decade (FAO, 2010 2012). For example, the proportion of forest cover in Cambodia ranged from 73-74% of country landmass between 1969 and 1990 (Savet & Sokhun, 2003), and decreased to 57% between 1990 and 2010. In addition, the proportion of agricultural land expanded from 26% to 31% between 1997 and 2007 (Broadhead & Izquierdo, 2010) and to 32% in 2011 (FAO, 2014). Agricultural expansion is a significant factor in Cambodia's deforestation (Poffenberger, 2009) and has directly impacted forest cover (Broadhead & Izquierdo, 2010).

In the 2000s, the forest-dependent population comprised about 1.4 million of the 11 million people in Cambodia (Poffenberger, 2006). Forests are necessary for rural livelihoods and a healthy environment, and serve as a vital source of staple foods and wood products for many of the poorest people (FAO, 2012; Hansen & Neth, 2006); as such, forests contribute to poverty-alleviation strategies (Wunder, 2001). In addition, forests play a major role in climate change through their role in carbon sequestration (Salati & Nobre, 1991). Deforestation has had negative ecological and environmental consequences (Zhao et al., 2006) through the release of CO_2 (Detwiler, 1986; Houghton, 1999; Searchinger et al., 2008), impact on water quality (Johnes & Heathwaite, 1997; Sliva & Williams, 2001; Tong & Chen, 2002), alteration of regional climates (Zhang & McGuffie, 2001), and a loss of biodiversity (Haines-Young, 2009; Reidsma et al., 2006).

Land-change scientists acknowledge driving forces (Wood & Handley, 2001), or keystone processes (Marcucci, 2000), that affect the evolutionary trajectory of the landscape (Bürgi et al., 2004). The five major types of driving forces are socioeconomic, political, technological, natural, and cultural (Brandt & Primdahl, 1999; Bürgi et al., 2004). These scientists are also concerned about the transition of farming systems and rural migration, which are considered causes of land-use changes and deforestation (Carr, 2009).

Agricultural practices, especially the swidden practice, have been changing rapidly in Ratanakiri, reflecting a broader agricultural transition (Fox et al., 2009). The permanent replacement of the swidden practice by other land-use systems could result in the decline of plant diversity (Rerkasem et al., 2009).

Previous research has revealed that migrant encroachment also contributes to changes in forest cover. In the northwestern Cambodian province of Oddar Meanchey, it was estimated that the rural population increased about 12% per annum between 1998 and 2008, of which 9% was due to in-migration. Migrants often flow directly to rural areas seeking livelihood opportunities related to agriculture, resulting in the need to convert forests to agricultural land (Carr, 2004, 2009). Thus, detailed analyses at subnational levels are required (Barraclough, 2000) in order to better understand the social dynamics of agricultural expansion and tropical deforestation.

These findings are very important, but a few questions remain, such as how and why changes to the swidden practice are considered a critical factor to deforestation, and how migrants' access to land resources are contributing to forest cover changes. Therefore, this study aims to characterize the dynamics of forest cover changes caused by agricultural expansion, pinpointing patterns of agricultural land at a local level and then specifically addressing the critical question "why does agricultural expansion have such a significant impact on forest cover?"

2. Methods

2.1 Ground Truth

The subset image (ALOS PRISM 2011) covering the study area, described in Table 1 and Figure 1, was used in the participatory mapping of land-use patterns through discussion with villagers. After participatory mapping, we conducted ground truth with a GPS device and collected 273 training samples. Based on these, we developed a classification scheme (Anderson et al., 1976) containing three types of land use or cover: agricultural, forest, and other lands. Within the classification of agricultural lands, there were three sub-types of land use: farmland, paddy fields, and swidden/fallow fields. Farmlands represent land that is currently being cultivated for cashews, cassava, or rubber, and newly opened fields, where farmers had just cleared or burned trees. Paddy fields indicate land that was established during the Pol Pot Regime (1975-1979) and is used for wet-season rice cultivation. Swidden/fallow fields are mixed-use land.

Four types of forest cover – deciduous, evergreen, mixed, and secondary forest – were found and classified in this study area. Deciduous forests contain dry mixed deciduous trees and dry *Dipterocarp* trees. Evergreen forests are usually multi-storied forests where trees keep their leaves throughout the year. Mixed forests combined deciduous trees and evergreen trees in the same location. Secondary forests contain a dense layer of young trees that belong to the "forest cover" class. The other classes of land use/cover were shrublands, which refer to a combination of shrubs, grass, trees (FAO, 2010b), as well as marsh, sand and stone, and water. Marshes are dominated by herbaceous species, and are found near lakes, river banks, and around paddy fields. In some areas, marsh cover is a mixture of water and soil. Water refers to rivers and streams.

2.2 Image Interpretation

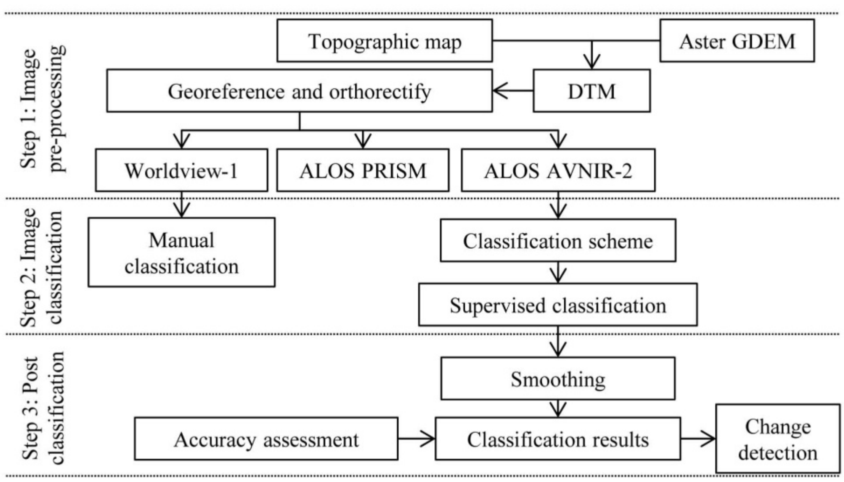

Figure 1. Three steps of the image classification process

Figure 1 presents the three-step procedure of image classification: image pre-processing, image classification, and post classification (Gao, 2009). First, raster and vector data were projected to the UTM coordination system (UTM WGS1984 zone 48N meters). We performed geometric calibration of images, through georeference and orthorectification, and applied these processes to every raster dataset, using 10 ground control points for three polynomials (Gao, 2009). We developed Digital Terrain Models (DTM) from the ASTER Global Digital Elevation Map (GDEM), and identified elevation points produced in 2002 by the Cambodian Ministry of Public Works and Transportation and Ministry of Land Management, Urban Planning and Construction for orthorectifying images. Second, we interpreted the ANVIR-2 images using the supervised classification method with the parametric rule of maximum likelihood. As part of the supervised classification procedure, 100 points for accuracy assessment and 173 points for developing signatures were randomized. The process of supervised classification was repeated several times, until results were consistent with the training samples. Third, a statistical filter was applied to eliminate clump areas smaller than 3×3 pixels. The overall accuracy assessment resulted in values between 85% and 89%. We applied raster overlapping methods to detect land-use/cover changes (Gao, 2009).

Table 1. Characteristics and usages of remote sensing data used in this study

No.	Sensors/data	Resolution	Acquisition	Usages
1	Aster GDEM	30 m	N/A	Procedure of orthorectification
2	PRISM/ALOS	2.5 m	16 Feb 2011	Support ground truth
3	AVNIR-2/ALOS	10 m	05 Feb 2007	Land cover classification
4	AVNIR-2/ALOS	10 m	16 Feb 2011	Land cover classification
5	Worldview-1	0.5 m	13 Feb 2012	Create mosaic of agricultural land

2.3 Processing Qualitative Data

We followed Maxwell (2013) to design our qualitative method, focusing on goals, conceptual framework, validity, and research questions. We also adopted ethnographic methodologies (Gobo, 2011) to collect current information. Individual interviews were conducted during field surveys through a semi-structured questionnaire in order to evaluate actual case studies, and group discussions were also conducted to determine land-use patterns. Participatory rural appraisal methods (Chambers, 1994a, 1994b, 1994c) were partly adopted during interviews, including participatory mapping, flow diagrams, and seasonal calendars (Narayasamy, 2009). We analyzed the collected qualitative data based on five steps: (1) initial coding and memo writing, (2) focused coding and memo writing, (3) new data collection via theoretical sampling, (4) continuing to code, memo and use theoretical sampling, and (5) shortening and integrating memos (Charmaz, 2000, 2006). Finally, we used constructivist grounded theory, a method of constructing theory that researchers systematically developed from collected data (Mills et al., 2006). The method was adopted to express views derived from the collected data, with the intention of transforming social data into theory. Table 2 illustrates the field research activities.

Table 2. Summary of field surveys

No.	Research periods	Main Activities	Outcomes
1	From 15 November 2012 to 25 December 2012	Ground-truthing	Collection of training samples for image classification
		Individual interview	Understanding of land-use history for every training sample
2	From 02 February 2013 to 23 March 2013	Processing qualitative data	Collection of in-situ information related to changes in land use

2.4 Research Location and Sampling Size

Ratanakiri Province is located in northeastern Cambodia with a land area of 11,721 km^2 and a population of 150,466 in 2008. Its population increased by 4.6% between 1998 and 2008, and almost 85% of provincial residents depend on agricultural livelihoods (National Institute of Statistics [NIS], 1998, 2008). Ratanakiri is one of the most remote provinces from the capital city, Phnom Penh. It is a mountainous area, with elevation ranging from 74 m to 1,624 m and boasts rich and diverse vegetation. Ratanakiri Province is bordered by the provinces of Mondulkiri to the South and Stungtreng to the West, and by the countries of Laos and Vietnam to the North and East, respectively. The study area includes the Sesan Commune and the southern area of the Nhang Commune, located 61 km to the East of the provincial capital of Banlung (Figure 2). The Sesan Commune is administered by the district of Ouyadav, while the Nhang Commune falls under the administration of the district of Andong Meas.

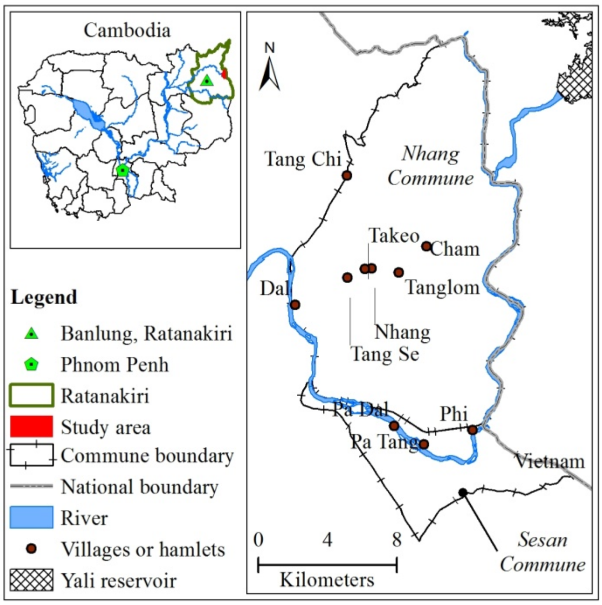

Figure 2. Map of the study area in Ratanakiri Province, Cambodia

The study area contained seven villages, one hamlet, and two migrants' villages, populated with 557 households that had an average of 6.74 individuals per household. Approximately 102 households were in Phi Village, 79 in Pa Dal Village, 40 in Pa Tang Village, 25 in Nhang Village, 130 in Tang Se Village and its hamlet Tanglom, 63 in Tang Chi Village, and 65 in Dal Village. More than 90% of the total population in these villages is dependent on agricultural livelihoods (NIS, 2008) and belong to the Djarai ethnic minority group. The hamlet of Cham comprised 46 households, with most villagers originating from Kampong Cham Province, located north of Phnom Penh. The "Cham" ethnic label, as used in Cambodia, covers virtually all Muslims in the country (Trankell, 2010). The population of the hamlet of Takeo comprised only seven households of the total population of the study area. Residents of this hamlet belong to the Khmer, the predominant ethnic group in Cambodia.

In addition to the land needs of the above-mentioned indigenous people, migrants are also increasingly seeking land in order to develop their livelihoods, largely from agriculture. We deliberately selected Phi Village as the leading example because of its remoteness and traditional practices, while the other villages were targeted for validating information. For individual interviews, 30 families were randomly selected from Phi, 7 from Pa Tang, and 10 from Pa Dal. As key informants of agricultural practices, land use, and livelihood, the village chief and security keeper from Tang Se, the village chief from Nhang, religious leaders from Cham, and one migrant from Takeo contributed to this study.

The government also requires land use for economic development; for example, Cambodia's 2001 Land Law introduced economic land concessions for increasing revenue that allows agricultural development companies (ADC) receiving contracts from the government to develop industrial plantations (Royal Government of Cambodia [RGC], 2001). This multi-faceted competition for land within the country is greatly increasing pressure on limited land resources, with agricultural expansion affecting forest cover, and with a corresponding need to characterize the dynamics of forest cover changes.

3. Results

3.1 Land Cover Classification

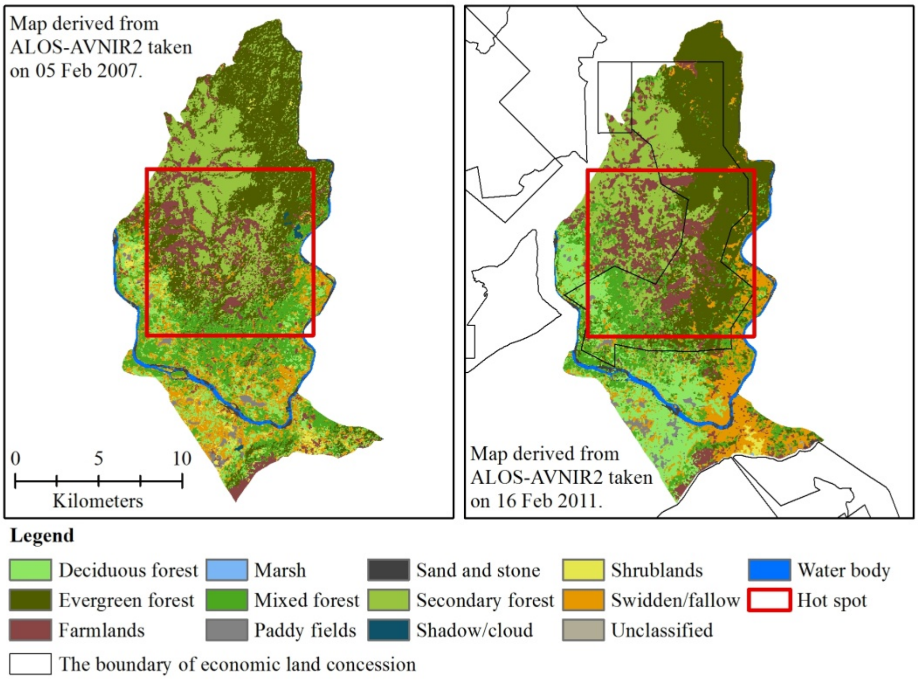

Figure 3. Land-use/cover maps derived from satellite images in 2007 and 2011

Note: The boundary data of economic land concession was collected at http://opendevelopmentcambodia.net.

Table 3. Results of land-use/cover classification and their changes from 2007 to 2011

No.	Land uses/covers	Classification results (ha)		Land-use changes 2007–2011	
		2007 (Year)	2011 (Year)	Change (ha)	Change (%)
1	Deciduous forest	2,083	2,923	840	-3.4
2	Evergreen forest	6,799	7,200	401	1.62
3	Farmlands	2,525	3,327	802	3.25
4	Marsh	9	17	8	0.03
5	Mixed forest	3,986	3,540	-446	-1.81
6	Paddy fields	271	297	26	0.11
7	Sand and stone	362	280	-82	-0.33
8	Secondary forest	4,698	3,847	-851	-3.45
9	Shrublands	453	104	-349	-1.41
10	Swidden/fallow	3,013	2,685	-328	-0.33
11	Water body	407	467	60	0.24

Note. + = Increase, - = Decrease. The classification accuracy is 85.7% in 2007 and 89.2% in 2011.

Land use in the study area has undergone dramatic modification (Table 3), and in 2007, land-use transitions became more apparent; for example, farmlands covered 2,525 ha, paddy fields were 271 ha, and swidden/fallow covered 3,013 ha. In addition, deciduous forest coverage was approximately 2,083 ha, while evergreen forests occupied 6,799 ha. Mixed forest coverage was 3,986 ha, while secondary forests and shrublands accounted for 4,698 ha and 453 ha, respectively.

By comparing the land-use classification in 2007 and 2011, we could easily see that the land uses was seriously changing during the study period. In 2011, farmlands increased to 3,327 ha and paddy fields increased to 297 ha. The coverage of swidden/fallow lands was 2,685 ha, deciduous forest coverage was approximately 2,923 ha, and evergreen forests occupied 7,200 ha. Mixed forests, secondary forests, and shrublands occupied 3,540 ha, 3,847 ha, and 104 ha, respectively. During the period 2007–2011, farmlands increased by approximately 802 ha and paddy fields by 26 ha, but swidden/fallow lands decreased by 328 ha. Deciduous forests and evergreen forests increased by approximately 840 ha and 401 ha, respectively. The coverage of mixed forests decreased by 446 ha and secondary forests by 851 ha. Shrublands covered 349 ha.

3.2 The Impact of Agricultural Expansion

Table 4 illustrates the land-use/cover changes during the study period and the impacts of agricultural expansion on forest cover types. For example, farmlands had an influence on deciduous forest of about 155.3 ha and effected evergreen forest by about 245.1 ha. In addition, 268.7 ha of mixed forest were converted to farmlands and 456.6 ha of secondary forests were developed for cash crop farming. About 10.9 ha of paddy fields were converted to farmlands and 183.4 ha of swidden/fallow lands were transformed into farmlands. Swidden/fallow threatened 1,018.9 ha of deciduous forest and 156.5 ha of evergreen forest. The impact of swidden and its fallow on mixed forest covered 341.4 ha. This traditional farming system also influenced 35.9 ha of secondary forests.

Table 4. Land-use/cover changes between 2007 and 2011 detected in raster format (Unit: ha). The table is read as the change in land cover in 2011 (DOWN) from land cover in 2007 (ACROSS)

2007 / 2011	Deciduous forest	Evergreen forest	Farmlands	Marsh	Mixed forest	Paddy fields	Secondary forest	Shrublands	Swidden/ fallow
Deciduous forest	1,057	35	58.7	0.3	369.9	23.8	7.2	15.2	503.5
Evergreen forest	50	4,461.1	424.2	0.3	878*	1.5	790.3*	0.3	181.1
Farmlands	155.3	245.1	1,164.1	1.7	268.7	10.9	456.6	30.1	183.4
Marsh	1.6	0.4	0.0	0.0	2	0.0	0.0	0.1	1.8
Mixed forest	386.7	1,147.9**	184.8	0.2	1,526.2	7.3	197.6	0.7	514.6
Paddy fields	107.6	0.1	1.1	0.0	0.3	155.1	0.0	0.1	6.4
Sand and stone	15.5	26.8	1.8	5.8	5.7	0.7	0.0	0.1	14.3
Secondary forest	6.9	1,064.9**	1,078.5	0.4	110.6	0.2	2,390.1	0.0	44
Shrublands	229	21.6	14.9	1.9	14.6	27.6	0.7	36.3	104
Swidden/fallow	1,018.9	156.5	139.4	3.8	341.4	93.1	35.9	20.3	1,146.7
Water body	20.8	5.4	0.2	0.4	11.4	0.0	1.4	0.0	5.6

Note. * = examples of inherently dynamic, ** = examples of forest disturbance. For a discussion about (* and **), refer to section 4.4.

3.3 Agricultural Mosaic

To gain an enriched understanding of agricultural expansion, we digitized land-use parcels from a 2012 Worldview-1 (100 km^2) image using ArcMAP 10.1. The flow of image processing was presented in Figure 1, and the image in Figure 3 illustrated the "hot spot" zone, where agricultural expansion had the greatest influenced on forest cover. To create an agricultural mosaic land-use map, we employed digital land-use parcels combined with ground truth information. The agricultural mosaic signifies diversification of agricultural land uses located in the forest landscape. The map and its statistics are summarized in Figures 4 and 5.

Every type of agricultural land including cassava farms accounted for 21 ha. Cassava mixed cashew, in which cashew trees were grown alongside cassava plants, accounted for 7 ha. Forest clearing plots covered over 488 ha. Fallow lands amounted to 247 ha and rubber plantation developed by ADC accounted for 97 ha. New cashew farms, which contain young cashew trees, accounted for 153 ha. Newly opened fields recorded the highest extent, at 506 ha. Old cashew farms occupied 408 ha and paddy fields took up 28 ha. Rubber farms developed by the locals covered 62 ha. Swidden fields occupied 47 ha, with swidden changes over 69 ha where swidden agriculture as the multiple cropping systems had been transformed into mono-cropping system for cash crop production. Unclassified farms totaled 21 ha per the field survey.

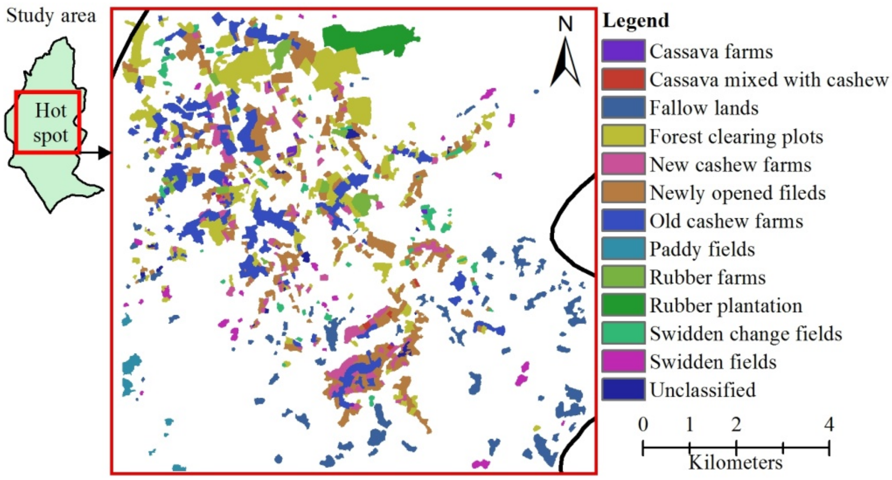

Figure 4. Map of exquisite land uses derived from Worldview-1 image illustrating an agricultural mosaic

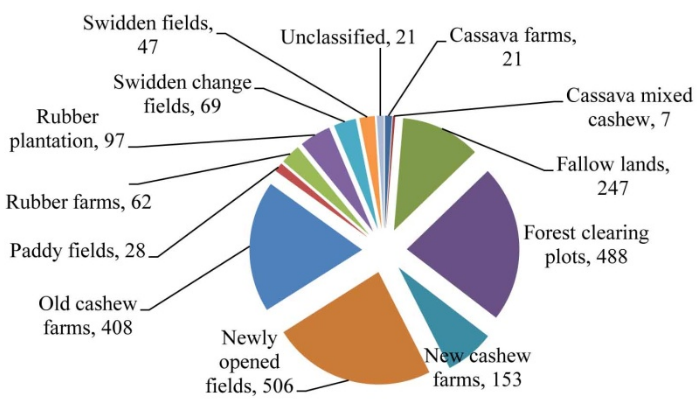

Figure 5. Composition of agricultural land uses in the selected area of forest landscape (ha)

4. Discussion

In this study, we conducted supervised classification with the maximum likelihood classification method due to the unique information classes on the ground. Results show that trends in land-use changes within the study area primarily originate from forestland that is converted for agricultural uses. While the accounting of land-cover changes is limited to direct human-induced changes, distinction between natural and human-induced changes cannot be identified using remote sensing data alone; as such, contemporary in-situ information may be required (Rosenqvist et al., 2003). Thus, without applying qualitative methods, we could not fully determine how the land use changed (Maxwell, 2013).

4.1 Transitions in the Farming System

We generally found a shift in traditional cultivation practices near water sources, such as rivers or streams (Figure 6). Traditional practices are based on a multiple cropping system in which rice, the staple food of indigenous people, is normally cultivated. During fieldwork, 16 different crop species were counted, with five of these species occurring on every plot of farmland. Some shifting cultivators arranged the swidden fields according to their topographical distribution and soil type; for example, fruit trees were grown at the highest elevation or next to the edge of the forest, while vegetable species such as chili peppers and eggplant grew next to the farmhouse. Our sample farmhouse (Figure 6) was a small house built on a swidden farm that was used for storing rice as well as a place to live during planting season. The vegetable crops here included cucumber, gourds, and watermelon, grown alongside rice. Bananas grew next to the water source. Between one and three years ago, many swidden fields were converted to fallow lands, and farmers would often clear a plot of land next to their former field. The size of fallow lands ranged from 0.5 ha to 1.6 ha, similar to the size of the swidden fields. The size was noted to be dependent on the number of family members (Hor, 2012).

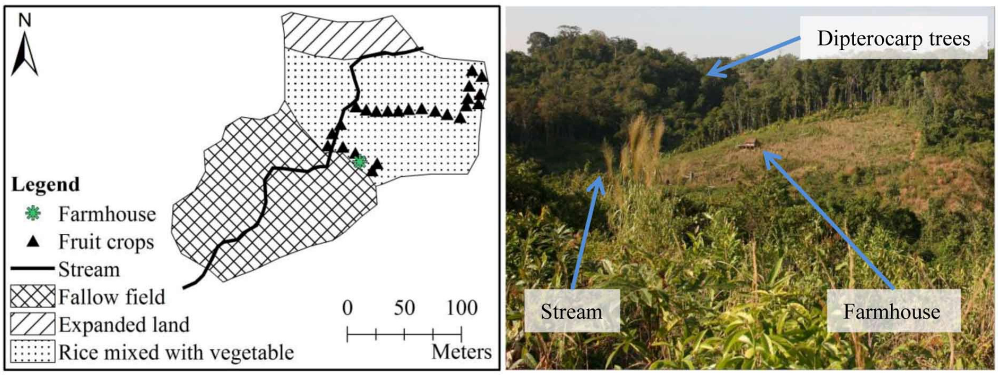

Figure 6. A farm arrangement and photo of traditional swidden agriculture

In contrast, most shifting cultivators changed to a mono-cropping system, focusing on production of cash crops, such as cashew, rubber, or cassava to increase their income. They learned to cultivate cash crops from other villagers or migrants but did not take into account the physical structure of cashew plants, which led to rice being grown under cashew trees, as shown in Figure 7.

Figure 7. Left image shows a new cashew farm in which cashew trees were one year old. Right image shows three-year-old cashew trees and expanded land for rice production

The swidden-change farming system required additional land every year because indigenous farmers deliberately cultivated rice with cashews. The rice grew well in the first year but the yield gradually decreased due to the shading of the rice field by the maturing cashew trees. Typical farms are usually between 0.5 ha and 5 ha, and the size of the expanded land was usually between 0.6 ha and 1 ha per year (measured by GPS device and Worldview-1 image). Therefore, this transition to a cash-crop farming system has the potential to change the amount of forest cover.

4.2 Accessibility of Land Resources

Poffenberger (2009) reported that migrant encroachment is contributing to land-cover change in Cambodia, as they seek forest lands to farm or resell. In Tang Se and Nhang, we found that migrants accessed land resources with the intention of improving their livelihoods through agriculture, and land brokers were paid to provide real estate services. Although the relationship between land brokers and land-use changes has not been thoroughly investigated in previous academic studies, our field survey clarified that land-resource users appeared to more easily access forest lands for farming or resale through land brokers. Overall, villagers have increasingly regarded their local lands as marketable commodities and have responded to market forces by developing more of their forest lands for increased income (Fox et al., 2008, 2009).

Migrant farmers primarily develop forest lands for cash crops (e.g., rubber, cashews, or cassava) because they believe that these crops have the greatest potential to improve their livelihood; as such, they tend to access and purchase prime lands for agricultural use. This situation established a revitalized land market of real property investment, in which land is a marketable commodity due to demand.

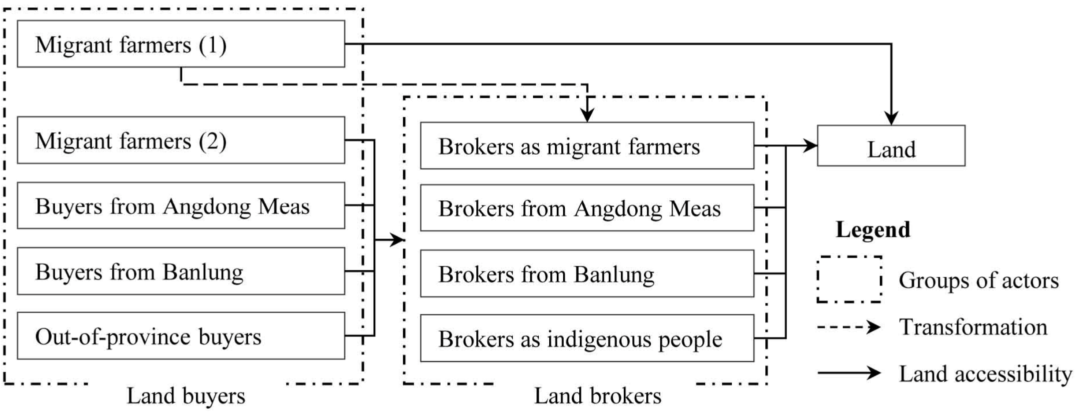

Figure 8. Land accessibility conducted at the local level, forming a market structure

4.2.1 Land Buyers

Figure 8 illustrates land resource accessibility, highlighting the roles of two main actors – land buyers and land brokers – who play important roles in the trading of land resources. Within our study area, lands were increasingly regarded as marketable commodities when migrants or indigenous people became land brokers, or market intermediaries who matched demands between buyers and sellers (Dowall & Leaf, 1991). Land buyers can be subdivided into five categories. The first category includes migrant farmers [Migrant farmers (1)] who were the first to settle in the area. Based on the interviews, when farmers acquired large areas of forest lands or farmlands, they were initially faced with labor shortages. At the same time, growing demand for lands increased their land value, leading them to sell some parts of their lands to other land users who also relied on agriculture for their livelihood. This situation also led them to become land brokers (Broker as migrant farmers), who served to attract farmers or other buyers.

The second category includes migrant farmers [Migrant farmers (2)] who need lands only to sustain their livelihoods. The farmers in this category came from central Cambodia, where their livelihood depended on fishery. When aquatic resources become difficult to obtain, they sought lands for cash crop production. Some of these farmers were previously workers or house servants in Thailand or Malaysia. After migrating from these countries, they required lands to sustain their livelihood. Primarily, the farmers in this category purchased lands from farmers in the first category.

The third category includes the land buyers [Buyers from Angdong Meas] who live in Ou Kob, the center of the Angdong Meas district. They are mostly “middle men” who exchange agricultural products and try to create opportunities by expanding agricultural lands. The fourth category includes outsiders who live in Banlung [Buyers from Banlung], and the fifth category includes land buyers who are not residents of the Ratanakiri Province [Out-of-province buyers]. Land buyers in this category were people whose primary income is from the agricultural sector. There were a few land buyers in this category who directly bought lands from indigenous people.

4.2.2 Land Brokers and the Market

Land buyers accessing land resources through land brokers can be subdivided into four categories. The first category includes land brokers [Brokers as migrant farmers] who transformed land from ordinary farmers [Migrant farmers (1)], as mentioned above, and the second group includes Ou Kob residents [Brokers from Angdong Meas] The third group originated from Banlung [Brokers from Banlung], though members of this category were rare in the study area. The fourth group was comprised of indigenous people themselves [Brokers as indigenous people], the number of which was usually between one and three in the villages of the study areas other than Phi, Pa Dal, and Pa Tang.

The value of each land depends on its characteristics. For example, if a land is used for cashew trees, the value would be equivalent to a new motorbike, with prices ranging between US$500 and US$1,800, depending on the size of the total parcel. If land is covered with secondary forest, the value could be about US$500, again depending on the total size of the parcel and the types of crops currently planted.

Some land buyers enlarged their land through the purchase of new farms or by extending the boundary during subsequent seasons. Extension of boundaries, however, is dependent on land availability around the farmland; for example, if land buyers purchased land from indigenous people, these land boundaries are not often clearly or officially defined, but based on an agreement between the buyer and seller.

4.2.3 Land-Use Control

Without land-use control, the accessibility of migrant farmers would likely result in a sense of insecurity about being able to maintain forest resources. In this view, zoning entails the delineation of a community into districts or zones, within which certain activities are permitted and others are prohibited; however, there are no easy solutions to the problems related to accessibility of land (Dale & McLaughlin, 2003), especially, in the context of accessing rural land for livelihood betterment within our study location. Farmers in every village recognized their land ownerships differently.

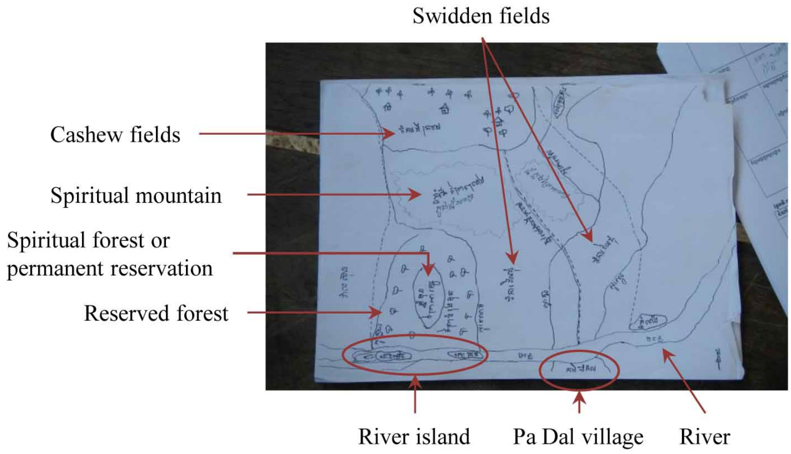

Figure 9. Map of natural resources drawn by Pa Dal villagers

Djarai villagers who live in Phi Village have created a specific zoning system, classifying land resources into five categories: village area, funeral forest, spiritual forest, hunting area, and agricultural area. These categories are generally used in every village with Djarai people in the study area; however, the exact locations of these areas have not been identified. Pa Dal villagers also created their own resource map in an effort to identify where to farm cash crops, conduct swidden, and cultivate wet-season rice (Figure 9). Although the systems are slightly different between these two villages, those indigenous villagers who live in Phi and Pa Dal villages were eager to possess the communal land title. Due to the 2001 Land Law, however, migrant farmers who accessed land resources in nearby Tang Se or Nhang, are not allowed to receive the communal land title. Therefore, in order to control land uses in this area, effective property rights regimes must specify both individual and collective titles. Unfortunately, these property regimes have not been functioning well in this area.

We can learn from a successful case in Krala Village, located in the Chum District of Ratanakiri Province. Non-governmental organizations (NGOs) in this area played a vital role in strengthening indigenous institutions and establishing clear policies on land use and tenure, and the villagers successfully built on new market opportunities while sustaining their forest resources and cultural institutions (Fox et al., 2009). The best scenario to enhance tenure security is a combination of (1) long-term NGO support for livelihood development, (2) high pre-existing levels of community solidarity, (3) processes designed with a view of engagement and with recognition by relevant subnational authorities, and (4) laws to moderate pre-intervention levels of outside pressure on lands (Adler et al., 2009).

4.3 Land Concession

In Cambodia, land resources are not only a requirement of local people or landless people but also a requirement of the government, which uses lands for economic development. In 2001, the Cambodian government re-enacted the land law that allowed the government to transfer “state public land” to “state private land,” as a precondition to allocate concessions for various purposes. For example, the Cambodian government allocated some state lands to political elites and foreign investors in the form of an “economic land concession,” which was estimated to cover approximately 50% of the country’s arable lands (Neef et al., 2013). Rubber plantations appeared in this area and the companies signed an agreement with the Ministry of Agriculture, Forestry and Fisheries to receive 8,654 ha for planting industrial crops such as acacia or rubber. Land uses appeared to be diversified as a result.

Our results show that land resource users including indigenous people, migrants, and ADCs actively developed forest lands for cash crop production. Access to natural resources is essential for sustainable poverty reduction (Baumann, 2002) and the government established land concessions in response to this social and economic initiative (Cambodia, 2001). However, every stakeholder has the same rights to economic development or livelihood improvement.

4.4 Inherently Dynamic Landscape

An inherently dynamic landscape is the natural succession in which pioneer vegetation evolves over time to shrublands and, subsequently, into forest (Bürgi et al., 2004). According to the change detection analysis (Table 4), we observed changes in the function of vegetation, creating an inherently dynamic landscape. For example, 790.3 ha of evergreen forests were converted from secondary forest, and 878 ha of mixed forest were transformed into evergreen forest. This illustrates that the quality of forest lands can recover when left undisturbed. In contrast, forest quality decreases when disturbed by logging; for example, we saw 1,064.9 ha of secondary forest and 1,147.9 of mixed forest converted from evergreen forest.

5. Conclusion

This study revealed the dynamics of forest cover changes caused by agricultural expansion, pinpointing the patterns of agricultural land uses in the study area. Both remote sensing applications and qualitative methods were applied to understand the relationships between land-use changes and agricultural practices at the community level across a wide range of research questions. The amount and trends of forest cover changes were observed through analysis of remote sensing data and the causes of the changes were revealed through interviews with various actors as well as ground truthing during the field survey. Overall, we found that the introduction of cash crop production and commercial plantations had been effecting agricultural practices and causing drastic changes in forest landscape.

At the local level, we also found three triggers for the forest development: conversion of swidden farming into a mono-cropping system, access of migrant farmers to land resources without land-use control, and government-induced land concessions. For the first trigger, although conversion of swidden into a mono-cropping system could be prevented, to some extent, by external support, these changes were found throughout the study area. Within the framework of the mono-cropping system, indigenous farmers have to expand their lands and develop forests for rice production year after year, regardless of the agricultural market. For the second trigger, migrant farmers have high demands for access to agricultural lands that were converted from forest lands without land administration, though increased regulation would help to form a real property market. For the final trigger, the government re-enacted a land law that allows agricultural development cooperation to develop plantations, resulting in a rapid acceleration of deforestation.

The first trigger can be easily combined with the second trigger, so further unexpected challenges to land resources are likely to appear and affect the forest landscape. At the same time, the third trigger has the potential to confound the situation at a subnational level due to increasing demands on lands for agricultural development. In conclusion, agricultural expansion appears to have been a significant factor that has impacted forest cover at the local level. These have collectively diversified agricultural landscapes, leading to changes in forest landscape.

These results should be considered in maintaining a sustainable agricultural practice in Cambodia. The combination of quantitative and qualitative surveys applied in this study may prove to be a useful approach for designing areas in which forest and agriculture are dominant, and will be increasingly helpful in managing a sustainable landscape both in forest and agriculture.

Acknowledgements

This work was supported by JSPS KAKENHI Grant Number 21405032. Additionally, we would like to thank the Royal University of Agriculture (RUA), Provincial Department of Agriculture (PDA) of Ratanakiri Province, and local NGOs that facilitated our work in the study area and provided us with vital information. We would also like to thank Mr. Mao Ratana (RUA lecturer), Mr. Seav Thea (RUA staff), Mr. Thon Narun (PDA officer), and Mr. Veoun Vinichhai (RUA MSc student), who supported us during our fieldwork.

References

Adler, D., Ironside, J., & Ratanak, M. (2009). *Mapping and Tenure Security in Cambodia's Indigenous Communities.* Cambodia: Heinrich Böll Stiftung.

Anderson, J. R., Hardy, E. E., Roach, J. T., & Witmer, R. E. (1976). A Land Use And Land Cover Classification System For Use With Remote Sensor Data. *Geological Survey Professional, 964*, 1-41.

Barraclough, S. L. (2000). *Agricultural Expansion and Tropical Deforestation: International Trade, Poverty and Land Use* (pp. 129). In K. B. Ghimire (Ed.). US: Routledge.

Baumann, P. (2002). *Improving access to natural resources for the rural poor: A critical analysis of central concepts and emerging trends from sustainable livelihoods perspective*. Livelihood Support Programme: FAO.

Brandt, J., Primdahl, J., & Reenberg, A. (1999). *Rural land use and landscape dinamics analysis of "driving forces" in space and time*. In R. Krönert, J. Baudry, I. R. Bowler & A. Reenberg (Eds.), *Land-use changes their environmental impact in rural area in Europe* (pp. 81-102). Paris, France: UNESCO.

Broadhead, J., & Izquierdo, R. (2010). *Assessment of land use, forest policy and governance in Cambodia*. Phnom Penh, Cambodia: FAO.

Bürgi, M., Hersperger, A. M., & Schneeberger, N. (2004). Driving forces of landscape change – current and new directions. *Landscape Ecology, 19*(8), 857-868. http://dx.doi.org/10.1007/s10980-004-0245-8

Carr, D. (2004). Proximate Population Factors and Deforestation in Tropical Agricultural Frontiers. *Population and Environment, 25*(6), 585-612. http://dx.doi.org/10.1023/B:POEN.0000039066.05666.8d

Carr, D. (2009). Rural migration: The driving force behind tropical deforestation on the settlement frontier. *Progress in Human Geography, 33*(3), 355-378. http://dx.doi.org/10.1177/0309132508096031

Chambers, R. (1994a). Participatory rural appraisal (PRA): Analysis of experience. *World Development, 22*(9), 1253-1268. http://dx.doi.org/10.1016/0305-750X(94)90003-5

Chambers, R. (1994b). Participatory rural appraisal (PRA): Challenges, potentials and paradigm. *World Development, 22*(10), 1437-1454. http://dx.doi.org/10.1016/0305-750X(94)90030-2

Chambers, R. (1994c). The origins and practice of participatory rural appraisal. *World Development, 22*(7), 953-969. http://dx.doi.org/10.1016/0305-750X(94)90141-4

Charmaz, K. (2000). Grounded theory methodology: Objectivist and constructivist qualitative methods. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp. 509-536). Thousand Oaks, CA: Sage.

Charmaz, K. (2006). *Constructing grounded theory: a practical guide through qualitative analysis*. London: Sage.

Detwiler, R. P. (1986). Land use change and the global carbon cycle: the role of tropical soils. *Biogeochemistry, 2*(1), 67-93. http://dx.doi.org/10.1007/BF02186966

Dowall, D., & Leaf, M. (1991). The Price of Land for Housing in Jakarta. *Urban Studies, 28*(5), 707-722. http://dx.doi.org/10.1080/00420989120080881

FAO. (1997). *State of the world's forests*. Rome, Italy.

FAO. (2010). *Global Forest Resources Assessment*. Rome, Italy.

FAO. (2012). *State of the world's forests*. Rome, Italy.

FAO. (2014). FOASTAT database. Retrieved from http://faostat3.fao.org/faostat-gateway/go/to/download/R/RL/E

Fox, J., Mcmahon, M., McMahon, D., & Poffenberger, M. V. J. (2008). *Land for My Grandchildren: Land-Use and Tenure Change In Ratanakiri: 1989-2007*. Cambodia: CFi&EWC.

Fox, J., Vogler, J. B., & Poffenberger, M. (2009). Understanding Changes in Land and Forest Resource Management Systems: Ratanakiri, Cambodia. *Southeast Asian Studies, 47*(3), 309-329.

Gao, J. (2009). *Digital analysis of remotely sensed imagery*. New York, NY: McGraw-Hill.

Gobo, G. (2011). *Ethnography*. In D. Silverman (Ed.), *Qualitative research* (3rd ed., pp. 15-35). Chennai, India: Sage.

Haines-Young, R. (2009). Land use and biodiversity relationships. *Land Use Policy, 26*(1), 178-186. http://dx.doi.org/10.1016/j.landusepol.2009.08.009

Hansen, K. K., & Neth, T. (2006). *Natural forest benefits and economic analysis of natural forest conversion in Cambodia*. Phnom Penh, Cambodia: CDRI.

Hor, S. (2012). *Traditional agricultural practice on shifting cultivation of Djarai ethnic group in northeastern Cambodia* (pp. 23-24). Paper presented at the spatial fusion analysis and common ground information includes any of useful techniques of advanced GIS for regional resources and ethnological studies, Shinshu University, Nagano Prefecture, Japan.

Houghton, R. A. (1999). The U.S. Carbon Budget: Contributions from Land-Use Change. *Science, 285*(5,427), 574-578.

Johnes, P. J., & Heathwaite, A. L. (1997). Modelling the impact of land use change on water quality in agricultural catchments. *Hydrological Processes, 11*(3), 269-286. http://dx.doi.org/10.1002/(SICI)1099-1085(19970315)11:3%3C269::AID-HYP442%3E3.0.CO;2-K

Marcucci, D. J. (2000). Landscape history as a planning tool. *Landscape and Urban Planning, 49*(1-2), 67-81. http://dx.doi.org/10.1016/S0169-2046(00)00054-2

Maxwell, J. A. (2013). *Qualitative research design: an interactive approach*. In V. Knight (Ed.). California: SAGE.

Mills, J., Bonner, A., & Francis, K. (2006). Adopting a constructivist approach to grounded theory: implications for research design. *International Journal of Nursing Practice, 12*(1), 8-13. http://dx.doi.org/10.1111/j.1440-172X.2006.00543.x

Narayasamy, N. (2009). *Participatory rural appraisal: principles, Methods and Application*. New Delhi: Sage.

National Institute of Statistic (NIS). (1998). *General Population Census*. Cambodia. Retrieved from http://celade.cepal.org/redkhm/census/khm1998 or http://www.opendevelopmentcambodia.net/census-data

National Institute of Statistic (NIS). (2008). *General Population Census*. Cambodia. Retrieved from http://celade.cepal.org/redkhm/census/khm2008 or http://www.opendevelopmentcambodia.net/census-data

Neef, A., Touch, S., & Chiengthong, J. (2013). The Politics and Ethics of Land Concessions in Rural Cambodia. *Journal of Agricultural and Environmental Ethics, 26*(6), 1085-1103. http://dx.doi.org/10.1007/s10806-013-9446-y

Poffenberger, M. (2006). People in the forest: community forestry experiences from Southeast Asia. *International Journal of Environment and Sustainable Development, 5*(1), 57-69. http://dx.doi.org/10.1504/IJESD.2006.008683

Poffenberger, M. (2009). Cambodia's forests and climate change: Mitigating drivers of deforestation. *Natural Resources Forum, 33*(4), 285-296. http://dx.doi.org/10.1111/j.1477-8947.2009.01249.x

Reidsma, P., Tekelenburg, T., van den Berg, M., & Alkemade, R. (2006). Impacts of land-use change on biodiversity: An assessment of agricultural biodiversity in the European Union. *Agriculture, Ecosystems & Environment, 114*(1), 86-102. http://dx.doi.org/10.1016/j.agee.2005.11.026

Rerkasem, K., Lawrence, D., Padoch, C., Schmidt-Vogt, D., Ziegler, A. D., & Bruun, T. B. (2009). Consequences of Swidden Transitions for Crop and Fallow Biodiversity in Southeast Asia. *Human Ecology, 37*(3), 347-360. http://dx.doi.org/10.1007/s10745-009-9250-5

Rosenqvist, Å., Milne, A., Lucas, R., Imhoff, M., & Dobson, C. (2003). A review of remote sensing technology in support of the Kyoto Protocol. *Environmental Science & Policy, 6*(5), 441-455. http://dx.doi.org/10.1016/S1462-9011(03)00070-4

Royal Government of Cambodia (RGC). (2001). *Land Law*. Cambodia. Retrieved from http://www.opendevelopmentcambodia.net/laws-regulations

Salati, E., & Nobre, C. A. (1991). Possible climatic impacts of tropical deforestation. *Climatic Change, 19*(1-2), 177-196. http://dx.doi.org/10.1007/BF00142225

Savet, E., & Sokhun, T. (2003). National forest policy review. In T. Enters, Q. Ma & R. N. Leslie (Eds.), *An overview of forest policies in Asia* (pp. 93-108). Bangkok, Thailand: FAO.

Searchinger, T., Heimlich, R., Houghton, R. A., Dong, F., Elobeid, A., Fabiosa, J., & Yu, T. H. (2008). Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. *Science, 319*(5,867), 1238-1240.

Sliva, L., & Williams, D. D. (2001). Buffer zone versus whole catchment approaches to studying land use impact on river water quality. *Water Research, 35*(14), 33462-3472. http://dx.doi.org/10.1016/S0043-1354(01)00062-8

Tong, S. T. Y., & Chen, W. (2002). Modeling the relationship between land use and surface water quality. *Journal of Environmental Management, 66*(4), 377-393. http://dx.doi.org/10.1006/jema.2002.0593

Trankell, I. (2010). Songs of Our Spirits: Possession and Historical Imagination among the Cham in Cambodia in Cambodia. *Asian Ethnicity, 4*(1), 37-41.

Wood, R., & Handley, J. (2001). Landscape Dynamics and the Management of Change. *Landscape Research, 26*(1), 45-54. http://dx.doi.org/10.1080/01426390120024475

Wunder, S. (2001). Poverty Alleviation and Tropical Forests - What Scope for Synergies? *World Development, 29*(11), 17817-17833. http://dx.doi.org/10.1016/S0305-750X(01)00070-5

Zhang, H., & McGuffie, K. (2001). The compounding effects of tropical deforestation and greenhouse warming on climate. *Climate Change, 48*(3), 309-338. http://dx.doi.org/10.1023/A:1010662425950

Zhao, S., Peng, C., Jiang, H., Tian, D., Lei, X., & Zhou, X. (2006). Land use change in Asia and the ecological consequences. *Ecological Research, 21*(6), 890-896. http://dx.doi.org/10.1007/s11284-006-0048-2