Global Environmental Change 22 (2012) 418–429

Contents lists available at SciVerse ScienceDirect

Global Environmental Change

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

Trends, drivers and impacts of changes in swidden cultivation in tropical forest-agriculture frontiers: A global assessment

Nathalie van Vliet [a,*], Ole Mertz [a], Andreas Heinimann [b], Tobias Langanke [a], Unai Pascual [c,d], Birgit Schmook [e], Cristina Adams [f], Dietrich Schmidt-Vogt [g], Peter Messerli [h], Stephen Leisz [i], Jean-Christophe Castella [j], Lars Jørgensen [a], Torben Birch-Thomsen [a], Cornelia Hett [b], Thilde Bech-Bruun [k], Amy Ickowitz [l], Kim Chi Vu [m], Kono Yasuyuki [n], Jefferson Fox [o], Christine Padoch [p], Wolfram Dressler [q], Alan D. Ziegler [r]

[a] Department of Geography and Geology, University of Copenhagen, Oster Voldgade 10, 1350 Copenhagen K, Denmark
[b] Swiss National Centre of Research (NCCR) North-South, Centre for Development and Environment (CDE), University of Bern, Hallerstrasse 10, 3012 Bern, Switzerland
[c] Department of Land Economy, University of Cambridge, 19 Silver st. Cambridge, CB3, 9EP, UK
[d] Ikerbasque, Basque Foundation for Science, Alameda Urquijo, 36-5 Plaza Bizkaia, 48011 Bilbao Bizkaia, Spain
[e] ECOSUR (El Colegio de la Frontera Sur) Av del Centenario Km 5.5, Chetumal, Q. R00, CP 77900, Mexico
[f] Laboratório de Ecologia Humana, Escola de Artes, Ciências e Humanidades, Universidade de São Paulo, Brazil
[g] Centre for Mountain Ecosystem Studies, Kunming Institute of Botany, Chinese Academy of Sciences, Heilongtan, Kunming 650204, China
[h] Centre for Development and Environment (CDE), University of Bern, Hallerstrasse 10, 3012 Bern, Switzerland
[i] Department of Anthropology, Colorado State University, Fort Collins, CO 80525, United States of America
[j] Institute of Research for Development (IRD) and, Centre for International Forestry Research (CIFOR), PO Box 5992, Vientiane, Lao PDR
[k] Department of Agrculture and Ecology, University of Copenhagen, Thorvaldsensvej 40, 1871 Frederiksberg, Denmark
[l] Department of Economics, Clark University, 950 Main Street, Worcester, MA 01610, USA
[m] Faculty of Geography, University of Science, Vietnam National University, Hanoi, 334, Nguyen Trai, Thanh Xuan, Hanoi, Vietnam
[n] Center for Southeast Asian Studies, Kyoto University, Kyoto 606-8501, Japan
[o] East-West Center, 1601 East-West Road, Honolulu, HI 96848 USA
[p] Institute of Economic Botany, New York Botanical Garden, Bronx, NY 10458, USA
[q] Anthropology, School of Social Science, University of Queensland, St Lucia, Queensland, Australia
[r] Geography Department, National University of Singapore, 1 Arts Link Kent Ridge, Singapore 117570, Singapore

ARTICLE INFO

Article history:
Received 15 December 2010
Received in revised form 12 October 2011
Accepted 22 October 2011
Available online 28 January 2012

Keywords:
Land use change
Swidden cultivation
Drivers
Impacts
Forest-agriculture frontiers
Metaanalysis

ABSTRACT

This meta-analysis of land-cover transformations of the past 10–15 years in tropical forest-agriculture frontiers world-wide shows that swidden agriculture decreases in landscapes with access to local, national and international markets that encourage cattle production and cash cropping, including biofuels. Conservation policies and practices also accelerate changes in swidden by restricting forest clearing and encouraging commercial agriculture. However, swidden remains important in many frontier areas where farmers have unequal or insecure access to investment and market opportunities, or where multi-functionality of land uses has been preserved as a strategy to adapt to current ecological, economic and political circumstances. In some areas swidden remains important simply because intensification is not a viable choice, for example when population densities and/or food market demands are low. The transformation of swidden landscapes into more intensive land uses has generally increased household incomes, but has also led to negative effects on the social and human capital of local communities to varying degrees. From an environmental perspective, the transition from swidden to other land uses often contributes to permanent deforestation, loss of biodiversity, increased weed pressure, declines in soil fertility, and accelerated soil erosion. Our prognosis is that, despite the global trend towards land use intensification, in many areas swidden will remain part of rural landscapes as the safety component of diversified systems, particularly in response to risks and uncertainties associated with more intensive land use systems.

* Corresponding author. Tel.: +45 35 32 25 00; fax: +45 35 32 25 01.
E-mail addresses: nvv@geo.ku.dk (N. van Vliet), om@geo.ku.dk (O. Mertz), andreas.heinimann@cde.unibe.ch (A. Heinimann), Tla@geo.ku.dk (T. Langanke), up211@cam.ac.uk (U. Pascual), bschmook@ecosur.mx (B. Schmook), cadams@usp.br (C. Adams), peter.messerli@cde.unibe.ch (P. Messerli), Steve.Leisz@colostate.edu (S. Leisz), j.castella@ird.fr (J.-C. Castella), lj@geo.ku.dk (L. Jørgensen), tbt@geo.ku.dk (T. Birch-Thomsen), cornelia.hett@cde.unibe.ch (C. Hett), thbb@life.ku.dk (T. Bech-Bruun), vukimchi@hus.edu.vn (K.C. Vu), kono@cseas.kyoto-u.ac.jp (K. Yasuyuki), foxj@eastwestcenter.org (J. Fox), w.dressler@uq.edu.au (W. Dressler), geoadz@nus.edu.sg (A.D. Ziegler).

0959-3780/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.gloenvcha.2011.10.009

1. Introduction

Land use and land cover change in tropical forest-agriculture frontiers is a major concern for local, national and global environmental management. Land use transitions can be major drivers of deforestation and other types of habitat degradation (Lambin et al., 2001). Although land use transformations do not follow a fixed pattern (Lambin and Meyfroidt, 2010), the rapidity with which they can happen and the uncertain direction that they may take can aggravate their impacts on ecosystems. Large areas of the forest agriculture frontier are still occupied – partly or fully – by swidden cultivation (also known as shifting cultivation or slash-and-burn – see Mertz et al. (2009) for a definition of swidden and the different terms used for this form of agriculture). Swidden has been the dominant agricultural system in the tropics well into the second half of the 20th century and is often cited as a rational choice for forest farmers under prevailing demographic (e.g., low population densities), environmental (e.g., poor soil quality) and economic (e.g., unequal access to markets) and cultural conditions (Fox et al., 2000; Ickowitz, 2006; Mertz, 2002; Nielsen et al., 2006).

In the last few decades, however, political and economic pressures have encouraged or enforced changes from swidden to more intensive agriculture practices or to other types of land use designed to conserve biodiversity, and preserve ecosystem services, including carbon storage. In addition, the persistent general ignorance of many governments and policy makers regarding the beneficial aspects of swidden has contributed to its so-called demise in some areas (Padoch et al., 2007). Nevertheless, much is still unknown about the exact extent of swidden, its contribution to farmers' livelihoods, its ecological impacts, and the rate at which it is changing. Understanding these processes of change is essential for generating the knowledge that is required to make reasonable decisions at various scales concerning which land uses to pursue or promote, and which land uses to discourage or abandon.

The importance of forest-agriculture frontiers for regional and global environmental management calls for a global assessment of the trends, drivers and impacts of changes in land use patterns. A few studies have provided global estimates on changes in cropland, agricultural intensification, tropical deforestation, pasture expansion, and urbanization (Lambin and Geist, 2006; Rudel et al., 2005) but none of these have focused on changes in swidden cultivation. While a recent review for Southeast Asia (Mertz et al., 2009) provides some answers for that region, comparable reviews are not yet available for Latin America, the Caribbean, Africa and the Pacific regions. The present study is the first attempt to systematically review and analyze swidden patterns at the global scale and to draw general lessons from published case studies across the tropics. The objective of this paper is thus to explore the multiple interactions between the transformation of swidden areas into other land uses and the effects of these transformations on the pursuit of rural livelihoods and the maintenance of ecosystem services. Our specific objectives are therefore to identify (1) the current dynamics of swidden in tropical forest areas; (2) the drivers of change in swidden; and (3) the livelihood and environmental consequences of these transitions in areas where swidden is replaced by other land use types.

2. Methodology

Our meta-analysis follows what Lambin and Geist (2006) call an *a posteriori* comparison of already-published case studies. We recognize several caveats to generating global/regional knowledge from local case studies (Messerli et al., 2009). For example, the case studies themselves may be biased towards the following: (a) interesting issues or hot-spots; (b) publications in English; (c) outcomes that lend themselves to publication; or (d) a particular discipline (Rudel, 2008). Nevertheless, this approach is the only expedient way to derive a global synthesis of the trends, drivers, and potential impacts.

We searched the ISI Web of Knowledge using the following key words: (swidden or shifting cultivation or (slash and burn)) and (change or driver* or impact). We selected case studies published in the last ten years (2000–2010), representing changes occurring between 1995 and 2010.We also asked for the contribution of several experts on the subject to provide a list of publications that could not be retrieved via ISI and that should be considered in this study. Only data published in peer reviewed journals, Ph.D. dissertations and specialised books were selected. We selected publications with a longitudinal approach, specifically describing land use change in areas where swidden is either maintained (stable, intensified) or changing into other types of land use, as well as publications that analyze drivers of change and/or impacts of these changes on livelihoods and/or the environment. The case of observation in our meta-analysis is the geographical site: in general, one site is described per publication but some publications describe several sites. A total of 111 publications were analyzed with information on 157 sites: 92 in Asia and Pacific, 20 in Africa and Madagascar; and 45 in Latin and Central America (Fig. 1). Eighty five percent of the time periods analyzed end between 2000 and 2005.

We divided the reported land use transformations into changes in the extent of swidden cultivation (103 case studies), changes of fallow length (59 case studies), and changes in other land use types present in landscapes formerly or still dominated by swidden (133 case studies) (Table 1). For each case study, we did not directly link plot-level changes in swidden area with changes in area of other land use types because they may have been independent at the landscape scale. As a result, we did not indicate which specific land uses are strictly replacing swidden. Rather, we reported relative changes in all land use types that are occurring simultaneously at the local level. We computed a correspondent factor analysis to test whether changes in swidden area were correlated with regions (Table 1).

We grouped the main drivers of land-use change following the classification of Geist and Lambin (2002) (Table 2). Information about the drivers of the increase and decrease in swidden were provided in 31 and 25 cases, respectively. We computed a cluster analysis (using Euclidean distance) of case studies to identify the combinations of drivers that explain the changes observed in swidden for different regions. The impacts of the transformation of swidden landscapes on livelihoods and the environment were reported in 91 and 130 case studies, respectively. All but one of these case studies described impacts in areas where swidden systems are intensified or where other permanent land use types are increasingly dominant. Only one case (in Ecuador) reported ecological and livelihood impacts of a swidden system where fallow length was increasing.

3. Results and discussion

Out of the 157 case studies reviewed, 103 specifically reported changes in the extent of swidden cultivation. Swidden area was reported to have decreased in 55% of all cases, increased in 32%, and un-changed in 13% (Fig. 2). Additionally, opposing trends were observed locally in most regions. For example, in Lao PDR, swidden area decreased in five cases but increased or remained stable in four others. The only countries where only one trend was identified, with at least two case studies reporting it, were the following: Democratic Republic of Congo and Madagascar where

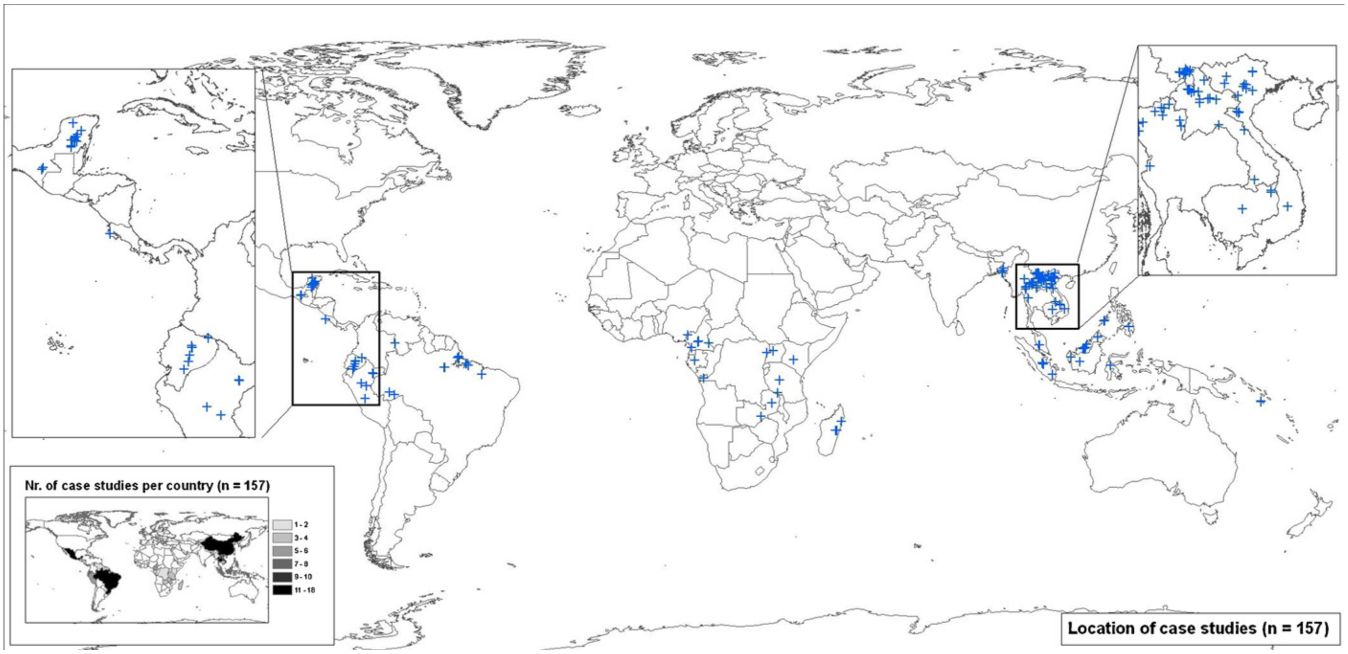


Fig. 1. Location of case studies ($n = 157$).

swidden area increased; China, Cambodia and Thailand where swidden area decreased; and Bangladesh and Solomon Islands where swidden area remained stable. The correspondence factor analysis (axis $F1$ and $F2$ explaining 98% of the variance) showed a significant correlation ($p = 0.003$) between regions and swidden area change. Central Africa and Madagascar were correlated with an increase of swidden area, South East Asia was correlated with a decrease of swidden area and Solomon islands were associated with stable swidden area.

3.1. Swidden persistence

Swidden persistence is observed in Central Africa and Madagascar, where 90% of the cases reported an increase or no change of swidden area. The increase or no change in swidden area is also reported in about 60% of the case studies in Central and Latin America. To a lesser extent, increases were reported in East Africa (40%) and Southeast Asia (28%). Economic and demographic drivers appear to have influenced an increase of swidden in many areas. In Madagascar, for example, the socio-demographic context leading to the increase of swidden include the increase of rural population and rural areas being increasingly integrated into a market oriented economy (Kull et al., 2007; Tachibana et al., 2001). Studies conducted in Costa Rica (Kull et al., 2007) and Mexico (Pascual and Barbier, 2007) found that out-migration or off-farm employment can counter these effects. In Gabon, the establishment of logging camps with higher living standards than surrounding villages and the associated development of roads, has created a population influx and increased swidden in response to increased food demand (Laurance et al., 2006). Agriculture and land policies have also influenced the increase of swidden area in different ways. For example, in the state of Acre (Brazil), development policies and land tenure reform facilitated the transformation of local livelihoods from forest extractive activities (rubber tapping) to swidden or ranching (Salisbury and Schmink, 2007). In contrast, the absence of land titles in Madagascar have led to an increase of swidden area, as it prevented farmers from intensifying agriculture and producing crops using more intensive techniques (Styger et al., 2007). In other places, the sudden stop or absence of government support for cash crops or cattle ranching explains the increase in swidden area: e.g. in Costa Rica (Kull et al., 2007), Mexico (Chowdhury, 2006), Cameroon (Sunderlin et al., 2000), and Ecuador (Rudel et al., 2002).

Our study shows that the above mentioned drivers often occur in combination. In fact, it is the combination of factors rather than the individual factors themselves which best explain the changes in swidden. The cluster analysis of case studies based on the drivers of swidden change identified three main combinations of drivers that lead to swidden increase, i.e. C2: a complex combination of economic drivers (road and market development and economic structures), policies (particularly agricultural policies) and demographic changes (population growth and in-migration) mainly observed in cases from South America and SE Asia; C6: economic opportunities (road and market development) mainly observed in South America, Central Africa and SE Asia; C1: in-migration observed in Central Africa, Central America, South America and SE Asia (Figs. 3 and 4).

3.2. Changes in fallow length

Reductions in fallow length were observed in the majority of cases for which information was available, possibly portending a decline in the sustainability of the system. A total of 49 out of 59 case studies reported a decrease in fallow length in areas where swidden was either expanding and/or being replaced by permanent land use (Table 1). Only four cases, all in the Amazon region, reported an increase in fallow length. Population growth, which often increases competition for land, is one cause of the shortening of forest fallow periods. Also, the high travel cost to distant old-growth forest sways people to clear younger fallows that are closer to human settlements. The marginal increase in fallow length observed in the Amazon seems to be partly driven by concerns with reduced productivity of cash crops because of pests, weed pressure and other biotic factors (Rudel et al., 2002), as well as an increased demand for cheap construction materials that can be harvested from mature fallows. There, the average size of annually cropped fields has decreased significantly; and the size and age of fallows has increased (Padoch et al., 2008).

Table 1
Changes in swidden area, fallow length and other permanent land uses for different tropical forest regions.

Region	Swidden area			Fallow length			Other permanent land uses												
	In	De	NC	In	De	NC	PA	U	Agr	Mf	De.l	Veg	Mon	MixF	AnCr	PdR	Gp	C	ID
Central Africa	2–6	1			4,105	2	1		2,54		4		1		2				
East Africa	17	15,16,18	19		16,17,18, 19,79,90					16				15	15,16, 18,90,103				
Madagascar	7, 20–22				20						20			20					
Central America	7,12–14	8,10,11	9		8–10,12, 13,75,80, 104			75		74	14,75			74	13,75,78, 81,82, 85,92		8, 9,11, 13,85,92		75
South America	24–26,30, 33,34,37, 39	26, 27–29, 31,32,39	36	29,33	30,34,35, 36, 37, 39,69		24	29, 30,68	30,36	29,30, 41,39, 69,73			87	27,29,30, 61,63, 68–70	26,29, 30,63		24–26,30, 32,34,63	30	
Southeast Asia and Pacific Islands	47,60,65, 66,84,88, 91,95	40,42,45, 46–53,55, 57–59,62, 65,71,72, 76,77, 81–84, 88,90,93, 94,96	40,45,47, 56,61,86, 97, 98		23,26,41, 42,46,48, 56,60,71, 83,84,88, 91,93,107, 108,110	65,84, 86,91, 97	40,51,58, 67,71, 76,94	101				44,57, 65,89	38,42, 44,46–51, 62,64–66, 67,71,77, 96,101, 102,106, 109	42,45,47, 71,77,83, 86,88,107	23,38,40, 43,44,47, 52,56–60, 66,83,84, 89,96,107, 110,111	38,44, 46–49, 51,52,57, 60,71,83, 86,88,89, 93,96,99, 100,107, 109,110			

Sources: 1. (van Vliet, 2010); 2. (Mertens et al., 2000); 3. (Sunderlin et al., 2000); 4. (Bogaert et al., 2008); 5. (Makana and Thomas, 2006); 6. (Laurance et al., 2006); 7. (Kull et al., 2007); 8. (Cochran, 2008); 9. (Radel et al., 2010); 10. (Pascual and Barbier, 2005); 11. (Schmook and Radel, 2008); 12. (Gurri and Moran, 2002); 13. (Turner et al., 2001); 14. (Vester et al., 2007); 15. (Ovuka, 2000); 16. (Itani, 2007); 17(Walker and Desanker, 2004); 18. (Kakeya et al., 2006); 19. (Araki, 2007); 20. (Messerli, 2004); 21. (Klanderud et al., 2010); 22. (Styger et al., 2007); 23. (Lestrelin and Giordano, 2007); 24. (Salisbury and Schmink, 2007); 25. (Ludewigs et al., 2009); 26. (de Rouw et al., 2005); 27. (Lewis, 2008); 28. (Steward, 2007); 29. (Padoch et al., 2008); 30. (Sirén, 2007); 31. (Gray et al., 2008); 32. (Perreault, 2005); 33. (Rudel et al., 2002); 34. (Lindell et al., 2010); 35. (Arce-Nazario, 2007); 36. (Hamlin and Salick, 2003); 37. (Coomes et al., 2000); 38. (Thongmanivong et al., 2005); 39. (Freire, 2007); 40. (Rasul and Thapa, 2003);41. (Rasul et al., 2004); 42. (Fox et al., 2008); 43. (Ducourtieux et al., 2006); 44. (Fujita et al., 2006); 45. (Fu et al., 2009); 46. (Xu et al., 2009); 47. (Fox and Vogler, 2005); 48. (Fu et al., 2005); 49. (Manivong and Cramb, 2008); 50. (Hu et al., 2008); 51. (Fox et al., 2009); 52. (Guo et al., 2002); 53. (Ziegler et al., 2009a); 54. (Rerkasem et al., 2009b); 55. (Sandewall et al., 2001); 56. (Thongmanivong and Fujita, 2006); 57. (Thongmanivong et al., 2005); 58. (Kinzelmann and Nampanya, 2004); 59. (Saphangthong and Yasuyuki, 2010); 60. (Robichaud et al., 2009); 61. (Brondizio, 2004); 62. (Heinimann et al., 2007); 63. (Futemma and Brondizio, 2003); 64. (Ichikawa, 2007); 65. (Hansen and Mertz, 2006); 66. (Hansen, 2005); 67. (Belsky and Siebert, 2003); 68. (Brondizio et al., 2003); 69. (Porro, 2005); 70. (Sears et al., 2007); 71. (Dressler and Puhlin, 2010); 72. (Cramb et al., 2009); 73. (Pinedo-Vasquez et al., 2001); 74. (Chowdhury, 2006); 75. (Cayuela et al., 2006); 76. (Hares, 2009); 77. (Pedersen, 2003); 78.a (Ochoa-Gaona and Gonzalez-Espinosa, 2000); 79. (Chidumayo, 2002); 80. (Hartter et al., 2008); 81. (Munos, 2006); 82. (Keys, 2004); 83. (Vu, 2007); 84. (Leisz et al., 2007); 85. (Chowdhury and Turner, 2006); 86. c (Vien et al., 2009); 87. (Barlow et al., 2007); 88. (Castella et al., 2005); 89. (Thanapakpawin et al., 2007); 90. (Mangora, 2005); 91. (Folving and Christensen, 2007); 92. (Chowdhury, 2006); 93. (Jakobsen et al., 2007); 94. (Muller and Zeller, 2002); 95. (Tachibana et al., 2001); 96. (Miyamoto, 2006); 97. (Reenberg et al., 2008); 98. (Birch-Thomsen et al., 2010); 99. (Linquist et al., 2007); 100. (Dressler, 2006); 101. (Rist et al., 2010); 102. (Abdullah and Hezri, 2008); 103. (Mwavu and Witkowski, 2008); 104. (Dalle and de Blois, 2006); 105. (Brown, 2006); 106. (Xu, 2006); 107. (Dendi et al., 2005); 108. (Gafur et al., 2000); 109. (McMorrow and Talip, 2001); 110. (Turkelboom et al., 2008); 111. (Valentin et al., 2008).

I: increase; D: decrease; NC: no change; PA: protected areas; U: urbanization; Agr: agroforestry systems; Mf: manged fallows; De.l: degraded land; Veg.: vegetables or flowers; Mon: monoculture tree crops; MixF: mixed fruit trees; AnCr: annual crops; PdR.: paddy rice; Gp: grass pasture; C.: charcoal extraction; ID: illicit drugs.

Table 2
Variables used to describe the drivers of the transformation of swidden landscapes (based on Geist and Lambin, 2002) and its impacts on livelihoods and the environment.

Drivers	Demographic drivers	(in/out) migration
		Population growth
		Population distribution
	Economic drivers	Road network
		Logging and mining infrastructure development
		Market development
		Economic structures (e.g. credit, cooperatives)
		Urbanization
		Agro technical innovations
	Policy and institutional drivers	Public policies (e.g. land use, forest, agriculture)
	Social and cultural drivers	Public attitudes towards swidden
		Social trigger
	Environmental and biophysical drivers	Environmental and biophysical drivers (slope, topography, fires, droughts, floods and pests etc.)
Impacts	Livelihood impacts	Income
		Labour demand
		Equity (including gender, ethnic, age class equity)
		Food security
		Access to land
		Health and education
		Demographic stability (e.g. no out-migration)
		Social networks
		Conflicts
		Cultural identity
	Environmental impacts	Soil fertility
		Soil erosion
		Invasive species
		Weed pressure
		Agrobiodiversity
		Biodiversity
		Forest cover
		Carbon sequestration
		Water quality

3.3. Swidden in transition

The demise of swidden appears to be a reality in many forest agriculture frontiers, especially in Southeast Asia, as others have already reported (Padoch et al., 2007). The results of the cluster analysis indicated three main combinations of drivers that lead to swidden area decrease: C5: market development and population growth mainly observed in cases from SE Asia but also from South and Central America and Madagascar; C4: policies (particularly conservation policies) mainly in SE Asia but also in East Africa; C7: economic structures, population growth and conservation policies mainly in SE Asia but also in Central America and East Africa (Fig. 4).

The changes of swidden cultivation in Southeast Asia appear to be faster than in other regions, likely in part due to government policies that have curbed swidden via prohibition or incentivizing its conversion to permanent agriculture (Fox et al., 2009; Padoch et al., 2007; Ziegler et al., 2009b). Throughout the region, swiddeners have been marginalized by laws that criminalize their practices, land laws that restrict the use of land to permanent agriculture or forestry, and the expansion of forest departments and conservation organizations, which sometimes evict swiddeners from lands under their control through resettlement (Dressler and Puhlin, 2010). However, the knowledge of the scale of swidden area change and number of people dependant on this system is still largely anecdotal (Schmidt-Vogt et al., 2009), perhaps with the exception of Lao PDR (Messerli et al., 2009). In many countries, the negative perception of swidden has been translated into policy documents, laws, and practices, ranging from the tagging of swidden cultivators as "lower quality people" in Southwest China to "isolated backward populations" in Indonesia (Li, 1999) and to "pyromaniacs" in Madagascar (Kull et al., 2007). Furthermore, policies for establishing permanent agricultural land uses are common in the Brazilian Amazon and include exemptions of agricultural incomes from taxation, rules determining land tenure security, progressive land taxes encouraging clearing and conversion to pasture, and credit schemes that subsidise corporate livestock ranches (Binswanger and Deininger, 1997). Likewise, the government in Madagascar has also a long history of attempting to

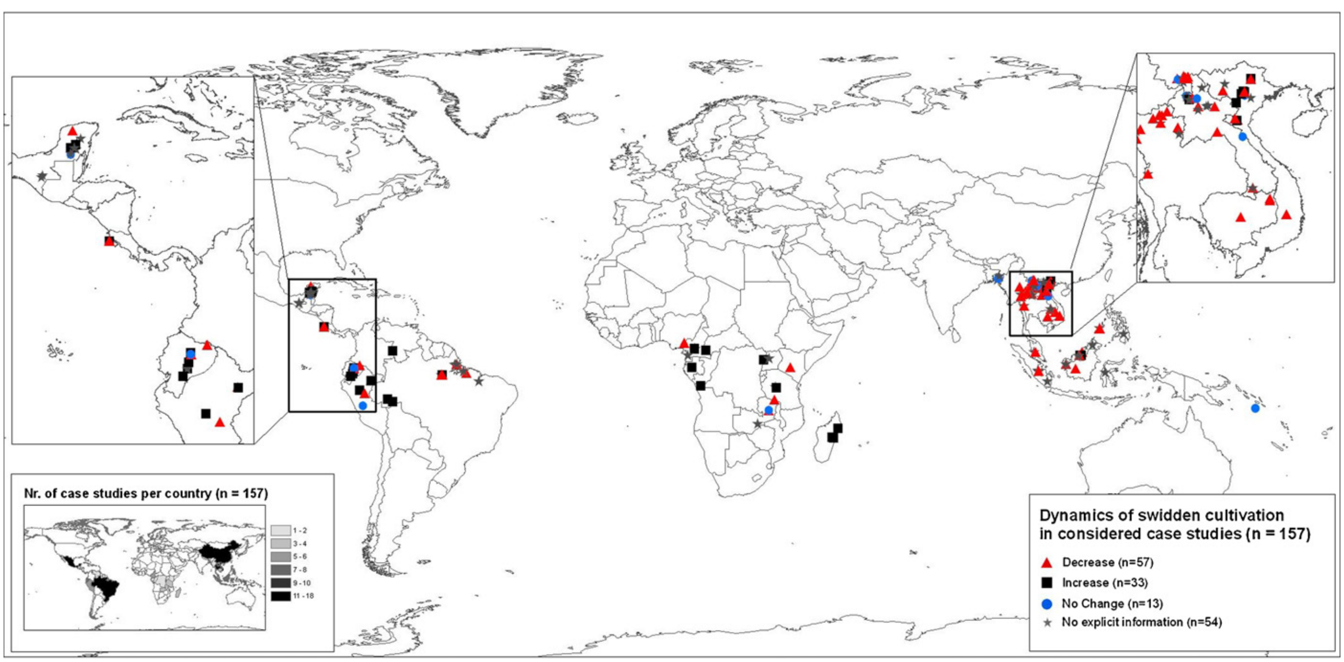


Fig. 2. Change (or no change) in swidden areas considered in case studies ($n = 157$).

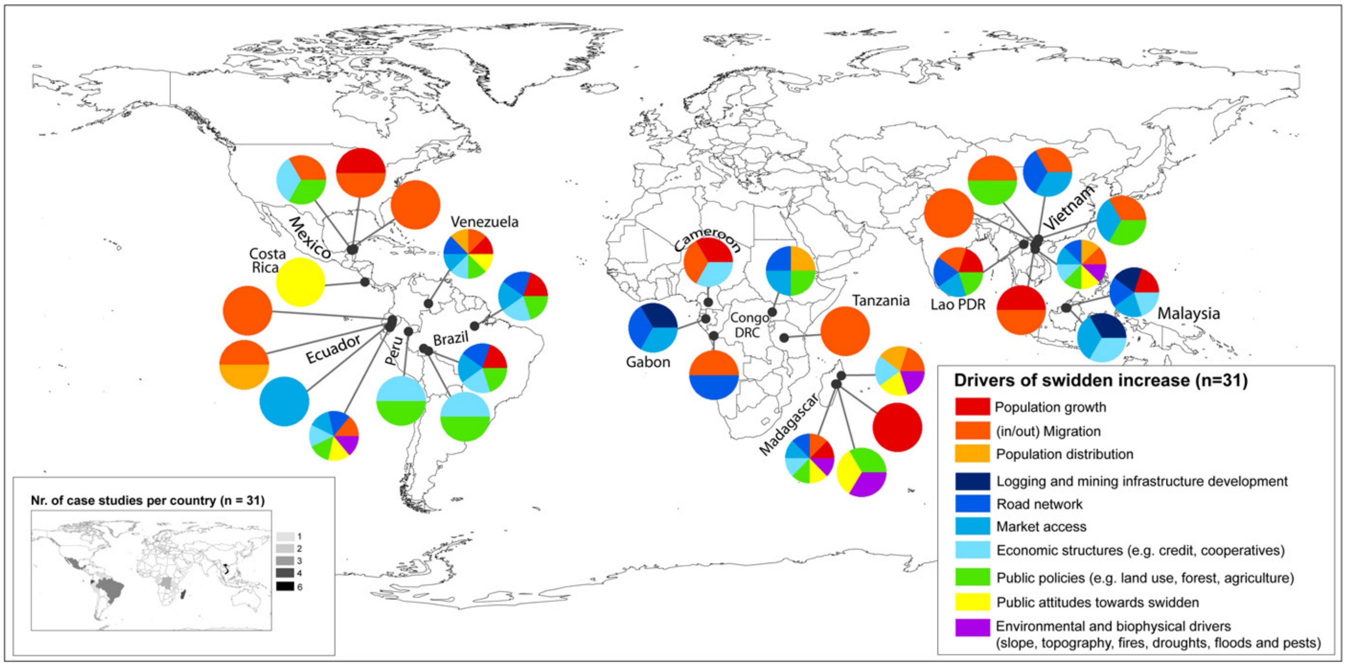
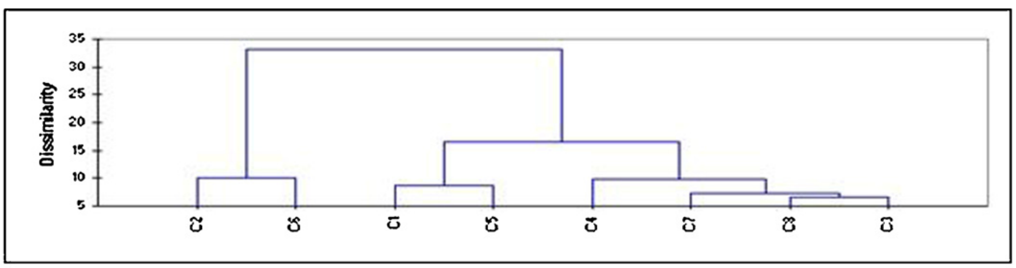


Fig. 3. Drivers of increase in swidden area ($n = 31$) (each pie shows the drivers mentioned for each of the case studies).



Groups	Combination of drivers that describe each group (based on the value of centroïds for each cluster)	Regions							Swidden change		
		CA	EA	SA	CAM	SEA	M	Sal	increase	decrease	stable
C2	road development market development policies population growth in migration	0%	13%	38%	13%	25%	0%	0%	63%	0%	37%
C6	road development market development	28%	0%	43%	0%	28%	0%	0%	85%	15%	0%
C1	in migration	20%	10%	20%	20%	30%	0%	0%	100%	0%	0%
C5	market development population growth	3%	0%	9%	3%	79%	3%	3%	13%	73%	7%
C4	policies	7%	13%	0%	7%	73%	0%	0%	20%	60%	20%
C7	economic structures population growth policies	0%	17%	0%	16%	67%	0%	0%	0%	100%	0%
C8	public attitudes	0%	0%	38%	13%	25%	25%	0%	43%	29%	29%
C3	economic structures	0%	0%	67%	8%	17%	0%	8%	18%	54%	28%

Fig. 4. Results of the cluster analysis of case studies based on the drivers of swidden change (the numbers in each cell indicate the % of cases from each cluster group that belong to each region, or to each swidden trend). Definitions of the drivers of change listed are found in Table 2.

end swidden agriculture, arguing that the demise of swidden will promote biodiversity conservation and increase crop yields enough to balance rising populations (Hume, 2006). Integration with large regional markets sometimes lures farmers away from swidden to other activities. In Sarawak (Malaysia), many areas under swidden have decreased rapidly because of land development for oil palm plantation (Cramb, 2007; Fox et al., 2009; Hansen and Mertz, 2006). Similar developments are occurring in Lao PDR and China, where large scale conversion to rubber is taking place (Sturgeon, 2005; Ziegler et al., 2009b). Swidden has also been decreasing in many areas of Vietnam and Lao PDR because of strict land allocation programmes and government-supported programmes focusing on wet rice cultivation (Muller and Zeller, 2002; Thongmanivong and Fujita, 2006). In Vietnam, investments in irrigation and infrastructure, combined with improved access to roads, markets, and services, allow agricultural productivity to sustain larger populations on virtually the same area that was previously used by swiddeners (Muller and Zeller, 2002).

The transition of swidden to permanent agriculture, such as monoculture tree crop plantations, annual cash crops and paddy rice, together with the expansion of protected areas are therefore common trends in Southeast Asia (Figs. 5 and 6). East African case studies mainly described the increase of annual crops. In Zambia, the introduction of credits for agricultural inputs in the early 1990s helped semi-permanent hybrid maize cultivars slowly replaced the local swidden system (Kakeya et al., 2006). Meanwhile, the main land cover conversion in Uganda was from forests/woodlands to sugarcane plantations, threatening the availability of land for use by the local population (Mwavu and Witkowski, 2008). In Central Africa, swidden remains dominant but locally competes with food crops (such as banana and plantain) (Mertens et al., 2000; Sunderlin et al., 2000), cocoa production under agroforestry systems and land alienation for the establishment of protected areas (van Vliet, 2010). In Central and South America, swidden lands are threatened by the expansion of pasture for cattle grazing, the establishment of fruit trees and annual crops, and charcoal

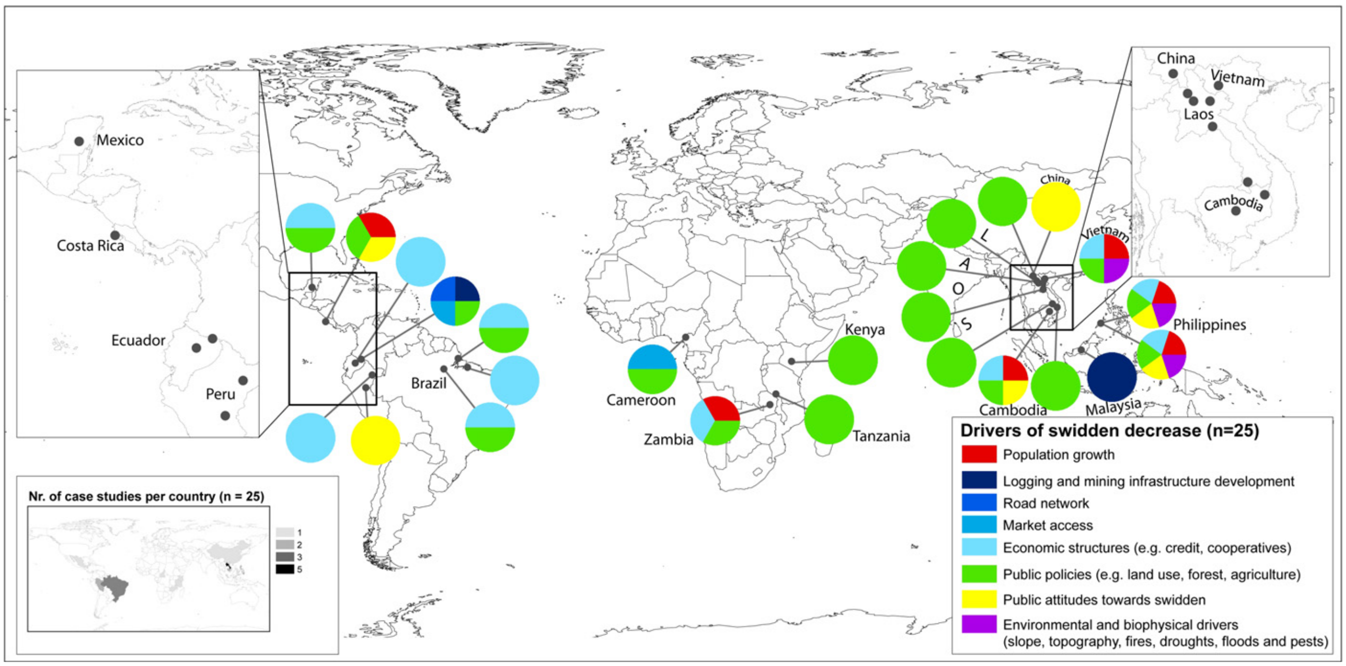


Fig. 5. Drivers of decrease in swidden area ($n = 25$) (each pie shows the drivers mentioned for each of the case studies).

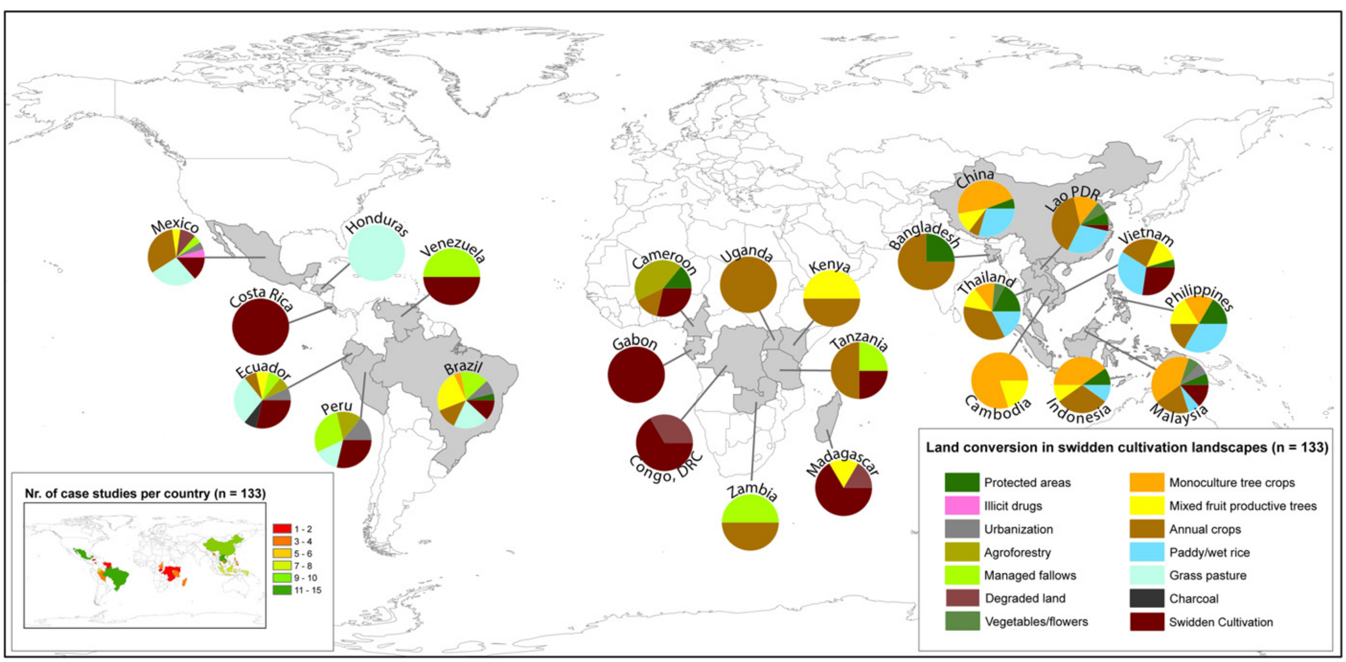


Fig. 6. Transitions of swidden landscapes ($n = 133$) (the portion in each pie shows the number of case studies reporting a transition towards land use type X).

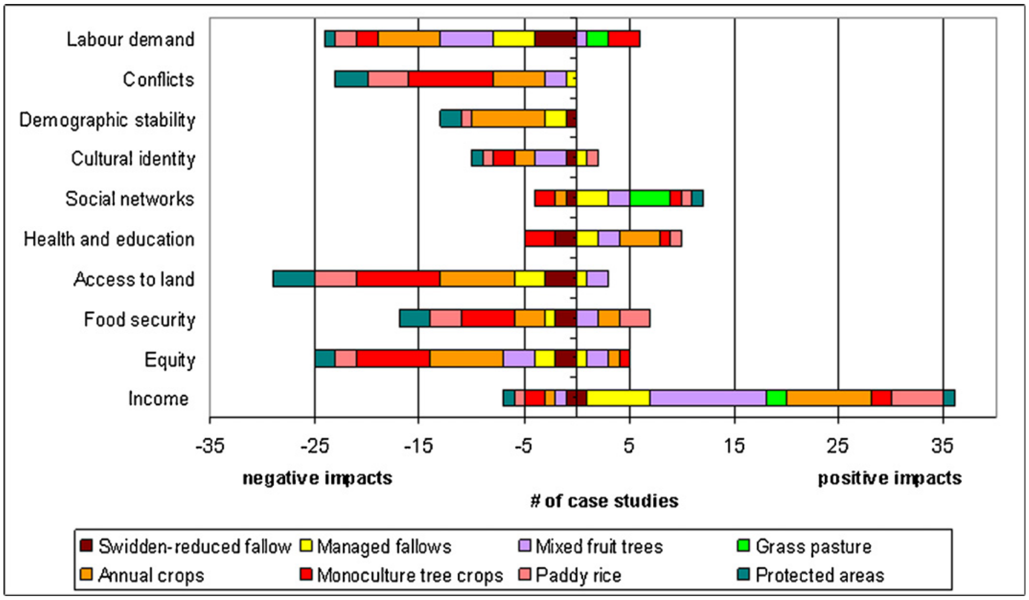


Fig. 7. Impacts of the transformation of swidden landscapes on local livelihoods and per land use category ($n = 91$) (the negative side of axis X shows the number of case studies mentioning a deterioration or a negative impact on each of the variables, the positive side shows the number of case studies mentioning an improvement or a positive impacts on each of the variables).

extraction. For example, major trends in the southern Yucatan (Mexico) are from swidden to grass pasture and annual cash crops such as chilli. Indeed, out-migration in Mexico has led a shift to less labour-intensive agricultural activities and investment in land uses more compatible with migration, such as grazing pasture (Schmook and Radel, 2008).

3.4. Impacts on local livelihoods and the environment

The transition of swidden landscapes towards more intensive land uses has mainly translated into an increase in household income, particularly in cases where managed fallows (Padoch et al., 2008), mixed fruit trees (Fox et al., 2008; Fu et al., 2009; Xu et al., 2009), annual crops (Rasul and Thapa, 2003) or paddy rice (Xu et al., 2009) have expanded at the expense of swidden. However, the positive impacts on household income of various transitions, particularly those involving tree crops and permanent commercial agriculture, have often been offset by exacerbated inequities and increased conflicts over land (Dressler and Puhlin, 2010; Rist et al., 2010) (Fig. 7). Many of the land-use changes have led to positive changes in health, education (Cochran, 2008; Fox et al., 2008) and social networking (Dressler and Puhlin, 2010; Fox et al., 2008). However, they have also led to increased out-migration (Dressler, 2006; Itani, 2007; Kakeya et al., 2006) and loss in cultural identity (Cramb et al., 2009; Dressler and Puhlin, 2010; Fox et al., 2008; Xu et al., 2009).

Although the transformation of swidden landscapes has often been associated with higher incomes, its environmental consequences have often been negative (Fig. 8). These include a permanent decrease in forest cover at the landscape scale

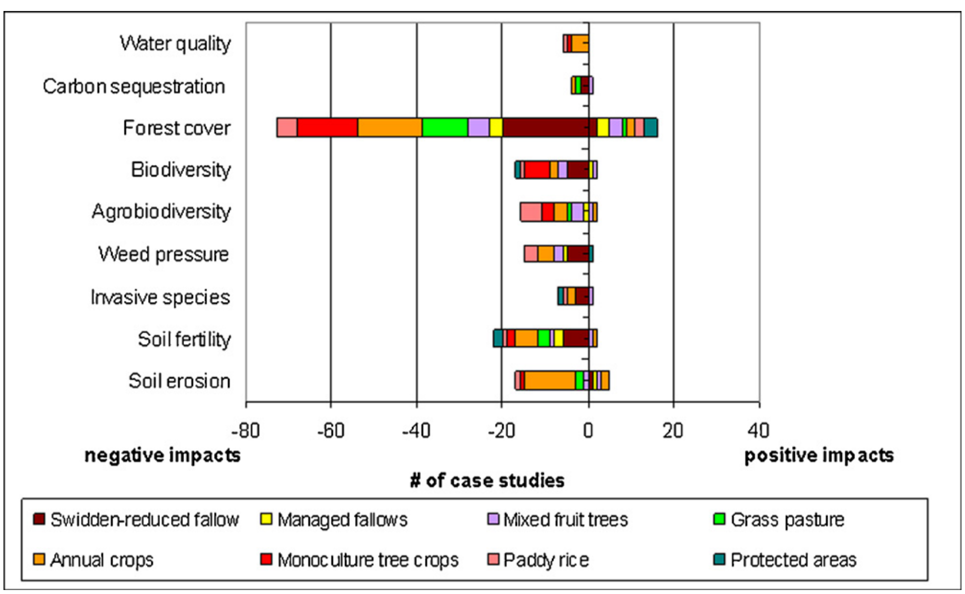


Fig. 8. Impacts of the transformation of swidden landscapes on environmental variables and per land use category ($n = 130$) (the negative side of axis X shows the number of case studies mentioning a deterioration or a negative impact on each of the variables, the positive side shows the number of case studies mentioning an improvement or a positive impacts on each of the variables).

combined with substantial losses of wild biodiversity and agrobiodiversity, increases in weed pressure, decreases in soil fertility, accelerated erosion, declines in stream water quality, and potential reductions in sequestered carbon. For example, the expansion of monoculture tree crops in Asia, reported to substantially increase household incomes, has most often increased deforestation, loss of biodiversity, and increased land conflicts (Barlow et al., 2007; Belsky and Siebert, 2003; Fox et al., 2008; Rist et al., 2010; Xu et al., 2009). Although less studied, the expansion of the low labour demanding cattle pasture has in some instances translated into increased household income and improved social networks, but with increased deforestation (Schmook and Radel, 2008). The establishment of protected areas and forest reserves may have helped to reduce deforestation trends, but these conservation measures have often translated into decreases in the amount of land available to maintain local food security (Belsky and Siebert, 2003; Thongmanivong et al., 2005; van Vliet, 2010). Soil erosion has increased and soil fertility decreased with increased paddy rice production (Vu, 2007; Ziegler et al., 2009a) and other annual crops produced in permanent fields (Itani, 2007; Ovuka, 2000; Ziegler et al., 2009a) at the expense of swidden systems. Wild biodiversity and agrobiodiversity have been eroded in the context of increased monoculture tree crops and paddy rice production particularly in South East Asia (Rerkasem et al., 2009b; Xu et al., 2009). Water quality is also threatened by the growing use of fertilizers and pesticides in areas where commercial agriculture and monoculture tree crops have replaced swiddening and water extraction for irrigation of paddy rice and annual crops increasingly results in stream desiccation (Dressler and Puhlin, 2010; Ziegler et al., 2009b). In contrast, less intensive and more diversified land uses, such as managed fallows and mixed fruit trees, generally increased household income and food security, at the same time maintaining forest cover, biodiversity, and soil fertility (Chowdhury and Turner, 2006; Messerli, 2004; Padoch et al., 2008; Porro, 2005; Sears et al., 2007; Xu et al., 2009).

Swiddening may promote biodiversity (Padoch and Pinedo-Vasquez, 2010) where short cultivation periods, long fallows, and the mosaic character of traditional systems maintains sufficient seed pools to allow the regeneration of diverse secondary forests (Rerkasem et al., 2009a). However, the increase of swidden cultivation with reduced fallow length has had continued negative effects on forest cover and the degradation of soil fertility in many places (Bogaert et al., 2008; Fox and Vogler, 2005; Lindell et al., 2010; Ludewigs et al., 2009; Tachibana et al., 2001).

4. Conclusions

In the 157 reviewed case studies conducted world-wide, swidden area decreased in more than half and increased or remained stable in the others. The majority cite policies and the development of market opportunities as the main drivers of change – yet regional differences exist. Forest and conservation policies, human resettlement, and market integration are primary drivers for swidden decrease in SE Asia. The main driver of swidden decrease in East Africa is the implementation of agricultural policies to encourage cash crop production. In South and Central America, the decline in swidden is driven by market integration together with policies that encourage cattle ranching and cash crops through credit or subsidies.

Swidden increase is clearly dominant in Central Africa and Madagascar, but is also reported in several case studies in Central and Latin America. Swidden remains important in areas where farmers have little access to credit, face high transactions costs, or where farmers have deliberately preserved multi-functionality as a strategy to cope with risk. The absence of policies that secure land tenure and promote agricultural intensification for national or international markets and population increase are cited as the main drivers of swidden increase. In a world characterized by risks and uncertainty, swidden cultivation is likely to remain an important land use type, whether as the main agricultural system or as a safety net, at least as long as forests outside protected areas are not fully converted into permanent agriculture or urbanized zones.

For many farmers, the shift from swidden to cash crops offers almost immediate economic benefits. But these changes may also have many long-term negative impacts on forests, biodiversity, ecosystem services, and local livelihoods. While the occurrence and extent of negative impacts is often location specific, their prevalence is somewhat ironic, because transformations away from swidden have often been encouraged to improve the sustainability of agriculture practices on tropical forest frontiers. Agricultural intensification has the potential for increasing local production and income, and for conserving forests that are no longer needed for a swidden cycle. However, the potential that intensification of agriculture can reduce cultivated areas and spare land is far from being systematically valid as agricultural intensification tends to be associated with agricultural expansion and deforestation in many cases (Angelsen and Kaimowitz, 2001; Rudel et al., 2009). Besides, agricultural intensification has often come along with increased inequality and conflicts which often arise from policies promoting such development.

Important to the international debate on climate change mitigation is that the transition from swiddening to many intensive cropping systems may reduce total carbon stocks. Time-averaged, above-ground carbon may decline more than 90% when long-fallow swidden systems give way to rotational systems with short fallows or are replaced by continuous annual crops, including oil palm (Bruun et al., 2009). Reductions of soil organic carbon on the order of 10–40% result from the conversion to continuous annual cropping (Bruun et al., 2009). The largest declines are associated with mechanically established plantations. The possibility that swiddening may sequester more carbon than some other tree-based and/or biofuel plantations opens the debate as to which of these types of ventures, if any, should qualify for REDD+ incentives.

This study, based on a meta-analysis of local case studies, has been useful in making qualitative assessments of regional and global patterns of land use change in swidden landscapes. However, the results need to be taken with caution given the biases inherent of meta-analysis for generation global or even regional knowledge from local case studies (Messerli et al., 2009; Rudel, 2008). Besides, conclusions based on this approach for regions constrained by the limited availability of case studies (e.g. Africa and South America), are necessarily tentative. Furthermore, our approach, based on existing case studies conducted in different years and spanning different time periods, does not allow distinguishing regional land-use change trends over the same time period. We therefore stress the need to develop more standardized methods that allow generating quantitative information on land use changes in swidden landscapes at broader spatial scales and specific temporal units. Furthermore, the full livelihood impacts on rural communities involved in the transformations of swidden landscapes particularly those on health and education, social and cultural change remain poorly understood.

Acknowledgements

Work for this paper was supported by a grant from the Danish Social Science Research Council, the Global Land Project (GLP) and the Swiss National Centre of Competence in Research (NCCR) North–South. The authors are grateful for contributions by Daniel Muller and Patrick Meyfroidt.

This review identifies changes in swiddening world-wide over the last 10–15 years, explores the drivers of observed changes, and discusses how patterns of changes impact rural livelihoods and the environment.

Despite the global trend towards land use intensification, swidden remains a safety component of diversified systems, particularly in response to risks and uncertainties associated with more intensive land use systems.

Intensification in former swidden landscapes has generally increased household incomes, but has not translated into land sparing as it tends to be associated with agricultural expansion and deforestation.

References

Abdullah, S.A., Hezri, A.A., 2008. From forest landscape to agricultural landscape in the developing tropical country of Malaysia: pattern, process, and their significance on policy. Environmental Management 42, 907–917.

Angelsen, A., Kaimowitz, D., 2001. The Role of Agricultural Technologies in Tropical Deforestation. Cabi publishing, United Kingdom.

Araki, S., 2007. Ten years of population change and the chitemene slash-and-burn system around the Mpika area, Northern Zambia. African Studies Monographs 34 (Suppl.), 75–89.

Arce-Nazario, J.A., 2007. Human landscapes have complex trajectories: reconstructing Peruvian Amazon landscape history from 1948 to 2005. Landscape Ecology 22, 89–101.

Barlow, J., Mestre, L.A.M., Gardner, T.A., Peres, C.A., 2007. The value of primary, secondary and plantation forests for Amazonian birds. Biological Conservation 136, 212–231.

Belsky, J.M., Siebert, S.F., 2003. Cultivating cacao: implications of sun-grown cacao on local food security and environmental sustainability. Agriculture and Human Values 20, 277–285.

Binswanger, H., Deininger, K., 1997. Explaining Agricultural and Agrarian Policies in Developing Countries. FAO, Rome.

Birch-Thomsen, T., Reenberg, A., Mertz, O., Fog, B., 2010. Continuity and change: spatio-temporal land use dynamics on Bellona Island, Solomon Islands. Singapore Journal of Tropical Geography 31, 27–40.

Bogaert, J., et al., 2008. Fragmentation of forest landscapes in Central Africa: Causes, consequences and management. Patterns and processes in forest landscapes: Multiple use and sustainable management 67–87.

Brondizio, E., 2004. Agriculture intensification, economic identity, and shared invisibility in Amazonian peasantry: caboclos and colonists in comparative perspective. Culture & Agriculture 26, 1–24.

Brondizio, E.S., Safar, C.A., Siqueira, A.D., 2003. The urban market of Acai fruit (*Euterpe oleracea* Mart.) and rural land use change: ethnographic insights into the role of price and land tenure constraining agricultural choices in the Amazon estuary. Urban Ecosystems 6, 67–97.

Brown, D.R., 2006. Personal preferences and intensification of land use: their impact on southern Cameroonian slash-and-burn agroforestry systems. Agroforestry Systems 68, 53–67.

Bruun, T.B., de Neergaard, A., Lawrence, D., Ziegler, A., 2009. Environmental consequences of the demise in swidden agriculture in Southeast Asia: carbon storage and soil quality. Human Ecology 37, 375–388.

Castella, J.C., Boissau, S., Trung, T.N., Quang, D.D., 2005. Agrarian transition and lowland–upland interactions in mountain areas in northern Vietnam: application of a multi-agent simulation model. Agricultural Systems 86, 312–332.

Cayuela, L., Benayas, J.M.R., Echeverria, C., 2006. Clearance and fragmentation of tropical montane forests in the Highlands of Chiapas, Mexico (1975–2000). Forest Ecology and Management 226, 208–218.

Chidumayo, E.N., 2002. Changes in miombo woodland structure under different land tenure and use systems in central Zambia. Journal of Biogeography 29, 1619–1626.

Chowdhury, R.R., 2006. Landscape change in the Calakmul biosphere reserve, Mexico: modeling the driving forces of smallholder deforestation in land parcels. Applied Geography 26, 129–152.

Chowdhury, R.R., Turner, B.L., 2006. Reconciling agency and structure in empirical analysis: smallholder land use in the Southern Yucatan, Mexico. Annals of the Association of American Geographers 96, 302–322.

Cochran, D.M., 2008. Who will work the land? National integration, cash economies, and the future of shifting cultivation in the Honduran Mosquitia. Journal of Latin American Geography 7 (1).

Coomes, O.T., Grimard, F., Burt, G.J., 2000. Tropical forests and shifting cultivation: secondary forest fallow dynamics among traditional farmers of the Peruvian Amazon. Ecological Economics 32, 109–124.

Cramb, R.A., 2007. Land and Longhouse. In: Agrarian transformation in the uplands of Sarawak, NIAS Press, Copenhagen.

Cramb, R.A., et al., 2009. Swidden transformations and rural livelihoods in Southeast Asia. Human Ecology 37, 323–346.

Dalle, S.P., de Blois, S., 2006. Shorter fallow cycles affect the availability of noncrop plant resources in a shifting cultivation system. Ecology and Society 1, 1.

de Rouw, A., Soulilad, B., Phanthavong, K., Dupin, B., 2005. The adaptation of upland rice cropping to ever-shorter fallow periods and its limit. In: Bouahom, B., Glendinning, A., Nilsson, S., Victor, M. (Eds.), Poverty Reduction and Shifting Cultivation Stabilisation in the Uplands of Lao PDR: Technologies, Approaches and Methods for Improving Upland Livelihoods. National Agriculture and Forestry Research Institute, Ventiane.

Dendi, A., Shivakoti, G.P., Dale, R., Ranamukhaarachchi, S.L., 2005. Evolution of the Minangkabau's shifting cultivation in the west Sumatra highland of Indonesia and its strategic implications for dynamic farming systems. Land Degradation & Development 16, 13–26.

Dressler, W., Puhlin, J., 2010. The shifting ground of swidden agriculture on Palawan Island, the Philippines. Agriculture and Human Values 27, 445–459.

Dressler, W.H., 2006. Co-opting conservation: migrant resource control and access to national park management in the Philippine uplands. Development and Change 37, 401–426.

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

Folving, R., Christensen, H., 2007. Farming system changes in the Vietnamese uplands - using fallow length and farmers' adoption of Sloping Agricultural Land Technologies as indicators of environmental sustainability. Geografisk Tidsskrift-Danish Journal of Geography 107, 43–58.

Fox, J., et al., 2009. Policies, Political-Economy, and Swidden in Southeast Asia. Human Ecology 37, 305–322.

Fox, J., McMahon, M.D., Poffenberger, M., Vogler, J., 2008. Land for my Grandchildren: Land-Use and Tenure Change in Ratanakiri. Community Forestry International (CFI) and East West Center, Honolulu.

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.

Fox, J., Vogler, J., 2005. Land-use and land-cover change in Montane Mainland Southeast Asia. Environmental Management 36, 394–403.

Freire, G.N., 2007. Indigenous shifting cultivation and the new Amazonia: a Piaroa example of economic articulation. Human Ecology 35, 681–696.

Fu, Y.N., Brookfield, H., Guo, H.J., Chen, J., Chen, A.G., Cui, J.Y., 2009. Smallholder rubber plantation expansion and its impact on local livelihoods, land use and agrobiodiversity, a case study from Daka, Xishuangbanna, southwestern China. International Journal of Sustainable Development and World Ecology 16, 22–29.

Fu, Y.N., Guo, H.J., Chen, A.G., Cui, J.Y., 2005. Fallow agroecosystem dynamics and socioeconomic development in China: Two case studies in Xishuangbanna Prefecture, Yunnan Province. Mountain Research and Development 25, 365–371.

Fujita, Y., Thongmanivong, S., and Vongvisouk, T., 2006. Dynamic land use change in Sing district, Luang Namtha province, Lao PDR. On the Interactions between Population, Development, and the Environment. Ventiane.

Futemma, C., Brondizio, E.S., 2003. Land reform and land-use changes in the lower Amazon: implications for agricultural intensification. Human Ecology 31, 369–402.

Gafur, A., Borggaard, O.K., Jensen, J.R., Petersen, L., 2000. Changes in soil nutrient content under shifting cultivation in the Chittagong Hill Tracts of Bangladesh. Geografisk Tidsskrift, Danish Journal of Geography 100, 37–46.

Geist, H.J., Lambin, E.F., 2002. Proximate causes and underlying driving forces of tropical deforestation. BioScience 52, 143–150.

Gray, C.L., Bilsborrow, R.E., Bremner, J.L., Lu, F., 2008. Indigenous land use in the Ecuadorian Amazon: a cross-cultural and multilevel analysis. Human Ecology 36, 97–109.

Guo, H., Padoch, C., Coffey, K., Aiguo, C., Yongneng, F., 2002. Economic development, land use and biodiversity change in the tropical mountains of Xishuangbanna, Yunnan, Southwest China. Environmental Science & Policy 5, 471–479.

Gurri, F., Moran, E., 2002. Who is interested in commercial agriculture?: subsistence agriculture and salaried work in the city among the Yucatec Maya from the state of Yucatan. Culture and Agriculture.

Hamlin, C.C., Salick, J., 2003. Yanesha agriculture in the upper Peruvian Amazon: persistence and change fifteen years down the 'road'. Economic Botany 57, 163–180.

Hansen, T.S., 2005. Spatio-temporal aspects of land cover and land use changes in the Niah Catchment, Sarawak, Malaysia. Singapore Journal of Tropical Geography 26, 170–190.

Hansen, T.S., Mertz, O., 2006. Extinction or adaptation? Three decades of change in shifting cultivation in Sarawak, Malaysia. Land Degradation and Development 17, 135–148.

Hares, M., 2009. Forest conflict in Thailand: northern minorities in focus. Environmental Management 43, 381–395.

Hartter, J., Lucas, C., Gaughan, A.E., Aranda, L.L., 2008. Detecting tropical dry forest succession in a shifting cultivation mosaic of the Yucatan Peninsula, Mexico. Applied Geography 28, 134–149.

Heinimann, A., Messerli, P., Schmidt-Vogt, D., Wiesmann, U., 2007. The dynamics of secondary forest landscapes in the lower Mekong basin: a regional-scale analysis. Mountain Research and Development 27, 232–241.

Hu, H.B., Liu, W.J., Cao, M., 2008. Impact of land use and land cover changes on ecosystem services in Menglun, Xishuangbanna, Southwest China. Environmental Monitoring and Assessment 146, 147–156.

Hume, D.W., 2006. Swidden agriculture and conservation in eastern Madagascar: stakeholder perspectives and cultural belief systems. Conservation and Society 4, 287–303.

Ichikawa, M., 2007. Degradation and loss of forest land and land-use changes in Sarawak, East Malaysia: a study of native land use by the Iban. Ecological Research 22, 403–413.

Ickowitz, A., 2006. Shifting cultivation and deforestation in tropical Africa: critical reflections. Development and Change 37, 599–626.

Itani, J., 2007. Effects of scoci-economic changes on cultivation systems under customary land tenure in Mbozi district, Southern Tanzania. African Study Monographs 34 (Suppl.), 57–74.

Jakobsen, J., Rasmussen, K., Leisz, S., Folving, R., Quang, N.V., 2007. The effects of land tenure policy on rural livelihoods and food sufficiency in the upland village of Que, North Central Vietnam. Agricultural Systems 94, 309–319.

Kakeya, M., Sugiyama, Y., Oyama, S., 2006. The Citemene system, social leveling mechanism, and agrarian changes in the bemba villages of northen Zambia: an overview of 23 years of "fixed point" research. African Study Monographs 27, 27–38.

Keys, E., 2004. Commercial agriculture as creative destruction or destructive creation: a case study of chili cultivation and plant-pest disease in the southern Yucatan region. Land Degradation & Development 15, 397–409.

Kinzelmann, L., Nampanya, S., 2004. Changes in Houay Cha village – from shifting cultivation to integrated upland farming. Shifting Cultivation and Poverty Eradication in the Uplands of the Lao PDR, 42. NAFRI, Ventiane, pp. 9–439.

Klanderud, K., et al., 2010. Recovery of plant species richness and composition after slash-and-burn agriculture in a tropical rainforest in Madagascar. Biodiversity and Conservation 19, 187–204.

Kull, C.A., Ibrahim, C.K., Meredith, T.C., 2007. Tropical forest transitions and globalization: neo-liberalism, migration, tourism, and international conservation agendas. Society & Natural Resources 20, 723–737.

Lambin, E.F., Geist, H.J., 2006. Land-use and land-cover change. In: Local Processes and Global Impacts, Springer, Berlin.

Lambin, E.F., Meyfroidt, P., 2010. Land use transitions: socio-ecological feedback *versus* socio-economic change. Land Use Policy 27, 108–118.

Lambin, E.F., et al., 2001. The causes of land-use and land-cover change: moving beyond the myths. Global Environmental Change 11, 261–269.

Laurance, W.F., Alonso, A., Lee, M., Campbell, P., 2006. Challenges for forest conservation in Gabon, Central Africa. Futures 38, 454–470.

Leisz, S., Rasmussen, K., Olesen, J.E., Vien, T.D., Elberling, B., Christiansen, L., 2007. The impacts of local farming system development trajectories on greenhouse gas emissions in the northern mountains of Vietnam. Regional Environmental Change 7, 187–208.

Lestrelin, G., Giordano, M., 2007. Upland development policy, livelihood change and land degradation: interactions from a Laotian village. Land Degradation & Development 18, 55–76.

Lewis, J.A., 2008. The power of knowledge: information transfer and acai intensification in the peri-urban interface of Belem, Brazil. Agroforestry Systems 74, 293–302.

Li, T.M., 1999. Marginality, power and production: analyzing upland transformations. In: Li, T.M. (Ed.), Transforming the Indonesian Uplands: Marginality, Power and Production. Harwood Academic, Amsterdam.

Lindell, L., Astrom, M., Oberg, T., 2010. Land-use change versus natural controls on stream water chemistry in the Subandean Amazon, Peru. Applied Geochemistry 25, 485–495.

Linquist, B., Trosch, K., Pandey, S., Phouynyavong, K., Guenat, D., 2007. Montane paddy rice: Development and effects on food security and livelihood activities of highland Lao farmers. Mountain Research and Development 27, 40–47.

Ludewigs, T., D'antona, A.d.O., Brondizio, E., Hetrick, S., 2009. Agrarian structure and land-cover change along the lifespan of three colonization areas in the Brazilian Amazon. World Development 37, 1348–1359.

Makana, J.R., Thomas, S.C., 2006. Impacts of selective logging and agricultural clearing on forest structure, floristic composition and diversity, and timber tree regeneration in the Ituri Forest, Democratic Republic of Congo. Biodiversity and Conservation 15, 1375–1397.

Mangora, M.M., 2005. Ecological impact of tobacco farming in miombo woodlands of Urambo District, Tanzania. African Journal of Ecology 43, 385–391.

Manivong, V., Cramb, R.A., 2008. Economics of smallholder rubber expansion in Northern Laos. Agroforestry Systems 74, 113–125.

McMorrow, J., Talip, M.A., 2001. Decline in forest area in Sabah, Malaysia: relationship to state policies, land code and land capability. Global Environmental Change 11, 217–230.

Mertens, B., Sunderlin, W.D., Ndoye, O., Lambin, E.F., 2000. Impact of macroeconomic change on deforestation in south Cameroon: integration of household survey and remotely-sensed data. World Development 28, 983–999.

Mertz, O., 2002. The relationship between fallow length and crop yields in shifting cultivation: a rethinking. Agroforestry Systems 55, 149–159.

Mertz, O., et al., 2009. Swidden change in Southeast Asia: understanding causes and consequences. Human Ecology 37, 259–264.

Messerli, P., 2004. Alternatives a la culture sur brulis sur la falaise Est de Madagascar: stratégie en vue d'une gestion plus durable des terres. University of Bern, Bern.

Messerli, P., Heinimann, A., Epprecht, M., 2009. Finding homogeneity in heterogeneity – a new approach to quantifying landscape mosaics developed for the Lao PDR. Human Ecology 37, 291–304.

Miyamoto, M., 2006. Forest conversion to rubber around Sumatran villages in Indonesia: comparing the impacts of road construction, transmigration projects and population. Forest Policy and Economics 9, 1–12.

Muller, D., Zeller, M., 2002. Land use dynamics in the central highlands of Vietnam: A spatial model combining village survey data with satellite imagery interpretation. Agricultural Economics 27, 333–354.

Munos, E.G., 2006. Chaac, un dios entre milpa y el riego. Revista de Geografia Agricola 36, 43–53.

Mwavu, E.N., Witkowski, E.T.F., 2008. Land-use and cover changes (1988–2002) around Budongo Forest Reserve, Nw Uganda: implications for forest and woodland sustainability. Land Degradation & Development 19, 606–622.

Nielsen, U., Mertz, O., Noweg, G.T., 2006. The rationality of shifting cultivation systems: labor productivity revisited. Human Ecology 34, 210–218.

Ochoa-Gaona, S., Gonzalez-Espinosa, M., 2000. Land use and deforestation in the highlands of Chiapas, Mexico. Applied Geography 20, 17–42.

Ovuka, M., 2000. More people, more erosion? Land use, soil erosion and soil productivity in Murang'a District, Kenya. Land Degradation and Development 11, 111–124.

Padoch, C., Brondizio, E., Costa, S., Pinedo-Vasquez, M., Sears, R.R., Siqueira, A., 2008. Urban forest and rural cities: multi-sited households, consumption patterns, and forest resources in Amazonia. Ecology and Society 1, 3.

Padoch, C., Coffey, K., Mertz, O., Leisz, S., Fox, J., Wadley, R.L., 2007. The demise of swidden in Southeast Asia? Local realities and regional ambiguities. Geografisk Tidsskrift-Danish Journal of Geography 107, 29–41.

Padoch, C., Pinedo-Vasquez, M., 2010. Saving slash-and-burn to save biodiversity. Biotropica 42, 550–552.

Pascual, U., and Barbier, E., 2005. On-and off-farm labor decisions by slash-and-burn farmers in Yucatan, Mexico. Environmental Economy and Policy Research Discussion Paper Series No. 6, Land Economy Department, University of Cambridge, Cambridge, UK.

Pascual, U., Barbier, E.B., 2007. On price liberalization, poverty, and shifting cultivation: an example from Mexico. Land Economics 83, 192–216.

Pedersen, M., 2003. Agricultural Development through Non Agricultural Activities; the Influence of Off-Farm Activities on Agricultural Activities and Land-Use Practices in Agricultural Marginal Upland Areas of Northern Thailand. In: Mertz, O., Wadley, R.L., Christensen, A.E. (Eds.), Local Land Use Strategies in a Globalizing World: Shaping Sustainable Social and Natural Environments. Proceedings of the International Conference, August 21–23, 2003, Vol. 4., Institute of Geography, University of Copenhagen, Copenhagen, pp. 55–73.

Perreault, T., 2005. Why chacras (swidden gardens) persist: agrobiodiversity food security and cultural identity in the Ecuadorian Amazon. Human Organization 64, 327–339.

Pinedo-Vasquez, M., Zarin, D.J., Coffey, K., Padoch, C., Rabelo, F., 2001. Post-boom logging in Amazonia. Human Ecology 29, 219–239.

Porro, R., 2005. Palms, pastures, and swidden fields: the grounded political ecology of agro-extractive/shifting-cultivator peasants in Maranhao, Brazil. Human Ecology 33, 17–56.

Radel, C., Schmook, B., Chowdhury, R.R., 2010. Agricultural livelihood transition in the southern Yucatan region: diverging paths and their accompanying land changes. Regional Environmental Change 10, 205–218.

Rasul, G., Thapa, G.B., 2003. Shifting cultivation in the mountains of South and Southeast Asia: regional patterns and factors influencing the change. Land Degradation and Development 14, 495–508.

Rasul, G., Thapa, G.B., Zoebisch, M.A., 2004. Determinants of land-use changes in the Chittagong Hill Tracts of Bangladesh. Applied Geography 24, 217–240.

Reenberg, A., Birch-Thomsen, T., Mertz, O., Fog, B., Christiansen, S., 2008. Adaptation of human coping strategies in a small island society in the SW Pacific-50 years of change in the coupled human-environment system on Bellona, Solomon Islands. Human Ecology 36, 807–819.

Rerkasem, K., Lawrence, D., Padoch, C., Schmidt-Vogt, D., Ziegler, A., Bruun, T.B., 2009a. Consequences of swidden transitions for crop and fallow biodiversity in Southeast Asia. Human Ecology 37, 347–360.

Rerkasem, K., Yimyam, N., Rerkasem, B., 2009b. Land use transformation in the mountainous mainland Southeast Asia region and the role of indigenous knowledge and skills in forest management. Forest Ecology and Management 257, 2035–2043.

Rist, L., Feintrenie, L., Levang, P., 2010. The livelihood impacts of oil palm: smallholders in Indonesia. Biodiversity and Conservation 1, 9.

Robichaud, W.G., Sinclair, A.R.E., Odarkor-Lanquaye, N., Klinkenberg, B., 2009. Stable forest cover under increasing populations of Swidden cultivators in Central Laos: The roles of intrinsic culture and extrinsic wildlife trade. Ecology and Society 14.

Rudel, T., Coomes, O.T., Moran, E.F., Achard, F., Angelsen, A., Xu, J., Lambin, E., 2005. Forest transitions: towards a global understanding of land use change. Global Environmental Change 15, 23–31.

Rudel, T.K., 2008. Meta-analyses of case studies: a method for studying regional and global environmental change. Global Environmental Change 18, 18–25.

Rudel, T.K., Bates, D., Machinguiashi, R., 2002. A tropical forest transition? Agricultural change, out-migration, and secondary forests in the Ecuadorian Amazon. Annals of the Association of American Geographers 92, 87–102.

Rudel, T.K., et al., 2009. Agricultural intensification and changes in cultivated areas, 1970–2005. Proceedings of the National Academy of Sciences of the United States of America 106, 20675–20680.

Salisbury, D.S., Schmink, M., 2007. Cows versus rubber: changing livelihoods among Amazonian extractivists. Geoforum 38, 1233–1249.

Sandewall, M., Ohlsson, B., Sawathvong, S., 2001. Assessment of historical land-use changes for purposes of strategic planning – a case study in Laos. Ambio 30, 55–61.

Saphangthong, T., Yasuyuki, K., 2010. Continuity and discontinuity in land use changes: a case study in Northern Lao villages. Southeast Asian Studies 47, 263–286.

Schmidt-Vogt, D., et al., 2009. An assessment of trends in the extent of swidden in Southeast Asia. Human Ecology 37, 269–280.

Schmook, B., Radel, C., 2008. International labor migration from a tropical development frontier: globalizing households and an incipient forest transition. The southern Yucatán case. Human Ecology.

Sears, R.R., Padoch, C., Pinedo-Vasquez, M., 2007. Amazon forestry tranformed: integrating knowledge for smallholder timber managemet in eastern Brazil. Human Ecology 35, 697–707.

Sirén, A., 2007. Population growth and land use intensification in a subsistence-based indigenous community in the Amazon. Human Ecology 35, 669–680.

Steward, C., 2007. From colonization to "environmental soy": A case study of environmental and socio-economic valuation in the Amazon soy frontier. Agriculture and Human Values 24, 107–122.

Sturgeon, J.C., 2005. Border Landscapes: The Politics of Akha Land Use in China and Thailand. University Washington Press, Seattle.

Styger, E., Rakotondramasy, H.M., Pfeffer, M.J., Fernandes, E.C.M., Bates, D.M., 2007. Influence of slash-and-burn farming practices on fallow succession and land degradation in the rainforest region of Madagascar. Agriculture, Ecosystems & Environment 119, 257–269.

Sunderlin, W.D., Ndoye, O., Bikie, H., Laporte, N., Mertens, B., Pokam, J., 2000. Economic crisis, small-scale agriculture, and forest cover change in southern Cameroon. Environmental Conservation 27, 284–290.

Tachibana, T., Nguyen, T.M., Otsuka, K., 2001. Agricultural intensification versus extensification: a case study of deforestation in the Northern-Hill Region of Vietnam. Journal of Environmental Economics and Management 41, 44–69.

Thanapakpawin, P., Richey, J., Thomas, D., Rodda, S., Campbell, B., Logsdon, M., 2007. Effects of landuse change on the hydrologic regime of the Mae Chaem river basin, NW Thailand. Journal of Hydrology 334, 215–230.

Thongmanivong, S., Fujita, Y., 2006. Recent land use and livelihood transitions in northern Laos. Mountain Research and Development 26, 237–244.

Thongmanivong, S., Fujita, Y., Fox, J., 2005. Resource use dynamics and land-cover change in Ang Nhai village and Phou Phanang National Reserve forest, Lao PDR. Environmental Management 36, 382–393.

Turkelboom, F., Poesen, J., Trebuil, G., 2008. The multiple land degradation effects caused by land-use intensification in tropical steeplands: A catchment study from northern Thailand. Catena 75, 102–116.

Turner, B.L.I., et al., 2001. Deforestation in the Southern Yucatán Peninsular region: an integrative approach. Forest Ecology and Management 154, 343–370.

Valentin, C., et al., 2008. Runoff and sediment losses from 27 upland catchments in Southeast Asia: Impact of rapid land use changes and conservation practices. Agriculture, Ecosystems & Environment 128, 225–238.

van Vliet, N., 2010. Participatory vulnerability assessment in the context of conservation and development projects: a case study of local communities in Southwest Cameroon. Ecology and Society 1, 5.

Vester, H.F.M., et al., 2007. Land change in the southern Yucatan and Calakmul Biosphere Reserve: Effects on habitat and biodiversity. Ecological Applications 17, 989–1003.

Vien, T.D., Rambo, A.T., Lam, N.T., 2009. Farming with Fire and Water. Kyoto University Press, Kyoto.

Vu, K.C., 2007. Land Use Change in the Suoi Muoi Catchment, Vietnam: Disentangling the Role of Natural and Cultural Factors. Katholieke Universiteit, Leuven.

Walker, J.C., Desanker, L., 2004. The impact of land use on soil carbon in Miombo Woodlands of Malawi. Forest Ecology and Management 203, 345–360.

Xu, J.C., Lebel, L., Sturgeon, J., 2009. Functional links between biodiversity, livelihoods and culture in a Hani swidden landscape in Southwest China. Ecology and Society 14, 20.

Xu, J.C., 2006. The political, social, and ecological transformation of a landscape – the case of rubber in Xishuangbanna, China. Mountain Research and Development 26, 254–262.

Ziegler, A.D., Bruun, T.B., Guardiola-Claramonte, M., Giambelluca, T.W., Lawrence, D., Nguyen, T.L., 2009a. Environmental consequences of the demise in swidden agriculture in Montane Mainland SE Asia: hydrology and geomorphology. Human Ecology 37, 361–373.

Ziegler, A.D., Fox, J.M., Xu, J., 2009b. The rubber juggernaut. Science 324, 1024–1025.