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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

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A B S T R A C T

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).

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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

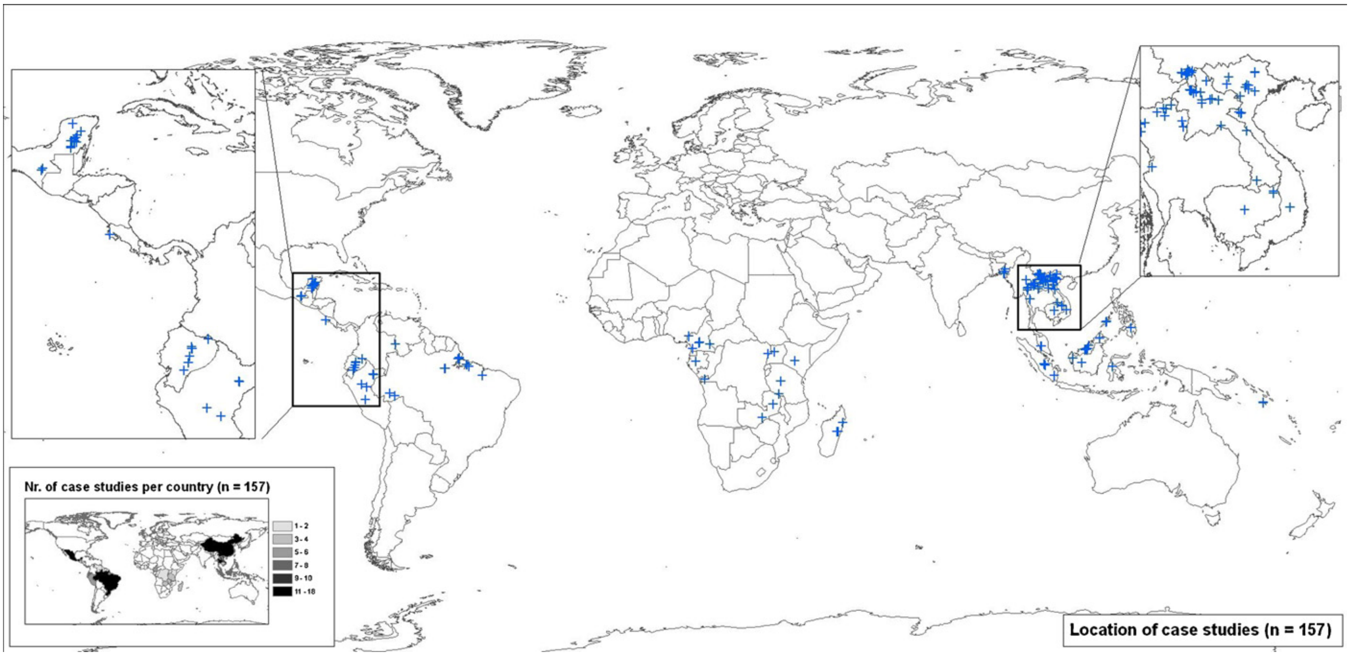


Fig. 1. Location of case studies ($n = 157$).

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.

	Swidden area			Fallow length			Other permanent land uses												
Region	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

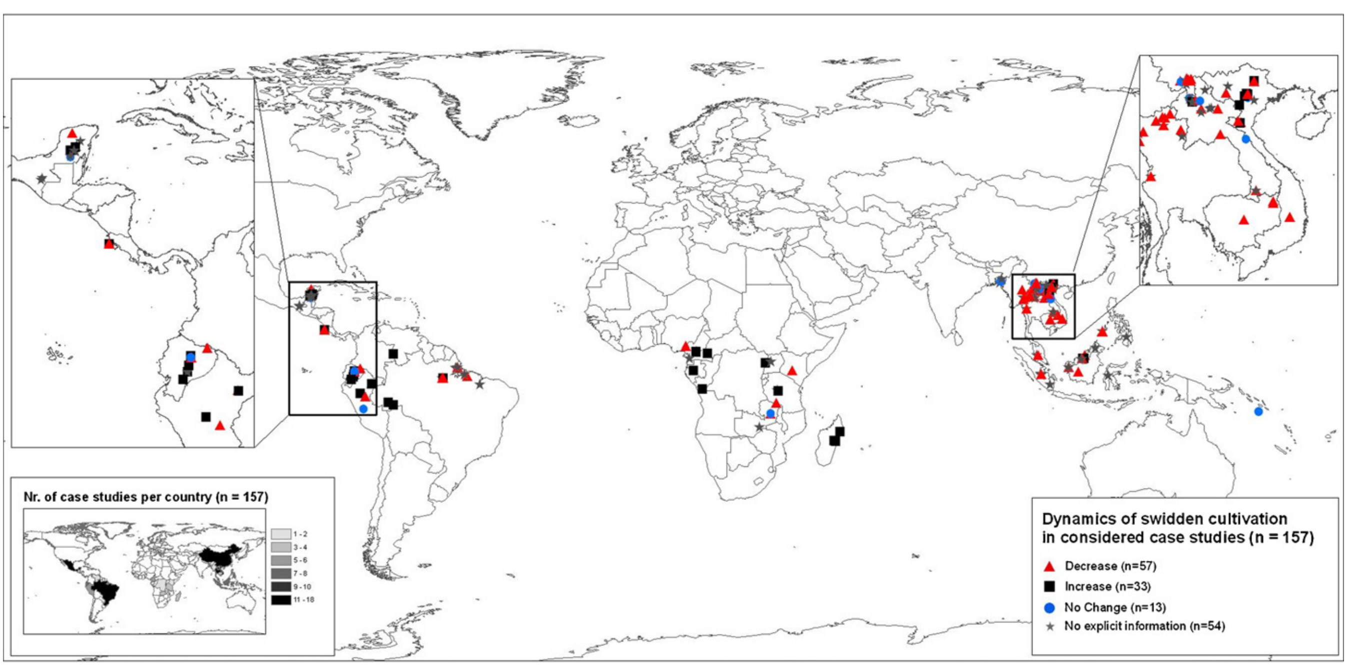


Fig. 2. Change (or no change) in swidden areas considered in case studies ($n = 157$).

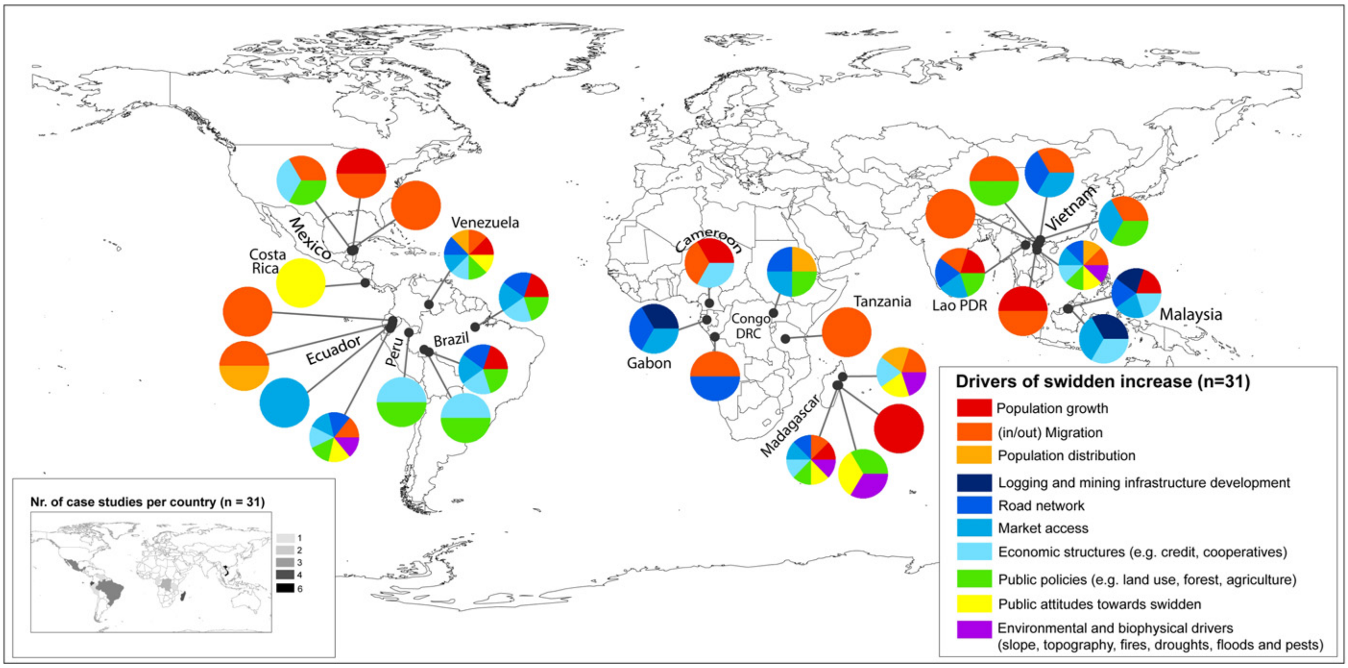
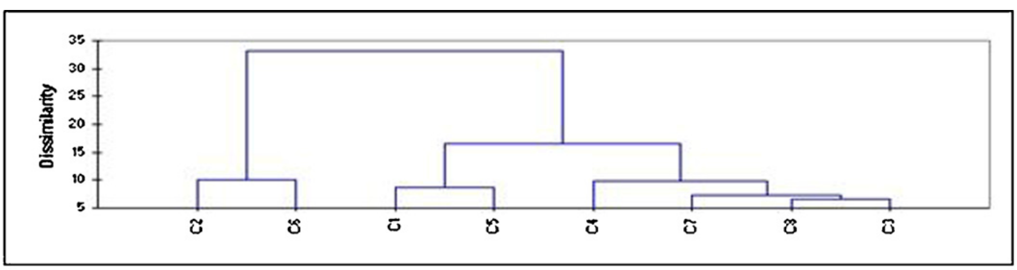


Fig. 3. Drivers of increase in swidden area ($n = 31$) (each pie shows the drivers mentioned for each of the case studies).



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

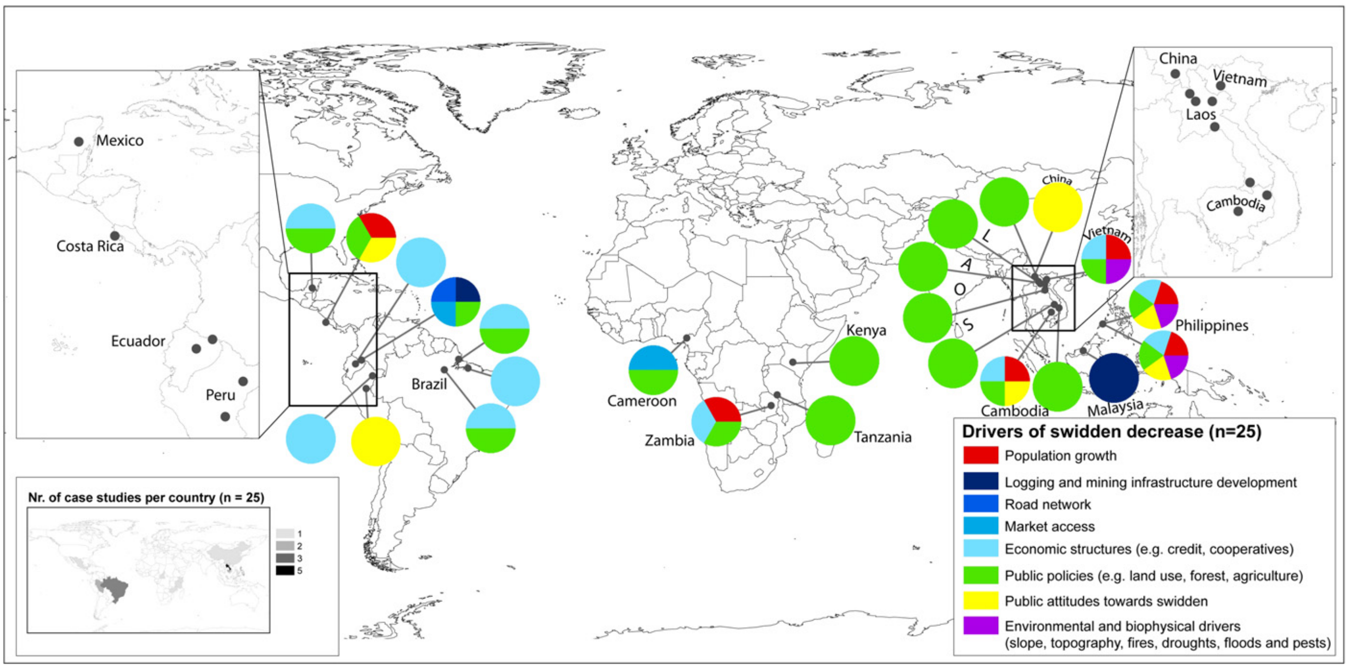


Fig. 5. Drivers of decrease in swidden area ($n = 25$) (each pie shows the drivers mentioned for each of the case studies).

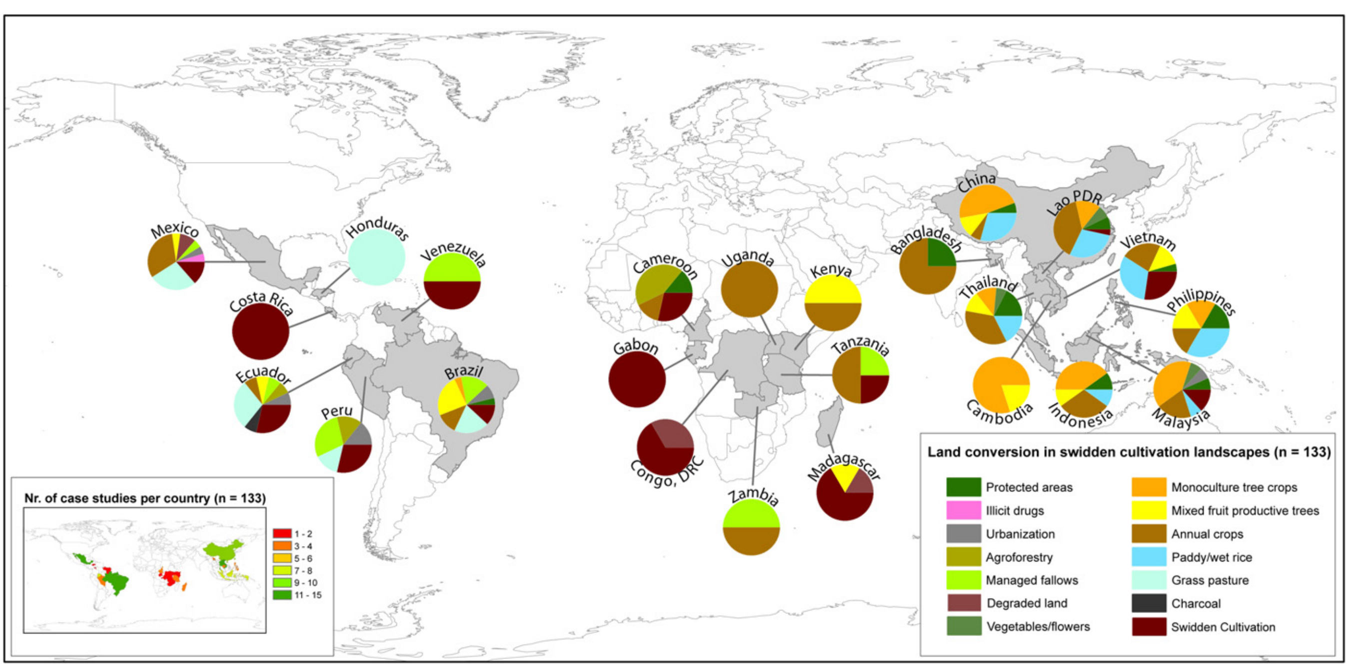


Fig. 6. Transitions of swidden landscapes ($n = 133$) (the portion in each pie shows the number of case studies reporting a transition towards land use type X).

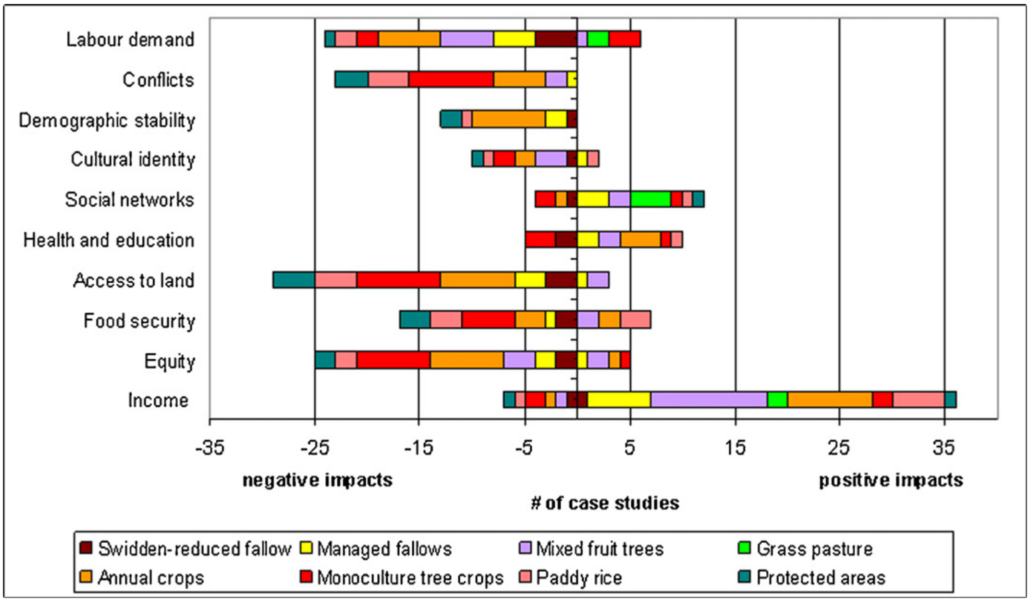


Fig. 7. Impacts of the transformation of swidden landscapes on local livelihoods and per land use category ($n = 91$) (the negative side of axis X shows the number of case studies mentioning a deterioration or a negative impact on each of the variables, the positive side shows the number of case studies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

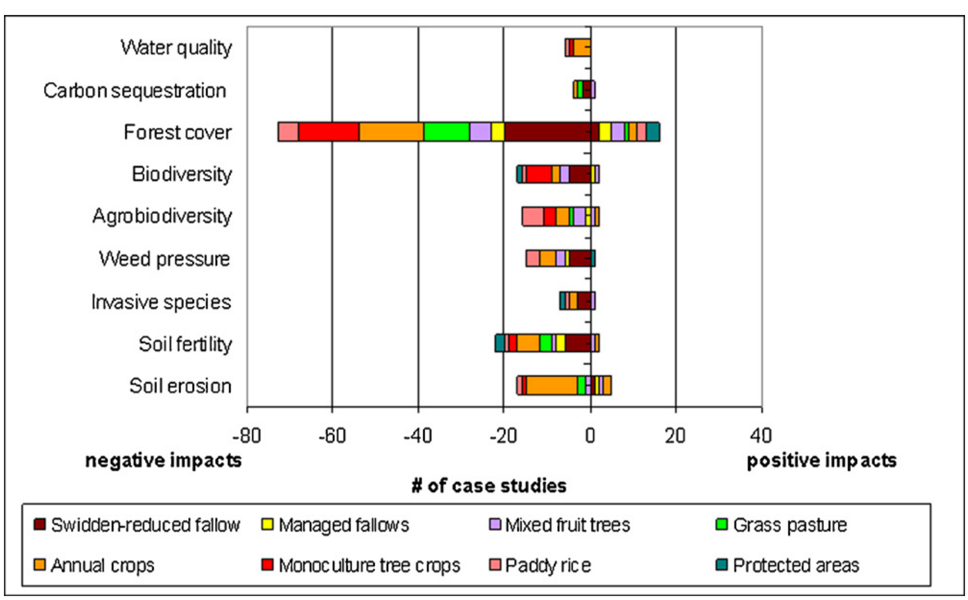


Fig. 8. Impacts of the transformation of swidden landscapes on environmental variables and per land use category ($n = 130$) (the negative side of axis X shows the number of case studies mentioning a deterioration or a negative impact on each of the variables, the positive side shows the number of case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

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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.

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