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Land-Use Strategies of Farmers in Responding to Rising Land-Use Pressures in the Southeastern Forest Region of Madagascar: A Comparative Study between Lowland Households and Hillside Households

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Abstract

An alternative production system to slash-and-burn cultivation is urgently required to satisfy both increasing subsistence needs and environmental conservation objectives in the rainforest region of Madagascar. This paper investigates the current land-use management practices of smallholder farmers that have faced tight land-use pressures due to rapid population growth and stricter forest protection laws. Spatio-temporal patterns of land use were analyzed for lowland and hillside households by using data obtained from a ground survey of 316 fields. Both household groups retained longer fallowing periods for upland rice cultivation (lasting 5.4 to 6.8 years) than those previously reported (of 3 to 5 years). Recent dynamic changes in the agricultural systems included bottomland saturation with irrigated paddies and a rapid transition of coffee-growing areas into slash-and-burn and terraced paddy areas, in order to meet subsistence needs. A shift in dependence from slash-and-burn cultivation to lowland paddies was particularly significant among lowland households due to the expansion of terraced paddies and adoption of a double-cropping system in the irrigated lowlands. The hillside households intensified cassava cultivation in short-term fallowing periods, as also reflected by their high dependence on cassava for caloric consumption. The difference in countermeasures adopted by both household groups to deal with land-use pressures was partly due to the accessibility to extension services. The results suggest that such intervention to promote intensification in lowland paddies was apparently an effective approach to reduce dependence on slash-and-burn cultivation. Given the limited land areas in which to further expand paddy fields, higher crop productivity is needed in the future to achieve a smooth transition to an agricultural system not dependent on slash-and-burn practices.

Discipline: Agricultural environment
Additional key words: forest conservation, irrigated lowland, slash-and-burn, tree-based cash cropping

Introduction

Slash-and-burn cultivation (known locally as *tavy*) is the predominant farming system in eastern Madagascar. However, the intensive practice of *tavy* in line with population growth has been condemned as a major factor in deforestation and land degradation for more than a hundred years.[2,7] There has been growing international concern in recent years over the ongoing practice of *tavy* that threatens one of the world's richest biodiversity hotspots.[14] In response to rising environmental concerns, stricter forest protection laws had been enacted during the past decades to curb further encroachment of *tavy* upon the primary forests.[9] While land-use pressures are being tightened in the hillside and forest areas, a transition from *tavy* to alternative production systems is urgently needed to maintain subsistence food production, as well as to achieve environmental conservation objec-

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tives.

Attempts have been made to encourage agricultural intensification and diversification, especially in the irrigated lowlands and the traditional agroforestry system based on such tree crops as coffee and various fruits. Messerli (2000)[13] emphasized the importance of concomitant development of the market and infrastructure sectors to promote the agroforestry system. The introduction of technology to intensify lowland rice cultivation includes the System of Rice Intensification (SRI), the planting of improved varieties, and the double-cropping of rice and rotations with leguminous crops.[4] Yet, the rate of adopting these farming alternatives differs significantly at both the regional and household levels, and the dependence on *tavy* persists in most cases. This case study focused on the current dynamics in land-use changes of individual households within a typical mountainous area where the locals have faced rising land-use pressures in eastern Madagascar. The study area is particularly important from a conservation perspective, as it includes a narrow strip of the forest corridor linking Ranomanafa National Park (NP) in the north with Andringitara National Park (NP) in the south, both major habitats of unique flora and fauna of this island.[6]

The high population pressures due to endogenous demographic growth and immigration from the highlands, as well as relatively favorable access to transportation, markets, and extension services characterize the local factors behind changes in land use. This study compared the current land-use strategies of lowland households and hillside households, assuming that both are subject to different levels of exogenous influences. The lowland households nestled within low-lying hamlets have better access to extension services and markets than households settled on the upper hillsides (hillside households) away from those hamlets. Demographic, geographical, and political factors are presumably comparable as both household groups live based on traditional farming practices within the same area. Moreover, food consumption patterns assumed to be a direct consequence of changes in land-use management were also monitored. Given the results and based on the farming practices of smallholder farmers to meet their subsistence and cash needs, we will discuss the future perspectives regarding land use and food production systems in the southeastern forest region of Madagascar.

Methodology

The study area of Tolongoina is located along the eastern edge of the forest corridor with a number of micro-watersheds, where mountainous valleys with steep slopes, deeply cut ravines, and small bottomlands form the typical landscape pattern of the region (Fig. 1). The commune of Tolongoina covers an area of 53.8 km^2 and consists of 13 *fokontany* (the country's smallest administrative unit) where the local ethnic group, the *Tanala*, typically forms low-lying hamlets and grows subsistence crops of rice and cassava by combining slash-and-burn practices on the hillsides with irrigated paddy cultivation at the bottom of valleys. The administrative center of Tolongoina (21°33′25″ S, 47°30′40″ E, 390 m a.s.l.), where the main local market exists, is situated at the cross-point of a railway linking the provincial capital of Fianarantsoa to the coastal town of Manakara and the major regional road that runs along the eastern side of the corridor. With relatively favorable transportation access, permanent cash crop production (e.g., coffee, banana, sugarcane, fruit trees) had been widely integrated into existing agricultural systems (known locally as *tanimboly*). Moreover, the population density of the study area has sharply increased from 20 to 78 persons per km^2 between 1952 and 2007.

Twenty-four households were selected based on completely random sampling from the villages (*fokontany*) of Tsimbahambo and Laditra (a total of 167 and 113 households, respectively) in the Tolongoina commune. Half of the participants resided in the main low-lying hamlets of the village (lowland households), with the other half individually settled on the hillside away from those hamlets (hillside households). Nine heads of the lowland households and three heads of the hillside households were members of *Koloharena*, the local farming cooperative. The *Koloharena* cooperative, in cooperation with development aid projects, provides its members with training programs on advanced agriculturally alternatives and techniques (e.g., apiculture, SRI, fish nurseries), and cheaper access to equipments and seeds (e.g., mechanical weeders). During the rainy season of 2008, a ground survey was conducted with the participation of landowners to identify all of their fields. A field was defined as a continuous spatial management unit with the same land-use history. We traced the field boundaries with GPS (eTrex Venture HC, Garmin). Then we determined the size, location, slope angle, and distance to each homestead by using GPS tracking data and GPS analysis software (Kashimir3D ver.8.8.1). While tracing the fields, we conducted semi-structured interviews with the locals regarding their farming practices, including land-use history over the past decade, cultivation techniques, characteristics of fallow vegetation, and agricultural productivity.

The types of land use were first classified into three major agricultural systems based on local classifica-

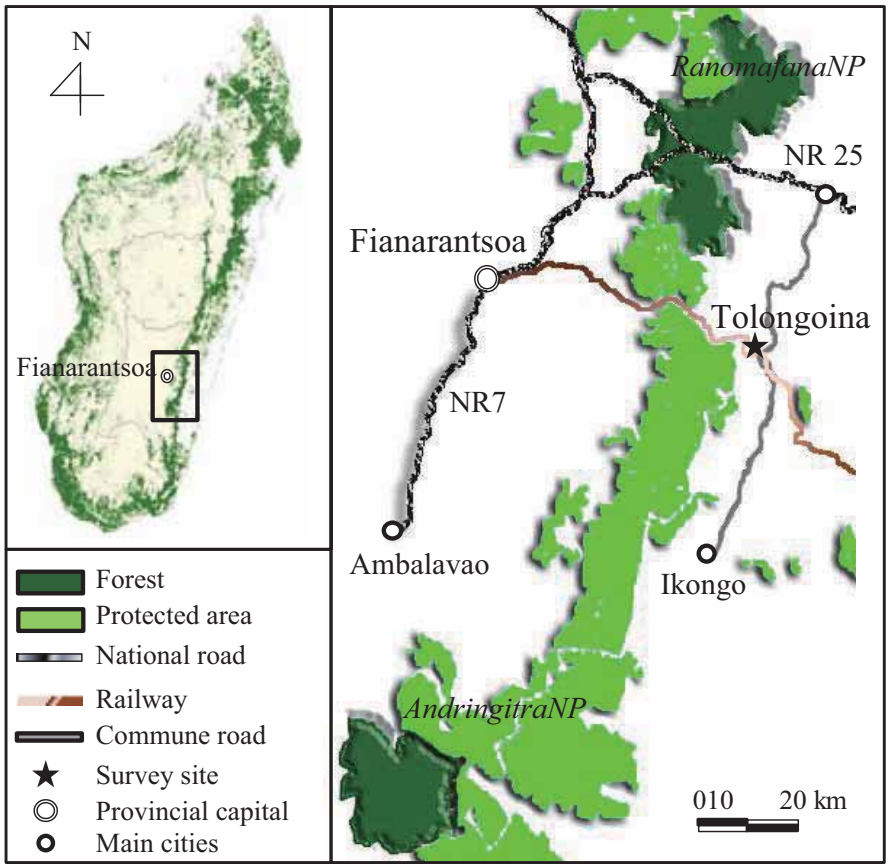


Fig. 1. Map of the study area

tions—lowland paddy (*tanimbary*), slash-and-burn (*tavy*), and tree-based cash cropping (*tanimboly*). Second, each system was divided into the following types based on the differences in crops and fallow vegetation as follows: rice monocropping (R), double-cropping of rice (R-R), and double-cropping of rice and legumes (R-L) for the *tanimbary* system; shrubby and woody fallow (*kapoka*), herbaceous fallow (*hibohibo*), upland rice-based cropping (UL_Rice), exclusive cassava cropping (UL_Cassava) and other crops (UL_Others) for the *tavy* system; and coffee and fruit trees (Coffee/Fruits) and sugar cane (Sugar) for the *tanimboly* system. UL_Rice, UL_Cassava, and UL_Others were identified as the fields with rice, cassava, and other crops as the first crop after fallow. For more convenient analysis, all fields under the *tanimboly* system except the sugar-cane type were classified as the Coffee/Fruits type. This includes the fields under monocropping and the mixed cropping of coffee, banana, and fruit trees. Those fields that were transformed from other land-use types during the past decade were recognized as recently transformed fields.

In the following year, five households from each household group were randomly selected for monitoring daily food consumption. The amounts of rice and cassava, and the number of consumers (0.5 person when <10 years old) were recorded for every meal from January to May 2008. The consumption of rice and cassava was calculated as caloric values by using conversion equations of 3.5 kcal per g of white rice [8] and 1.4 kcal per g of fresh cassava root,[1] respectively. The consumption of other cereals, tubers, leguminous crops, and animal products were minimal, and therefore excluded from the calculation of caloric values. JMP8 (SAS Institute Inc.) software was used in conducting statistical analysis.

Results

1. Comparison of land-use patterns between lowland- and hillside- households

The hillside households are located 1.2 km farther in distance from the administrative center of Tolongoina and 100 m higher in elevation than the lowland households (Table 1). The size of households did not differ between the two groups, both comprising 5.9 persons on average. The ground survey identified 316 fields with 87 ha in total area, within a 3-km radius from the adminis-

trative center, and between 380 m and 880 m in elevation. The mean landholdings of the lowland and hillside households were 2.9 ha and 4.2 ha, respectively. The hillside households allocated a significantly greater proportion of land holdings to the slash-and-burn (*tavy*) system, and a smaller proportion to the permanent crop (*tanimboly*) system as compared to lowland households (Table 2). In addition, the high ratio of cultivated areas to fallow areas corresponded to the significantly shorter fallow periods for hillside households than for lowland households. The average fallow lengths for hillside households before upland rice and cassava cultivation were 5.4 years and 3.0 years, respectively, while those of lowland households were 6.8 years and 4.9 years, respectively (Table 3). The total paddy holdings for both lowland and hillside households were comparable at about 0.5 ha (Table 2). However, the lowland households practiced the double-cropping of rice or rice-legume rotation in 92% of their total paddy

Table 1. Location of homesteads and family structure of lowland and hillside households

Household group	n		Elevation of homestead	Distance to administrative center of Tolongoina	Age of respondant	Number of household members	
						>10, 10	<10
			(m)	(m)		years old	
Lowland	12	mean	405	1396	41	2.9	3.0
		s.d.	35	212	9	1.0	1.6
Hillside	12	mean	505	2641	46	3.3	2.6
		s.d.	106	953	11	1.4	1.7

s.d.: standard deviation among the households for each group (n=12).

Table 2. Comparison of land-use patterns between lowland and hillside households

Land-use type	Field size (are)		Occupation in total land holdings (%)	
	Lowland	Hillside	Lowland	Hillside
Slash-and-burn (*Tavy*)				
Fallow (*kapoka*)	96 ± 951	123 ± 170	29.6	22.1
Fallow (*hibohibo*)	27 ± 39	67 ± 114	9.1	15.4
UL_Rice[2]	30 ± 32*	79 ± 67	9.9*	22.5
(rice)	(16 ± 23*)	(56 ± 56)	(5.3)	(16.9)
(cassava)	(14 ± 21)	(23 ± 30)	(4.5)	(5.7)
UL_Cassava	25 ± 24	50 ± 52	12.1	15
UL_Others	3 ± 6	2 ± 6	1.1	0.3
Lowland paddy (*Tanimbary*)				
Rice monoculture	5 ± 9	15 ± 24	1.7	3.6
Rice-Rice	31 ± 39	25 ± 28	10.7	6.0
Rice-Legume	13 ± 21	8 ± 14	4.7	1.9
Permanent crop (*Tanimboly*)				
Coffee/fruit trees	44 ± 38	39 ± 43	16.7	9.4
Sugar cane	14 ± 31	9 ± 20	4.4	1.5
Land-use type means				
Slash-and-burn (*Tavy*)	181 ± 129	320 ± 266	61.8*	76.9
Lowland (*Tanimbary*)	50 ± 44	48 ± 39	17.1	11.5
Permanent crop (*Tanimboly*)	58 ± 52	48 ± 54	21.1*	11.5
Total landholdings	289 ± 177	417 ± 320	100	100

1: Mean values ± standard deviation of 12 households for each household group.
2: UL_Rice includes the rice fields as the first crop after fallow and cassava fields as the second crop after rice.
*Significant difference between the means of village and hillside households with the student's t-test at P<0.1.

Table 3. Comparison of fallow length under different fallow vegetation and cropping systems between lowland and hillside households

	Household group	Number of fields	Fallow years[1]	
			year	s.d.[2]
Land-use type				
Fallow (*kapoka*)	Lowland	31	5.8[ab]	3.6
	Hillside	29	6.0[ab]	2.8
Fallow (*hibohibo*)	Lowland	11	4.5[bc]	3.0
	Hillside	18	3.2[c]	2.5
UL_Rice	Lowland	17	6.8[a]	2.9
	Hillside	22	5.4[b]	3.4
UL_Cassava	Lowland	13	4.9[b]	3.5
	Hillside	14	3.0[c]	2.1
UL_Others[3]	Lowland	4	9.8	0.5
	Hillside	1	7.0	7.0

1: Fallow years indicate the length of fallow periods after the most recent cultivation for *kapoka* and *hibohibo*, and before the present cultivation for UL_Rice, UL_Cassava, and UL_Others cropping systems.
2: s.d. standard deviation
3: The data of UL_Others are excluded from the statistic analysis because of the small samples.
Mean values in a column followed by the same alphabets are not significantly different with the student's t-test at $P<0.10$.

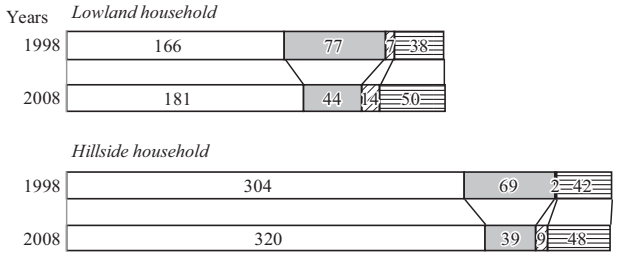


Fig. 2. Changes in land use over the past 10 years for lowland households (two top bars) and hillside households (two bottom bars)
(Numbers in the bars denote the mean size per household (area) of the respective land uses.)
□ : Slash and burn (*tavy*), ▩ : Coffee/fruit trees (*tanimboly*), ▨ : Sugar cane, ▤ : Lowland paddy (*tanimbary*).

areas, whereas the value was only 69% on average among hillside households.

Figure 2 shows the changes in land use over the past decade. The reduction of coffee/fruits fields was most significant for both household groups. Among the total reduction of 7.4 ha of coffee/fruits fields for all 24 households, 65%, 21%, and 14% of the areas were transformed into *tavy*, lowland paddies, and sugarcane fields, respectively. The mean extended lowland paddy area was twice as large among lowland households (12 ares per household) than hillside households (6 ares per household). Rice monoculture was predominant in these newly extended paddy fields (data not shown). Most sugarcane fields resulted from a recent transition from the original coffee/fruits fields.

2. Geographical characteristics of different land-use types

Table 4 summarizes the mean values of slope angle, distance, and relative elevation to homesteads for the respective land-use types. The household group means and land-use type means are shown since the unbalanced ANOVA did not detect interaction between the land-use type and household group for any of the dependent variables at 10% probability. Newly extended paddy fields were found at significantly higher elevations with greater slopes (13.1 ° on average) than the conventional paddies, most of which were located at the bottom of valleys with flat and gentle slopes (5.2 ° on average). Within the *tavy* system, shrubby fallow (*kapoka*) was found in much more remote areas at higher altitude with steeper slopes than the herbaceous fallow (*hibohibo*). Although not statistically significant, single-cassava cropping (UL_Cassava) was being practiced closer to homesteads with slower slopes than upland rice-based cropping (UL_Rice).

3. Food consumption patterns of lowland households and hillside households

Rice and cassava consumption fluctuated inversely: rice consumption was high during the harvest periods of

dry-season rice (Jan. to Feb.) and wet-season rice (May), while cassava consumption increased from March to April as a substitute for reduced rice consumption (Fig. 3). The caloric intake of farmers was significantly more dependent on cassava among hillside households than among lowland households. Among hillside households, the caloric intake from cassava was comparable to that of rice at 970 to 990 kcal per person per day in March and April.

Discussion

1. Intensification and expansion of the lowland paddy system

In this paper, we have focused on in-depth information from a small number of households, in order to visualize a detailed picture of individual changes in land use. Data reliability was maximized by having the same research team visit the fields many times to confirm certain items of information in repeated encounters with the respondents, while conducting concurrent field research. A three-year period of research prior to this study and the first author's fluency in the local language also helped to increase the reliability of the dataset obtained.

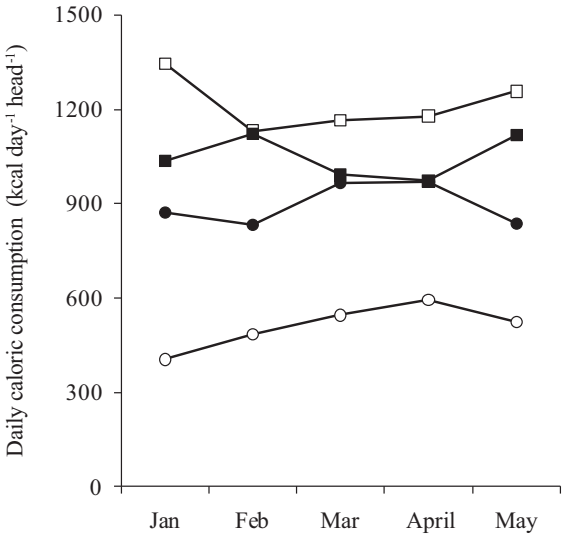
The results showed that both household groups, particularly lowland households, intensified lowland cultivation by adopting the double-cropping of rice and expanding terraced paddies. Previous studies reported that such intensification in lowland paddies reduced land-use pressures on the hillsides in similar mountainous areas of the world.[5,11,15] As the double-cropping of rice was not common in the lowlands of the *Tanala* region in the 1980s[19] or earlier,[10] this farming practice was probably widely adopted over the past few decades. The introduction of rotating rice and leguminous crops (groundnuts and common beans) was also initiated by a recent USAID-funded project through the *Koloharena* cooperative.

Most of the newly extended paddies were terraced on slopes as a result of transformation from the original coffee/fruits fields and hillside fallows, thereby suggesting that little open land remains in the bottomlands. Rakotoasimbahoaka et al. (2007)[16] reported recent bottomland saturation with irrigated paddies in line with population growth in other villages of the same region. These terraced paddies were developed at the expense of permanent cash crops and in areas with considerable slopes. The predominant practice of rice-monoculture implies the difficulties in cultivating dry-season crops due to less favorable irrigation conditions found in those

Table 4. Geographical characteristics of different land-use types

	n	Slope (°)		Distance to homestead (m)		Relative elevation to homestead (m)	
		mean	s.d.[2]	mean	s.d.	mean	s.d.
Land-use type means							
Slash-and-burn (*Tavy*)							
Fallow (*kapoka*)	50	24.1^{a}	(11.1)	755^{a}	(596)	67^{a}	(91)
Fallow (*hibohibo*)	28	16.2^{cd}	(8.7)	401^{cde}	(484)	29^{b}	(61)
UL_Rice	37	23.3^{ab}	(12)	692^{ab}	(562)	63^{a}	(75)
UL_Cassava	28	19.4^{bc}	(10.9)	548^{abcd}	(501)	42^{ab}	(59)
UL_Others1	5	14.7	(3.5)	559	(443)	45	(57)
recently transformed	29	17.3^{cd}	(8.4)	770^{a}	(634)	32^{bc}	(57)
Lowland pady (*Tanimbary*)							
old	48	5.2^{e}	(3.5)	650^{abc}	(623)	-24^{d}	(92)
recently transformed	24	13.1^{d}	(6.4)	412de	(475)	14^{c}	(60)
Permanent crop (*Tanimboly*)							
Coffee\Fruits	50	17.1^{cd}	(12.2)	542^{bcd}	(484)	24^{bc}	(76)
Sugar	17	18.1^{cd}	(10.5)	188^{e}	(171)	22^{bc}	(27)
Household group means							
Lowland	164	16.6^{A}	(10.9)	678^{A}	(591)	56^{A}	(77)
Hillside	152	17.3^{A}	(11)	495^{B}	(597)	3^{B}	(77)

1: The data of UL_Others are excluded from the statistic analysis because of the small samples.
2: s.d. standard deviation Mean values in a column followed by the same alphabets are not significantly different with the student's t-test at P<0.10.



ANOVA

	f	Rice	Cassava
Month	4	†	ns.
Household	1	**	**
Interaction	4	ns.	ns.

Fig. 3. Comparison of daily caloric intake per capita from rice and cassava between lowland and hillside households for each month

—□— : Rice_Village household, —■— :Rice_Hillside household, —○— : Cassava_Village household, —●— : Cassava_Hillside household.

newly extended terraced paddies. A further expansion of terraced paddies would proceed into areas with steeper slopes, leading to increased wages for constructing a unit area of paddies. Therefore, improving the yield of rice and leguminous crops in conventional lowland paddies, along with further disseminating double-cropping techniques, will become more important in maintaining a steady increase in stable crop production.

2. Dynamics in hillside vegetation and land uses

Based on satellite images and aerial photographs taken between 1950 and 1985, Green and Sussman (1990)[7] revealed that flatter lands were being cleared more rapidly, with forests only remaining in the steeper escarpment of eastern Madagascar. This finding supports the results of our study in which tree and shrubby fallows (*kapoka*) were mostly found in remote and high-altitude areas with steep slopes, while herbaceous (*hibohibo*) fallows were found relatively close to the homesteads. This implies that land areas close to homesteads were first cleared long ago, and thus advanced to the later stage of fallow succession (*hibohibo*). The upland rice was mostly grown on *kapoka* fallows having a relatively long fallow length. According to respondents, the farmers' selective allocation of rice on *kapoka* fallows was due to low yield expectations and the need for labor-intensive weeding when cultivating upland rice on *hibohibo* fallows. Styger et al. (2007)[17] also mentioned a sharp decline in yield expectations of upland rice in line with advancing succession of fallow species in northeastern Madagascar. The declining yield expectations are presumably associated with the concomitant occurrence of soil nutrient depletion,[2,18] low biomass inputs as ash nutrients,[18] and severe weed damage. Therefore, farmers may prefer to cultivate more cassava, in order to maintain adequate food production under agronomically adverse fallow conditions. However, there are concerns over the low protein content of cassava. A previous study reported lower caloric intake during the lean period around March, resulting in seasonal increases in malnutrition in the rural areas of Madagascar.[3] Food consumption patterns among the hillside households (i.e., high dependence on cassava for energy) suggest unfavorable nutritional balances during the lean period. Consequently, an excessive dependence on cassava could aggravate local food security in terms of food nutrition.

Both household groups substantially reduced coffee/fruit land areas by transforming those areas into the slash-and-burn system and terraced paddies over the past decade. The urgent need to increase self-sufficiency in staple crops due to soaring rice prices, falling coffee prices, and rapid population growth were probably the major motivating factors behind this significant land-use transition. The price of coffee produced domestically continued to decline in line with international market values from 1.19 USD per kg in 1998 to 0.37 USD per kg in 2008, while the price of rice almost doubled during the same period (FAOSTAT 2011). Given the relatively favorable transportation access to the study area, the significant decline of the tree-based cropping system sug-

gests that market and infrastructural development will not be enough to promote the agroforestry system. The cultivation of sugarcane used mainly for local rum production recently increased, despite the ever-present risk of being arrested or fined under law that strictly prohibits the home brewing of rum. Laney (2002)[12] identified a positive land-use change from excessive slash-and burn cultivation to greater vanilla production in a densely populated area of northern Madagascar. Other replacements for the conventional coffee crop or the development of value-added products should be explored to maintain the resilience of cash income sources.

Conclusion

This case study was conducted in a relatively populated area in the southeastern forest region of Madagascar. A comparison of land-use strategies between the lowland households and hillside households suggested that the intensification and expansion of lowland paddies were apparently an effective approach to reduce local dependence on slash-and-burn cultivation. However, since the newly extended paddies proceeded into steeper and less irrigable areas after saturation in the bottomlands, a future strategy should focus on increasing crop productivity within limited lowland paddies. Given the significant downward trend in coffee production, alternative cash crops or value-added products should also be considered. Without the intervention needed to induce these approaches, the hillside landscape may turn monoclonal with degraded and herbaceous fallows for cassava cultivation, and with terraced paddies on steep slopes. This scenario would certainly aggravate the food security and income resilience of local farmers, and may further jeopardize forest conservation policy.

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