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Using Geographic Information Systems to Assess Possibilities of Expanding Traditional Agroforestry in Slash-and-Burn Zones in Madagascar

Simon Michel Nambena

*Beforona is a mountainous region in eastern Madagascar, where slash-and-burn cultivation (*tavy*) has been practiced for several generations to produce rice, the staple food of the Malagasy people. This system of cultivation has long been unsustainable (deforestation, erosion, loss of soil fertility, etc). Other types of cultivation considered more sustainable were inventoried in a study, particularly the irrigated rice field and traditional agroforestry system known as* tanimboly *found in the valleys. On the basis of research results, data were incorporated into a Geographic Information System (GIS) to elaborate descriptive models using different parameters related to this farming system. Spatial distribution of* tanimboly *shows that more than 90% is concentrated along small streams, in concave areas, and not on slopes and hillsides.* Tanimboly *becomes scarcer as the distance from the forest edge approaches 2 km, and surface areas are drastically reduced in proportion to distance from roads. GIS and regression models made it possible to identify potential areas for* tanimboly*. Relations between the various parameters were calculated using logistic regression functions to predict occurrence of the* tanimboly *phenomenon in nonsampled zones. It appears that farming strategies are particularly influenced by infrastructure.*

The need for more sustainable farming options

Madagascar has many highly diversified ecological features: humid forests from the north to the south on the eastern side, xerophytic bushes in the extreme south, and dense dry forests on the western side (Figure 1). In the east, where rainfall can be as high as 2500–3500 mm per year, slash-and-burn cultivation (*tavy*) dominates the agricultural landscape. Ecological and socioeconomic data were obtained by the Terre Tany/BEMA (Bilan écologique de la culture sur brûlis à Madagascar) project—concerned with ecological evaluation of *tavy* in Madagascar and financed by the Swiss National Science Foundation—between 1994 and 2001, within a relatively limited zone. This zone can be considered representative of eastern Madagascar, where *tavy* is the main agricultural activity among peasants. The study site is located in the rural commune of Beforona, 160 km east of the capital.

The region is dominated by fallow, which constitutes a transition between degraded pseudosteppe vegetation in the east and dense humid forest in the west. The altitude varies between 350–750 m, and the topography is highly uneven. There are very narrow V-shaped valleys with steep slopes often greater than 60%.

Expanding *tanimboly*

Tavy is the main ecological problem in the region. Every farmer interviewed practices *tavy* around the Vohidrazana Forest (a forest near the study site). In addition, given the high rate of population growth, the frequency of fallow cuttings has greatly increased. Before the 1970s, the average period of fallow was between 15 and 20 years. A study of vegetation dynamics in Beforona by Pfund et al (Projet Terre-Tany/BEMA 1997) revealed that the duration of the fallow period lasts between 5 and 6 years in new fallow zones, 4 years at older exploited sites, and between 3 and 5 years on the degraded soils, where the plots are highly subdivided. This phenomenon was confirmed in an analysis by Brand et al (Projet Terre-Tany/BEMA 1997), which shows that the deforestation process increased from 21.2 hectares/year (1957–1967) to 39.3 hectares/year (1967–1987), 46.5 hectares/year (1987–1994), and finally 51 hectares/year between 1994 and 1997.

The agricultural labor involved with *tavy* absorbs most of the farmers' agricultural calendar and can take up to 200 days annually for each household. Although slash-and-burn agriculture is considered a nonsustainable system, the same farmers have other more sustainable options at their disposal, such as irrigated rice culture and perennial cultures. The latter are often found in the narrow valleys and consist of traditional agroforestry systems or fruit-tree gardens known locally as *tanimboly*, where farmers produce coffee, banana, and other fruit. These products are harvested during the year and are the

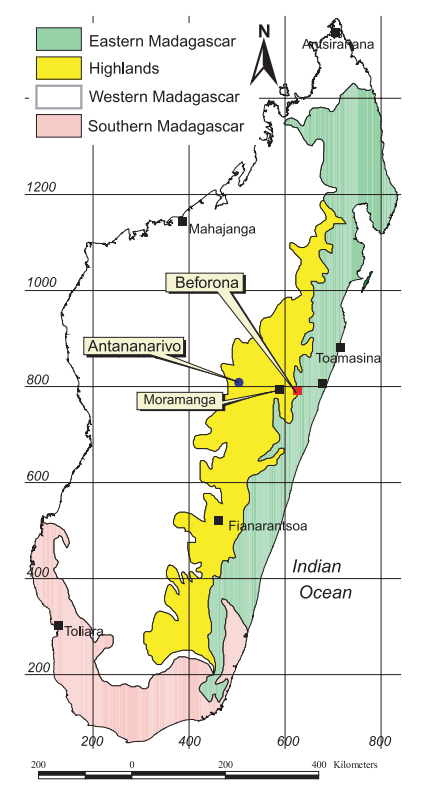


FIGURE 1 The 4 agroecological regions in Madagascar, with location of the study area (Beforona). (Source: Bied-Charreton et al 1981, in Projet Terre-Tany/BEMA 1997)

principal source of income for farmers, providing up to 40% of their total yearly incomes (Moor, in Projet Terre-Tany/BEMA 1998).

In November 2002, the Malagasy government implemented a law stipulating that any farmer who sets fire after cutting trees can be sent to prison for up to 5 years; nevertheless, the Ministry of Agriculture never proposed alternatives to *tavy*. For this reason, some solutions are proposed here, including expansion of orchards on the basis of farmers' know-how regarding available resources.

Using GIS to assess the potential for expansion of orchards

For many centuries, slash-and-burn systems have coexisted with different national and international policies and strategies characterized by repression. Yet, it was always impossible to apply laws, given the tolerance threshold allowed by the authorities and the institutions concerned. Because the law has now been reinforced and is being applied, we hypothesize that the orchards can be expanded in the long term. Based on their empirical traditional knowledge, farmers manage their fields in accordance with ecological parameters, resource quality, and existing socioeconomic conditions.

Different modeling methods were undertaken with version 7.2.1 of NT Arcinfo. During the first phase, a Digital Elevation Model including rivers from 1:50,000 maps was established. Next, the derived products (slope, exposition, etc) were calculated. The second phase of modeling consisted of overlaying the land use map compiled by Brand and Randriamboavonjy (Projet Terre-Tany/BEMA 1997), particularly with *tanimboly* plots. Finally, these blocs were analyzed using 6 geomorphological and socioeconomic parameters, to explain the spatial distribution of these plots (Figure 4):

- *Slope:* Because of the abundance of steep slopes in the region, cultivation is independent of slope values. The maximum slope value where fields are found is about 30%. When the slopes are greater than 125%, the orchards are replaced by other types of cultivation such as *tavy*, second-year cultivation of ginger or cassava, or the land may even be left fallow.
- *Relief form:* The concave parts of the land are highly prized by farmers for orchards (Figure 3). There are many reasons for the choice of such sites. They present a relatively humid microclimate, compared with rectilinear or convex relief forms. Nutrients are deposited in these zones, and soil is more fertile, which is a necessary condition for initial installation. Moreover, convex areas are prone to erosion and are also directly exposed to wind, which makes them relatively dry.
- *Hillside exposures:* Flat exposure, corresponding to 0% slope, is greatly preferred for the installation of agroforestry systems. However, the geomorphology offers very limited areas of this type. Currently 38% of flat land is used

FIGURE 2 Multiple crops are grown in orchards, in a sustainable form of land use called *tanimboly*. Orchards provide food for household consumption and are also a source of cash crops (ie, regular income). (Photo by author)

FIGURE 3 Vacant sites for potential new orchards are plentiful on fallow land and could be used to expand *tanimboly*. Orchards are usually concentrated in valleys, but recent plantations have also made use of favorable conditions on concave terrain at higher altitudes. (Photo by author)

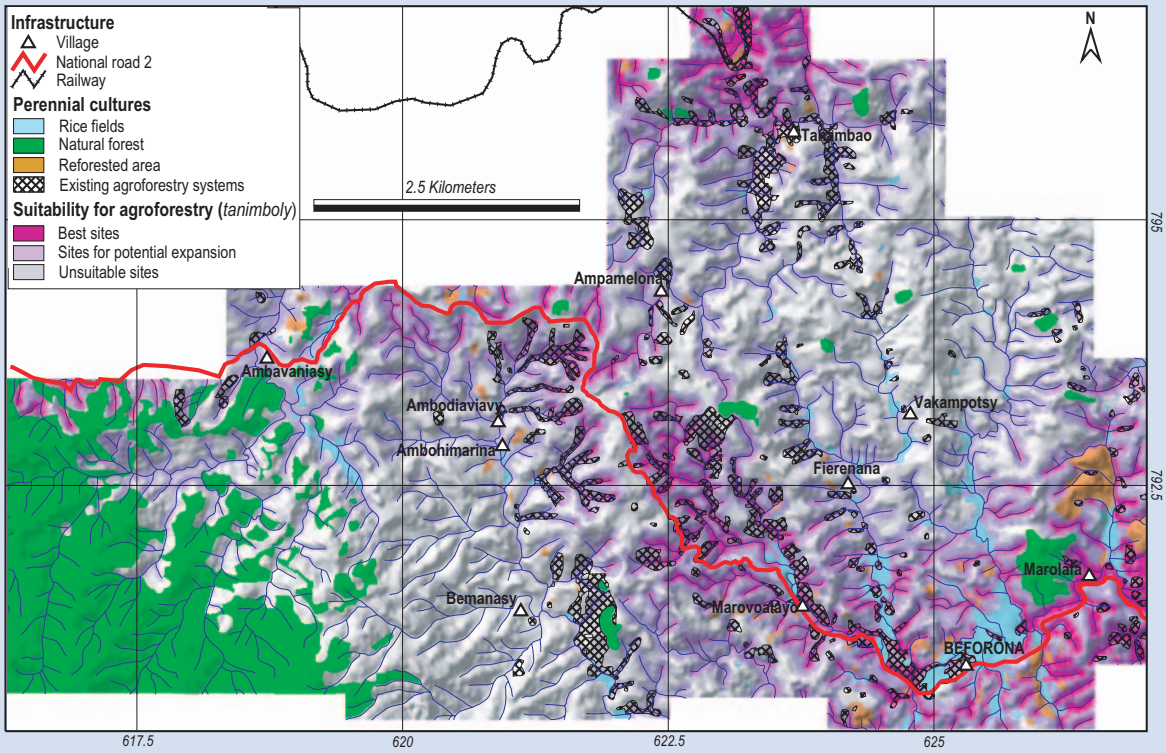
for *tanimboly*. Orchard installation on other topographic exposures is done rather more at random. Orchards are first installed on a flat surface and then expanded according to suitable morphology (Figures 2 and 3).

- *Distance from a forest corridor:* The distance from a forest corridor is an indicator of the intensity of the practice. A distance of 2 km from the forest edge is the point at which species composition and orchard surface areas change drastically. In addition, the relative distribution shows that the other types of cultivation, especially *tavy*, predominate near the forests.
- *Distance from a road:* The study area is located along the national road, with the farthest point about 3 km from the road. This relatively small distance indicates that orchard installation depends on the presence of a permanent road. Large orchards are concentrated along the roads (0–500 m away). The areas decrease with increasing distance from a main road or railway: if the distance is greater than 1.5 km, the size of orchards gradually diminishes.
- *Distance from a village:* Because farmers prefer to install their orchards near their houses, the most ancient plantations are concentrated around the villages. After these preferred sites are occupied, new installations appear along the rivers. A regression model showed that proximity from rivers and roads was the most significant indicator, whereas slope values and topography do not have significant impact on orchard distribution.

The modeling thus also took account of socioeconomic parameters, demonstrating that this model can analyze farmers' strategies for installing orchards. However, the model does not show the complete ecological potential of land suitable for agroforestry.

Without considering forest distribution, fallow and annual cultivation are randomly distributed according to the quality of the site, although it can be observed here that the quality of the site is not involved. Of the 572 hectares of good sites, only 15% are occupied by orchards, whereas the remaining surfaces are left fallow or used to grow annual crops (67%). However, it should be noted that rice fields (9%) also compete for good sites. Twenty-two per cent of the orchards

FIGURE 4 Digital terrain model resulting from the study of geomorphological and socioeconomic conditions for the potential expansion of agroforestry. (Map by author)



are installed on "bad quality sites." There are several reasons for this: sites belonging to farmers who have no choice in installing their plots; sites that are not as bad as they may appear, because some parameters were not included in the modeling (land tenure or cultural problems); and sites where some important parameters were not considered (pedology, fallow age, commercialization). The land use types and corresponding percentages of area suitable for agroforestry are shown in Table 1.

Making agroforestry attractive and cost efficient

Constraints on effective commercialization

Until now commercialization of orchard crops has been limited to coffee and bananas. Sugarcane is locally transformed to rum, and other fruits generally rot on the site. Resources are underexploited because of the lack of options for commercialization in the region. Farmers have developed the following alternative strategies:

- Because an orchard produces fruit only 3 years after it is planted, farmers prefer to grow annual crops (rice, ginger, cassava, etc) to boost their income.
- Given the need for income, good land is used for annual crops.
- Agricultural techniques remain traditional and cannot satisfy the quality and quantity requirements of the market.
- In some cases, land-tenure systems do not allow the practice of perennial cultivation because land is usually linked to lineage rather than individual ownership.

Suggested action

Motivating peasants to reduce slash-and-burn agriculture, while simultaneously installing new orchards or expanding others, will mean taking action in the following areas:

- *Promoting new and more efficient agricultural techniques:* Although this zone is part of a region that exports Malagasy

TABLE 1 Land use types and percentage of area suitable for agroforestry (*tanimboly*).

Land use	Suitability for agroforestry	Area (hectares)	% of total suitability class	Subtotal (hectares)
Natural forest	Unsuitable sites	487.2	20	680.5 (14%)
	Potential for expansion	168.3	9	
	Best sites	25.0	4	
Fallow and annual crops	Unsuitable sites	1856.8	76	3655.5 (75%)
	Potential for expansion	1413.7	77	
	Best sites	385.0	67	
Reforestation	Unsuitable sites	13.8	1	71.7 (1%)
	Potential for expansion	35.6	2	
	Best sites	22.2	4	
Rice fields	Unsuitable sites	16.5	1	129.1 (3%)
	Potential for expansion	58.8	3	
	Best sites	53.8	9	
Agroforestry	Unsuitable sites	68.4	3	317.1 (7%)
	Potential for expansion	162.5	9	
	Best sites	86.3	15	
Villages	Unsuitable sites	0.1	0	1.9 (0%)
	Potential for expansion	1.2	0	
	Best sites	0.6	0	
Total	Unsuitable sites	2442.9	100	4855.7 (100%)
	Potential for expansion	1840.1	100	
	Best sites	572.8	100	

crops, it has been left to use traditional techniques, resulting in the persistence of slash-and-burn agriculture.

- *Solving land-tenure problems:* Land registered in a cadastre with a title is currently very rare. All the land left fallow at present is tied to lineage; only orchards, reforested land, and rice fields are owned by individuals. Land registration is so expensive that peasants prefer to keep traditional boundaries, where all individuals linked by lineage can use fields after negotiation.
- *Improving infrastructure:* The rugged topography of the whole region inhibits development, especially regarding transport. Although both the national road and the railroad pass through this zone, in some communes even small trails are lacking. Sometimes producers have to walk for an entire day to sell their crops.
- *Organizing a favorable trading system:* Because of lack of information, farmers are at the mercy of middlemen. In fact, they do not know the selling prices of their products; the middlemen set prices to their own advantage.

FURTHER READING

Chou YH. 1997. *Exploring Spatial Analysis in Geographic Information Systems*. Santa Fe, NM: OnWord Press.

Projet Terre-Tany/BEMA, editor. 1997. *Un système agro-écologique dominé par le tavy: La région de Beforona, falaise Est de Madagascar*. Cahiers Terre-Tany 6. Antananarivo, Madagascar: Projet Terre-Tany/BEMA [Bilan écologique des cultures sur brûlis à Madagascar] and FOFIFA [Centre National de la Recherche Appliquée au Développement Rural]; Berne, Switzerland: Centre for Development and Environment.

Projet Terre-Tany/BEMA, editor. 1998. *Les stratégies endogènes et la gestion des ressources naturelles dans la région de Beforona. Les résultats des recherches pluridisciplinaires de la phase 1995–1998.* Cahiers Terre-Tany 8. Antananarivo, Madagascar: Projet Terre-Tany/BEMA [Bilan écologique des cultures sur brûlis à Madagascar] and FOFIFA [Centre National de la Recherche Appliquée au Développement Rural]; Berne, Switzerland: Centre for Development and Environment.

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Simon Nambena is currently engaged in research for a PhD thesis on natural resource management at the University of Antananarivo; he is focusing on the extrapolation of locally obtained research results on alternatives to slash-and-burn agriculture to the regional level. He is also working as manager and GIS and remote sensing specialist for DERAD, a consulting agency for rural research and development in Madagascar.