Chapter 18
Mobilizing Farmers' Knowledge of the Soil

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One way in which a culture can be read is through the way its people control their material environment, and through the knowledge that accompanies it. Such knowledge is part and parcel of social representations, which are ways of imagining daily life and the world, as developed, shared and transmitted within a community. They set up a consensual reality, and orientate the behaviour of a group, with the view of controlling the social, material, and ideological environment (Lévy and Lussault 2003).

In rural communities, control and use of land is one arena where "local" or "indigenous" knowledge is one of the main determinants. We will focus on such "local land knowledge". While there is a purely anthropological interest in these folk representations and classifications (Friedberg 1992; Holman 2005), there is also a practical interest in how this rural knowledge interfaces with the external stakeholders' ideas that are often derived from popularized scientific knowledge. In every project concerning rural areas, indigenous knowledge (particularly among the farmers) must be recognized and taken into account in order to bring about consensus between various stakeholders on actions to be carried out (Dupré 1991; Roose, 1994).

An example from Madagascar will show how the mobilization of rural knowledge about the soil, and close observations of cultivated soils and indigenous agricultural practices, are particularly important components of projects aimed at achieving sustainable agriculture.

Separated with South-East Africa by the Mozambique Channel, Madagascar is the fourth largest island in the world, and contains a wide variety of landscapes and ecosystems. Its ancient isolation has permitted an exceptional evolution of life. As a result, Madagascar is classified as a "biodiversity hotspot"—a region where a large concentration of endemic species are threatened by loss of habitat (Myers et al. 2000). Nevertheless, for centuries, it has faced a high loss of habitat and species due

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to deforestation and conversion of primary vegetation. Most of the Malagasy people (people of Indonesian, Arabian and African origin who inhabit Madagascar) depend to a high degree on natural resources, with about three quarters of this population living as subsistence farmers. The East of Madagascar is a warm-, rainy-, formerly forested- and moderately populated-lowland. The Highlands, the grassy elevated center of the island, is drier and more highly populated. A prominent forested escarpment forms the boundary between the eastern lowlands and the central Highlands.

The agricultural practices in the Highlands, with their Indonesian-looking landscapes of impeccably terraced rice fields, contrasts with the basic slash-and-burn prevailing practices (called *tavy* in the native language) of the Eastern people, often considered as "forest people" (Le Bourdiec 1974, Rabearimanana 1988). The wealth of knowledge that the Highlands farmers have about their soils and erosion control had been studied earlier (Rakoto-Ramiarantsoa 1995; Blanc-Pamard and Rakoto-Ramiarantsoa 2006). In contrast, little is known about the Eastern populations. This chapter will focus on them.

The repetitive *tavy* practices are the principal causes of the deforestation in this area (Coulaud 1973; Rakotovololona 1987; Green and Sussman 1990). But deforestation is not Madagascar's only environmental problem. Soil erosion is another process with major sustainability impacts (Ravel 1989). From the first experimental studies carried out in the rainy Betsimisaraka region [along the National Road 2 (RN2)], the zones of *tavy* have generally been described as zones of high erosion (Bailly et al. 1976; Ratovoson 1979; Rossi 1979; Raunet 1997). The lack of agricultural land in the narrow valleys, combined with strong population growth, is pushing farmers to farm steep slopes with agricultural practices which do not always seem to take the risk of erosion into account. Under the highly erosive climate of the East, the long and steep slopes have the highest risk of erosion (Malvos et al. 1976). Recently Brand and Rakotovao (1997) found, on a plot cropped in upland rice, a loss of soil to be 14.6t/ha/year, confirming high diffuse erosion potential of tavy. Landslides are another important source of erosion in this region subjected to hurricanes (Brand 1997). Yet erosion must be put into perspective with other risks (floods in bottoms during storms) and soil degradation processes (compaction, nutrient depletion) that are worse problems (Brand and Rakotovao 1997).

Nevertheless, in one area in the South-East inhabited by the Tanala ("the forest people"), several geographers have long been astonished that they could not observe signs of erosion in the landscapes, despite the systematic practice of *tavy* in geographical conditions typical of the East (Le Bourdiec 1974; Battistini 1965 cited by Le Bourdiec). This region, thus, seems to be an exception, departing from the proposition "*tavy* induces erosion". The aim of GEREM, our research program (2004-2007) was to contribute knowledge to support rural development compatible with forest conservation projects. The projects managers asked us questions concerning erosion risk management in order to protect the railway line Fianarantsoa-East Coast (FCE) that passes through Tanala region, and is essential to its economic life. The surrounding cultivated land and the *tavy* practiced by the

Tanala were particularly suspected of promoting erosion. An anti-*tavy* policy and a more-or-less forced adoption of alternatives to slash-and-burn have been considered. We therefore undertook a multidisciplinary reconnaissance study of land bordering the FCE railway in Tanala country, near the towns of Tolongoina, and Manampatrana.

Episodes of mass erosion (landslides) and rill erosion are observed locally, in particular along the railway, but these are neither invasive nor generalized as one would expect to observe considering the geographical conditions [marked relief, 2500 mm of rain, frequent hurricanes], the practices of *tavy*, and what the literature tells about the effects of *tavy*. These first observations confirmed the earlier geographers' observations of limited signs of erosion in this region when compared with Betsimisaraka RN2 sites further north, and other less rainy, less mountainous and *tavy*-free regions (such as the Alaotra region) that are devastated by *lavaka* erosion, the well-known type of Malagasy erosion. In the Alaotra region, grassy hills made of ferralitic alteration materials are literally open-ripped by deep ravines called *lavaka* (Tassin 1995, Wells and Andriamihaja 1997). The railway problems appeared to be due to the susceptibility (in the east-Malagasy climate) of badly maintained railway embankments and trenches, especially following two sequential, huge hurricanes in 2000. Tanala farming systems were not directly implicated. Insidious erosive processes (sheet erosion, landslides hidden by the rapid return of vegetation) were looked for in the Tanala *tavy* landscapes on several village territories, but no massive erosion symptoms were found on the studied area (Rakotonirina 2005; Rakotoson 2006). Still, farmers did not practice any "anti-erosive installations" that are strongly advised by the engineering departments to fight erosion in agricultural land subjected to an erosive climate.

As a hypothesis, the rare occurrence of erosion in the Tanala region may be explained by a good adaptation of the typical Tanala *tavy* to climatic-high erosivity, topographic-high erosion susceptibility and variable soil's erosion susceptibility. Beneath these adapted practices may exist specific knowledge of the soils. We thus sought to explain the limited erosion in the Tanala agricultural lands by applying scientific survey methods of soil science, agronomy and human geography: the study of the soils in their human, ecological, and climatic environment; the study of farming practices at plot and landscape levels, and the collection of rural knowledge (Milleville 1987; Blanc-Pamard 1986; Soulard 2005).

18.1 The Tanala of Tolongoina

The Tanala region is a narrow band between the Central Highlands and the coastal areas in the East of Madagascar, along a forested escarpment running North-South and commonly called the "Tanala cliff" (Fig. 18.1). It presents many similarities with the RN2 Betsimisaraka region. To the West of the forested bordering escarpment, an herbaceous plateau at an altitude of 800-1300 m comprises the territory of the Betsileo people, with rice fields in hollows and on terraces, and

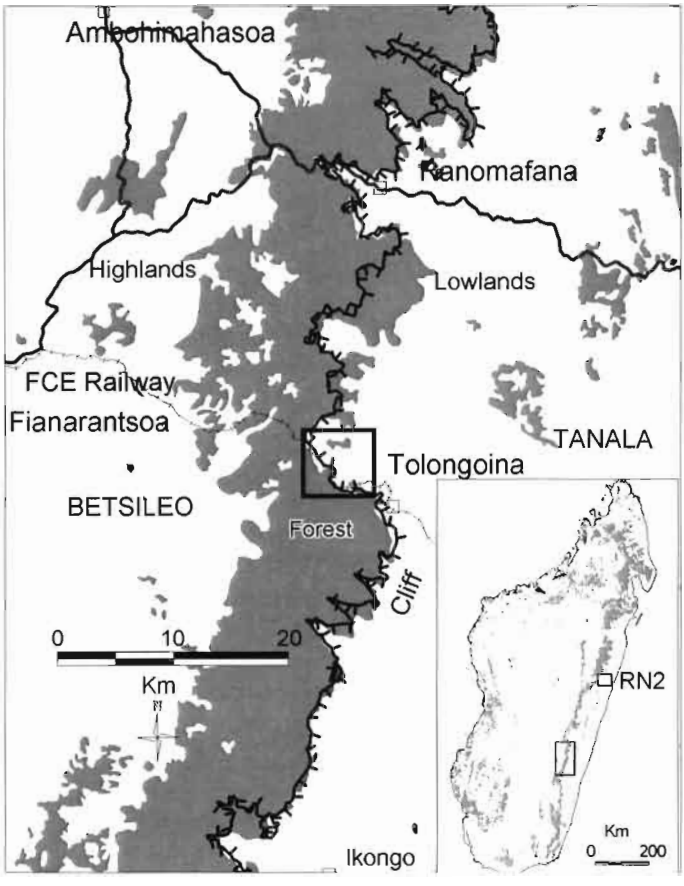

Fig. 18.1 Tanala land in its regional environment; location of RN2 Betsimisaraka region to north also shown on index map of Madagascar. (sources G. Serpantié, FTM)

cattle farming. The Tolongoina zone at the foot of the cliff (300–800 m) consists of hills with steep slopes and narrow valleys. On the cliff sides and the hills, where the villages and the main agricultural lands are established, one finds patches of an evergreen forest, mostly on the tops. The shrubby and herbaceous secondary vegetations, respectively called *kapoka* and *roranga*, extend each year a little further up the hillsides. With more than 2500 mm of annual rain and frequent hurricanes (about one every three years), the climate is one of the most erosive of Madagascar, similar to the RN2 Betsimisaraka region.

According to available 1/500,000 geomorphologic maps (Riquier 1968; Delenne et al. 1980), the Tolongoina zone presents the same types of landscapes and soils as the Betsimisakara region that has been the subject of considerable experimental research on erosion. Situated at the foot of an escarpment, these two regions contain gneissic bedrock, and have deeply dissected relief, in the form of hills with steep slopes with ferralitic soils, or Ferralsols (FAO 2006). The soils of the sandy river

terraces are Fluvisols, and the soils of marshy places are Eutric Cambisols (Brand and Rakotondranaly 1997).

Surrounded by the coastal people and those of the Highlands, the Tanala have maintained their ethnic identity. People of Ikongo, not far from Tolongoina, have effectively resisted the domination of the Central Highlands people, the Merina (Ardant du Picq, 1912; Beaujard 1983).

Tavy is the main Tanala cropping system, applied to the forested hillsides or more generally formerly forested slopes. Its record goes back to the most ancient sources of Tanala history—from the first population called "Vazimba" (Beaujard 1983), to the second population coming from the eastern coast in the 12th century (Solondraibe 1986). This temporary cultivation belongs to the class of the shifting cultivation systems or to the fallow system, depending on the crop and fallow durations (Ruthenberg 1971). Successively, the vegetation is cleared; the cut vegetation lies drying then is burned. Rice or beans are then sown into seed holes. Manual weeding and protecting against birds take place while the crops grow. After the harvest, cassava cuttings are planted with a worn spade without tillage, after some clearing without fire. Growing cassava is hoed with a spade. Once the cassava is harvested, the land lies fallow until future use. Linton (1933) noted in the Ikongo zone a fallow duration of 5 to 10 years.

Apart from the rice-cassava *tavy* on the hillsides, the farmers also grow banana and sugar cane (which they transform into local rum) on the bottom lands, rice in drained marshland (*horaka* rice), and irrigated rice on terraced bottoms. Rice and cassava constitute staple foods, whereas banana and sugar cane play a commercial role, having now largely replaced coffee as the dominant cash crops of the region. The formerly forested Tanala land has been, in large part, converted little by little to a shrubby cover (*kapoka),* and then to an herbaceous cover *(roranga)* by repeated *tavy* and induced bush fires (Linton, 1933; Serpantié et al. 2007).

18.2 Methods

Two tracts of Tanala land at the foot of a cliff, bordering the railway, were selected in separate villages in the commune of Tolongoina. The choice of these villages depended on criteria deemed relevant for the study of erosion, as impacted by *tavy* and the degree of deforestation. The agricultural territory of Ambalavero still has 31% forest cover, whereas the more ancient Ambodivanana has only 10% remaining. These forest patches are mainly situated on the hilltops. The well-covered and *roranga*-free Ambalavero territory (Fig. 18.2) had experienced very little exploitation at the beginning of the 20th century according to an early reconnaissance survey of the region (Delpy 1903). In contrast, Ambodivanana, with more *roranga* and less forest suggests that deforestation had taken place long before (Fig. 18.3). It is confirmed by Delpy's map.

Both territories include the forested top of the cliff (over 1100 m), the side of the cliff (30° to 60° slopes), and the hill zones (dissected relief with an average altitude

Fig. 18.2 Ambalavero landscape (source IRD-G. Serpantié) (see as color plate following *Index*)

Fig. 18.3 Ambodivanana landscape: view of a Betsileo immigrant collapsed rice field terrace on *foringa* medium steep slope (source IRD-G. Serpantié) (see as color plate following *Index*)

of 550 m and 20° to 40° slopes). The Ambalavero and Ambodivanana agricultural territories have population densities of 27 and 43 inhabitants per km^2 respectively.

Studying the Tanala soils, landscapes and agricultural practices were the first fieldwork in 2005, allowing a progressive integration in the community. Then we managed to collect (through semi-directed surveys) various discourses about the soil, the *tavy*, erosion, and the way these underlie (or justify) their practices. Formal inquiries on agricultural and socio-economic issues were carried out on a sample of 15 farms in each village. The information obtained here was confirmed in 2007 by the inhabitants of a third village, Tolongoina.

The study of the soils in their landscape followed the methodology described by Randriamboavonjy (1995). A variety of soil profiles with differing vegetation histories on both the cliff zone and the hills zone were examined. Field and laboratory tests were done to characterize water infiltration rates and other parameters assessing sensitivity to erosion. Soil results will be presented first, before moving to a description of the main cropping system, *tavy*, and then to the farmers' views on soils, erosion, and farming practices. Finally, these results will be examined in context to make it possible to evaluate the real risk of erosion and describe the way this potential problem is currently managed. After discussing the nature of this management and the limits of local and current scientific knowledge, we will conclude with recommendations for sustainable management, within a framework recognizing increasing population density and the necessity of forest conservation.

18.3 Results

18.3.1 Observed Hillside Soils

The soil surface generally has an aggregated structure, and does not show physical or biological surface crusts. Only the forests have an organic A_0 layer that can be up to 10 cm deep. The A-horizon shows a variable thickness (10-40 cm; 20 cm mean), independent of the present vegetation or topographic position. Clay content (20% mean) is significantly lower on the tops, and under *roranga* vegetation or cultivation (10%), testifying to the phenomena of impoverishment in these positions and under this vegetation. More or less strong colouring indicated the clay content and not organic matter content, with the impoverished soils being the darkest.

The A-horizon under *kapoka* and *roranga*, (50-55% porosity) are significantly less permeable (water infiltration rates of 100-1000 mm/h) than the soils under forests and crop cultivation, which have an aggregated and friable structure (>60% porosity, >1000 mm/h). But the *roranga* soil's lower permeability still allow for infiltration of most of the rainfall events, as intensities rarely exceed 100 mm/h. Being rich in decomposing organic matter and iron, soil aggregates in surface horizons are, in most cases, quite stable and well-protected from erosion by rain splashing.

The deeper soil layers often have massive structure and higher clay contents than the surface layers. Soils at the top and bottoms of toposequences tend to have thick, clay-rich B-horizons that limit water infiltration—thus these are at high risk of water saturation and runoff under heavy rainfall conditions such as typical of a hurricane. In these cases, first components being eroded after clearing and burning are light and detached particles such as plant debris, charcoal fragments, loose sand, and disrupted soil aggregates (in the case of trampling or tillage). In contrast to these more erosion-susceptible soils, soils on the middle of hillsides, because of deep layers with lower clay contents, are at lower risk.

Current vegetation creates or reveals variations in erosion-susceptibility. The observed loss of clay of soils under degraded *roranga* vegetation indicates that

these badly protected soils have been subjected to fine particle-selective erosion by rainwater. Their lighter texture leads them to be more susceptible to rill erosion by runoff. On the hilltops, the impoverished surface layer is erosion-susceptible too, if not covered by dense forest cover, where tree roots facilitate rainfall infiltration through the B-horizon.

Another major erosion process exists in soils with light cohesiveness—mass erosion. If tested with the penetrometer, Ferralsols of the Tanala region have a significantly lower cohesion than the Highlands savanna Ferralsols under another climate. But sometimes they have compact, deep layers, locally present as discontinuous ironpans. On very steep slopes (40° and more), when rainfalls in hurricane weather exceed deep infiltration capacity, soils with high infiltration rates are favourable to landslides after liquefying intermediate layers. Soil disturbance by human activities such as tillage, terracing and excavation may favour landslides on less sloping land. Such landslides may start under forest cover, or after soil crumbling around the wind-shaken isolated tree trunks. Some red soils under forest testify to such natural truncations of the brown A- and yellow B-horizon.

18.3.2 Current Practices of Tavy in a Forestless Society and Impacts

Tavy is applied widely in the forested or formerly forested hillsides. *Tavy* has resisted the migration of Betsileo people coming from the Highlands and renowned for being the best farmers in Madagascar, with their terraces and their skills at handling the *angady* (a ploughing spade) and developing rice irrigation in the bottoms around the marshes already cropped by Tanala (*horaka* rice field). The Tanala farmers, however, are famous for their handling of the *goro* (machete), the main tool for *tavy* in shrub vegetation. An examination of current *tavy* practices highlights multiple dimensions: the positioning of fields in the landscape, the soil preparation method, and the features of the cultivation-fallow cycle. These essential points will be dealt with in the section on the Tanala representations of their own practices.

An objective indicator of land fertility status in *tavy* regions has to take into account the main historical crop in *tavy* systems—upland rice. The percentage of farmers in Ambalavero growing upland rice was 44% in 2006, compared to only 9% in Ambodivanana. The controlling factor limiting rice production in Ambodivanana is soil fertility. The impact of temporary cultivation on soil fertility depends on many features, most importantly, fallow duration and reserve of forested land. Both population growth and scarcity of available forests under favourable climate (less than 800 m on this escarpment, Serpantié et al. 2007) have contributed to reducing the fallow period. The Madagascar government's Contractualised Forest Management system, set up in 1999, promoted conservation rules and gave the community responsibility for the management of their forests. In exchange for this new right, the community was obliged to commit itself to limit *tavy* to the four

year-old shrubby or herbaceous fallows. Today, farmers clear no more forests or five years-old *kapoka*, and no longer let their land lie fallow more than two years. They are torn by these new regulations that reduce both fallow duration (traditional duration is five years and more) and available agricultural land.

In Ambalavero, whereas much of the land is still not degraded, the current farming system has reduced its sustainability with such short fallows. Locally new *roranga* are observed.

With a higher current population density, Ambodivanana, which has been exploited for a longer period than Ambalavero, shows a much more degraded environment, with the presence of large *roranga* spaces (about 25%). An important feature to take into account is the number of shrub tavy on a same place: each re-growth is slower than previous one (Pfund 2000). Furthermore, vegetation has a species composition that is pushed toward fire-favourable species (ferns and grasses) producing *roranga* vegetation. In Ambodivanana, there are more signs of rill erosion; surface soils contain less clay. Following the *tavy* carried out on immature shrubby fallows or on degraded *roranga*, rice yields were too low and many farmers gave up on attempts at upland rice production, keeping cassava cropping. Even though a degradation of soil is admitted by most of the farmers, their other production techniques have not changed. As in all Tanala villages, they use no chemical products or manure. The degraded land is the principal problem of this village. The excessive number of repeated shrub clearings, or the shorter fallow periods, or the frequent burning of shrubs may lead to the same problems.

Another factor impacting vegetation regeneration (Randriamalala et al. 2007) and erosive risk (Brand and Rakotovao 1997) is the level of physical disturbance of the soil. In Tanala land, the *tavy* remains fortunately without tillage. Weeds are removed by hand or cautiously with a worn spade. The only places where the Tanala farmers plough or irrigate are rice fields on Fluvisols and terraces on gently sloping bottomlands. This tricky work is mostly done by their Betsileo workers.

Due to food constraints and the necessity of a cash income, agriculturally less-and-less efficient lands are, paradoxically, destined to be more intensively farmed. Technical options of new varieties and intensive cropping systems are very limited or unsuitable due to additional risks or investment costs (Serpantié et al. 2007). Development projects for other income-generating activities are still rare in this region, or neglected by people suffering at a more elementary level from difficult access to basic services (hospitals, schools, irrigation dams, roads). Tolongoina, the largest village, with a market and health care facilities, is three hours away on foot, and neither Ambodivanana nor Ambalavero have their own schools. And according to the Tanala farmer, recommended changes might paradoxically entail the loss of his only wealth—his land.

18.3.3 Tanala representations of the land

The Tanala express their representations of the land in various dimensions: physiographic, economic, dynamic, and most certainly symbolic, the latter requiring

further studies in order to be understood. The terms land and soil are both called "*tany*".

18.3.3.1 Land quality references

The Tanala represent their environment and land by reference to the physical geographic settings and current or former biologic configuration. *An'ala*, the forest area, refers to forest- covered areas even if most of these lands have shifted to a predominantly herbaceous vegetative cover, as in Ambodivanana village. The villagers implicitly refer to the past. The Tanala also use specific vocabulary to describe the location of their land in the landscape, their fields, and the abruptness of the slopes (Table 18.1).

Table 18.1 Tanala vocabulary for description of land

	Vocabulary	
Subject	*Malagasian*	English or *Latin name*
Geomorphology	*an-tety*	forest peaks and plateau
	amboditety	foot of the cliff
	vohitra	steep sloped hills
Slope	*harana*	very steep slopes
	foringa	medium steep slopes
	harenana	shelves
Valleys	*gebona*	small valleys on the hillside and bottoms
	farihy	hollows
	horaka	marshes
Plot orientation	*mianatsimo loha*	northern exposition (good) « heads turn to the South »
Vegetation and fields	*tavy*	slash and burn action, and all temporary field following it
	kapoka	shrubby fallow
	roranga	herbaceous cover after many *tavy* and bushfires
	ala (Tanala)	forest (Forest People)
	tavy ala	field derived from clearing a forest
	tavy jinja	field derived from clearing a shrubby fallow *(jinja* = to mow)
Plant species as indicators of good soil	*longoza*	*Aframomum angustifolium*
	harongana	*Harungana madagascariensis*
	dingana vavy	*Psiadia altissima*
Indicators of bad soil	*ringotra*	*Dicranopteris linearis*
	ampanga	*Pteridium aquilinum*
	anjavidy	*Erica spp.*
	radriaka	*Lantana camara*
	tenina	*Imperata cylindrica*
Agricultural tools	*angady*	spade
	goro	machete
	fitomboaka	seeding stick

Table 18.1 (continued)

Subject	Vocabulary *Malagasian*	English or *Latin name*
Soil description	*tany*	soil, earth, land of ancestors
	tany mainty	"A_0" horizon, organic layer (only under forest)
	tany roaka	"A" horizon after slash and burn
	volondohan-tany	"A" horizon of a cultivated soil ("hair on the head of the soil")
	tany mena mavo	"red yellow soil" ("B" red yellow horizon)
	tany mena voalohany	"first red soil" ("B" red horizon)
	andrin tany	"soil pillar" ("C" red horizon)
	tain kenkana	worm casts
	tany menaka	"fatty soil"
	tsiron-tany	"soil taste" (nutrients, fertility, organic matter)
Soil properties	*malemy*	loose, kind
	tsara	good
	mainty	black
	mahery	hard or strong
	am-patrana	where it is hard
	ratsy	bad
	mena	Red
	mafana	Warm
	manara	Cold
	maditra	tired, exhausted. Generally associated to *roranga* vegetation
	masiaka	harsh, nasty. Used about interdictions (*fady*)
Erosion and runoff	*tany toha*	landslides
	tany miambaka	rectilinear cracks
	longeona	underground channels
	abilema	mudslide in FCE railway trenches and embankments
	ranovohitra	very important runoff events

For the same position in the landscape, vegetation (density and species) is considered as the first indicator of land quality; secondary forests and shrubby fallow *kapoka* lands are preferred. The dominance of ferns, *Ericaceae*, and *Imperata cylindrica,* in herbaceous *roranga*, is evidence of bad land quality.

Soil is the second ecosystem compartment to be taken into consideration for agricultural activity, endowed with various properties linked with the success or the challenges of crop production. The forest soils contain four distinct horizons:

- The organic layer, called *tany mainty* ("black soil") is said to be made up of decomposing leaves, branches, and small underground animals that contribute to this decomposition. This soil is therefore charact erized by constant moisture content, and contains the element that bestows fertility on the soil (*tsiron-tany,* "soil taste"). It roughly corresponds to the top of the A-horizon (also noted A_0).
- When the forest disappears, the surface soil is called *tany roaka*, equivalent to the base of the A-horizon, after the high organic matter, and low density A_0-layer has been burnt-up or scattered. An aggregated structure, dark brown color, and the presence of worm castings are characteristics of this layer.

- Underneath is an intermediary zone, the *tany mena-mavo* (red-yellow soil). This more compact layer contains roots, and can be seen as equivalent to the B-horizon or the CB- horizon of rejuvenated soils.
- Red soil underlies the red-yellow layer. It is called *andrin-tany* ("soil pillar"). It is very deep, and characterized by its remarkable uniformity. It can be seen as equivalent to the C-horizon.

The adjectives used to describe soil's agricultural properties refer first to **colour**. The black soils, as opposed to red ones, are the best for agricultural activity, and they are typical of Tanala land. According to the Tanala farmers, the reason for good black soils on Tanala lands is the presence of forests; in contrast, the bad red soils on Betsileo lands are associated with deforestation. **Biology** is another indicator in land agricultural quality. Earthworms are a good indicator for soil fertility of the *tany roaka* layer. Furthermore, **exposure** is an essential property determining land quality. In this very humid zone with steep terrain, the best lands are those that receive enough sunshine. This allows for more rapid evaporation, and makes soil dryer and "warmer". Good exposures are those from the North and the East. Land parcels with bad exposures, South and West, remain wet and *manara* ("cold"). These wet soils are too plastic, becoming compacted and poorly aerated when trampled by cattle.

The various names for soil components indicate a lexicon that is not only metaphorical, but is also frequently inspired by the human body and human characters. The "head" of the field is the part situated at a higher altitude, and the "head" of the soil is the A-horizon. The land is *masiaka* (literally: harsh, nasty) when prohibitions (*fady*) enforced by religious or magical sanctions (taboos), whose violation may cause the person's death, are associated with it. The *masiaka* character of the *tany* is said to be linked to the character of the former inhabitants who instituted the taboo. The *tany* can also be *maditra* (indomitable; a term commonly used to describe a stubborn person or child), and *mahery* (strong) when it requires a lot of work, namely ploughing, in order to produce, as in Betsileo country. However, with the expansion of herbaceous *roranga*, there are more-and-more *tany maditra* and *mahery* on the Tanala lands. According to the farmers, the successive bushfires and *tavy* burning in these places are the main reasons for the soils becoming *maditra* or *mahery*. Repeated fire (*tavy* and bushfires) is seen as a threat to soil fertility because the fires burn the soil fauna that contribute to the production of *tsiron-tany*.

18.3.3.2 Soil evolution and erosion

The farmer thinks that a cultivated soil evolves differently according to its topographic position:

- The soils that get most rapidly impoverished are the summit soils. They do not allow a faster return to shrubby vegetation.

- The summit soils are linked to the slope soils. Indeed, the forest presence on the peaks maintains soil water on the slopes, whose soils then remain loose and favourably suited for agriculture, thanks to the moisture transfer from the summit.
- The mid-slope zone of medium slopes is known as the most resistant to erosion and runoff. Temporary cropping has less impact on soil at this topographic level, which therefore seems the most sustainable one.
- The small valleys on the hillside and bottoms are considered the most fragile zones, but are also the most fertile, because of the presence of more *tsiron-tany*.

According to the farmers, the main erosion process is landslide. The main factor stems from the loose *malemy* characteristic of Tanala soil. Landslides take place especially on steep slopes in the cyclonic season. Rainwater and infiltrating runoff make the soil very loose by penetrating through cracks near the roots or underground channels *(longeona)*. In addition, the wind causes the trees to sway, thus increasing the cracks nears the roots, and may even uproot them. The runoff then finds an "entry" that will provoke the landslide. Slopes bottoms are the wettest parts, and that is why bank landslides are frequent there. However, in their view, landslides on railways represent another erosion process, caused by the daily roaring of trains, and by the fact that the soils of the artificial embankments and trenches are less resistant.

During the first *tavys*, little surface erosion is observed, thanks to a permanent vegetation cover on the soil. The exceptions typically involve recently cleared and burned or weeded plots, and cyclonic rains where extreme runoff episodes wash away plant litter, charcoal and ashes. But these runoff events do not lead to loss of either soil fertility or soil itself. In contrast, repetitive *tavy* with short fallows progressively causes the disappearance of the first layers (*tany mainty* and *tany roaka*) and the uncovering of the deeper, less fertile layers, such as the ironpans. But shorter fallows and frequent bushfires change the character of the vegetation (more herbaceous, less covering *roranga*), and transform the soil. Such an evolution is understood as inevitable.

From their point of view, the dominant, visible mass erosion phenomena are not seen as having, in themselves, significant impacts on agricultural productivity. A landslide does not prevent them from planting either cassava or rice on the same place the following year. The only inconvenience they mention is the destruction of crops in the heap of fallen earth and landing zones. Swamp rice fields at the base of the landslide are thought to indeed thrive due to improved soil fertility —the belief being that marsh soils are too high in organic matter and too low in mineral content. Erosion by landslides therefore seems to be unpredictable, and of little net economic impact. As a consequence, the issue of risk management does not arise.

Despite the discrete but well-known processes of erosion, the Tanala do not directly express the notion of fighting against it; erosion is either seen as slow and inevitable (long term erosion in the case of short fallow periods), or as without consequences (local landslides).

18.3.4 Tanala representations of their own practices

We are now going to examine more closely whether the Tanala link their actions to their knowledge about soil and erosion. We will then examine their practices in light of agronomy and soil science knowledge. In the general view of farmers, *tavy* in itself does not have a negative impact, but the sustainability of soil fertility depends most importantly on factors such as fallow duration, fallow management, and the cumulative number of burnings. A minimum fallow duration of five years without bushfire is necessary for the soils to recover the required qualities for rice growing. But due to external forces such as population growth and forest management regulations, it is becoming more difficult to make a five-year fallow. Farmers have to return more often to the same parcel. On the whole, no immediate and general link has therefore been found between *tavy* and erosion in the collected rural Tanala knowledge. But as we will see, most of their practices are done in order to provide against soil losses, and to provide for the maintenance of fertility.

18.3.4.1 An adapted crop location

Farmers dislike the quality of summit soils, and this leads to those being the last to be cleared. The loss of earnings is the primary cause that keeps them from deforesting the summits. Since those soils become rapidly impoverished, and since the fallow lands do not regenerate well, the initial clearing of a summit forest is less profitable than that of a slope when it comes to establishing an agricultural domain. They also think that maintaining forests on the crests is useful to the slope soils and springs. The mid-slope zone of medium slopes is known as the topographic zone that best resists damage from temporary crops. It is also the one that is most often cultivated by *tavy*, and the zone where the farmer's hut is typically built, either on a shelf or on a constructed terrace, surrounded by perennial crops.

The slope bottoms and small hollows are recognized as fragile but fertile. It is the zone of permanent crops: coffee, sugar cane, banana, and fruit trees. This strategy makes it possible to avoid ploughing the soil, or to leave it bare while making good use of the fertilizing elements that are deposited on it by the wash off of ashes and organic matter on the slope under the effect of local runoff after heavy rains. The marshes and small valley bottomlands are highly prized spaces because of their high fertility, despite their narrowness and the risks of cyclonic floods. They represent the domain of *horaka* rice planting. With irrigated rice fields on the alluvial margins of marshes and on small terraces in the most stable places, they are permanent rice cultivation systems. When cyclones flood the rice, the farmer's rely on *tavy* production for subsistence.

By practicing *tavy* almost exclusively at the mid-slope level on *foringa* (medium steep), and by avoiding all the other locations, the Tanala therefore avoid more runoff-prone areas or areas with high risks of landslides. By leaving parts of forests on the peaks, they avoid worsening the production of runoff from up-slope zones.

18.3.4.2 A minimum soil structure modification

In the Tanala region, the soil is *malemy* (loose). This generalized representation affects their technical choices; it limits any inclination towards deep tilling of the soil, and guides the type of clearing methods chosen. In order to prepare the soils before cultivation, the Tanala farmers do not take out the stumps, for fear of leaving big holes in the ground. Heavy rains might wash some soil away and cause a serious landslide. On the other hand, progressive rotting of these stumps gives natural soil fertilization. Rice is planted in seed holes dug with a stick. Cassava is planted by lightly pushing a worn spade into the ground diagonally, parallel to the slope, so as to create a little opening where the cutting will be placed. Permanent crops are planted by cutting and seedlings. The base and roots of the weeds are left in place, and provide some protection against direct effects of rain and runoff on soils.

When asked about the effects of soil tillage like ploughing, the farmers mention multiple disadvantages, as well as useless and tiring work. Ploughing a loose soil would inevitably provoke the erosive loss of fertile soil, and the less-productive red layers will rapidly appear at the surface. Ploughing also requires additional operations, such as stump removal. Furthermore, ploughing must be done every year, as the soil hardens more quickly. Finally, turning the soil over every year does not allow fallow regeneration, which should create a humus-bearing horizon. Regular fertilizer input would be needed, which is an extra expenditure. According to the farmers, ploughing is justified only when the soil begins to be hard and unproductive. All these techniques address the concern of not excessively loosening the earth; the weather and fallow maintain it naturally loose, rendering it useless and risky to loosen it more. But farmers in the old villages are now hesitating; in order to deal with the low fertility status of their soils, Ambodivanana farmers are thinking they might have to plough, despite the risks, in an attempt to improve the crop yields.

18.3.4.3 Temporary crops and long-duration fallowing

In the view of the Tanala farmers, in order to maintain their loose and soft quality, the soils need a periodic return to native vegetation status without fire for a minimum period of five years and a limited cultivation period, generally one year of rice or bean followed by one or two of cassava. Yet, an impoverished soil will take more time to regain its *kapoka* status, and will increase the necessary fallow period.

The positive effects of the fallow on the soil are attributed to the restoration of the *tsiron-tany* due to vegetation regeneration, the work of underground animals, and the final burning. Fallow is favourable not only on the following rice crop, but also on the cultivated plots down-slope, since the fallow reduces runoff from uphill. Therefore, the length of the farming-fallow cycle is very important in order to enable the soils of the region to be productive in the long term.

Permanent crops (coffee, banana, sugar cane) constitute a complementary strategy for the management of the land. Historically, permanent crops have generally taken up about a third of the land; another third is devoted to temporary crops, and the last third lies fallow. However, temporary crops have tended to increase in importance over the years, and this generally has been to the detriment of the fallow land and sometimes to the oldest permanent crops.

In summary, a link does indeed exist between *tavy* practices and knowledge expressed on erosion. The management of this risk, however, is not given as the only justification for these practices.

18.4 Discussion and conclusion

The issue that was raised earlier concerned the search for an underlying [and largely unspoken (outside of this community)] Tanala land-management system that would explain the low occurrence of demonstrable erosion features on Tanala land, where erosion due to a rainy climate and slope steepness is typically a serious risk. Because signs of erosion are often masked by vegetation or otherwise not readily apparent, it is more difficult to comprehend than in other regions. Farmers, the forest department, scientists and railway managers each have a major role to play in erosion control, and reconciliation between their different perspectives and sources of knowledge is needed.

18.4.1 New data

According to our observations often confirmed by rural Tanala knowledge, erosion may occur in *tavy* fields, but rarely and differently according to a variety of ecosystem and management conditions. First, *tavy* leads to an erosion of only the organic surface layer (A_0) that may have been partially destroyed by burning of biomass. The erodibility of most soils of the middle hillsides remains low, as vegetation is not degraded by multiple *tavy*, short fallows, or bushfires. It is the best place for annual crops without tillage. Bourgeat et al. (1973) had similar findings for Highlands' Ferralsols. But degradation of vegetation after repeated *tavy* practices, short fallows and frequent bush fires, increase erosion and clay-impoverishment; this loss of clay results from insidious selective diffuse erosion under poor vegetative cover. The number of tavy and bush fires, position of remaining cover in the landscape, fallow duration, cropping practices, degree of slope, local soil type, and texture of the subsoil are the many sources of variation of local erosion risk.

So the scientific knowledge, systematically relating *tavy* to severe erosion may have been distorted by hasty generalization of the results of first experiments in the 1960's (Serpantié et al. 2006). Experiments of 1990's gave some new perspectives

but the sampling was also very limited (one plot, one year). In 1995, in Beforona, a 144 t/ha/year loss of soil from ploughed fields planted to ginger was measured, whereas *tavy* upland rice lost 14.6 t/ha/year, young fallow 5.5 t/ha/year, and the *kapoka* only 0.37 t/ha/year (Brand and Rakotovao 1997). These data suggest much higher erosive losses with the ploughing system. It should be pointed out that the average annual amount of soil loss for the overall *tavy* system is a composite of the measured cropped and fallow values ("only" 4.4 to 5 t/ha/year).

The type of vegetal cover and the level of soil disturbance are generally the only two factors studied by experimentation on "erosion plots." Our field studies of the soils show that many other factors need to be taken into account in the management of erosive risk; first, the position in the landscape, and this is precisely taken into account by the farmers. Thus, the real yearly erosion average in young *tavy* landscapes is probably less than 5 t/ha/year; but it will increase with time. The addition of new scientific knowledge is helping us to recognize the importance of local practices and the relevance of local knowledge.

18.4.2 Understanding the underlying rationale of tavy

Although their tools are rudimentary, Tanala practices can be interpreted as comprising multiple precautions to prevent soil loss. The Tanala manner of conducting *tavy* and its implicit rules (the essential characteristics of which are summarized below) are key to these erosion-vulnerability reduction practices:

Principle 1: Use of a passive space management system—as much as possible, avoiding practicing *tavy* in areas that entail high risks of runoff or of mass-erosion starting points: *gebona* dips, *harana* steep slopes, hillside bottoms. Permanent crops are grown on risky areas. Degraded and impoverished *roranga*, are avoided. Summits are avoided because fallow soils do not regenerate well (refer to principle 3). Additional erosive risk reduction practices include conservation of summit forests and of fallow lands upstream from a *tavy*.

Principle 2: Soil structure is not to be disrupted, or if so, then as little as possible and for the shortest period possible. This minimizes the risk of loosened soils being washed away by runoff, and leads to fallow lands regenerating better (refer to principle 3).

Principle 3: Temporary farming and long fallow: let the slope ecosystem heal for as long as possible after disruption. The soil structure will remain stable to allow cropping on non-ploughed soils (refer to principle 2).

A fourth principle was gathered by Le Bourdiec (1974): Clearing forests (primary or secondary) preferably to *kapoka* fallows, the Tanala telling that erosion develops more after a shrubby fallow. This principle implied mobility. Currently, this principle cannot be gathered nor followed, since forest remnants are now largely protected as reserves, and since villages are definitely sedentary.

These linked technical principles can be qualified as "passive," given that they are not actions as such, but are rather passive acts: abandoning fields, not working the

soil, avoiding certain areas. However, these are definitely management principles. Only forests are not spared, as these so-called "forest people" are in fact, pioneers and farmers. This rudimentary technical approach is due not to agricultural ignorance, but rather is a form of environmental economy, in harmony with other aspects of temporary farming such as ecosystem management (weed control, nutrient availability), labor economy, and social organization economy. Therefore, a management system for erosion risk does indeed exist, and explains some *tavy* features.

Although often demonized in the scientific and technical realm, *tavy*, as conducted by the Tanala, seems particularly adapted to this topographically varied and very humid zone. Such a cultural adaptation was already noted by Kottak (1971). However, adapted does not mean sustainable. Denying the erosive risk would be as fallacious as denouncing *tavy*. Reality is complex, and requires a combination of various angles of approach, several levels of observation and care in generalization. Our GEREM study seems to reconcile mono-disciplinary scientific knowledge that appeared contradictory. Perhaps early science conclusions have to be blamed for not sufficiently referring to experimental conditions and for inappropriate generalization. Erosive manifestations truly increase in formerly deforested villages, like Ambodivanana. The proposition that "*tavy* induces erosion" on Ferralsols has been confirmed in the long term only in the case of high population density and non-mobile settlements. This is precisely the case in the highly populated Betsimisaraka zones of RN2, where erosion has been studied through experimentation. Furthermore, not all *tavy* systems are equal in soil losses. In villages that have been deforested for less than a century, and where deforestation has not yet reached the crests, local practices and knowledge make risk mitigation still possible. The resident population density, the time elapsed since deforestation began, and less careful practices due to land scarcity might constitute aggravating risk factors, and might not be addressed by local knowledge. However, borrowing from other bodies of knowledge with the view of adapting to current population density requires prudence. Adopting the agricultural management system of the Betsileo region, renown for its sophisticated farmers, would lead to even worse catastrophes. This is illustrated by the example of a Betsileo migrant in Ambodivanana who, despite being in a highly erosive environment, attempted to construct terraced rice fields on ordinary *foringa* slopes; the failure is seen in Fig. 18.3.

18.4.3 Fortuitous or Intentional Management?

The link between the detailed practices and the farmers' knowledge of their environment has been confirmed and shows that this management is reasoned and so, intentional. For the soil scientist and the agronomist, it is reasonable from the point of view of a sustainable production if minimum fallow duration without bushfires is respected. Thanks to it, erosion has minor economic consequences. Managing erosive risk is not the only aim of the Tanala way of temporary cropping.

Their very old system of practices is an integral part of their identity, and has enabled them to build their territory and their society. Thus, the Tanala have not developed concepts or theories (in their representations or in their language) to view the management of potential erosion. Their theory is the Tanala practice itself. Under these conditions, changing practices would endanger a tried and shared system. But general conditions are shifting and population pressure is growing. The question of current concern becomes: have Tanala local knowledge and practices been able to adapt to current conditions?

18.4.4 Limits to Tanala knowledge and scientific knowledge

Both the scope and the limits of the indigenous knowledge that underlies rural practices, as well as the scope and the limits of scientific knowledge that underlies technical advice, have to be examined in an integrated manner in order to identify correspondences and divergences. In terms of limitations, Tanala concepts place too much emphasis on the forest and on soil colour. Despite a high deforestation rate, their region remains *an'ala* (in the forest). When they refer to the Betsileo region as "deforested", they do not mention the climatic and relief conditions that are different from those in their region. Black soil *"mainty"* is highly valued by the farmers, but as far as the soil scientist is concerned, this color, in the soils of this region, often indicates low clay content (a phenomenon of impoverishment) rather than good soil condition and erosion resistance. The disappearing of the dark A-horizon may have happened under forest cover, before the first tavy, but organic matter may have a sufficient level in such "red soils". This makes it hard to say that soils with red or yellow-coloured surface horizons are systematically "degraded" soils. When the farmers refer to the degraded *roranga* soils as *mahery* (hard), they seem to reflect the soil's impoverished nature due to its low fertility and diffuse erosion rather than its massive structure. Granted, forest and kapoka soils are the loosest, but it has not been established that the impoverished *roranga* soils are so excessively indurated or massive that they need to be ploughed. Ploughing them may help to improve mineralization first. They know the erosive risk that awaits them when they begin to plough or irrigate slopes, but do not have enough knowledge to replace their practices. The farmers' body of knowledge is only compatible with conditions of low population.

In many other domains, there is a high degree of convergence between local bodies of knowledge and scientific expertise about the soils and their use, although the superposition of the arguments is certainly not perfect. For example, some aspects of Tanala knowledge about the relationship between peak and slope soils and the effect of the crest forest on infiltration do converge. But the superposition of the discourses also makes it possible to measure the superiority of some aspects of Tanala knowledge in relation to scientific knowledge, which is necessarily limited by investigation costs or excess of specialization. The farmers' knowledge sometimes anticipates science. The negative effect of ploughing on fallow

regeneration that was mentioned by the farmers was recently confirmed by Randriamalala et al. (2007) on fallows of the Betsileo forest. Therefore, the farmers' practices of minimum disturbance of the soil match the most recent agro-ecological knowledge. The farmers also bring us information on the role of exposure on soil features. Malagasy people attach major importance to cardinal directions in their symbolic view of the world. But verifiable microclimatic information is probably at work here.

According to the farmers, summit forests maintain the moist state of cultivated-slope soils. That relates back not only to topsoil's water-holding capacity and runoff control, but also perhaps to other unknown local forest properties and ecosystem relationships, such as microclimate, and sources of seeds and fauna for fallow.

18.4.5 Enriching the search for consensual solutions

Our ultimate goal was to help develop a new, "consensual" action plan consistent with both forest conservation and sustainable production. Studying the details of soil representations has made it possible to understand why the prohibition to clear remaining peak forests was respected and even encouraged by the farmers of Ambalavero. Indeed, this global injunction does not contradict local knowledge on forests functions (protection of slopes and springs, conservation of nearby wood resources), and does not cost much socially (since summits fields are the least sought-after parcels). On the other hand, the conservation of all the five-year fallows remaining on hill slopes recommended to the community by the Forest Service, is contradictory to the Tanala's third and fourth principles of land management, and reduces the available land.

New practices that are viewed as compatible with local knowledge will have the best chance of adoption, but new knowledge is also needed. Demographic growth, poverty, and forest conservation restrictions might, for lack of knowledge on alternatives, lead the farmers to practice techniques they know to be environmentally damaging. In Ambodivanana in particular, attempts are being made to extend rice fields by building terraces with irrigation canals on hill slopes; subsidence has been common here. On the hills, ploughing and terrace construction to increase farmable acreage can be expected to result in massive erosion.

Despite reaching their ecological limits at a period when population densities are crossing thresholds never experienced by the Tanala population, the knowledge of farmers gives a pathway to managers and agricultural research. The Tanala principles and practices—emphasizing minimal soil disruption, covering by withered weeds, a fallow system, and taking soil types and their plant communities into account—are principles that are compatible with the agro-ecological techniques studied at the Madagascar agronomic center (FOFIFA), such as no tillage systems (Rasimalala 2004) and integrated agro-forestry systems (Nambena 2003, Nambena 2004). The challenge that remains is to find ways to work together with the Tanala

people on these techniques in order that they might be adapted to the Tanala context—its culture, lifestyle, and economic realities.

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