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Agroecosystem and Farmer Practices and Knowledge in Madagascar's Central Highland: Toward Improved Rice-Based Systems Research

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AGROECOSYSTEM AND FARMER PRACTICES AND KNOWLEDGE IN MADAGASCAR'S CENTRAL HIGHLAND: TOWARD IMPROVED RICE-BASED SYSTEMS RESEARCH

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ABSTRACT

Madagascar has 1.3 million ha planted to rice, but has been a net rice importer for more than a decade. Research on rice and rice-based farming systems seeks improved production and restored rice self-sufficiency. With 350,000 ha of lowland rice, the Central Highland is the country's most important rice-growing region. A diagnostic survey of farmer practices and knowledge was conducted in the region as a collaborative effort by national researchers and the International Rice Research Institute. This paper synthesizes the survey results, describing rice agroecosystems, the whole-farm system, farmers' land-soil categories, rice crop management, rice cultivars, soil nutrient management, and social organization. Implications for further research are suggested. Such research would seek to build upon existing farmer practices, knowledge, and resources, and would deal with the whole-farm system, germplasm improvement, and low-input soil nutrient management. Modifications of a Food and Agriculture Organization fertilizer program are suggested.

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Rice is grown on about 1.3 million ha in Madagascar and accounts for 40-50% of the value of agricultural production. Annual rice production (2.1 million t) and yield (1.8 t/ha), however, have been stagnant, and the rice-growing area has not increased significantly over the last decade. Annual per capita rice consumption (135-150 kg) for the population of 10 million is high. As a result, Madagascar imported an average of 126,000 t/yr in 1971-85 after having been a net rice exporter. The government has tried unsuccessfully to improve rice production and distribution since 1972 by forming state companies for milling and marketing, rationing consumer supplies, trying to substitute wheat for rice, forming more farmer cooperatives, building small irrigation dams, calling for decreased consumption, and increasing prices paid to producers.

Research on rice and rice-based farming systems in Madagascar is conducted by the Foibem-Pirenena Momba ny Fikarohana Ampiharina Amin'ny Fampandrosoana ny Ambanivohitra (FOFIFA, the National Center for Applied Research in Rural Development) in collaboration with the Institut de Recherche sur l'Agronomie Tropicale (IRAT), the Direction de la Coopération au Développement et de l'Aide Humanitaire (DDA), and the International Rice Research Institute (IRRI). FOFIFA's Département de Recherche Développement (DRD) and Département de Recherche Agronomique (DRA) are also collaborating with the Programme Engrais Malagache of the Food and Agriculture Organization of the United Nations (FAO-PEM) to test the effects of fertilizer on rice yield in the Central Highland region.

The Central Highland is the most important of Madagascar's rice-growing areas, with about 350,000 ha of lowland rice (Ponnamperuma 1986). Rice variety-fertilizer trials were conducted in the region in the 1960s and 1970s, with yields ranging from 4.2 to 6.6 t/ha (M. Arraudeau, IRRI, pers. comm.). An IRRI agricultural anthropologist and researchers from DRD conducted a diagnostic survey of rice agroecosystems and farmer circumstances, practice, and knowledge in the Central Highland. This paper relates the survey findings and discusses their implications for research, including ways to make the FAO-PEM work more farmer-appropriate. The substantial rice research conducted in Madagascar and reported by the French is not covered, although such information would need to be included in a wider review of important past research.

METHODS

A general overview of the Central Highland agroecosystem was gained from secondary data. Field research was conducted in Madagascar from 17 Jan to 14 Feb 1988. Small samples of randomly selected rice farmers were interviewed in 12 widely separated Central Highland valleys, including 7 in which FAO-PEM was conducting trials and demonstrations. Respondents were Merina (one of 21 Malagasy ethnic groups) farmers from valleys in the Antananarivo area and Betsileo (another ethnic group) farmers from the Fianarantsoa area. Individuals and groups were interviewed by the anthropologist and DRD and DRA researchers.

Interviews were open-ended and interactive, but structured by a set of guide issues. Issues emerging as important during the interviews or field visits were explored in depth with farmers. As a result, interviews intentionally evolved over the survey period following a changing set of guide issues, and proceeding from more general to more specific lines of inquiry as data and understanding were accumulated. Research sought not only to describe farmer practice, but also to understand the perceptions and technical knowledge underlying practices. It was assumed that understanding why farmers do what they do—e.g., not using inorganic fertilizer because of the perception that soils become compacted—provides a necessary (although not sufficient) basis for research leading to the development and transfer of farmer-appropriate innovations.

In this paper, frequencies or percentages are usually unspecified, because only a few farmers were interviewed at many sites, and because interview content differed by farmer, location, and stage of the field study. For the same reasons, the discussion of ways to make research more farmer-appropriate—rather than being conclusive—is best considered preliminary, subject to further research or formal survey.

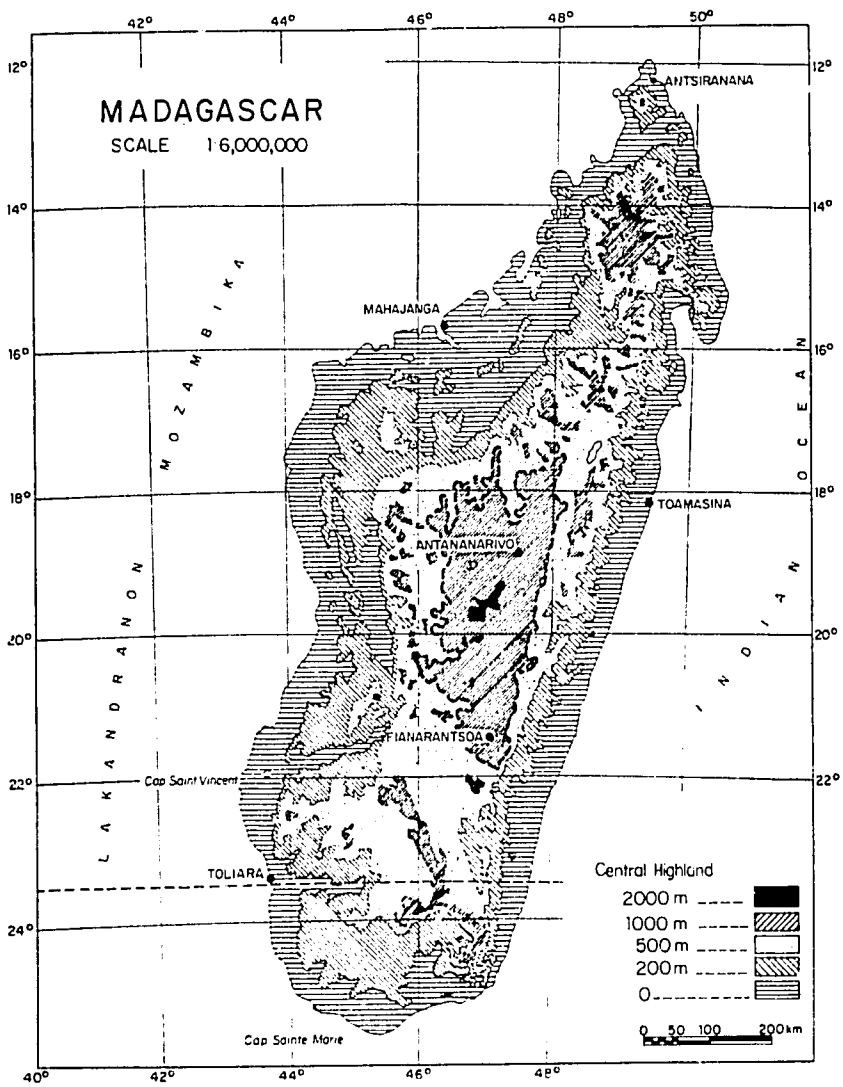
THE CENTRAL HIGHLAND AGROECOSYSTEM

Madagascar's Central Highland covers 120,000 km² (of the country's 587,000 km²). One crop of rainfed or partially irrigated rice is grown per year in valleys covering a total of 9,000 km² at 1,200-1,800 m elevation above sea level (asl). The remaining land area is used for upland crops, pasture, and forest groves. The Central Highland (Fig. 1) is an uplifted, folded, and faulted metamorphic precambrian basement of graphite gneiss overlaid by an extensive erosion-prone mantle of red ferrallitic clays. Gneiss outcrops have weathered, leaving granite-quartzite landscape high points.

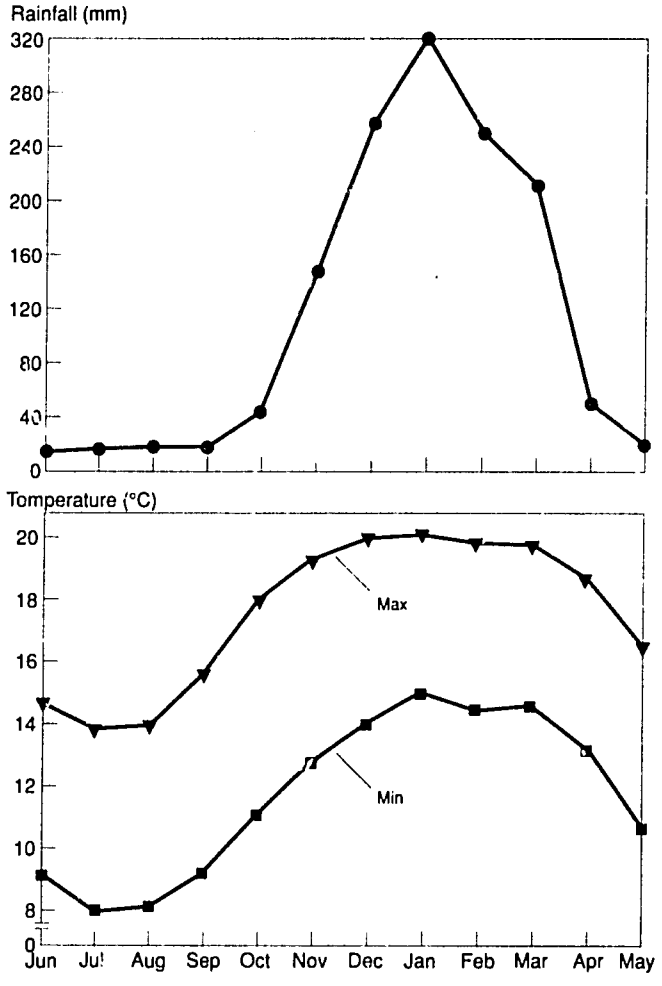
Lowland rice soils are characterized by ferrallitic clays with little organic matter, low cation exchange capacity, low base status, and low pH (4.0-5.0). These soils contain high amounts of Al and Fe hydroxides; are deficient in available N and P; and are often deficient in K, S, and Zn. Fe toxicity is common. Although the soils are highly weathered, the fertility of valley alluvia depends on original constituent elements and age. Above 2,000 m asl, shallow grey sandy soils are found, sometimes as small basins of quartzite sand (Jolly et al 1984, Ponnamperuma 1986).

Mean annual temperatures are 16-19 °C. Frost sometimes occurs above 1,500 m asl. Rainfall is affected by the interaction of a predominant southeast trade wind and the NNE-SSW orientation of the island. Annual rainfall exceeds 1,500 mm on the eastern slopes of the Central Highland and is usually less than 1,500 mm on the western slopes. A warmer rainy season spans November to March or April; a dry and cool season occurs from June to October (Fig. 2,3).

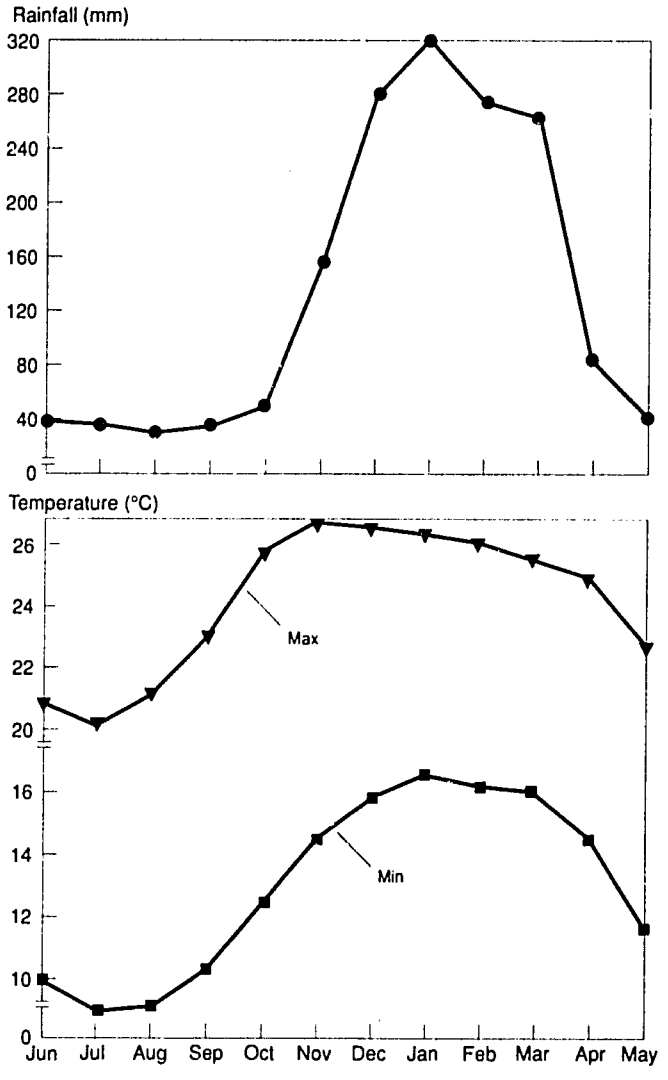
Narrow upstream sections and small alluvial upfilled areas make up the two main rice environments found in the small rice-growing valleys of the Central Highland (Raunet 1986). The narrow upstream sections can be subdivided into a) poorly drained areas without definite alluvium upfilling, typically with waterlogged peaty soils (100-150 cm thick) above a sandy substratum; b) upstream nonpeaty courses (best suited for rice cultivation) with loamy clay soils over humic clay with sandy substratum; and c) old terraces that lie 1-3 m above the waterlogged bottom and have poor yellow-grey,



1. The Central Highland of Madagascar.



2. Rainfall and temperature in the northern Central Highland of Madagascar (9 stations), 1930-60. (Banque de Donnes Agroclimatologiques, pers. comm.)



3. Rainfall and temperature in the southern Central Highland of Madagascar (7 stations), 1930-60. (Banque de Donnes Agroclimatologiques, pers. comm.)

sandy-clayey hydromorphic soils above a sandy substratum. Lateral fringes of upstream valleys are sandy, sometimes peaty, with groundwater upwells. Rice seedbeds are often planted in these areas (Raunet 1986). The small alluvial upfilled areas lie somewhat downstream (Fig. 4, 5). Clayey hydromorphic soils over sandy substratum are typical (Raunet 1986).

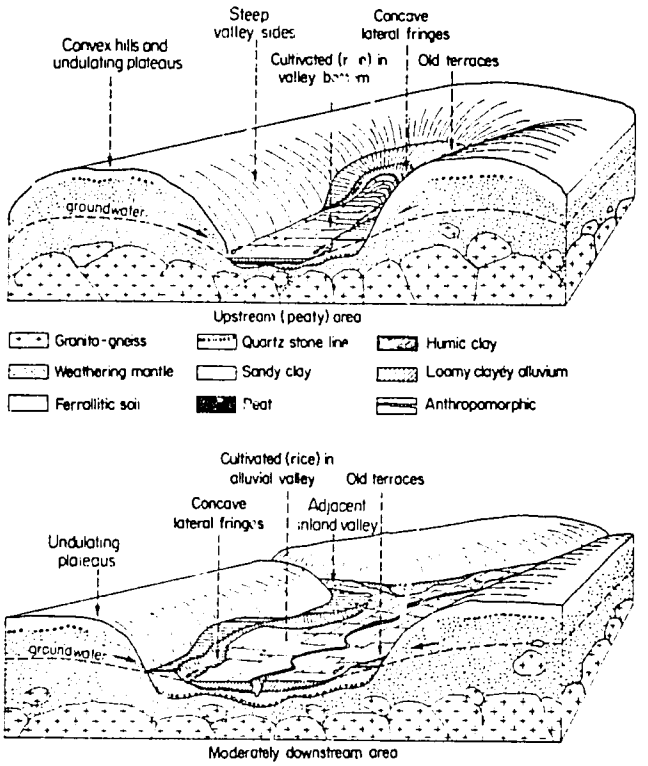
DIAGNOSTIC SURVEY FINDINGS

Findings from the diagnostic survey are presented in six sections. First is a sketch—synthesized from all the data—of the whole-farm system. Farmers' land and soil categories are described next, providing the basic structure of management practices within the agroecosystem. Rice crop management, farmers' rice cultivars, and farmers' soil nutrient management practices are presented in subsequent sections. In each section, farmers' technical knowledge or the perceptions underlying their practices are discussed. Changes in social organization are described in the final section.

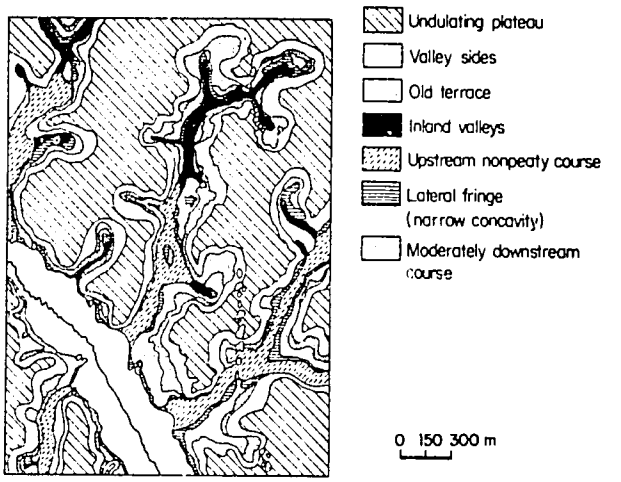
The whole-farm system

Central Highland farmers managed lands from valley floor to nearby hilltop. Enterprises included lowland rice, upland crops, pasture and livestock, and forest groves. Main upland crops were maize, cassava, sweet potato, potato, taro, various types of beans, banana, sugarcane, and vegetables (Fig. 6). Rice was the preferred staple; but substantial quantities of root crops were consumed.

Upland crops were cultivated on flat, unbunded terraced areas slightly above, or as islands within bunded ricelands, and on the concave lateral fringes, old terraces, and steep valley sides adjacent to moderately downstream alluvial valleys. Cropped areas were carefully managed. Diversion ditches had been constructed around sloping fields, usually along an inverted "v" line on the upslope edge. Larger fields had approximate contour ditches running through middle portions. Ditches featured sod upper banks to slow soil runoff, and loose soil lower banks to absorb runoff. Many fields were



4. Central Highland valleys: upstream and moderately downstream areas (adapted from Raunet 1976).



5. The Central Highland valleys (adapted from Raunet 1976).

bench-terraced using a spade and visual estimates of contour (Fig. 7).

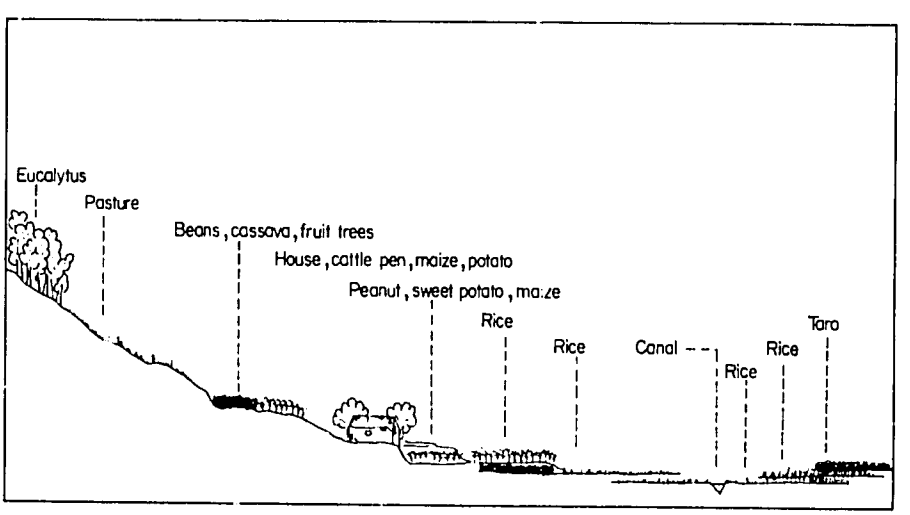
Cattle holdings had reportedly decreased over the previous 10-15 yr from about 10 to 2-3 head/family due to theft and unspecified diseases. Cattle had traditionally provided draft, farmyard manure (FYM), and capital for social events such as exchange labor. In recent years, pastures had been increasingly privatized (from communal ownership). Annual burning continued, supposedly for the resulting green flush.

The single largest cash source for most farmers was sale of root and vegetable crops. Many families received remittances from members living and working in cities (e.g., Antananarivo, Fianarantsoa). Other cash sources were farm labor, masonry, carpentry, and charcoal. Since the 1970s, when natural gas prices rose sharply, farmers produced charcoal and firewood for urban areas from eucalyptus (*Eucalyptus* spp.) trees planted since the 1920s. Farmers harvested woodlots every few years, yearly rotated cut areas, or sold standing wood to charcoal makers.

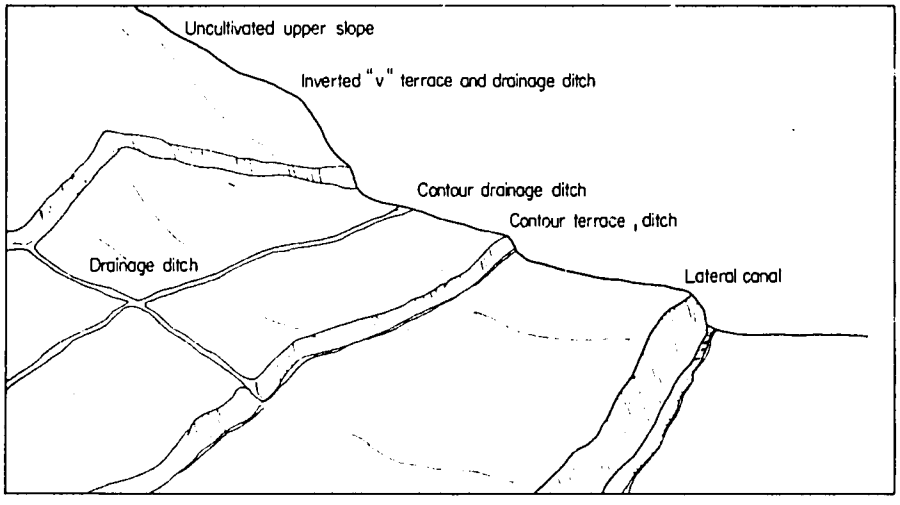
Farmers' land and soil categories

Farmers' land, soil, and—since these are often inherent in the terms—hydrological categories were elicited to understand related management decisions. The categories described were shared by essentially all farmers interviewed.

Farmers classified their riceland (*tany vary*) first by landscape position: narrow upstream courses (*ambony toerana, lohasaha*) or wider downstream alluvial valleys (*heniheny*). Upland islands in rice areas were *tanjona* (Table 1). Farmers distinguished soils (Table 2) by color (e.g., blue-grey *tany manga* or white *tany fotsy*), texture (e.g., sandy *tany*



6. From trees, pasture, upland crops, to ricefield—schematic.



7. Terraces and drainage ditches constructed by spadework along valley margins.

fasika to clayey *tany dilatra*), and qualities such as peatiness (*tany fompitra*). Farmers described fertility levels and management practices associated with the various lands and soils. For example, while dark clayey *tany mainty-dilatra* soils were considered richer and more productive, sandy *tany fasika* soils were valued because they require no draining and hence less labor for land preparation, weeding, and harvest.

Annual flooding of lower alluvial sections causes substantial crop losses once or twice every 10 yr. Submergence and waterlogging were severe problems described as *mihinan tena* or "rice eats itself." Drought-delayed transplanting was reported to occur only once every 10-15 yr. Accordingly, fertile lands, if prone to floods or waterlogging, were valued less than areas with poorer soils.

Respondents had 0.25-5.0 ha for an average of about 0.9 ha of riceland per family (FAO-PEM trial cooperators had an average of 1.7 ha). Most land was farmer-owned, although in some valleys up to 50% of the farmers may have tenanted 30% of the land (an estimate, because the government prohibited share tenancy, and farmers were reluctant to discuss the issue). Tenants reported paying a one-third share. Merina farmers had 1.5-2.2 ha/family of upland holding, and Betsileo farmers about 0.4 ha/family.

Rice crop management

Ninety percent of the rice around Antananarivo and 70% in the Fianarantsoa area was transplanted at the beginning of the wet season (*vary vakiambiaty*) in November-January. Except for a small area of "third season" rice, the rest was sown in April-June and transplanted in August-October (*vary aloha*). The survey focused on the wet season crop.

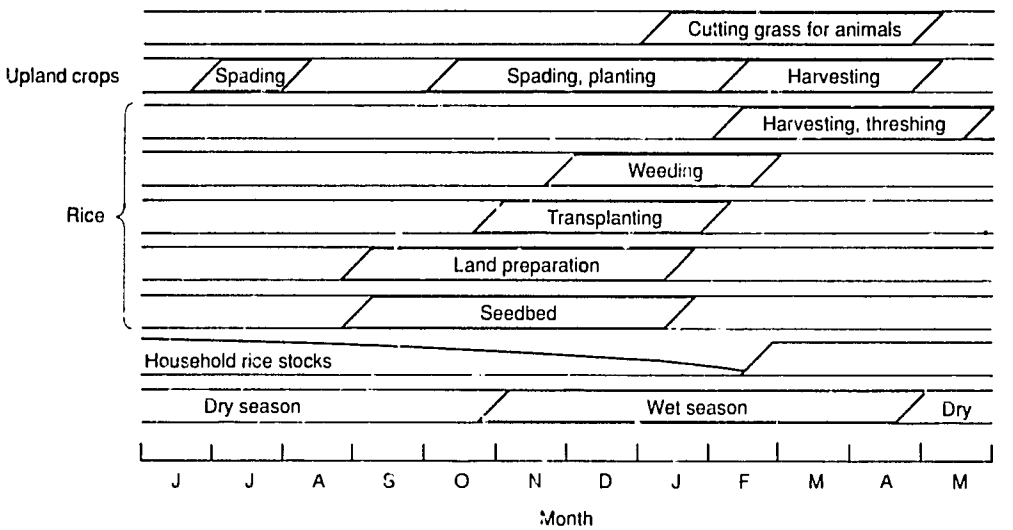
Seedbeds were prepared and sown as early as September (Fig. 8), next to canals or in upstream valleys with groundwater upwells. Traditional cultivar seedlings commonly remained in seedbeds for 60-90 d or more due to low temperatures (a 120-d growth duration at sea level increases to 180 d

Table 1. Descriptors of farmer land categories, Central Highland, Madagascar.

Category	Translation and descriptors
Tany vary	Riceland; irrigated and rainfed
Heniheny	Wider lowland plain of small alluvial valleys
Lohasaha	Narrow upper valley: upstream courses
Ambony toerana	Upper terraces
Tanjona	Upper cap or upland "island" in ricefield
Tavety	Upland areas, including those adjacent to ricefields
Sakamainty	Rainfed

Table 2. Descriptors of farmer soil categories, Central Highland, Madagascar.

Category	Translation and descriptors
	Color
Tany manga	Blue-grey: humic gley-mineral hydromorph; need to spade; rich
Tany mainty	Black: rich clayey or poor peaty/waterlogged
Tany mavo	Yellow: poor
Tany fotsy	White: sandy, less labor needed, lower yield
Tany mena	Red: upland soil, add to peat
	Texture
Tany dilatra	Clayey: richer
Tany fasika	Sandy: poorer
Tany fompitra	Deep or peaty: peaty or water upwelling
Tany horaka	Muddy: no need to plow or spade
Tany fotaka	Mud: plain mud
Honahona/Heniheny	Soft or boggy: lowland plain/alluvial valley
	Other characteristics
Mandrevo	Deep: peaty soil or spring
Loharano	Spring or source: water upwelling in ricefield
Tany manta	Uncooked or unripe: infertile, peat being treated
Mihareraka	Tired soil: from fertilizer use or cropping
Tany masaka	Cooked or fertile: fertile/treated peat soil
Mafana	Hot: more fertile soil
Mangatsiaka	Cold: temperature/poor soil
Ranontambiazina	Red-brown scum: possibly Fe^{++} scum
Tany tofan	"Add soil on": upland soil added to peat



8. Cropping calendar showing availability of household rice stocks.

at 1,200-1,400 m asl) and to water availability in main fields. Most farmers applied manure, and some applied inorganic fertilizers to the seedbeds.

Farmers performed little or no maintenance work on the (mostly seasonal) irrigation and drainage systems. Some cleaned secondary canals next to their fields; but there was little cooperative labor on upstream sections. No respondent recalled ever having worked on construction of an irrigation or drainage system. Most said that systems maintenance was needed, but that upstream users took more than their share of water. Only more closed corporate communities reported communal maintenance work.

Land preparation traditionally combined plowing, spading, and animal trampling. Although some fields were first plowed or spaded in the dry season (September), most were plowed or spaded and then harrowed or trampled (driving oxen around a field for puddling) once the rains arrived. Lack of draft animals had resulted in a shift from plowing plus trampling to plowing once or twice and harrowing twice. Both methods required about 30 person-d/ha. Alternative land preparation sequences included spading + harrowing plowing + spading, and plowing twice + harrowing once. Farmers without access to animals or those who preferred deeper tillage on darker, heavier soils used a long-handled spade (*angady*) for plot preparation. Spading alone required about 60 person-d/ha. In the areas surveyed, 1-9 t/ha of FYM (5-30 carts, 200-300 kg/cart) was incorporated at land preparation.

Transplanting was done in November-January. Merina (Antananarivo area) farmers measured rice area by *vavy* ("woman"): by their definition, 30 women transplant 1 ha in 1 d. Women (hired or exchange) transplanters reported 33 person-d/ha for pulling, transporting, and transplanting. Betsileo farmers (Fianarantsoa) measured ricefields in are (0.01 ha) and reported 16 person-d/ha for the same operations. Reasons for the substantial difference in reported labor are not apparent. More than 90% of the Central Highland rice area was random transplanted. The rest was row transplanted and weeded by rotary weeder. Besides easier weeding, reported benefits of row planting were higher yield due to more tillering and more root space per plant, taller straw, and more grain per panicle. Farmers used 90-100 kg/ha seed for row planting and up to 150 kg for random planting, with the difference possibly due to the use of 4-6 plants/hill for random planting, and 3-4 plants/hill for row planting. Some farmers planted older drought-delayed seedlings at about a 45° angle to get better re-rooting (*ketsa mandry* "reclining transplanting"). Others transplanted slightly deeper, using a tin thumb sleeve to push the seedlings into the mud.

Fields were weeded once or twice. Hand weeding alone required 30 person-d/ha. The 20 person-d/ha required for row-planted fields included 6 for rotary weeding. Rice weeds (*ahidratsy*) included *Echinochloa colona*, *Cyperus difformis*, *Ischaemum rugosum*, *Leersia hexandra* and (unidentified) *tsiriry*, *tsiparifary*, *tsikerekerana*, *valatendro*, and *volontany*.

Farmers reported few insect pest problems. Rice hispa (*Dicladispa armigera* and *Trichispa sericea*, both locally *hao*) was a problem in some areas in 1984-85 and, to a lesser extent, in 1986-87. Government-supplied "DDT" (a name farmers applied to most pesticides) solved the problem. A few reported chronic stem borer *Maliarpha separatella* (locally *fano*) damage. Birds and rats were reportedly problems exacerbated by asynchronous planting and closeness to eucalyptus forests. Birdwatching by children and limited rodenticide use were reported countermeasures.

Harvest spanned February-May, with dates depending on elevation. Most rice was harvested in March-April. Merina farmers reported 21 person-d/ha for cutting, tying, and transporting to threshing floors. Betsileo farmers used 30 person-d/ha to cut, carry, stack, and compact their rice. Nine to 20 person-d/ha were required for threshing. More labor was needed if threshed stalks were further beaten with sticks or cleaned by hand. Betsileo farmers threshed after sheaves had been stacked and grain had ripened. Drying, winnowing, and storing accounted for another 17 person-d/ha.

Table 3. Reported rice crop labor (person-d/ha), alternative operations, and differences between Merina and Betsileo (Madagascar) ethnic groups.

Operation	Labor (person-d/ha)		
	Alternative	Betsileo	Merina
Land preparation			
All spading	60	30-60	30-60
Plowing, spading, and trampling	30		
Plowing once and harrowing twice	30		
Spading and harrowing	30		
Plowing and spading	30		
FYM application		4	4
Transplanting		16	33[a]
Weeding		20-30	20-30
All hand weeding	30		
Rotary and hand weeding	20		
Harvesting		30[b]	21
Threshing		10-20	10-20
Winnowing		10	10
Drying		3	3
Storing		4	4
Totals		128-177	135-184

[a]Reasons for reported difference between groups were not apparent. [b]Betsileo cut, carried, piled, and compacted sheaves for ripening.

About 160 person-d were necessary to produce rice on 1 ha (Table 3). Reported yields were up to 3.0 t/ha with FYM and up to 5.0 t/ha with FYM plus inorganic fertilizer (usually not more than 32 kg N and 32 kg P).

Rice cultivars

Information about farmers' rice cultivars was gathered to elucidate potentials and problems. One to four cultivars were planted in each valley visited, with most farmers planting only one traditional (e.g., *Miakim-po*, "beloved" or "ancestral"; *Ordinare*, "ordinary"; or *Vary Gasy*, "from Madagascar") cultivar (Table 4). Among desired characteristics (in order of importance) were a) high yield, b) tolerance for adverse soils, c) cold tolerance, d) early maturation or short duration, e) good taste, f) less grain to produce a given amount of cooked rice, and g) less drying loss.

Many farmers knew of but were unable to obtain improved variety seed. Some Antananarivo area farmers planted pureline selections like *Rojo Fotsy* ("white chain," 1285)—released in the late 1950s—which is fertilizer responsive, tastes good, does not shatter, but requires more labor, ostensibly for weed control. *Rojomena* ("red," 2822), a cold-tolerant, early-maturing pureline selection identified in the early 1970s and subsequently tested, reportedly yielded 4.5-6.0 t/ha when 48 kg each of N, P, K were applied. Some Fianarantsoa area farmers planted 1632 (Chianan 8), released in the 1960s. The variety is high yielding and blast resistant compared with *Vary Lava*, but is hard to thresh and mill.

Farmers' soil nutrient management

Given their low income and little available cash, respondents practiced low-input soil nutrient management strategies and a range of practices that optimize available inputs. Farmers matched cultivars, soils, and allocations of FYM and inorganic fertilizer. One group found the traditional *Vary Lava* unresponsive to NPK fertilizer, but responsive to FYM (suggesting severe micronutrient deficiencies); the traditional *Vary Mena Fohy* was responsive to fertilizer but more responsive to FYM; and the introduced 1632 was very responsive to fertilizer and less responsive to FYM (Table 5).

Table 4. Rice cultivars of Merina farmers in Antananarivo area.[a]

Cultivar	Translation and descriptors
	Pureline selections/improved varieties
Rojo Fotsy	"White chain" (1285); good yield, large grain, needs fertilizer; does not shatter; hard to grow; good taste, sweet (*mamy*); 3.0 t/ha with manure but without fertilizer; for sale
Rojo Mena	"Red" (2822); early maturing, cold tolerant; 4.5-6.0 t/ha with 45 kg N, P, K + 13 carts manure; for sale
1632	Chainan 8; released variety; grown on fertilizer trials; 5.8 t/ha with fertilizer; hard to thresh and mill
Varim Panjakana	"Government rice"; can refer to any of the above
#10	Like Botramanitra; 4.5 t/ha: tany mainty + 16 kg N, P, K + 10 carts manure
Kiviravina	Possibly Rojo Fotsy
	Traditional cultivars
Vary Botry	"Round rice"; cold tolerant; heavy grain; need less to cook same amount; 3.0-3.6 t/ha with good water control
Vary Lava	"Long grain"; 2.0 t/ha without fertilizers; 4.0 t/ha with fertilizers; more susceptible to stem borer than 1632
Vary Manga Taho	"Blue stalk"; 5.0 t/ha with 30 kg N, P, K + FYM; less drying loss
Botramanitra	Early maturing
Trafon'omby	Red from white Kiviravina over 10 seasons; 3.0 t/ha with manure but no fertilizer on tany manga + mainty soils
Miakim-po	"Beloved" or "ancestral" variety
Ordinare	"Ordinary" rice
Vary Gasy	Any rice from Madagascar

[a]Only cultivars/varieties encountered in the Antananarivo area are listed here as examples. Many more exist in the region.

In three villages, Betsileo farmers planted their higher yielding *Vary Lahy*, which needs more care, on richer dark clayey soils (Kottak 1980) (Table 6). A group of Merina farmers compared a single local cultivar planted on different soils: yields were 2.8 t/ha on dark clayey *tany mainty* plus *tany manga*, 2.2 t/ha on clayey *tany dilatra*, and 1.6 t/ha on yellowish *tany mavo*. They also compared yields of three traditional varieties on two local soils (Table 7).

FYM was the farmers' main soil amendment. Some farmers mixed *dingandingana* (*Psidia altissima*) leaves with the FYM (effects of this practice are not known). To produce FYM, cattle were kept in semisubterranean stone-walled pens; all rice straw was saved and used for fodder and bedding; and additional weeds (*antsoro* for bedding and *vilona* for

Table 5. Betsileo farmer-reported yields (t/ha) by cultivar and inputs.

Input	Vary Lava	Vary Mena Fohy	"Japonea"/1632
No FYM/fertilizer	2.0	1.5	1.0
Manure only	3.0	4.0	2.0
Fertilizer	2.0	3.0	4.0
FYM + fertilizer	3.0	4.0	4.5

Table 6. Cultivars planted by Betsileo farmers in fields (no.) having various soil types.[a]

Cultivar	Soil type			Total
	Fasika/baibo (sandy)	Fotaka (clayey)	Other or combination	
Vary Angika	8	0	3	11
Vary Lava	5	11	7	23
Vary Lahy	5	27	7	39
Vary Ambalalava	1	3	3	7
Other or combination	4	8	6	18
Total	23	49	26	

[a]Data for 3 villages in 1967 (Kottak 1980).

Table 7. Merina farmer-reported yields (t/ha) by variety and soil.

Variety	Soil type	
	Tany dilatra	Tany mainty (boggy)
Rojo Mena	3.5	3.0
Rojo Fotsy	3.5	3.0
Vary Botry	3.6	3.1

feed) were added from December to May. Bedding was maintained during rainy periods.

Adult animals produced 3-10 carts of FYM/season. The quantity varied by the amounts of straw and weeds added, moisture content, the estimated weight of a cartload (200-350 kg), and "seasoning" of the pen. Production was low until the pen floor became compacted and conditioned with a first manure layer. A few farmers without animals cut grass and bedding for animals owned by others in exchange for the FYM produced. When available, some purchased FYM at US$2.00-2.50/cart. One farmer bought ox dung and composted it in a pit. A widespread complaint was lack of FYM because of fewer animals. Farmers hauled FYM from pen to field by oxcart. Fianarantsoa farmers had traditionally diverted water into pens to wash the resulting slurry down to nearby fields. The method is no longer used, apparently due to watershed degradation and lack of water in the dry season. The method was not used in the wet season because well-directed delivery of the slurry was impossible. Manure application strategies varied. In general, farmers applied 30-50% of their FYM to upland crops, leaving 1.2-7.0 t/ha for rice. Some farmers rotated application on different parcels each year. Most respondents applied more FYM to less fertile soils — e.g., more to *tany fasika* or to waterlogged or peaty *tany mainty* and less to clayey *tany mainty* or *tany dilatra*. A positive response, however, may have been due to texture rather than fertility, although both may be correlated (H.U. Neue, IRRI, pers. comm.). Farmers had apparently modified their peaty rice soils in the Antananarivo area: about 5% of the riceland had waterlogged *honahona* or peaty *tany fompitra* soils to which farmers had added upland *tanety* red clayey soils (*tany mena*). Soil had been removed from adjacent slopes, transported, and spread on top of the peat. The process had been repeated for several years until water percolation had decreased. Seedlings in beds treated with the upland soils reportedly had shallower rooting, were easier to pull, and suffered less damage, probably because of pH change, better nutrient supply, and changed temperature regime (H.U. Neue, IRRI, pers. comm.). Farmers agreed that peaty soils treated with upland soils changed from *mangatsiaka* (cold), *tany manta* (infertile or unripe), or springs (*loharano*) to *mafana* (hot) and *tany masaka* (cooked or fertile). Soils also changed from too boggy to firm enough to support animal draft. If cultivars "that do not like water" (i.e., are sensitive to Fe toxicity) were planted, then fields had to be drained after transplanting, and more weed control was required. A field amended with upland soil was compared with an adjacent untreated field. The untreated field showed poorer plant stand and substantially more signs of Fe toxicity. Farmers also reported rice sterility (*manakofa*) on untreated fields.

All farmers wanted to use inorganic fertilizer. About 30% of the respondents (including those who had received fertilizers through FAO-PEM, an FAO seed multiplication program, or a previous government credit program) had used inorganic fertilizers on rice in the previous few years. Chemical fertilizers were imported and mostly available as complete NPK fertilizers. Application rates were 24-40 kg N/ha, 11-18 kg P/ha, and 20-33 kg K/ha. Chemical fertilizers were applied to plots having good water control. Farmers paid less attention to inherent soil fertility and more to rice variety in applying inorganic fertilizers. Equal rates were used on both sandy (*tany fasika*) and clayey (*tany dilatra*) soil, but more was applied to the pureline selection *Rojo Fotsy* than to traditional *Vary Lava* (which lodges and has low N response).

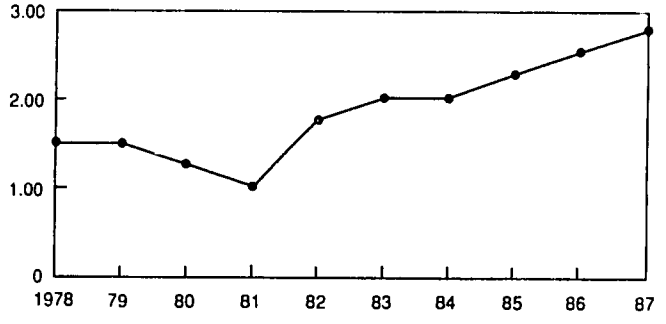
Poor availability and high cost constrained inorganic fertilizer use. Amounts of fertilizer imported and allocated to the Central Highland fluctuated. About 25% of imported fertilizers were used for rice. In 1982, for example, 32,150 t were imported: 7,500 t (23%) were used for rice, and 4,889 t (15%) were allocated to the Central Highland (FAO 1986) (Table 8). Inorganic fertilizer cost increased to almost triple the price paid to farmers for rough rice (Fig. 9). Purchase of fertilizer was also difficult, because farmers often had to buy extra rice for consumption as early as July. In early 1988, fertilizer (11-10-13) cost about US$0.23/kg, while rough rice sold for US$0.08-0.10/kg and milled rice cost about US$0.30/kg.

Inorganic fertilizer was reportedly easier to apply evenly than organic fertilizer, and growth response was faster. Farmers called inorganic fertilizer *zezika vazaha* ("foreigner ma-

Table 8. Fertilizer imports, allocation for rice, and allocation for Central Highland (t), 1977-87.[a]

Year	Imported (t)	Rice allocation		Central Highland allocation	
		tons	%	tons	%
1977				2997	
1978				2771	
1979				2886	
1980				5902	
1981				4974	
1982	32150	7500	23	4889	15
1983	26132	6575	25	13193	50
1984	17497	4450	25	7779	44
1985					
1986					
1987	44000				

[a]Source: FAO 1986.



9. Ratio of cost to farmer of 11-10-13 fertilizer to price paid to farmer for rough rice.

Table 9. Merina farmers' categories for fertilizer and manure.

Malagasy	English	Farmer comments
Zezika omby	Ox manure	Dung + rice straw + bedding grass
Zezi pahitra	Farmyard manure	Same as ox or cattle manure
Zezika kisoa	Pig manure	For maize; rich, but many weeds
Zezika akoho	Chicken manure	Rich, but no commercial sources
Zezika vazaha	"Foreigner manure"	Inorganic fertilizers
Taim boalavo	Rat feces	Reference to complete fertilizer

nure"). Manures—also *zezika*—were named according to animal source (*zezika omby* from cattle and *zezika akoho* from chickens) (Table 9). Almost all respondents claimed that continued fertilizer use made topsoils shallower, harder, or more compacted, and that "the fertility is drawn up" (*ny heriny mitondra mangnanika*). After 2-3 yr, soft topsoils that were 30 cm deep using fertilizer and manure would be 10 cm deep if fertilizer alone was used. Application of inorganic fertilizer was reported to ease tillage on rehabilitated peat areas. Rather than shallower soil, a reason for the reported effect might have been shallower rooting depth due to a shallower traffic pan and or compaction, in turn, due to changing plowing methods (H.U. Neue, IRRI, pers. comm.).

Farmers were uninformed about fertilizer composition. Although a few said N, P, and K are three "foods" needed by the rice plant, no farmer could distinguish among elements or among different types of fertilizers. Extension agents may have contributed to the lack of understanding by referring to complete fertilizer as *taim boalavo* (rat feces) on the assumption that farmers would be unable to understand fertilizer composition.

Social organization

Central Highland communities were changing from closed corporate societies structured by kinship and traditional social relationships to open societies based on cash/market economies. Existing patterns of kinship and social stratification had developed in the 18th century under Merina and Betsileo state-level societies. The French colonial period (1895-1960) had had little effect on local community life. Families were still known as descendants of *andriana* (nobles), *hova* (commoners), or *andevo* (slaves). *Andevo* descendants still had limited access to resources, and *andevo* women still did much of the transplanting and hand weeding. Farmers continued to be members of a named descent group that was usually confined to a single village (there were up to several descent groups per village).

Land was inherited patrilineally. Seniority of descent was important: older brothers inherited more. Land was rarely bought or sold in areas where tradition was maintained, but it could be acquired by *vola mody* ("money going home"), a practice by which cash is loaned in return for land use and is ceded to the creditor if the loan is not repaid. The practice supported farmer reports that credit was expensive or unavailable. Traditional patron-client relationships also served to redistribute wealth. Wealthier farmers slaughtered a cow or ox to provide food for transplanters and harvesters. Workers received a share of the rice harvest. Feasts were also given at funerals and other social-ceremonial occasions.

At the time of the survey, more farmers were employing wage labor for US$0.40-0.50/person per d because it was less expensive. A Betsileo farmer paid US$6.33 for hired labor for harrowing and transplanting a given area, but spent the equivalent of US$18.33 for traditional payment in food and rice. The change to hired labor was difficult because other villagers accused such farmers of being arrogant or of violating traditional values. The reported decrease in number of cattle per family may have been partly due to the preference for paying cash instead of keeping animals for exchange and ceremonial occasions. True exchange labor (*dina*, "agreement") continued in smaller, usually poorer, but more egalitarian communities. Families worked as groups to transplant and harvest, and exchanged roughly equal amounts of labor. The system reportedly worked best among members of the same descent group. Some wealth and labor continued to be redistributed through *atsagana*, by which children of poorer relatives are

commonly fostered or informally adopted by wealthier relatives.

Respondents agreed that communal cooperative efforts were minimal or nonexistent. No one offered a solution to the problem of poor cooperation in the management and use of irrigation systems. A much greater portion of one valley visited was irrigated as a result of a set of weirs constructed by the government; but the government had to hire a person to control the weirs.

IMPLICATIONS FOR RESEARCH

The diagnostic survey revealed three areas of essential research needs: a) the whole-farm system, b) germplasm improvement, and c) low-input soil nutrient and water management (although past work by French and Malagasy scientists needs to be reviewed). This section discusses implications for the FAO-PEM project and IRRI's collaboration in Madagascar. The discussion of these issues is not conclusive, since the survey was based on broad-scale and "rapid" diagnostic techniques.

The whole-farm system

Several interdependent components and processes of the whole-farm system require further field investigation by DRD-FOFIFA to provide a better understanding and assessment of farm management.

Rice cultivars. Farmer-desired cultivar characteristics were as expected: higher yields, cold tolerance, early maturation, good taste, and minimal loss in drying and cooking. Compared with Southeast Asian farmers, farmers in Madagascar mentioned relatively few varietal problems. A more complete understanding of farmer management adaptations would shed light on varietal needs. For example, Betsileo farmers stacked harvested sheaves to allow ripening, but they did not mention uneven ripening as a problem. They did not report "difficult to thresh," although hand cleaning after initial threshing is common, adding considerably to threshing labor.

Seed rates and transplanting. Farmers used somewhat high rice seeding (90-150 kg/ha) rates. These may have been overreported and could be checked at sowing. Further work is needed if the reported rates are correct. Farmers can be asked reasons; and technical issues (e.g., low germination or seedling survival rates, or dense planting) need to be explored. Some farmers transplanted older seedlings delayed by drought at an angle, keeping more root area in the top few centimeters and possibly avoiding toxicities at deeper depths. This practice can be tested.

Rice pests. Hispa and stem borer were reported insect pest problems. Monitoring of pests and their damage will be needed as responsive varieties are adopted. The existence of potential pests—not only of those presently identified—must be established before new cultivars are released on a large scale. Farmers' cultivars and the low levels of N applied may have suppressed but not eliminated potential pests. Monitoring of pesticide use will be needed as innovations are adopted. The degree of damage from rats and birds—reportedly problems in some areas—is unknown and may have been underestimated by farmers (M. Arraudeau, IRRI, pers. comm.). Data concerning weeding labor (hand or rotary plus hand weeding) and losses due to insufficient or poorly timed weeding need to be reviewed.

Labor and land preparation. Farmers used less labor for rice cultivation by changing from spading to plowing and from trampling to harrowing. More data are needed concerning a) effects of changing cultivation practices on human and animal labor use, b) effects of changing cultivation practices on soil conditions and plant growth, and c) constraints and systems-appropriate adaptations of desirable changes. Care is needed to understand the system. Although farmers reported draft constraints because of cattle theft and diseases, they actually may have preferred smaller herds, because they were switching from trampling to harrowing and were using more wage labor and less traditional exchange. It is also possible that wealth was being "banked" in eucalyptus groves rather than cattle.

Farmer modification of peat soils. Adding upland red ferrallitic soils to peaty or waterlogged soils reportedly improved fertility, reduced Fe toxicity, and provided support for animal tillage. Changes over time for these anthropomorphic soils need to be monitored. If evident improvements are short-lived, alternative amendments or improvements of the practice (along with economic analysis) should be investigated.

Inorganic fertilizer use, perceptions, and constraints to use. Many farmers throughout the Central Highland said continued fertilizer use makes soils hard and shallow. Past research on the effects of fertilizer management on soil fertility and sustainable crop production should be reviewed. Future work should consider not only the issue of nutrient deficiencies, but the interrelationships of physical and chemical problems as well. Farmers allocated available FYM and inorganic fertilizer to rice and to upland cash crops. The marginal returns to different inputs for the different enterprises of the whole farm need to be known to develop systems-relevant technologies for farmers.

Madagascar imports expensive mixed fertilizers. Farmers usually purchased rice at the time fertilizers were needed and reportedly could not afford fertilizers at more than two times the price of rice. More data are needed on family cash flows to determine the amounts of fertilizer farmers can afford given present pricing policies and to develop appropriate alternatives.

Farmers knew neither the composite elements of inorganic fertilizers nor the results of FAO demonstrations. This lack of farmer knowledge is a constraint to efficient application. The degree of farmer technical knowledge, however, suggests that farmers would understand and utilize more information. The methods and assumptions that local extension services use need to be examined, and ways to improve the dissemination of information to farmers have to be developed in collaboration with FOFIFA.

Pasture burning. Farmers carefully managed cropped upland areas, but annually burned upper pastures—supposedly for the green flush—and thus were contributing to soil erosion. The French Government had conducted research on improved pasture and controlled burning but was unable to change farmer practice. Recent research compared water runoff for forested, terraced, unburned, and burned areas. The data suggest that pasture burning leads to greater water runoff in December, possibly a) allowing earlier rice transplanting and b) supplying additional nutrients (Rakotomanana 1987) (Table 10). If correct, intensification through double cropping could contribute to more burning and soil erosion. Ecosystem damage already appears to be severe, and alternatives to this unsustainable farmer practice are needed. More research is needed on water runoff and soil losses for burned and unburned areas. Once reasons for burning are determined, ecologically sound, appropriate alternative technologies need to be developed.

Social and institutional inequality, credit, and cooperation. Inequality is a feature of Central Highland communities. Information is needed regarding a) the division of people into descendants of nobles, commoners, and slaves; b) proportions of tenant and owner farmers; c) differences in resource access vis-à-vis the divisions; and d) the effects of these factors on the whole-farm system. While some technologies are neutral relative to social strata, the potential differential suitability of other innovations to particular groups needs to be known.

Credit is usually needed to purchase inorganic fertilizers but is unavailable or very expensive. The interrelationship of credit availability and informal credit systems (such as *vola mody*) with the existing social structure needs to be identified to develop sound alternatives. FAO-PEM is testing a new approach in which groups of 10-30 farmers are organized and loaned money for fertilizer. Fertilizer is applied to given fields at FAO recommended rates of 30 or 60 kg N, 60 kg P, and 45 kg K/ha. Fields are measured and fertilizers allocated. If yields are greater than a baseline amount, cash from sales is saved for next year's fertilizer. To get a better idea of the complex interactions, this approach needs to be monitored in terms of participants, actual fertilizer use (rates applied and allocation to different crops), returns, repayment, and sustainability.

Improved water management is needed in many of the valleys, but little communal cooperation was noted. FIKRIFAMA (Christian Rural Development and Water Resources Program), a nongovernment organization, is successfully working with farmers to supply drinking water to villages. Farmers must request assistance and supply sand and gravel from local sources. FIKRIFAMA provides survey work and materials not locally available (cement, pipe, and taps). All villagers provide labor, with richer persons not allowed to hire others to do their share. This program needs to be examined because of its potential for improving communal cooperation.

Table 10. Water runoff (mm) in areas above ricefields for different land uses and treatments,[a] Central Highland, Madagascar, 1985-86.

Land use or treatment	Month						Total
	Nov	Dec	Jan	Feb	Mar	Apr	
Reforested pine	0	0	1	0	8	0	9
Unburned grassland	0	0	4	4	1	2	11
Burned grassland	0	26	41	42	74	11	194

[a]Adapted from Rakotomanana 1987; data from Manakazo.

Germplasm improvement

Rices that yield well under stresses of low temperature, Fe toxicity, other adverse soil conditions, and excess water are needed. Promising germplasm is being identified via screening by FOFIFA and IRRI for cold tolerance and adaptability to poor soils.

Traditional materials. Farmers reported relatively high yields for certain traditional cultivars at low input levels. These are "best bets" for more difficult (i.e., waterlogged, submergence-prone) rice environments and should be used as parents in breeding programs. Screening should follow farmer practice regarding soils, lands, and management.

Excess water. The FAO-PEM avoidance of flood-prone lands somewhat parallels farmer practice: Farmers use less manure and fertilizers on these lands for fear of inputs being washed away. Submergence tolerance is needed for valleys that flood annually and seriously damage crops in 1 out of 5 yr. Screening and testing for resistance to waterlogging and Fe toxicity are needed. Because of the large proportion of such areas and relatively high yields of farmers' materials, trials should include longer duration, medium deepwater local varieties adapted to poorly drained lands.

Low-input soil nutrient management strategies

Farmers were dependent on low-input soil nutrient management strategies. Past and current research conducted in Madagascar on this issue must be strengthened. FOFIFA has tested the effects of FYM alone and with low rates of inorganic fertilizer on the yield of local and improved varieties. The IRRI-Madagascar project tested small amounts of inorganic fertilizers added to FYM prior to application, as well as seedling root dipping of P fertilizer. Rice yield increased as a result of a) change from farmer variety to improved variety only, b) change to researcher's fertilizer use only, and c) changes in both varietal change and fertilizer use. Not surprising, the strong positive interaction suggests that both fertilizer and responsive, tolerant varieties are needed to gain the benefits of either (Table 11). This work directly compliments informal farmer experiments with different varieties and inputs. Results need to be shared with farmers. Although farmers reported no positive soil nutrient effects from their upland legume crops (because P rather than N was the limiting factor), grain and pasture legumes as a component of the rice system have been tested. Past research needs to be reviewed, and possibly more is needed to identify nutrient deficiencies

Table 11. Contribution of use of fertilizer and improved variety to rice yield (t/ha), Sambaina, Manjakadriana, 1985-86 wet season.[a]

Site	Farmer variety and fertilizer	Farmer variety, researcher fertilizer	Researcher variety, farmer fertilizer	Researcher variety and fertilizer
1	1.3	1.9	1.5	2.3
2	1.3	1.6	1.6	2.5
3	1.6	-	-	3.3
4	1.7	-	-	4.2
5	-	-	2.3	3.9
6	-	-	2.9	5.5
7	-	-	2.5	4.5
8	-	-	2.1	3.1
9	1.5	2.2	-	-
Mean	1.5	1.9	2.2	3.7
Av increase due to fertilizer				0.4 t/ha (+ 27%)
Av increase due to variety				0.7 t/ha (+ 43%))
Av increase due to variety + fertilizer				2.2 t/ha (+146%)

[a]Source: Hoopper 1987, Table 18.

and disorders, interrelations among rice cultivars and soil-water management, and economically sound alternatives.

FAO-PEM trials and demonstrations

The FAO-PEM experiments show that, despite problem soils, rice production in the Central Highland can be increased with inorganic fertilizer (P, N), improved varieties, and improved water management (especially drainage). Experiments seek to determine response curves of rice cultivars to N, P, K, and S on different soils in Central Highland valleys. Rice varieties are pureline selections 1632 (Chianan 8) and 1285 (Rojofotsy). In 1987-88, 89 experiments were located in 8 valleys. Selection of valleys was based on accessibility, good water control, and farmer receptivity. Soils were classified as mineral hydromorphs on the alluvial plains and organic hydromorphs in middle and valley head areas. Seventy (79%) of the 89 trials were placed on mineral hydromorphs. In each valley, most of the 10-12 trials were located on one soil type.

The diagnostic survey suggests several modifications for the FAO-PEM trials. Emphasizing a need for increased farmer participation, results would be more appropriate and representative if a) trials would also be placed across farmer-categorized land and soil types; b) results would be better communicated to farmers; c) the project would include simple farmer-managed trials using lower fertilizer levels; and d) some "best bet" local cultivars would be tested. Location of the trials adequately reflects the proportion of mineral to organic soils. Farmer land and soil categories, however, are fairly complete and do not contradict technical classifications. Trials might be of more immediate relevance to farmers if placed on two or three of the major farmer-defined land-soil-hydrological types in each of the valleys.

Farmers in the survey were uninformed about experimental results. Trials could be accompanied by clear, simple signs describing treatments; results could be written and communicated in similar terms and made available; and guided farmer field days could be conducted. Results could be presented using local land-soil classifications. Simple farmer-managed verification trials testing single variety x fertilizer treatments are needed when recommendations are refined and propagated. Site selection and crop management may be left to the farmer. Farmer adoption and adaptation of recommendations should be monitored to identify constraints and enhance the technology transfer process.

CONCLUSIONS

Central Highland farmers and the Malagasy Government want to increase rice yields. Most farmers do not produce enough to feed their families and must buy additional rice from the market. The government wants to decrease rice imports. FOFIFA and other research organizations in Madagascar are already addressing key questions related to improving rice production in the Central Highland and throughout the country. More support and collaboration are needed to solve the most urgent problems. Potential benefits from rice varietal improvement and use of inorganic fertilizers are being explored by FOFIFA, IRAT, DDA, FAO-PEM, and IRRI. Release of new materials, however, has been limited, and fertilizer use by farmers is constrained by scarcity and prohibitive cost. Although fertilizer policy changes are necessary, research seeking better on-farm productivity and sustainability based on low inputs is essential.

A substantial portion of future research should be based on an understanding of the whole-farm system, which implies building on farmer practices and perceptions. Farmers have adapted management strategies tuned to interacting opportunities and constraints. Farmer perceptions and knowledge—technically correct or incorrect—underlie practices and decisions. Such examples as farmers' matching of soils, rice cultivars, and inputs, or farmer lack of knowledge concerning inorganic fertilizer composition provide information needed

for the development of appropriate innovations. Farmer adaptation and adoption of innovations will be essential to regain national self-sufficiency in rice.

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