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Indigenous fruit trees of Madagascar: potential components of agroforestry systems to improve human nutrition and restore biological diversity

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Key words: biodiversity, domestication, ethnobotany, gender, indigenous knowledge**,** non-timber forest product

Abstract. Biodiversity in Eastern Madagascar is threatened by slash and burn agriculture, which is resulting in species extinction, land and soil degradation and rural impoverishment. An ethnobotanical study was undertaken to determine the domestication potential of indigenous fruit tree species as components of agroforestry systems. Four major selection criteria were used: nutritional and income needs of the population, diversification of the agroecosystem, and protection of plant and animal diversity. At three sites, Andasibe, Masoala and Ranomafana, in the humid primary forest region of Eastern Madagascar, a total of 150 wild fruit species from 82 genera and 42 families, of which 85% were indigenous and 92% of woody habit, were identified. In contrast to most of the deforested areas in Madagascar, the rural population in these areas possess an intimate knowledge of indigenous plant resources. Most of the indigenous fruits are collected from the forest but for a few species, domestication is initiated by managing naturally established species or by planting individual trees in agricultural fields. Wild fruits supplement the daily diet, substitute for exotic fruits, gain importance during periods of food shortage and are most appreciated by children. Commercialization of wild fruits is mainly undertaken by the poorer section of the population. Gender related differences in knowledge and preferences on species were identified and related to the respective household responsibilities. A list of the 26 priority species was established based on the preferences of children, women and men at the three sites. Local, fruit-eating lemur species are also highly dependent on indigenous fruit trees and are crucial for successful regeneration of forest vegetation.

Introduction

Madagascar has one of the richest diversity of flora and fauna in the world, with more than 12,000 plant species, of which 80% are endemic (Perrier de la Bathie, 1936; Humbert, 1959; Dejardin et al., 1973; Schatz et al., 1996). The flora and fauna are threatened by deforestation for expansion of new agricultural land. In recent years, the rate of deforestation has increased dramatically resulting in high biodiversity loss and species extinction (Green

and Sussman, 1990), soil degradation and rural impoverishment (Ministère de l'Economie et du Plan, 1990). There is an urgent need to stop this environmental, economic and social degradation. Strategies and solutions need to be developed to stop widespread slash and burn practices and to replace them with sustainable resource management.

The flora of Madagascar has provided local people with firewood, timber, medicinal plants, fiber, oil, resins, fodder, vegetable, nuts and fruits for centuries. Wild fruits and nuts were always of special interest as food sources for local people (Ferraro, 1994; Isaia, 1995). Information on indigenous fruit trees of Madagascar is scarce and infrequently mentioned in botanical works and inventories (Abadie, 1953; Turk, 1995). Essential knowledge about the use of forest resources in Madagascar lies with the rural population. There is major potential to harness the food and cash crop potential of wild species (Leakey and Newton, 1994).

This ethnobotanical study was developed (1) to obtain a better understanding of the knowledge of rural populations on indigenous fruit tree species, (2) to identify the potential of these species to improve nutrition, generate new income, to conserve and safeguard the genetic resources and (3) to contribute to a sustainable use of the natural resource base.

The objectives of this study were: (a) to identify and characterize the indigenous fruit tree species in the Eastern Region of Madagascar, (b) to understand the role and importance of wild fruits for human consumption and local markets, (c) to determine the level of species exploitation and (d) to prioritize the species by local peoples' preferences. The aim was to rank the 10 to 20 most preferred species at different sites of the eastern region as an essential step to prioritizing their domestication.

Study area and methodology

Madagascar, the world's fourth largest island, lies in the Indian Ocean (11°57′–25°35′ S and 43°14′–50°27′ E) (Davis et al., 1994). The study was realized within the eastern zone of Madagascar which is characterized by a humid to perhumid, temperate to warm climate. Altitudinal range lies between 0 to 1000 m above sea level. The average annual rainfall exceeds 1500 mm with two dry months. The mean annual temperature lies between 21° to 24 °C. The forest vegetation is classified in Humbert's phytogeographic division as dense humid forest at low and medium altitude (Humbert, 1965; Koechlin et al., 1974; Razanaka, 1989).

Subsistence farming is the dominant agricultural activity. The staple food crop is rice, either irrigated in valley bottoms or cultivated on uplands. Traditionally primary or secondary forests are slashed and burned (*tavy*) to produce upland rice. After the first year of rice production, maize, beans, sweet potatoes and manioc are planted for the two following years before the fields are abandoned. Permanent fields contain banana intercropped with coffee,

exotic fruit trees and a number of various annual crops. Cattle are raised extensively. Main cash crops are rice, coffee, exotic fruits, ginger, vanilla, clove and some non-timber forest products.

Three different sites were selected for the field work in collaboration with the on site development and conservation projects. The sites were Masoala, Andasibe and Ranomafana (Figure 1). Characteristics for the three sites are given in Table 1. The criteria for village selection were: (1) proximity to the primary forest, (2) forest extraction essentially for domestic uses, and (3) villages at a given site were selected in different altitudes in order to obtain a wider range of rainforest vegetation composition. Two to three villages were visited in each site.

The different research steps and methods used were:

- Species inventory: collection and identification of botanical specimens of indigenous woody species (including trees, shrubs, palms, and epiphytes).
- Characterization of the species with the aid of local botanical experts (project staff and people in the villages): botanical characteristics, ecological requirements and multiple uses of the species etc.
- 12 individual interviews (50% women and 50% men) in each village (resulting in 24 interviews per site and 72 interviews in total) were held. The dialogue focused on the importance of wild fruits in nutrition, intensity of exploitation, the place of wild fruit trees in the agricultural system, commercialization activities with wild fruits, opinion and preferences on the uses of the identified species. The questionnaire was semi-structured to allow a dynamic, lively discussion.
- Children, women and men were grouped separately to classify species and to identify the most preferred species according to criteria selected by each group (Gueye and Schoonmaker Freudenberger, 1991)
- Informal market surveys in the regional centers and market places (Martin, 1995).

Results

Species diversity

In total, 150 species from 82 genera and 42 families were identified (Table 2). The exhaustive list of species, their occurrence in the three sites and their vernacular names are reported in Table 3. This is the first inventory of species with edible fruits as mentioned by the local population. In each of the three sites a similar number of species, genera and families were found. Figure 2 indicates that out of the total 150 species, 102 species have been identified solely either in Andasibe, Masoala or Ranomafana. Only 20 species occurred in all three sites and 28 species were represented in two of the three sites. This is an indication of high biodiversity and site specificity of species distribution.

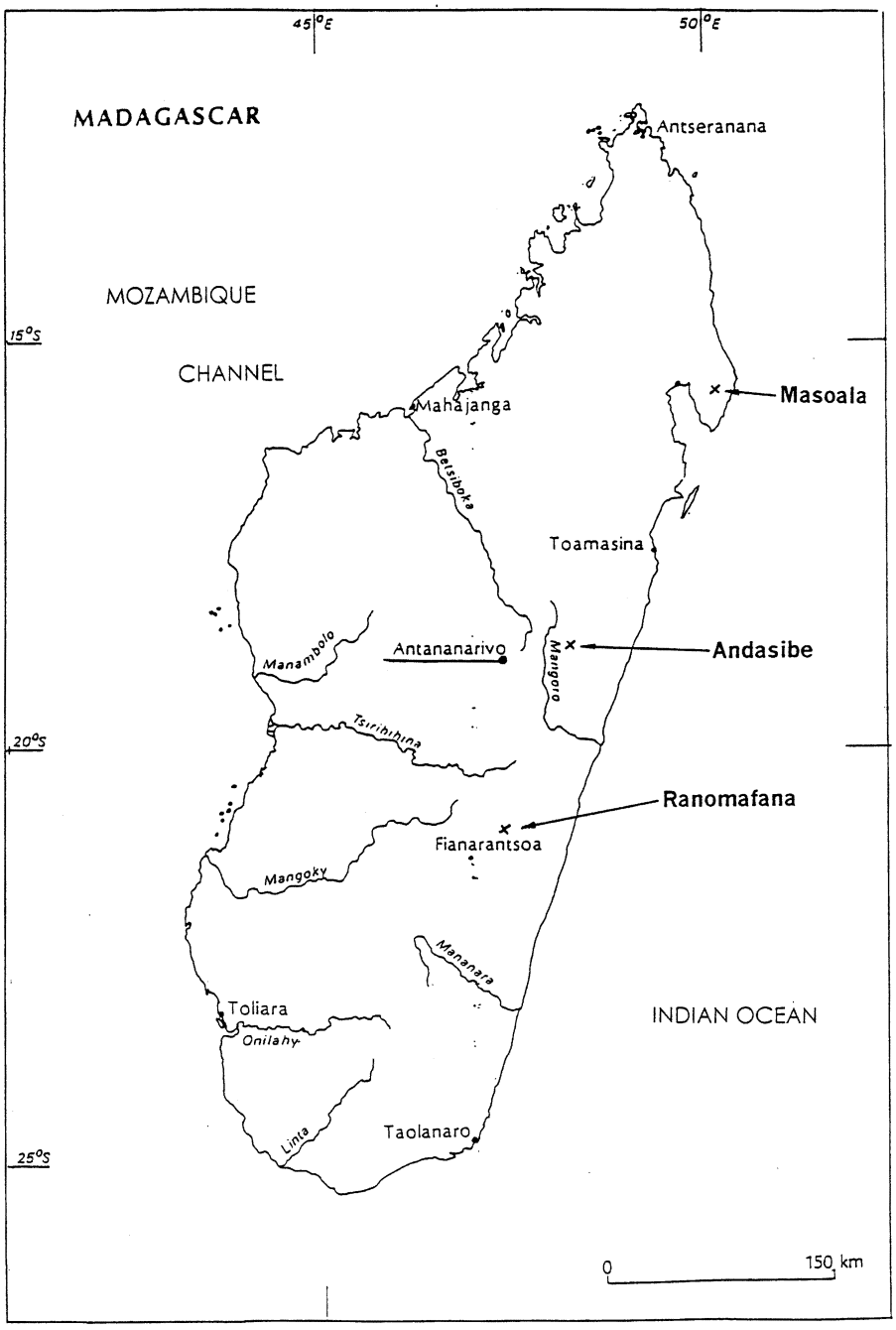

Figure 1. Map of Madagascar.

Table 1. Characteristics of the field research sites (Andasibe, Masoala and Ranomafana), Eastern region of Madagascar.

Characteristic	ANDASIBE	MASOALA	RANOMAFANA
Altitude (m)	850–1100	0–1200	400–1400
Rainfall (mm)	1700	2200–4000	2300–3000
T mean (°C)	19 °C	24 °C	21 °C
Vegetation	Humid midland primary forest	Humid lowland primary forest	Humid low- and mid-land primary forest
Ethnic groups	Betsimisaraka	Betsimisaraka	Betsileo and Tanala
Villages, altitude (m.a.s.l.), distance to market (km)	Volove, 680 m, 16–20 km Akondromora, 643 m, 11–16 km	Tanandavaely, 12 m , 30 km Ampokafo, 290 m, 40 km Manakambahiny, 250 m, 35 km	Bevoahazo, 850 m, 10 km Miaranony, 650 m, 10 km

Table 2. Number of indigenous fruit tree species, genera and families inventoried in the three sites Andasibe, Masoala, Ranomafana, Eastern region, Madagascar.

Sites	Number of species	Number of genera	Number of families
TOTAL	150	82	42
Andasibe	66	49	32
Masoala	79	57	31
Ranomafana	73	48	33

Thirty-seven species were identified only to the genus level, due to the absence of botanical reference material in Madagascar. The most important families include Apocynaceae, Clusiaceae, Moraceae, Myrtaceae, Rubiaceae and Sapotaceae. Eighty percent of the species are endemic, 5% are indigenous and 15% are of exotic origin but occur spontaneously in the natural vegetation. Seventy-one percent of the species were trees or shrubs, 9% vines, 5% palms, 4% belong to the family of Pandanaceae, 3% were epiphytes and 8% had a herbaceous habit. Exotic and herbaceous species appear in the inventory because villagers described these species in the discussion on 'wild' fruit species.

Many genera of the identified endemic species can be found in other parts of the world. Examples are *Landolphia* sp., *Vangueria* sp., *Gambeya* sp., *Uapaca* sp. (Africa), *Carissa* sp. (India, Africa), *Garcinia* sp. (Borneo, Malaysia, South America and East and West Africa), *Syzygium* sp., *Pandanus* sp. (South East Asia), *Canarium* sp. (Borneo), *Eugenia* sp., *Rheedia* sp., *Omphalea* sp., *Salacia* sp. *and Mimusops* sp. (South America) (FAO, 1983; Verheij and Coronel, 1992; Maghembe, 1994; Villachica, 1996).

Table 3. Inventory of woody and herbaceous, indigenous and naturalized exotic fruit species in the three sites of Andasibe (AND or A), Masoala (MAS or M) and Ranomafana (RAN or R) with indication of occurrence (x) in each of the sites, Eastern region, Madagascar.

Scientific name	Family	AND	MAS	RAN	Vernacular name in Malagasy
Poupartia orientalis	Anacardiaceae		x		Sakoanala (M)
Sorindea madagascariensis	Anacardiaceae		x	x	Voasirindrina (M), Voasindrirna (R)
Anisophyllea fallax	Anisophylleaceae			x	Hazoharaka (R)
Polyalthia ghesquiereana	Annonaceae			x	Ambavy (R)
Cabucala cryptophlebia	Apocynaceae		x		Toalanosy (M)
Carissa edulis	Apocynaceae	x			Hazolahy (A) syn* Monty
Carissa edulis var microphylla	Apocynaceae	x			Hazolahy (A) syn Monty
Carissa sessiliflora	Apocynaceae		x		Voatsikopika
Landolphia gummifera	Apocynaceae		x		Voaheny mavo GF (M)
Landolphia myrtifolia	Apocynaceae	x		x	Vahimpingotra (A), Voaheny (R)
Landolphia myrtifolia crassipes	Apocynaceae		x		Voaheny madinidravina (M)
Landolphia sp	Apocynaceae			x	Voaheny medium leaves (R)
Mascarenhasia arborescens	Apocynaceae			x	Herotra hazo (R)
Tabernaemontana retusa	Apocynaceae	x			Montafara (A), syn. Montakala
Typhonodorum lindleyanum	Araceae	x	x	x	Via (A,M,R)
Beccariophoenix madagascariensis	Arecaceae		x		Angolafa (M)
Dypsis ceracea	Arecaceae		x		Lafaza (M)
Dypsis sp1	Arecaceae	x		x	Bedoda (A), Sira (R)
Dypsis sp2	Arecaceae		x		Tsingovatra (M)
Masoala madagascariensis	Arecaceae		x		Lontana (M)
Raphia ruffia	Arecaceae	x	x		Rofia (A), Rafia (M)

Colea fusca	Bignoniaceae	x	x	x	Antsasakampanarato (A) Akondrohazo, Goamargoza
Ophicolea floribunda	Bignoniaceae	x			Sifontsoa (A)
Phyllarthron madagascariensis	Bignoniaceae	x		x	Zahana (A) – Zahamboangy (R) syn Antohiravina
Bromelia ananas	Bromeliaceae		x	x	Mananasy gasy (M,R)
Canarium madagascariense	Burseraceae		x		Aramy be ravina (M)
Canarium sp1	Burseraceae	x			Ramy be (A)
Canarium sp2	Burseraceae	x			Ramy madinidravina (A)
Canarium sp3	Burseraceae			x	Ramy (R)
Cordyla haraka	Cesalpiniaceae		x		Haraka syn Voahonda (M)
Dialium unifoliolatum	Cesalpiniaceae		x		Zana PF (M) syn Zana mena
Senna occidentalis	Cesalpiniaceae			x	Tsaramasondrano (R), syn Tsotsornangatra
Garcinia verrucosa	Clusiaceae	x			Voaditsaka, Vongo (A)
Ochrocarpos madagascariensis	Clusiaceae	x			Jabo (A)
Ochrocarpos orthocladus	Clusiaceae	x			Vongo (A)
Rheedia aphanophlebia	Clusiaceae			x	Voamalambotaho (R)
Rheedia madagascariensis	Clusiaceae		x		Voavohitra (M)
Rheedia mangorensis	Clusiaceae			x	Voatskimbakimba (R)
Rheedia sp1	Clusiaceae	x			–
Rheedia sp2	Clusiaceae			x	Voamalambotahy lahy (R)
Rheedia sp3	Clusiaceae			x	Vakamasina (R)
Symphonia louvelii	Clusiaceae		x		Voandrapotika (M)
Symphonia urophylla	Clusiaceae		x	x	Azinina (M), Voatsititinjaza (R)
Calopyxis sp	Combretaceae		x		Voamatavy, syn Tamenaka (M)
Combretum coccineum	Combretaceae		x		Manikibonga (M)
Terminalia catappa	Combretaceae		x		Antafana (M)
Terminalia ombrophila	Combretaceae		x		Mantady (M)
Dichapetalum chlorinum	Dichapetalaceae	x			Vahimazana (A) syn Vahintenako
Dichapetalum leucosia	Dichapetalaceae	x			Voandavenona
Dichapetalum pachypus	Dichapetalaceae	x			Voanjofo, Voandavenona (A), Vahindavenona

Table 3. Continued.

Scientific name	Family	AND	MAS	RAN	Vernacular name in Malagasy
Dichapetalum sp1	Dichapetalaceae		x		Voamatavy (M)
Dichapetalum sp2	Dichapetaladeae		x		Voajofo (M)
Diospyros haplostylis	Ebenaceae	x			Hazomainty (A)
Omphalea biglandulosa	Euphorbiaceae	x		x	Salehy (A), Voandramoha (R)
Uapaca ferruginea	Euphorbiaceae		x		Voapaka
Uapaca louvelii	Euphorbiaceae			x	Voapaka mena PF (R)
Uapaca sp	Euphorbiaceae		x		Vopaka mena (M)
Uapaca sp2	Euphorbiaceae		x		Voapaka fotsy PF (M)
Uapaca thouarsii	Euphorbiaceae	x	x		Voapaka (A), Voapaka mena (M)
Aphloia theaeformis	Flacourtiaceae	x	x	x	Rambafotsy (A,M), Fandramanana (A,R) Voafotsy
Ludia ludiaefolia	Flacourtiaceae	x			Fantsikakoho
Ludia madagascariensis	Flacourtiaceae	x			Lalangiala (A)
Ludia scolopioides	Flacourtiaceae	x			Fandirana (A), syn Hasambihy
Scolopia madagascariensis	Flacourtiaceae	x	x		Ravinavetro (A)
Flagellaria indica	Flagellariaeceae	x	x		Viko (A), Vahipiki
Psorospermum lanceolatum	Hypericaceae			x	Fanerana (R)
Salacia madagascariensis	Hippocrateaceae	x		x	Voantsimatra (A), Voamasoandro (R)
Beilschmiedia velutina	Lauraceae	x		x	Voakoromanga (A), Sarivanana (R)
Bakerella sp	Loranthaceae			x	Voatakasina (R)
Acridocarpus sp	Malpighiaceae		x		Tsararanonandroana (M)

Clidemia hirta	Melastomataceae	x	x	x	Kelymazana (A), Mazambody, Sombatra
Medinilla longifolia	Melastomataceae		x	x	Vatakasina (M), Kalamasambarika GF (R)
Medinilla macrophyma	Melastomataceae			x	Kalamasambarika (R)
Tristema virusanum	Melastomataceae	x	x	x	Voatrotroka
Tambourissa purpurea	Monimiaceae	x			Oditrovy (A), syn Ambora
Tambourissa trichophylla thouvenotii	Monimiaceae			x	Disohasaka (R), Amborasavoka
Ficus lutea	Moraceae		x	x	Amontana (M;R)
Ficus pyrifolia	Moraceae		x	x	Nonosay (M), Nonoka PF (R)
Ficus sp1	Moraceae			x	Famakilela GF (R)
Ficus sp2	Moraceae			x	Famakilela PF (R)
Ficus tiliifolia	Moraceae	x	x	x	Voara (M,A, R), Voara dambo (R), Voara tenany (R)
Ficus torrentium	Moraceae			x	Voara rano (R) syn Fohomponina
Morus alba	Moraceae			x	Voaroihazo (R)
Streblus dimepate	Moraceae		x		Hodipaso (M)
Treculia madagascarica	Moraceae		x	x	Ampalibeala (M) syn Avoha
Ravenala madagascariensis	Musaceae	x	x		Ravenala (A,M,R)
Maesa lanceolata	Myrsinaceae	x	x	x	Voarafy (A,M), Radoko (A),
Mauloutchia chapelieri chapelieri	Myristicaceae		x		Rara (M)
Eugenia jambolana	Myrtaceae	x		x	Rotra vazaha syn Robazaha (R)
Eugenia jambos	Myrtaceae	x	x	x	Zamborozana (A, R), Varotra (M)
Eugenia lokohensis	Myrtaceae	x	x	x	Gavoala (A,M), Hompa gavo (M)
Eugenia sp1	Myrtaceae	x			Gavoala be ravina (A)
Eugenia sp2	Myrtaceae			x	Voabe (R)
Psidium cattleianum	Myrtaceae	x		x	Goavitsinahy (A,R)
Psidium guajava	Myrtaceae	x	x	x	Goavibe (A), Gavo (M), Goavy gasy (R)
Syzygium bernieri	Myrtaceae		x	x	Varodalitra (M), Tsindrodrotra, Voaroipoitra (R)
Syzygium emirnensis var cuneifolia	Myrtaceae			x	Robary (R)

Table 3. Continued.

Scientific name	Family	AND	MAS	RAN	Vernacular name in Malagasy
Syzygium emirnensis	Myrtaceae			x	Rotra mena, Rotra ravimboanjo (R)
Syzygium sp1	Myrtaceae	x	x	x	Rotra fotsy (R), Rotra (M), Robary (A)
Syzygium sp2	Myrtaceae	x		x	Rotra mena GF (A,R), Robary (R)
Syzygium sp3	Myrtaceae		x		Varodalitra (M)
Syzygium sp4	Myrtaceae			x	Rotra laro (R)
Syzygium sp5	Myrtaceae			x	Rotra amboa (R)
Syzygium sp6	Myrtaceae	x			Rotra be ravina (A)
Syzygium sp7	Myrtaceae		x		Rotra be (M)
Syzygium sp8	Myrtaceae			x	Rotra mena vaventy ravine (R), syn Roipoitra
Noronhia sp	Oleaceae	x			Tsilaitra (A)
Pandanus concretus	Pandanaceae	x	x		Rambo (M), Vakoana (A)
Pandanus freycinetioides	Pandanaceae			x	Tsirika (R)
Pandanus pervilleanus	Pandanaceae		x		Akomorika (M)
Pandanus pulcher	Pandanaceae	x			–
Pandanus sp	Pandanaceae			x	Karaboboka (R)
Pandanus vandamii	Pandanaceae	x	x		Kararaka (M)
Paropsia madagascariensis	Passifloraceae		x		Fanonahona (M), syn Paiso ala
Passiflora foetida	Passifloraceae		x		Bongambosy (M)
Passiflora incarnata	Passifloraceae	x	x	x	Garana (A), Kilelaka (R) syn Voaloboka
Passiflora quadrangularis	Passifloraceae		x		Barbajina (M) syn Ngaringadinina (M)
Piper sp1	Piperaceae	x			Tsimperfery (A)
Piper sp2	Piperaceae			x	Sakarivo vahy
Dilobeia thouarsii	Proteaceae	x	x	x	Vivaona (A), syn Ramandriona (A,R), Vintanona (M) Volombodimbaona (A)
Rubus apetalus	Rosaceae			x	Voaroy fotsy, syn. Voaroy mainty (R)
Rubus myrianthus	Rosaceae			x	Voaroy saka (R) syn Voaroitsaka

Rubus rosaefolius	Rosaceae	x	x	x	Voandroy (A,M), Voaroy mena
Rubus sp	Rosaceae	x			Takohaka (A)
Breonia madagascariensis	Rubiaceae	x		x	Valompangady (A), Voakiringy (R)
Canthium sp	Rubiaceae		x		Tsifo (M)
Fernelia macrocarpa	Rubiaceae		x		Toalanosy (M) syn Kafeala
Mapouria apoda	Rubiaceae		x		Nofotrakoho (M)
Mussaenda arcuata	Rubiaceae	x	x	x	Anendengona (A), syn Anandaingo, Lenga (M)
Mussaenda lanciolata	Rubiaceae			x	Anambahy (R)
Rothmania poivrei	Rubiaceae		x		Mantalanimbe (M)
Rothmania sp	Rubiaceae	x			Taolanana (A)
Rothmania talagnignia	Rubiaceae		x		Mantanaly fotsy (M) syn Mantalanimpotsy
Sabicea diversifolia	Rubiaceae	x		x	Voaseva (A), Sevalahy, Sevatrandraka (A, R)
Vangueria edulis	Rubiaceae		x		Voavandrika (M), Vavandrika (M)
Citrus aurantifolium	Rutaceae		x		Tsioha (M), Voasary ala
Citrus aurantium	Rutaceae	x	x	x	Voangdy (M), Voangy ala (A,R)
Citrus medica	Rutaceae	x		x	Voasary gasy (R), Voatolongo (A,R)
Haplocoelum perrieri	Sapindaceae			x	Lanary madinidravina (R)
Plagioscyphus jumellei	Sapindaceae		x	x	Soretry (M), Lanary (R) syn. Valanary
Tinopsis apiculata	Sapindaceae	x			Volanary (A)
Faucherea manongarivensis	Sapotaceae		x		Vasihy (M)
Faucherea sp1	Sapotaceae		x		Nanto (M)
Faucherea sp2	Sapotaceae		x		Nanto – Makaka (M)
Chrysophyllum boivinianum	Sapotaceae	x	x	x	Famelona (A,M,R), syn Rahiaka (M)
Labramia costata	Sapotaceae	x	x	x	Todinga (A, M),
Mimusops lohindri	Sapotaceae		x		Voarantoala (M)
Vaccinium emirnense	Vacciniaceae	x			Voaramontsina (A)
Lantana camara	Verbenaceae	x	x	x	Radriaka
Aframomum angustifolium	Zingiberaceae	x	x	x	Longoza (A,R) Lingoza (M)

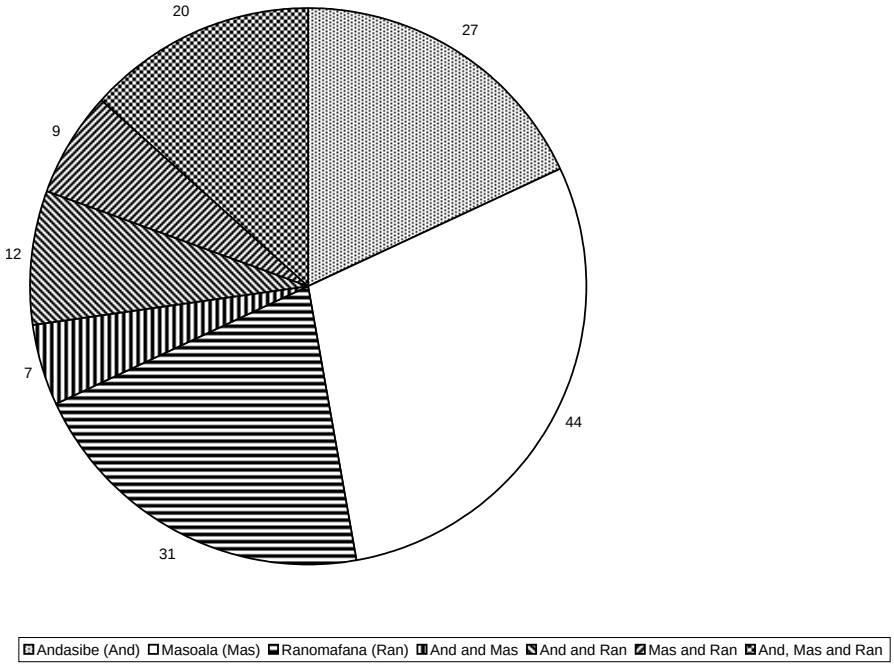

Figure 2. Distribution of the total 150 species among the three sites Andasibe (And), Masoala (Mas) and Ranomafana (Ran), Eastern region of Madagascar. The sectors show the number of species in one, two or all three of the sites.

Species management and utilization

The high fruit species diversity raises the question of their importance to the rural population. Are these species used and if so to what extent and intensity?

Three levels were considered in our analysis: (i) the collection of fruits from wild stands in the forest, (ii) the management and protection of naturally established species on agricultural land and, (iii) the cultivation of species in farmers fields. In the three sites, all farmers collected fruits from wild trees, while 60% were managing and maintaining wild fruit trees in the agricultural environment. Only few farmers planted wild fruit trees. Exotic fruit trees with established markets were present on 100% of the farms. The number of species exploited in the three sites is indicated in Figure 3.

Exotic fruit tree cultivation is diverse with a range from13 to 27 species in the three sites. Main exotic species were oranges and other citrus species, lychee, bananas, mangos and jack-fruit. For the wild fruit species, the intensity of species exploitation and management differs considerably. Major exploitation is on an extractive level with 36 to 77 species collected from the

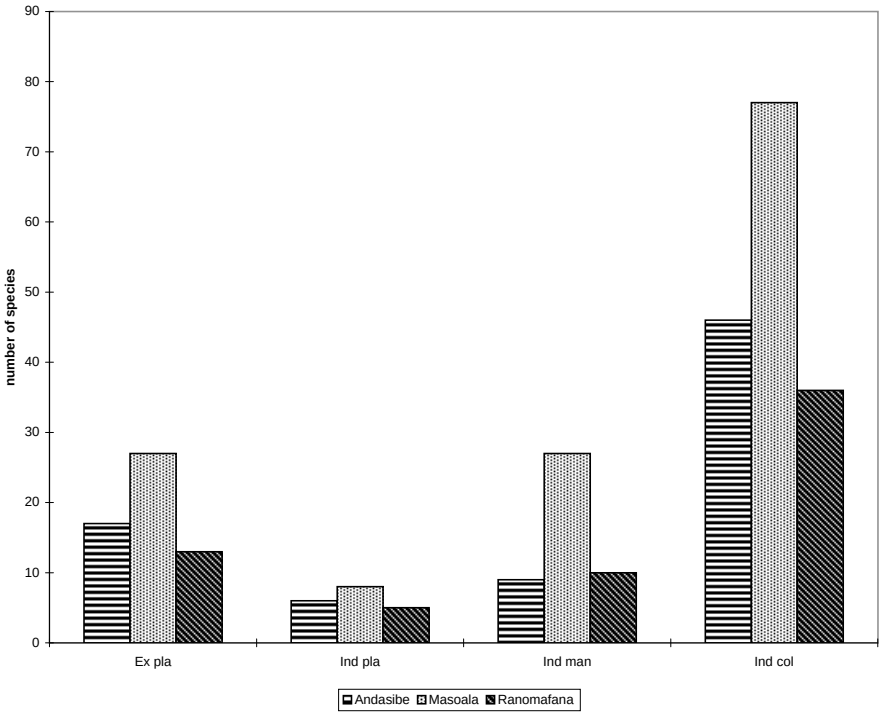

Figure 3. Number of exotic and indigenous fruit species used in the three sites Andasibe, Masoala, Ranomafana: Number of exotic species planted (Ex pla), indigenous species planted (Ind pla), managed (Ind man), collected (Ind col), Eastern region of Madagascar.

wild. The number of managed species was between nine and 27. Nevertheless, we recovered 10 wild species that have been planted on farms.

The number of species utilized also differs among the three sites. Villagers in Masoala exploit the largest number of species, followed by people in Andasibe and Ranomafana. Explanations and reasons remain at the stage of speculation, and research should be initiated to understand this phenomenon better. Some possible explanation could relate to the time of immigration and the duration of settlement in proximity to primary forest which would result in differences in the level of people's knowledge on indigenous vegetation and its utilization.

Planted species are either naturalized, rare exotic species (*Citrus aurantifolium, C. aurantium, C. medica, Syzygium jambos*), or rare forest species particularly appreciated for their multiple uses (*Sorindea madagascariensis, Carissa sessiliflora, Ficus* sp., *Eugenia* sp.). Managed species are essentially found in the banana fields or along field boundaries and paths. In Andasibe and Ranomafana the main practice of land conversion is based on slash and burn, and the managed species are part of secondary vegetation regeneration.

In Masoala, on the other hand, selective clearing is chosen for some of the fields (vanilla fields), and thus primary forest tree remnants are encountered as well as species regenerating after clearance. Management practices include cutting back of branches and weeding. The decision to manage a species or not is based on quality of fruits, multiple products of the species, manageable size and rarity of the species in natural vegetation.

Different collection intensities from wild tree stands exist ranging from (i) systematic collection in baskets every fruiting season, to (ii) occasional collection when encountered in the forest and brought back to the village in pockets, and to (iii) eating them in the forest without bringing them back to the village.

Taking into account the appreciation for fruits, their location and abundance, fruits with highest collection intensity were found to have a very good taste and came from frequently encountered species growing on fallow land or secondary forest near the village. Rare collection was noted for less tasty fruits regardless of their location and abundance. Favored fruits coming from rare primary forest species were also seldom collected. Reasons for this are the long distances to the trees, their low numbers and the difficulty of harvesting fruits from tall trees. Often, the lemurs picked the fruits before the people. We hypothesize that appreciated fruits from rare forest species (e.g. *Breonia madagascariensis, Cabucala cryptophlebia, Dichapetalum* sp., *Landolphia* sp., *Ophalea biglandulosa, Rheedia* sp., *Salacia madagascariensis*) are not optimally available to population.

Wild fruits represent an important supplement to the daily diet, which is mainly carbohydrate-rich and lacking important vitamins and micronutrients (Hardenbergh, 1997). Wild fruits also substitute exotic fruits during periods when they are not available. All family members eat wild fruits, but children are by far the main consumers. People regularly consume wild fruits, while traveling through the forest or working in the fields. Wild fruits are collected between October and May, the period of food shortage. During this time different types of foods collected from the forest, such as roots, tubers, honey, help in balancing the diet.

Wild fruit commercialization

In the villages near the forests, collected fruits are shared and not sold among the people. Farmers indicated that the main reasons for the lack of commercialization of these species were large distance to markets (10 to 40 km), problems with fruit conservation, and the low prices. Despite these statements, wild fruits can be found in the markets of regional centers. They are obtained principally from areas under fallow vegetation and not from primary forests. More then 20 species were inventoried in the different markets during our survey. The trade is not organized and prices are low. Unlike the exotic fruit sellers who buy the products from farmers, wild fruits are sold by the collector. Poor farmers who lack the cash to purchase exotic fruit for sale can

collect wild fruit and raise cash for family needs. The demand for wild fruits can be considerable because of their relative rarity on the market and the low prices. Fruits from primary forests may have a commercial potential if they can be processed in the village thereby adding value to the product and improving preservation. 'There have been relatively few systematic studies to characterize fruit products with commercial potential from the farmer-identified priority species' (Leakey, 1999).

Local knowledge, perceptions and preference for indigenous fruits

We asked men and women at the different sites to identify the factors that determined their preferences for native fruit species.

The factors determining species preferences were:

- the type of food produced (fresh fruit, vegetable, beverage, spice, oil)
- the means of preparation (direct consumption, oil extraction)
- fruits preferably consumed by adults or children
- preferences on consumption (very good fruits, non liked fruits)
- parts of the fruit consumed (seed, flesh, skin)
- medicinal value of fruit
- other edible parts (e.g. stem, leaves, flowers)

We observed differences in knowledge and perception between men and women. Men provided more specific information on ecological requirements of a very wide range of species including the rare species from the primary forests. Information included growth habit, phenology, association with plants and wild animals (lemurs, birds), species distribution and abundance in the area and exact location of individual trees. They had precise knowledge on wood properties for construction and tools. Men preferred sweet tasting fruits as well as oily seeds prepared by roasting, grinding, and cooking, which are served as a side dish or sauce with rice. Wild fruits that mitigate hunger were favored especially during food shortage periods where they can become essential parts of a meal.

Womens' knowledge focused more specifically on the species found in the surroundings of the village. Rare forest species, mentioned by men, were not always recognized by women. Preference for a species was based on its multiple uses, among which medicinal properties and nutritional quality of fruits including other edible plant parts (stem, leaves and flowers) were favored. Unlike the men who preferred sweet fruits, women preferred more acid-tasting fruits.

Discussion and decision-making process differed between the groups of men and women. Men tended to have a lot of arguments and long discussions and had difficulty achieving consensus. Women discussed in a more intensive and concentrated way, and came up faster with more precise and coherent decisions.

Children had a high knowledge of wild fruits. Groups of girls and boys

at ages between six and 14 years recognized 75% to 80% of all the species presented to them in the form of a branch with leaves. All the fruit species from the fallows were known. The unknown species were primary forest species. Although boys recognized more of the forest species than the girls did, they were often unable to describe the taste of the fruits. Children consume a wider range of wild fruits than adults, including the small, less tasty fruits. Adults recognize the special role of wild fruits in the nutrition of children. This was observed during one of the women's group discussion where they identified children's fruits as a separate category. Wild fruit trees are often protected in the landscape on the basis that children like to eat the fruits.

Gender differences in knowledge on specific natural resources is attributed to the gender related division of responsibilities, labor and expertise, control and interest at the intra-household, inter-household and community level (Rocheleau, 1988). These differences in knowledge related to responsibilities were well recognized in our study, for example, women don't travel as often and as far into the primary forest as men. Their activities are more concentrated around the village. Being responsible for childcare, women paid more attention to the medicinal values of a species.

Priority species

Each group of men, women and children were separately asked to select the ten most preferred species out of the locally present wild fruit species and to explain their choice. For the six priority species, the exercise of 'two by two comparison' of all possible combinations was done, identifying the preferred among the two species and by stating the arguments for and against each species (Gueye and Schoonmaker Freudenberger, 1991). Compared to the botanical inventory, where the exotic naturalized species represented 15% of all species, their part in the nominated preferred species were 35% in Masoala, 50% in Andasibe and even 60% in Ranomafana. Rare forest species didn't find as much attention in this preference ranking as the nearby abundant, naturalized exotic species growing in secondary vegetation. Despite the fact that these frequent species are preferably used and accepted by rural population, rare species with good domestication potential may not have been equally considered during this procedure.

Out of 150 species, 26 priority species have been selected based on preferences expressed by all the society groups at all three sites. Of the 26 species 17 species are indigenous and nine species are exotic and naturalized species (Table 4). A ranking of species is not applicable at this stage, as other criteria need to be addressed and assessed, such as propagation potential, species productivity, fruit quality and processing potential.

Table 4. Priority indigenous fruit tree species and priority exotic, naturalized fruit tree species identified by the rural population of Andasibe, Masoala, Ranomafana in the Eastern region of Madagascar.

Species	Family	Vernacular name
a) Indigenous species		
First choice, no ranking		
1. *Labramia costata*	Sapotaceae	Todinga
2. *Landolphia myrtifolia*	Apocynaceae	Voaheny
3. *Sorindea madagascariensis*	Anacaridiaceae	Voasirindrina
4. *Carissa sessiliflora*	Apocynaceae	Voatsikopika
5. *Salacia madagascariensis*	Hypocrateaceae	Voamasoandro
6. *Symphonia urophylla*	Clusiaceae	Azinina
7. *Rheedia aphanophlebia*	Clusiaceae	Vaomalambotaho
8. *Raphia ruffia*	Arecaceae	Raffia
9. *Eugenia* sp.	Myrtaceae	Rotra
10. *Syzygium* sp.	Myrtaceae	Rotra
Second choice, no ranking		
11. *Uapaca* sp.	Uapacaceae	Voapaka
12. *Faucherea* sp.	Sapotaceae	Vasihy
13. *Treculia madagascarica*	Moraceae	Ampalibeala
14. *Vangueria edulis*	Rubiaceae	Vavandrika
15. *Calopyxis* sp.	Combretaceae	Voamatavy
16. *Dilobeia thouarsii*	Protaceae	Vivaona
17. *Ficus tiliifolia*	Moraceae	Voara
b) Exotic and naturalised species (no ranking)		
1. *Psidium guajava*	Myrtaceae	Goavy be
2. *Psidium cattleianum*	Myrtaceae	Goavitsinahy
3. *Passiflora incarnata*	Passifloraceae	Garana
4. *Passiflora quadrangularis*	Passifloraceae	Barbajina
5. *Citrus aurantium*	Rutaceae	Voangidy
6. *Citrus aurantifolia*	Rutaceae	Tsioha
7. *Citrus medica*	Rutaceae	Voatolongo
8. *Eugenia jambolana*	Myrtaceae	Rotra vazaha
9. *Eugenia jambos*	Myrtaceae	Zamborozana

Peoples view on domestication of indigenous fruit species

Despite an already high diversity of planted exotic fruit trees, farmers expressed a desire to increase fruit tree cultivation for self-sufficiency needs especially for their children, and also for commercialization purposes. Preferences were given to exotic species whereas the following observations were made about the constraints to planting indigenous trees: (1) Indigenous fruit trees are present in abundance in the forest and even in the *Savokas* (fallowland). Fruits can therefore be obtained to a satisfactory level by collection; (2) Planting and management techniques for forest species are not

well known; (3) Some farmers weren't aware of the commercialization potential and, therefore, didn't see an incentive for planting the trees; (4) Ancestors did not plant forest trees and farmers were hesitant to change these traditions.

Advantages of indigenous fruit tree planting were seen (1) in a higher benefit from multiple uses of rare species; (2) in the high nutritional value of the fruits; (3) in the provision of appreciated food to children; and (4) in the adaptation of species to the local ecological conditions which facilitates a successful cultivation of the trees in agroforestry or reforestation activities.

Ecological importance of indigenous fruit species

In addition to their contribution to family nutrient resources, native fruit species have a major role to play in maintaining the process of forest regeneration.

Madagascar's primary vegetation species have a weak natural regenerative ability after slash and burn agriculture (Humbert, 1927; Lowry et al., 1997). The disturbed vegetation is quickly invaded by a few aggressive exotic species such as *Pteridium* sp., *Clidemia hirta, Lantana camara, Psidium cattleianum,* that suppress the regrowth of native species. Under such conditions floristic diversity of secondary vegetation may reach a pseudoclimax stage and never attain its original floristic diversity (Humbert, 1927; Lowry et al., 1997).

Madagascar has a low bird diversity and has only four frugivore bird species (Landgrand, 1990). Nectar-feeding bat species, which are common throughout most of the tropics, are also very rare in Madagascar with only three species. In this absence of vertebrate competitors, lemurs have developed since the middle Cretaceous and Paleocene, a coevolutionary relationship with flowering plants and play a crucial role as pollinator and seed disperser of many primary forest species (Sussman and Raven, 1978; Kress, 1993). Close relationships have also been reported between seed ingestion by lemurs and germination success in Malagasy monsoon rainforests (Scharfe and Schlund, 1989). Smith and Ganzhorn (1996) observed that 70% of the lemurs in 10 sites of evergreen forest of Madagascar were dominantly frugivore. The distribution of the primate Aye-Aye *Daubentonia madagascariensis* is closely linked with that of *Canarium* sp. (Iwano et al., 1991).

The complex interrelationships between mammals as pollinators and seed dispersers have a direct impact on the regeneration potential of many primary forest species. We hypothesize that increasing the indigenous fruit tree frequency in the landscape would not only provide food for rapidly dwindling lemur populations but would also facilitate and enhance fallow and forest regeneration of indigenous species due to increased seed dispersal by the lemurs. There is also the potential for increasing ecotourism activities and thus farmer incomes as a result of enhanced lemur activity in the study area.

Summary and recommendations

During this ethnobotanical study, 150 wild fruit species belonging to 82 genera and 42 families have been identified in the sites of Masoala, Andasibe and Ranomafana of the Eastern Region of Madagascar. Eighty percent of species were endemic and 92% were woody species. Two thirds of the species occurred solely in one of the three sites, indicating a locally restricted species distribution and a very high biodiversity.

We noticed in our study that there is not only a lack of botanical reference specimens in Madagascar (25% of our botanical samples could only be identified to the genus level), but also a major knowledge gap on potential uses of the primary vegetation species. The knowledge still resides with the rural population living in close relationship with the forest. We also observed that loss of local resource knowledge is underway where people live far away from primary forest areas. The loss of knowledge is expressed in a considerable knowledge difference between younger and older generations. Reduced knowledge about forests and their uses leads to alienation and indifferent attitudes of local people towards these resources and this results in haphazard exploitation of the forest resources. The vicious circle of primary forest destruction continues while traditional consciousness and natural resource management skills are being progressively lost.

This study has shown that indigenous fruit trees are used and appreciated by local people living close to primary forest. The major results of our study are:

(i) A large variety of fruits are extracted from wild stands. Domestication efforts were recognized for some selected species, by either protecting and managing naturally grown species or by planting individual trees on field boundaries.

(ii) Highest collection intensities for wild fruits were achieved close to the habitations. These locations refer to homegardens, perennial crop fields (coffee – banana fields, vanilla fields, clove fields), fallows and secondary vegetation. Fruits from the primary forest, even if most appreciated, were less often collected and are therefore not optimally available to population.

(iii) Preferences towards the indigenous fruit tree species varied within the community. Indigenous fruits can provide cash income for the poorer farmers. Wild fruits have a supplementary nutritional role in the daily diet, and contribute to food security in case of food shortages. Wild fruits are certainly most appreciated by children who collect and eat them regularly providing them with nutrients and vitamins. Adults preferred the fruit tree species having various multiple uses. Differences in gender preference were related to responsibilities in the household. While evaluating the potential of indigenous fruit trees as agroforestry species, the needs and preferences of the different users have to be taken into consideration, leading to different designs of tree integration in the agroforestry system such as integration into homegardens, perennial fields, forest gardens etc.

Future research on evaluation of the domestication potential for the 17 indigenous priority species should include assessments on:

(i) Tree growth and fruit productivity
This includes identification of ecological requirements (soil, climate, position in landscape and vegetation, and symbiotic relationships with beneficial microorganisms such as mycorrhizas) for optimal growth and fruit production, and the analysis of the potential of these species to accumulate and concentrate essential nutrients for humans in their fruits. Based on this information specific management interventions can be proposed and tested for the cultivation of the species in order to increase their productivity and the density of bioavailable nutrients in the agroforestry system.

(ii) Establishment and propagation
Needed baseline information involves reproduction biology, phenology and nature of seeds. Next to establishment experiments on seed propagation, vegetative propagation techniques (especially cuttings and air-layerings) will be of importance, making the propagation of plants independent on fruiting seasons and allowing the multiplication of selected superior genotypes.

(iii) Economic considerations
Economic considerations will include species productivity, identification of constraints and potentials on fruit marketing and product development potentials.

(iv) Fruit quality and fruit processing
Fruit quality concerns nutritional value, taste, etc of the fruits as well as their conservation properties and processing potentials

(v) People's knowledge, perception and behavior
In depth assessments on people's knowledge, perception and behavior will provide a better understanding on constraints and potentials of indigenous fruit tree domestication. The information gathered will be important for developing sustainable natural resource use strategies and for the integration of indigenous fruit species into agroforestry systems

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