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RESEARCH ARTICLE

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# Floristic diversity of patches generated by protected *Ficus* 'trees outside forests' in agricultural landscapes in Madagascar

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## Abstract

*Ficus* trees play an important role as key species in both ecological and sociocultural networks in Madagascar. This study focused on species of isolated *Ficus* growing in agricultural areas adjoining a forest corridor linking the Ranomafana and Andringitra National Parks in east-central Madagascar, with the aim of understanding the structural and floristic characteristics of the vegetation regenerating under these *Ficus* 'trees outside forests'. Two main aspects were studied: (1) the characteristics of the habitats under the crown of isolated *Ficus* species (*Ficus tiliifolia*, *Ficus reflexa* and *Ficus lutea*), and (2) the specific structure and composition of the vegetation under these *Ficus* trees: minimum area, species richness, floristic regularity, diversity and similarity, biological type, vegetation type, proportion of annual and herbaceous species, and seed dispersal methods. The results indicate that each of these three *Ficus* species has its own community composition. The vegetation under *F. reflexa* is a shrubby formation dominated by autochorous and zoochorous species located on high slopes with a minimum area of 6–12 $m^2$. The vegetation under *F. lutea* is a highly anthropized herbaceous formation dominated by autochorous species located on high slopes at an altitude of 1150–1200 m, with a southwest exposure and a minimum area that ranges from 6 to 9 $m^2$. Under *F. tiliifolia*, different types of plant formations are found in different topographic positions: herbaceous, shrubby or tree-like, with different modes of seed dispersal.

KEYWORDS
biodiversity, fig trees, forest regeneration, isolated trees, Madagascar, Ranomafana–Andringitra corridor

## Résumé

À Madagascar, les *Ficus* jouent un rôle prépondérant en tant qu'espèces clés dans les réseaux écologiques et socioculturels. La présente étude portait sur des espèces isolées de *Ficus* poussant dans des zones agricoles adjacentes à un corridor forestier reliant les parcs nationaux de Ranomafana et d'Andringitra dans le centre-est de Madagascar. Elle visait à comprendre les caractéristiques structurelles et floristiques de la végétation se

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régénérant sous ces « arbres en dehors de la forêt ». Deux aspects principaux ont été étudiés : (1) les caractéristiques des habitats sous la couronne d'espèces isolées de *Ficus* (*Ficus tiliifolia*, *Ficus reflexa et Ficus lutea*), et (2) la structure et la composition spécifiques de la végétation sous ces *Ficus* : superficie minimale, richesse en espèces, régularité floristique, diversité et similarité, type biologique, type de végétation, proportion d'espèces annuelles et herbacées, et méthodes de dispersion des semences. Les résultats révèlent que chacune de ces trois espèces de *Ficus* a sa propre composition communautaire. La végétation abritée par *F*. reflexa est une formation arbustive dominée par des espèces autochores et zoochores, située sur des pentes élevées, d'une superficie minimale de 6-12 m2. La végétation de *F*. lutea est une formation herbacée fortement anthropisée, dominée par des espèces autochores, située sur des pentes élevées à une altitude de 1 150-1 200 m, avec une exposition sud-ouest et une superficie minimale variant de 6 à 9 m2. Sous le couvert de *F. tiliifolia*, on trouve différents types de formations végétales dans différentes positions topographiques : herbacées, arbustives ou arborescentes, avec différents modes de dispersion des graines.

## 1 | INTRODUCTION

Madagascar is known for its remarkable and unique biodiversity, but its ecosystems are under threat (Gautier & Goodman, 2003). Strategies for nature conservation have been in place for several decades, essentially based on the creation of protected areas around the country (Chaboud et al., 2007; Méral et al., 2008). Yet until recently, scant attention has been paid to the biodiversity in rural areas occupied by Malagasy populations (Marie et al., 2009). Little is known, for example, about the structure of cultivated landscapes in Madagascar and their capacity to contain and/or maintain animal and plant species.

Most farmed landscapes in Madagascar are located on the margins of humid forests and are the result of forest that has been converted into arable land (sometimes long ago) cultivated for rice, cash crops (coffee, cocoa, cloves and vanilla) and food crops using slash-and-burn practices known as *tavy* (Carrière et al., 2023). These landscapes vary depending on their history, their location and the practices of the farmers who live there (Carrière et al., 2023). In order to conserve biodiversity and understand its current dynamics, it is important to identify which traditional practices contribute to maintaining biodiversity outside protected areas. Agricultural landscapes can host a range of agrobiodiversity that develops in relation to ecological, sociocultural and economic factors, as well as farmers' local knowledge (Brush & Perales, 2007; Heckler & Zent, 2008). Depending on the practices adopted, farmers can help to maintain or even increase the ecological value of agricultural landscapes (Berkes et al., 2000; Colding & Folke, 1997).

The Ranomafana–Andringitra forest corridor in central-eastern Madagascar connects the Ranomafana National Park to the Andringitra National Park: both are protected areas. The corridor has not escaped the conversion of forest landscapes (Carrière-Buchsenschutz, 2006) through slash-and-burn practices (ANGAP, 2001; Brand & Zurbuche, 1997; Erdmann, 2003). However, research by Martin et al. (2009) has shown that in the landscapes at the forest edges of the Ranomafana–Andringitra corridor, isolated trees can contribute to bird biodiversity.

In many places around the world, when forests are converted into farmland, some forest trees are conserved or even protected. These isolated trees are called 'trees outside forests' (TOFs). Various conservation approaches are now taking into account these trees in agricultural landscapes (Rawat et al., 2003; Tewari, 2009). Their presence in farming systems, as well as the incorporation of tree groves within farmland in an agroforestry approach, are widely recognised today as contributing to biodiversity in tropical and temperate agroecosystems (Aumeeruddy-Thomas & Michon, 2018; Genin et al., 2013). Under isolated trees, valuable biodiversity can thrive due to increased organic and mineral elements from animal excrement and vegetation litter that improve soil fertility, which then supports plant growth and species diversity (de la Peña-Domene et al., 2014; Harvey, 2000; Manning et al., 2006; Vergne et al., 2016).

Fig trees, species of the genus *Ficus*, are known to be key to complex networks of biotic interactions involving pollination and frugivory, with the latter contributing to seed dispersal. The genus consists of over 800 species found throughout the tropics, including Madagascar, which is home to 15 endemic *Ficus* species. A set of studies conducted by various research teams in Madagascar have demonstrated the importance of the biotic interaction networks associated with Madagascar's *Ficus* species (Martin et al., 2009; Rasplus et al., 2023). This is due to the strong appeal of their fruit to a wide spectrum of frugivores, including mammals, birds and insects (Berg, 1986; Berg & Wiebes, 1992; Lambert & Marshall, 1991; Shanahan et al., 2001). The combination of greater seed rain and improved growing conditions under isolated *Ficus* trees increase the density of plant species under their crown (Eden et al., 2015). Research has also shown that isolated *Ficus* trees are subject to social rules and practices by local communities, which tend to preserve them for their numerous practical and symbolic uses (Rafidison, 2013; Rafidison et al., 2020). These trees then become the

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nuclei of small tree groves resulting from under-crown regeneration facilitated by seed-dispersing animals (Rafidison, 2013).

This study aimed to investigate the floristic diversity related to isolated *Ficus* trees in two agricultural landscapes, Ambendrana and Ambohimahamasina, at the margin of the Ranomafana–Andringitra forest corridor. To this end, the characteristics of the vegetation developing under these *Ficus* TOFs were analysed in relation to the ecological parameters of the surrounding landscapes. Our main hypothesis was that there would be a relationship between the isolated *Ficus* trees in the area (*Ficus lutea*, *Ficus reflexa* and *Ficus tiliifolia*), the specific structure and composition of the vegetation under these *Ficus* trees (dispersal patterns, life forms, vegetation type) and the study area. The present study aims, firstly to show in detail the floristic diversity associated with isolated *Ficus* trees in two agricultural landscapes, Ambendrana and Ambohimahamasina, at the margin of the Ranomafana–Andringitra forested corridor. Subsequently, the characteristics of the vegetation developed under these *Ficus* trees are analysed in relation to the ecological parameters of the surrounding landscapes.

## 2 | MATERIALS AND METHODS

### 2.1 | Study area

The two study sites are located in the agricultural landscapes of the central-eastern highlands of Madagascar, in the villages of Ambendrana (District of Lalangina, rural commune of Androy, 21°22′46″ S; 47°18′34″ E) and Sahabe (District of Ambalavao, rural commune of Ambohimahamasina, 21°56′100″ S; 47°11′194″ E). These two villages are on the western edge of the forest corridor linking the Ranomafana and Andringitra National Parks (Figure 1).

The medium-altitude tropical climate is characterised by a hot rainy season (November to April), when 90% of the rainfall occurs, and a cool wet season (May to October) with drizzle and fog (Rafidison, 2013). The terrain is rugged with an altitude ranging between 1100 and 1300 m. The soils are ferralitic, red or yellow on red, lying over a Precambrian crystalline basement (Bésairie, 1973; Dubois, 1938). The landscape is a mosaic of dense natural forests (more or less secondary), patches of secondary recruits in various stages of regeneration, grasslands, eucalyptus, pine and acacia plantations, and crops on the slopes and in the lowlands (Martin et al., 2009; Randriamalala et al., 2007, 2012). The natural vegetation is a dense rainforest of *Tambourissa* (Monimiaceae) and *Weinmannia* (Cunoniaceae) (Goodman & Razafindratsita, 2001; Koechlin et al., 1974), which now exists only in a narrow band varying in width from 4 to 20 km, and commonly referred to as the forest 'corridor' (C.T.A. Fianarantsoa, 1999; Goodman & Razafindratsita, 2001).

### 2.2 | Study species

The choice of study species was based on three criteria: (1) their distinct role in the society of the local Betsileo people, (2) their location in an agricultural landscape, and (3) the development of vegetation in an area at least equal to the *Ficus* tree's crown. The three *Ficus* species found with these criteria in the study area were considered for this study:

1. *Ficus tiliifolia* is a medium-sized tree (maximum height: 25 m) with an upright trunk that is recognisable by its white bark, acuminate leaves and profusion of fruit on the branches and trunk (Berg, 1986; Rafidison et al., 2011). It plays an important socio-economic role for the local community and is protected. According to local knowledge and beliefs, this fig tree attracts water and fertilises the soil, and surrounding crops can benefit from it. It is also a source of food for humans and domestic animals; its fruit is highly appreciated, in addition to several other uses (Rafidison et al., 2020).
2. *Ficus lutea* is a tree with an upright trunk (maximum height: 23 m) that grows well on rocks (hemi-epiphytic), has large, elongated and very tough leaves, and produces figs with abundant white fuzz (Berg, 1986; Rafidison et al., 2011). According to local lore, it plays a role in protecting humans and animals, serves as a marker of social space, and is associated with different power networks determining the relationship between different Malagasy cultural groups (Rafidison et al., 2020).
3. *Ficus reflexa* is a small hemi-epiphytic tree (maximum height: 20 m) with small leaves that is easily recognised by the semi-permanent stipules of the terminal shoots (Berg, 1986; Rafidison et al., 2011). For the local population, this tree has the same sociocultural value as *F. lutea* and also plays an important role in forming the perimeter of zebu parks (Rafidison et al., 2020).

### 2.3 | Data collection

In order to identify isolated trees that met the selection criteria, all the agricultural land around the villages was surveyed. Ecological surveys were carried out in a minimum area representative of the vegetation under the crown of each *Ficus* tree. Parameters related to the habitat, the flora and the vegetation characteristics were recorded. To ensure the vegetation under the crown of each *Ficus* tree censused was representative, the minimum area under the crown was assessed by doubling the surveyed area in a nested square approach (Frontier & Pichod-Viale, 1998; Gounot, 1969). This consisted of establishing a one-metre square quadrat under an isolated *Ficus* tree and delimiting the area with string. All of the species found in this quadrat were recorded and counted. The area of the quadrat was then progressively doubled until no new species appeared in the area surveyed. When the minimum area was not reached, it was replaced by the total area of vegetation under the crown of the isolated *Ficus* individual surveyed.

In addition to the flora developing under the crown of each *Ficus* tree, we also recorded and coded the characteristic parameters of the landscapes in which these isolated *Ficus* trees are growing. The landscape parameters were: the geographical coordinates of the trees, their altitude and topographic position subdivided into five levels (1: ridge, 2: high slope, 3: mid-slope, 4: low slope, 5: lowland),

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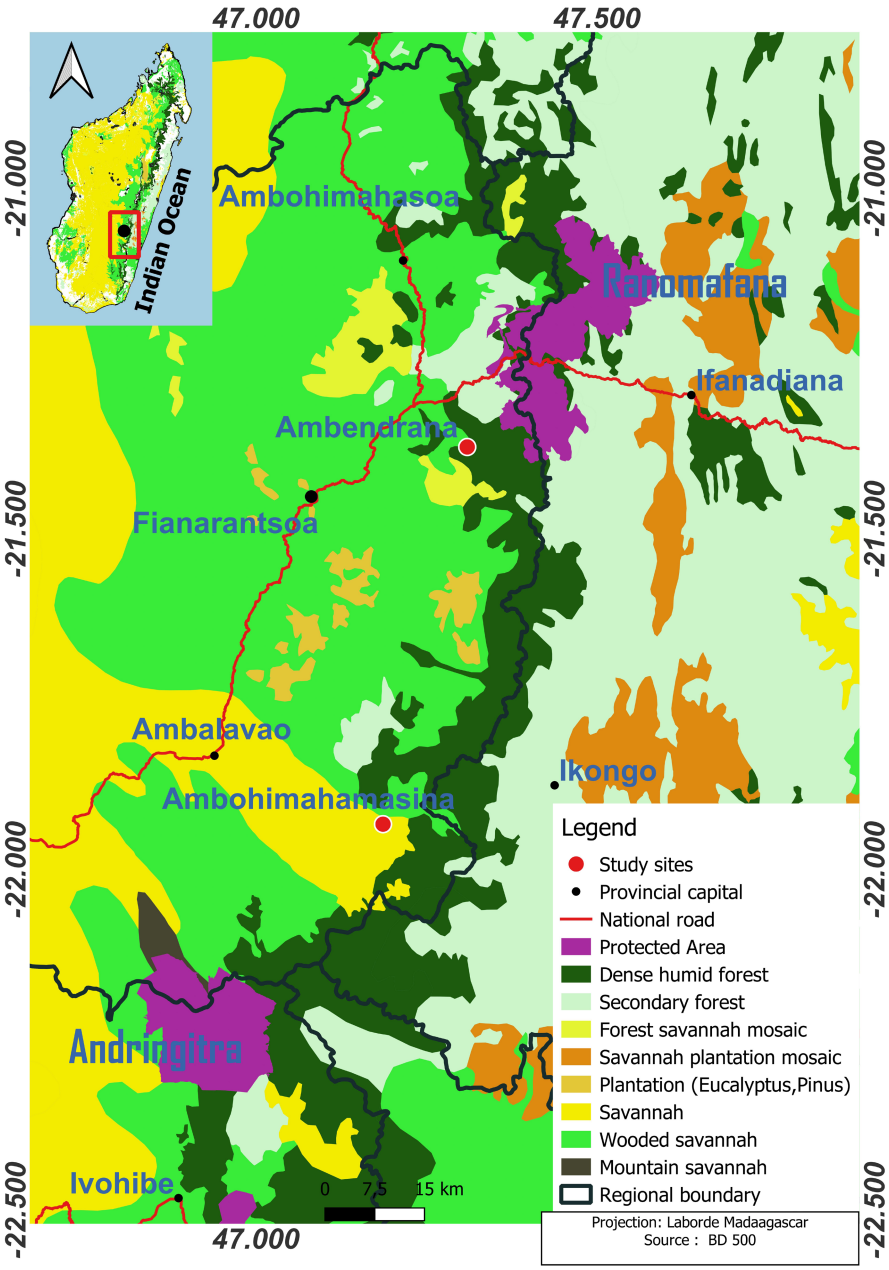


**FIGURE 1** Location and landscapes of the study area.

exposure of the slope (using a compass), and level of anthropization of the environment (1: low = when the proportion of cultivated plants in the landscape where the isolated *Ficus* grows did not exceed 35%; 2: medium = when the proportion of cultivated plants was between 36% and 65%; and 3: high = when the proportion of cultivated plants was greater than or equal to 65%).

Biotic parameters were also recorded. The characteristics related to these were: vegetation type (1: domination by herbaceous species; 2: domination by shrubby species; 3: domination by tree species); the distance to mature secondary forest representing a source of seeds (measured from the edge of the mature secondary forest closest to the tree using the geographical location of each isolated tree). The 55 floristic parameters were: species and family name; diameter at breast height (DBH) of woody individuals in centimetre (Godron & Forman, 1983), total tree height in metre; and the number of woody individuals over 1.3 m in height (Godron & Forman, 1983). For herbaceous individuals, cover was estimated using the chart for visual estimation of area ratios (Godron & Forman, 1983) and maximum height in metre. In addition, we recorded plant life forms, or morphological categories (Da Lage & Métaillié, 2000): tree, shrub, grass, lianas, ferns and epiphytes. Lastly, the species' dispersal mode was inventoried: anemochorous, zoochorous, autochorous and unknown, identified by observing the morphological characteristics of the seeds.

## 2.4 | Data processing

The floristic diversity of the area under a *Ficus* tree was characterised by: (i) species richness *S*, indicating the total number of species recorded within a reference area (Godron & Forman, 1983), which in this

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study was the ground covered by the projection of the *Ficus* crown; (ii) the Shannon diversity index: $H - \Sigma[(N_i/N) \times \log_2(N_i/N)]$ with $N_i$ abundance of the *i*th species with $i = 1$ to $S$ (species richness), and $N = \sum N_i$. The $H$ index approaches zero when one species dominates the stand under consideration and its value is equal to one (1) when all species have the same abundance (Dajoz, 1975). A high diversity index value indicates that the abundance of individual species is fairly equal or that a greater number of species make up the total sampled abundance. In contrast, a low diversity index value indicates a more organised system, except in the case of a monospecific stand or in a stand heavily dominated by one species (Frontier & Pichod-Viale, 1993). In this study, the surveyed area (crown area) did not allow the analysis of stratification to characterise vegetation structure; consequently, only the horizontal structure was considered: the arrangement and distribution of individuals in the stand along the horizontal plane. This involved (i) the percentage of annual (herbaceous) species and perennial trees and shrubs under isolated *Ficus*, and (ii) the basal area value ($G$) in each study plot. This is the basal area cover of the surface covered by tree branches at breast height in the case of trees (Gounot, 1969): $G = \Sigma\pi \cdot \mathrm{DBH}_i^2 / 4$, where $\mathrm{DBH}_i$: DBH of the *i*th individual; $N$: total abundance of woody species in the studied plot and $i = 1$ to $N$.

Correspondence Analysis (CA) was used to highlight (i) the relationships between the characteristics of the vegetation that develops under these three isolated *Ficus* species (*F. lutea*, *F. reflexa* and *F. tiliifolia*) and the structure and specific composition of the vegetation (modes of dispersal, biological types, vegetation type), and (ii) the relationships between an isolated *Ficus* and environmental parameters (altitude, topography, exposure, distance from the forest) and the representativeness of the plant formation (in the minimum area and inventory surface area) (altitude, topography, exposure, distance from the forest). A co-inertia analysis was chosen to rank the various abiotic factors likely to affect species distribution. This analysis couples tables by testing the existence of a co-structure between two individual-variable tables whose structure has been studied through a CA. This analysis consisted of two steps: (i) highlighting the presence of co-structure via a significance test between the environmental variables and the floristic and phytosociological variables, (ii) ranking the factors determining species distribution; the most decisive factors are those with the highest canonical weights (Dagnélie, 1977; Gouet & Philippeau, 1989).

## 3 | RESULTS

### 3.1 | Distribution of *Ficus* according to ecological, floristic and structural parameters

We censused a total of 55 individual fig trees belonging to three species showing a regeneration process under their crowns: *F. lutea* (8 individuals), *F. reflexa* (10 individuals), and *F. tiliifolia* (37 individuals). Of these 55 individuals, 21 were located in Ambendrana and 34 in Sahabe (Table 1). We then studied the area under their crowns in detail.

These isolated trees are located at altitudes ranging from 965 to 1235 m. They are mainly located on the lower slopes (30.35%) and upper slopes (60.71%), but can be found at the bottom (5.35%) to the top of hills (3.57%). The maximum distance between the isolated trees and the edge of the mature secondary forest in the corridor is 6 km as the crow flies, and more than 60% of the trees surveyed are located at a distance of 2 km or more from the forest.

The entire survey of under-crown vegetation yielded 269 species in 94 families, including 3 alien species and 57 forest species (tree, shrub and herbaceous) (grows naturally and abundantly only in the forest), 9 of which are endemic to Madagascar. With regard to the tree species for all vegetation sampled, 20 of the 26 species recorded (76.92%) were forest species. The most represented plant families were Asteraceae, with 35 species. In Ambendrana, 173 species in 55 families were recorded, and in Sahabe, 232 species in 78 families were recorded (Appendix A: Table A1). Some species were found on both sites.

The floristic richness, the dendrometric parameters and the arrangement and distribution of individuals along the horizontal plane under the different types of isolated *Ficus* are given in Table 2.

The mean species richness is $42 \pm 4.59$ species under *F. lutea*, $38.6 \pm 0$ species under *F. reflexa* and $30.73 \pm 3.45$ species under *F tiliifolia*. The surveyed areas under *F. lutea* and *F. reflexa* have higher floristic richness than the surveyed areas under *F. tiliifolia* ($p = 0.05 < 0.01$, DDL = 2, $F = 5.90$). A comparison of the floristic richness of Ambendrana and Sahabe shows that in Ambendrana, only a few nucleated *F. reflexa* (three individuals) and isolated *F. lutea* are found, so species richness on the whole is lower than in Sahabe.

Concerning the characteristics of the horizontal structure, *F. lutea* plots have the highest basal area values with $45.37 \pm 60.83\,\mathrm{m}^2$. *Ficus lutea* plants are large in size and diameter because they grow on rocky areas that are unsuitable for farming. The rare seeds of this tree that germinate can therefore grow for a long time without disturbance, producing large trees.

Considering the percentage of annual species (herbaceous) and perennial trees and shrubs, under the three types of *Ficus* (Table 3), there is no significant difference in the abundance between shrub ($p = 0.387$, DDL = 2, $F = 0.96$), tree ($p = 0.864$, DDL = 2, $F = 0.145$) and herbaceous ($p = 0.641$, DDL = 2, $F = 0.447$) species. *Ficus lutea* favours the establishment of herbaceous species, while *F. tiliifolia* favours the development of shrubby species; the plant formations under *F. reflexa* contain few herbaceous species.

The Shannon diversity index for the three species of isolated *Ficus* is shown in Table 3.

**TABLE 1** Distribution of isolated *Ficus* in the study landscapes.

| Site | *Ficus* species (*N*) | Number of individuals |
|---|---|---|
| Ambendrana | *F. lutea* Vahl | 0 |
| | *F. reflexa* Thunberg | 3 |
| | *F. tiliifolia* Baker | 18 |
| Sahabe | *F. lutea* Vahl | 8 |
| | *F. reflexa* Thunberg | 7 |
| | *F. tiliifolia* Baker | 19 |
| Total | | 55 |

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TABLE 2 Floristic richness, dendrometric parameters and arrangement and distribution of individuals along the horizontal plane under the different types of isolated *Ficus*.

| Type of *Ficus* | *Ficus lutea* (*amonta*) | *Ficus reflexa* (*nonoka*) | *Ficus tiliifolia* (*voara*) |
|---|---|---|---|
| Specific abundance | 42 ± 4.59 | 38.6 ± 0 | 30.73 ± 3.45 |
| Families | Asteraceae (*N* = 22) | Asteraceae (*N* = 23) | Asteraceae (*N* = 27) |
| | Poaceae (*N* = 8) | Poaceae (*N* = 13) | Poaceae (*N* = 16) |
| | Fabaceae (*N* = 7) | Fabaceae (*N* = 12) | Rubiaceae (*N* = 12) |
| Diameter of crown | 5.20 ± 1.53 m | 4.95 ± 1.46 m | 4.43 ± 1.85 m |
| Minimum area | 22.89 ± 13 $m^2$ | 4.67 ± 2.46 $m^2$ | 4.20 ± 2.62 $m^2$ |
| Tree (%) | 17.8 ± 13.14 | 15.57 ± 9.88 | 12.22 ± 10.19 |
| Shrub (%) | 43.8 ± 7.98 | 55.28 ± 47.74 | 41.25 ± 24.73 |
| Herbaceous (%) | 72.1 ± 34.01 | 88.71 ± 77.07 | 76 ± 47.68 |
| Basal area ($m^2$) | 45.37 ± 60.83 | 32.27 ± 19.28 | 13.22 ± 13.79 |

TABLE 3 Shannon diversity index under the three *Ficus* species.

| Type of *Ficus* | *Ficus lutea* (*amonta*) | *Ficus reflexa* (*nonoka*) | *Ficus tiliifolia* (*voara*) |
|---|---|---|---|
| Shannon diversity index Mean *H* | 4.94 ± 0.30 | 4.66 ± 0.76 | 4.17 ± 0.75 |

The Shannon diversity index varies between 4.17 and 4.94. These values for the three *Ficus* species show a highly significant difference ($p < 0.0001$, DDL = 2, $F = 23.05$). Under *F. lutea*, the diversity index is the highest ($H = 4.94$), while under *F. tiliifolia* ($H = 4.17$), it is the lowest. Indeed, under *F. lutea* the strong equality of the contributions of individual species is striking, reflecting a weak organisation in the system compared to the other two *Ficus* species.

### 3.2 | Factors determining the distribution of species under *Ficus* trees

The factor maps of the projection of the scatterplots of the 11 floristic variables (Figure 2a) with the 55 *Ficus* individuals (Figure 2b) in the co-inertia analysis show that the floristic variables contributing most to species distribution under *Ficus* trees are, in order of importance of canonical weight: seed dispersal mode (autochory or zoochory) and type of vegetation developing under the crown (herbaceous, shrubby or tree). Overall, individuals from Sahabe are grouped on the left side of the *x*-axis, while those from Ambendrana are on the right side. The synthesis of the two maps makes it possible to discern two subgroups: subgroup 1a consists of herbaceous formations dominated by autochores found under the *Ficus* species in Sahabe, whereas subgroup 2a consists of shrubby or tree-like formations dominated by zoochores found under the *Ficus* species in Ambendrana.

The projection on the main plane of the scatterplots of the 55 *Ficus* individuals with 30 environmental variables in the co-inertia analysis is presented in Figure 3; on the left is the representation of the standard basis (a), on the right, the scatterplot of the associated individuals (b). For both sites, the environmental variables contributing most to the formation in terms of their canonical weight are as follows: altitude (between 1150 and 1200 m and between 1100 and 1150 m); exposure (southeast, northeast, south, northwest, southwest); and topographic position (mid-slope, high slope, ridge).

The analysis of these maps makes it possible to differentiate two groups: group a consists of the plant formations sheltered by *Ficus* in Sahabe—herbaceous formations dominated by autochores characterised mainly by altitude (between 1150 and 1200 m), southwestern exposure, a mid-slope position, a strong degree of anthropization, and a minimum area between 6 and 9 $m^2$; group b consists of the plant formations sheltered by *Ficus* in Ambendrana—shrub or tree formations dominated by zoochores located on the upper slope or the summit at an altitude of 1100–1150 m, weakly anthropized, and south or north exposure.

In sum, each of the three *Ficus* species has its own community composition. The vegetation under *F. reflexa* is a shrubby formation dominated by autochorous and zoochorous species, located on high slopes with a minimum area of 6–12 $m^2$. The vegetation under *F. lutea* is a herbaceous formation dominated by autochorous species, located on high slopes, with a southwest exposure at an altitude of 1150–1200 m. It is a highly anthropized formation with a minimum area that ranges from 6 to 9 $m^2$. The vegetation under *F. tiliifolia* has different types of plant formations at different topographic positions: herbaceous, shrubby or tree-like, with different modes of seed dispersal.

## 4 | DISCUSSION

This study of the vegetation developing under three *Ficus* species reveals that several interdependent variables influence this development. These include floristic variables represented by dispersal mode and life form; ecological variables represented by topographic position, altitude and exposure; degree of anthropization; and social, cultural and agricultural development.

### 4.1 | Floristic variables of isolated *Ficus* trees

In the study sites of Ambendrana and Sahabe, *F. tiliifolia* is a frequently observed isolated tree under which there is vegetation development. This species represents 67% of the isolated trees showing this process.

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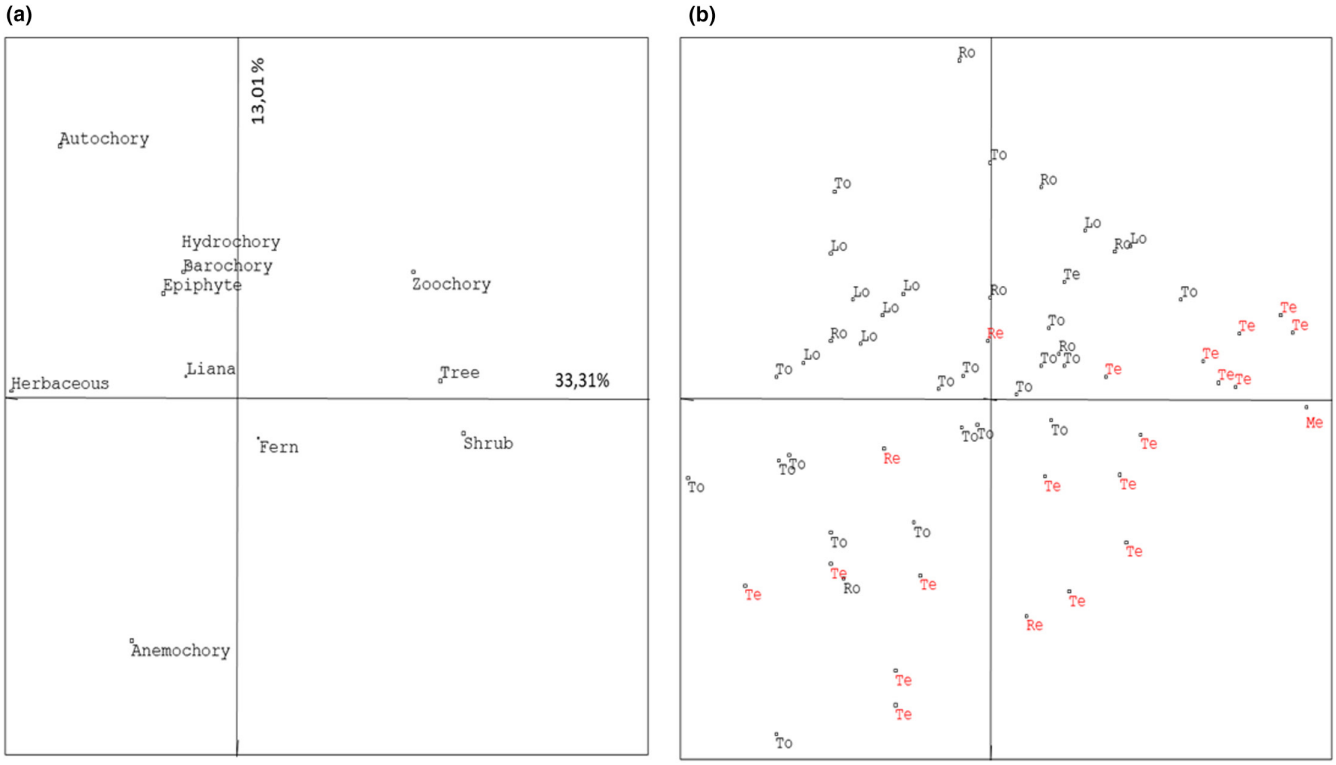


FIGURE 2 Factor maps in the 1–2 plane of the 11 floristic parameters (a) and the 55 *Ficus* individuals (b). In graph (b): L = *Ficus lutea*; R = *Ficus reflexa*; T = *Ficus tiliifolia*; red labels with the letter 'e' after a species designate Ambendrana, black labels with the letter 'o' designate Sahabe.

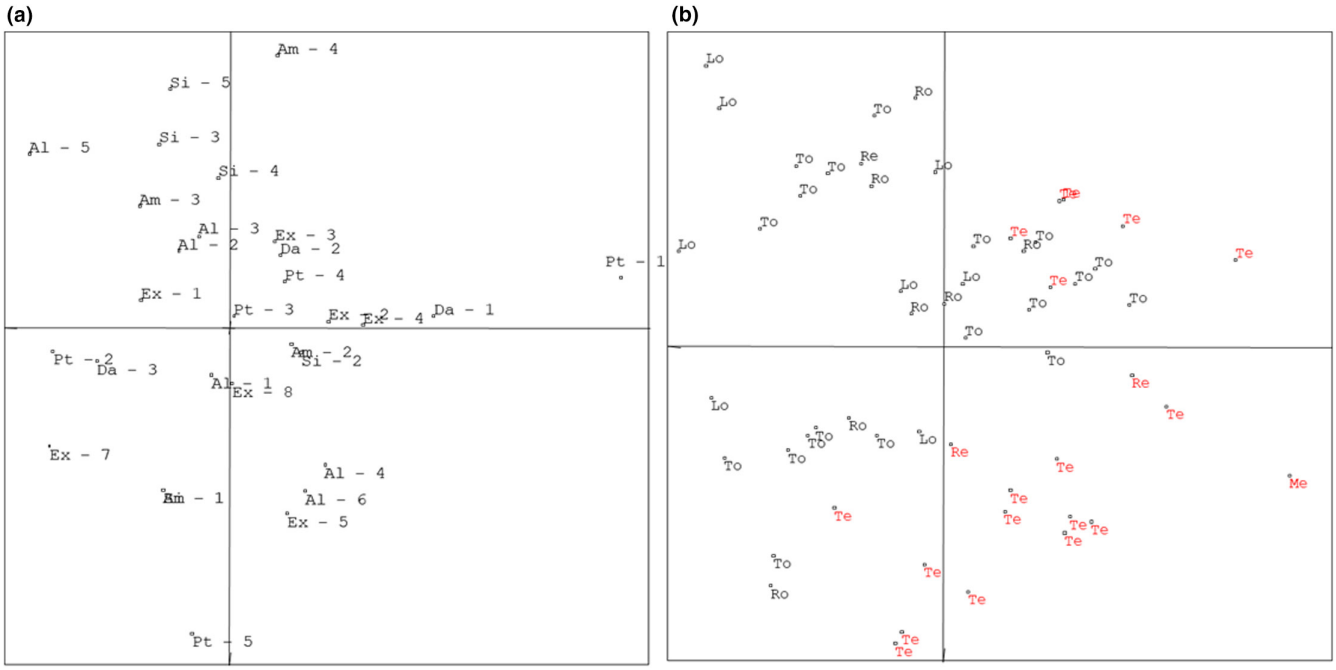


FIGURE 3 Factor maps in the 1–2 plane of the 30 environmental parameters (a) and the 55 *FIcus* individuals (b). In graph (a): Al, altitude; Am, minimum area; Da, degree of anthropization; Ex, exposure; Si, inventory area; the numbers after each variable correspond to the modalities. In graph (b), red labels with the letter 'e' after a species designate Ambendrana, black labels with the letter 'o' designate Sahabe.

In terms of the floristic characteristics of the vegetation that develops under the crown of these isolated trees of all three *Ficus* species, the Asteraceae family is most represented, followed by the Poaceae and Fabaceae families. However, under *F. tiliifolia*, the Asteraceae family is followed by the Poaceae and Rubiaceae families. The Asteraceae and Poaceae families are anemochorous species whose

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seeds are dispersed by the wind. The abundance of the Asteraceae and Fabaceae families under isolated *Ficus* trees is in line with the study of Vergne et al. (2016) regarding the relationship between the presence of isolated, broad-crowned trees and seed rain abundance.

The presence of these isolated trees should constitute the best microclimatic conditions for these anemochorous species, allowing them to establish themselves under these trees. The trees provide a favourable microclimate for the germination of their seeds. They can also provide supplements of organic and mineral matter that enrich the soil from leaves, fruits and dead branches (litter) to the droppings of animals that visit and perch on the branches (Carrière et al., 2002; Harvey, 2000; Harvey et al., 2004; de la Peña-Domene et al., 2014; Vergne et al., 2016). Elsewhere abundant Fabaceae and Rubiaceae families mostly include species with zoochorous fruits and/or seeds that attract frugivorous and granivorous animals. These animals then facilitate the dispersal of seeds consumed in the vicinity of isolated trees (such as the *Ficus* trees they frequent). These findings are consistent with various studies on the genus *Ficus* and on isolated trees in agricultural landscapes. The strong attraction of a wide spectrum of frugivorous animals (mammals, birds and insects) to the fleshy fruits of *Ficus*, the presence of branches and a favourable microclimate help explain why *Ficus* species are often found at the centre of complex biotic interactions and play a major role in wildlife food webs as well as in seed dispersal (Berg, 1986; Berg & Wiebes, 1992; Lambert & Marshall, 1991; Rasplus et al., 2023; Shanahan et al., 2001; Thorstrom et al., 2003). Isolated *Ficus* trees scattered across cultivated landscapes constitute a source of food for both ubiquitous and forest animals attracted to these trees.

Regarding basal area, the plots under *F. lutea* show the highest values. This is in line with the study of Rafidison (2013). The trunks developed under *F. lutea* trees are tall with a large diameter as they grow in rocky areas unsuitable for agriculture. The seeds of this tree, which are able to germinate in these rocky areas, can thus develop over long periods without disturbance, producing tall trees conducive to a large basal area.

Isolated *Ficus* species also have different roles in the regularity of the individual distribution of the different species that develop under their crown. The vegetation under *F. lutea* and *F. reflexa* grows in places unsuitable for agriculture. These trees are preserved or even protected in the landscape for sociocultural reasons (Rafidison et al., 2020). In contrast, *F. tiliifolia* is conserved in agricultural landscapes to promote soil fertility around and under the tree. The vegetation that develops under *F. tiliifolia* is cleared periodically to make use of the fertile cultivable area or can be grazed by animals (Rafidison, 2013; Rafidison et al., 2020). This more or less regular cultivation pattern is a disturbance that could be the cause of the uneven distribution of individuals in the vegetation observed. Studies by Randriamalala et al. (2012) have shown that regular ploughing and cropping practices alter post-cultivation species richness and the viability of seed banks in the soil (Randriamalala et al., 2014).

Under *F. lutea*, the diversity index is highest ($H = 4.94$), while under *F. tiliifolia* ($H = 4.17$) it is lowest. The strong equality of individual species under *F. lutea* shows that the species in its under-crown plant formation have a similar capacity to resist disturbance. *Ficus lutea* trees are primarily found in rocky environments where thin layers of soil between the rocks only permit the growth of herbaceous species with a nearly equal ability to withstand disturbance (Rafidison, 2013).

All of these differences between *Ficus* species could be related to the local uses and/or habitats in which the species grows. The main uses of the vegetation developed under *F. reflexa* are sociocultural (e.g. it protects humans and zebu from potential intangible and tangible attacks), so these trees are preserved in areas and the trees are not allowed to be cut down (Rafidison, 2013; Rafidison et al., 2020). Thus, the cultural factor is here crucial, strengthening the species' potential to develop in a given ecological environment.

## 4.2 | Isolated *Ficus* trees in rural landscapes

Although local practices are not necessarily directly aimed at protecting vegetation, the conservation of biodiversity in these cultivated landscapes where human activities dominate the landscape can be a consequence. By maintaining *Ficus* trees in rural landscapes, local people indirectly maintain the animal species that frequent these trees and the plant species dispersed by these animals. A high degree of anthropization encourages the development of herbaceous formations rich in autochorous species, while a low degree of anthropization favours the development of replacement vegetation dominated by shrubs or trees rich in zoochorous species. Moving away from the forest and closer to the village, the degree of anthropization increases, favouring the regression of shrub and tree species and the development of herbaceous species. These results are consistent with studies by Randriamalala et al. (2007, 2012) and Randriamalala (2009) on the influence of farming practices and the environment on post-cultivation forest dynamics. Along the same lines, the work of Styger et al. (2007) found that a high number of crop-fallow cycles (high anthropization of the site) and the repetitive frequency of fire leads to herbaceous formations and regressive dynamics.

These results confirm those of other studies on isolated trees and groves protected in agricultural landscapes by local traditional practices and how these can serve as a refuge for biodiversity relics (Berkes et al., 1995, 2000) and contribute to maintaining or increasing the ecological value of rural landscapes (Berkes et al., 2000; Carrière, 2003; Chazdon, 2008; Colding & Folke, 1997; Martin et al., 2009). They are comparable to the findings of Bodin et al. (2006) and Elmqvist et al. (2007) on the ecological effects of forest fragments maintained by local people in southern Madagascar. These show that, even if indirectly and unintentionally, the local conservation of sacred forests contributes to maintaining the ecological value of rural landscapes. Studies have also shown the role of *Ficus* species in maintaining sacred groves in the region of Antananarivo in semi-urban or surrounding rural landscapes (Aumeeruddy-Thomas et al., 2018).

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Moreover, some authors have argued that isolated trees in rural landscapes of Madagascar may be a relay point for frugivorous species that move from the forest environment to open environments (e.g. bats, birds, lemurs) (Martin et al., 2009; Viano, 2004). This would allow the maintenance of gene flow between farmland and the neighbouring forest corridor (Bacles et al., 2006; Manning et al., 2006) and could contribute to the process of rebuilding forest groves in cultivated landscapes through the nucleation phenomenon.

## 5 | CONCLUSION

This analysis of the relationships between the characteristics of the vegetation developing under isolated *Ficus* TOFs in the cultivated landscapes of Madagascar's highlands and environmental parameters indicates that the development of vegetation around these trees is influenced by several interdependent variables: seed dispersal mode, altitude, exposure, topographic position, degree of anthropization, and minimum surface area.

In both study sites and beneath the three species of *Ficus* considered, the vegetation varies depending on these variables. These findings validate our hypothesis that there is a relationship between the isolated *Ficus* trees in the region (*Ficus lutea*, *Ficus reflexa* and *Ficus tiliifolia*), the specific structure and composition of the vegetation under these trees (dispersal patterns, life forms, vegetation type), and the study area.

This study represents only a small part of the research on the rational management of plant biodiversity in fragmented environments located on the periphery of the forest corridor connecting the Ranomafana and Andringitra National Parks. A more detailed understanding of the role of isolated *Ficus* in the development of under-crown vegetation is a prerequisite for the design and implementation of conservation of local plant biodiversity. To extend this study, it would be beneficial to consider the roles and impacts of the presence of these isolated Ficus on the development of forest species in agricultural areas outside the forest.

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### CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

### DATA AVAILABILITY STATEMENT

The authors elect not to share data.

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## APPENDIX A

**TABLE A1** List of flora found under studied *Ficus* tree species.

| Family | Scientific name | Vernacular name |
|---|---|---|
| ACANTHACEAE | *Asystasia gangetica* | *Nosinosy* |
| ACANTHACEAE | *Dicliptera insularis* | - |
| ACANTHACEAE | *Hypoestes* sp. | *Tsipotika* |
| ACANTHACEAE | *Justicia gendarussa* | *Saridinga* |
| ACANTHACEAE | *Justicia* sp. | - |
| ACANTHACEAE | *Mimulopsis* sp. | *Beloalika madinidravina* |
| AMARANTHACEAE | *Achyranthes aspera* | *Tsipotika* |
| AMARANTHACEAE | *Cyathula* sp. | *Boroa vavy* |
| AMARANTHACEAE | *Cyathula uncinulata* | *Tangongo* |
| ANACARDIACEAE | *Rhus tarantana* | *Tarantana* |
| APIACEAE | *Centella asiatica* | *Talapetraka* |
| APIACEAE | *Foeniculum vulgare* | *Karotitsovaly* |
| APOCYNACEAE | *Carissa edulis* | *Fantsy* |
| APOCYNACEAE | *Carissa madagascariensis* | *Fantsimbala* |
| APOCYNACEAE | *Cynanchum leucanthum* | *Vahikintana* |
| APOCYNACEAE | *Hazunta modesta* | *Hazonta* |
| APOCYNACEAE | *Hazunta velutina* | *Hazontany* |
| APOCYNACEAE | *Landolphia* sp. | *Tandrokosymadinidravy* |
| AQUIFOLIACEAE | *Ilex mitis* | *Hazondrano* |
| ARALIACEAE | *Polyscias repanda* | *Saripahavalo* |
| ARALIACEAE | *Polyscias* sp. | - |
| ASCLEPIADACEAE | *Ascelepia fanticosa* | *Tsifanoro* |
| ASCLEPIADACEAE | *Ceropegia albisepta* | *Vahy* |
| ASCLEPIADACEAE | *Gomphocarcpus fructicosus* | *Fanory* |
| ASCLEPIADACEAE | *Pentopetia androsaemifolia* | *Tandrokosy* |
| ASCLEPIADACEAE | *Polystichum luctuosum* | *Apanganala* |
| ASPLENIACEAE | *Asplenium* sp. | *Apangamaitso* |
| ASPLENIACEAE | *Asplenium theciferum* | *Apangakaroty* |
| ASRTERACEAE | *Ageratum conizoydes* | *Tsiafakanakandriana* |
| ASRTERACEAE | *Bidens pilosa* | *Trakavola* |
| ASTERACEAE | *Ageratum* sp. | - |
| ASTERACEAE | *Brachylaena merana* | *Nananotsa* |
| ASTERACEAE | *Brachylaena ramiflora* | *Nananotsa* |
| ASTERACEAE | *Crassocephalum sarcovasus* | - |
| ASTERACEAE | *Elephantopus scaber* | *Tambako* |
| ASTERACEAE | *Emilia citrina* | *Tsiotsio* |
| ASTERACEAE | *Erigeron naudinii* | *Maitsoririnina* |
| ASTERACEAE | *Galinsoga parviflora* | *Anambito* |
| ASTERACEAE | *Graphalium undulatum* | - |
| ASTERACEAE | *Helichrysum attenuatum* | *Ahipotsy* |
| ASTERACEAE | *Helichrysum cordifolium* | *Fotsiavadika* |
| ASTERACEAE | *Helichrysum faradifani* | *Ahibalala* |
| ASTERACEAE | *Helichrysum rusillonii* | *Alamanitsa* |

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TABLE A1 (Continued)

| Family | Scientific name | Vernacular name |
|---|---|---|
| ASTERACEAE | *Helichrysum selaginifolium* | *Alaivana* |
| ASTERACEAE | *Helichrysum* sp. | - |
| ASTERACEAE | *Lactuca indica* | *Anamboraka* |
| ASTERACEAE | *Mikania scandens* | *Vahitsonjo* |
| ASTERACEAE | *Pluchea grevei* | *Sirasira* |
| ASTERACEAE | *Psiadia altissima* | *Dingadingana* |
| ASTERACEAE | *Psiadia salvoaefolia* | *Kizitina* |
| ASTERACEAE | *Senecio erechtiloides* | *Tsileompangady* |
| ASTERACEAE | *Senecio janjasioides* | *Kimboimboy* |
| ASTERACEAE | *Senecio* sp. | *Vahavihia* |
| ASTERACEAE | *Siegesbeckia orientalis* | *Satrikoazamaratra* |
| ASTERACEAE | *Sonchus oleraceus* | *Beroberoka* |
| ASTERACEAE | *Tagetes bipinnata* | *Rongonimbazaha* |
| ASTERACEAE | *Vernonia alleizettei* | *Sakatavy* |
| ASTERACEAE | *Vernonia appendiculata* | *Ambiaty* |
| ASTERACEAE | *Vernonia capitata* | *Kijeajea* |
| ASTERACEAE | *Vernonia moquinoides* | *Kandafotsy* |
| ASTERACEAE | *Vernonia secundifolia* | *Maranitsiatoraka* |
| ASTERACEAE | *Vernonia* sp. | - |
| BALSAMINACEAE | *Impatiens baroni* | *Kivolavola* |
| BROMELIACEAE | *Bromelia ananas* | *Mananasy* |
| CACTACEAE | *Rhipsalis baccifera* | *Taindelokarana* |
| CANNACEAE | *Canna indica* | *Tsipikopiko* |
| CARYOPHYLLACEAE | *Polycarpea heliantha* | - |
| CELASTRACEAE | *Celastrus* sp. | *Vahipiky* |
| CELASTRACEAE | *Gymnosporea* sp. | *Fantsinakolahy* |
| CELTIDACEAE | *Trema commersonii* | *Vakoka* |
| CELTIDACEAE | *Trema orientalis* | *Andrarezo* |
| CLUSIACEAE | *Garcinia aphanophlebia* | *Kimbaletaka beventiravina* |
| CLUSIACEAE | *Harungana madagascariensis* | *Harongana* |
| CLUSIACEAE | *Psorospermum fanerana* | *Fanera* |
| COMMELINACEAE | *Commelina madagascariensis* | *Tsimativonoina* |
| CRASSSULACEAE | *Kalanckoe pannosa* | *Felatanatsifoana* |
| CRASSSULACEAE | *Kalanckoe* sp. | *Kalanckoe* |
| CYATHEACEAE | *Cyathea coursii* | *Faho* |
| CYATHEACEAE | *Cyathea* sp. | - |
| CYPERACEAE | *Cyperus latifolius* | *Vendra* |
| CYPERACEAE | *Cyperus obtusifolius* | *Fitangosa* |
| CYPERACEAE | *Cyperus* sp. | *Telorirana* |
| CYPERACEAE | *Cyperus* sp. | *Sambalahy zozoro* |
| CYPERACEAE | *Killinga odorata* | *Nongo* |
| CYPERACEAE | *Pycreus mundii* | *Ahibita* |
| CYPERACEAE | *Scleria griegifolia* | *Vendrana* |
| DICHAPETALACEAE | *Dichapetalum* sp. | *Siraambo* |
| DIOSCOREACEAE | *Dioscorea bulbifera* | *Hofika* |

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TABLE A1 (Continued)

| Family | Scientific name | Vernacular name |
|---|---|---|
| DRACAENACEAE | *Dracaena reflexa* | *Tahavola* |
| DROSERACEAE | *Drosera madagascariensis* | *Mahatanando* |
| ERICACEAE | *Philippia floribunda* | *Anjavidy* |
| ERYTHROXYLACEAE | *Antidesma petiolare* | *Hazonovo* |
| ERYTHROXYLACEAE | *Erythroxylum nitidulum* | - |
| ERYTHROXYLACEAE | *Erythroxylum* sp. | *Silimena* |
| EUPHORBIACEAE | *Acalypha reticulata* | - |
| EUPHORBIACEAE | *Acalypha* sp. | *Sindahorolava* |
| EUPHORBIACEAE | *Caperonia* sp. | *Vahindambo* |
| EUPHORBIACEAE | *Croton horridus* | *Silifotsy* |
| EUPHORBIACEAE | *Croton hovarum* | *Silimainty* |
| EUPHORBIACEAE | *Croton trichotomus* | *Fotsiavadika* |
| EUPHORBIACEAE | *Dalechampia clematidifolia* | *Teloravina* |
| EUPHORBIACEAE | *Macaranga alnifolia* | *Tarambitina* |
| EUPHORBIACEAE | *Macaranga* sp. | - |
| FABACEAE | *Abrus precatorius* | *Vahimboamena* |
| FABACEAE | *Acacia* sp. | *Acacia* |
| FABACEAE | *Acacia farnesiana* | *Roy* |
| FABACEAE | *Albizzia gummifera* | *Volomborona* |
| FABACEAE | *Caesalpinia sepiaria* | *Rohinombilahy* |
| FABACEAE | *Cassia laevigata* | *Katsakatsaka* |
| FABACEAE | *Cassia mimosoides* | - |
| FABACEAE | *Clitoria* sp. | *Vahy dimy ravina* |
| FABACEAE | *Crotalaria grahaminea* | - |
| FABACEAE | *Crotalaria ibityensis* | *Crotalaria* |
| FABACEAE | *Crotalaria xanthoclada* | - |
| FABACEAE | *Desmodium ascendens* | *Mpangaladamba* |
| FABACEAE | *Desmodium barbatum* | *Tsilavondrivotra* |
| FABACEAE | *Desmodium incanum* | *Ravintantelisia* |
| FABACEAE | *Desmodium salicifolium* | *Pihidrano* |
| FABACEAE | *Mimosa aff. nossibeensis* | *Boroa* |
| FABACEAE | *Indigofera bojeri* | *Kijanobalala* |
| FABACEAE | *Vigna madagascariensis* | - |
| FLACOURTIACEAE | *Aphloia theiformis* | *Fandramanana* |
| FLACOURTIACEAE | *Casearia nigrescens* | *Hazonakolahy* |
| FLACOURTIACEAE | *Casearia* sp. | - |
| FLACOURTIACEAE | *Homalium* sp. | - |
| GESNERIACEAE | *Streptocarpus hilsenbergii* | - |
| GLEICHENIACEAE | *Sticherus flagellaris* | *Apangandrano* |
| HYPERICACEAE | *Psorospermum* sp. | *Hofikora* |
| ICACINACEAE | *Cassinopsis madagascariensis* | *Hazomafaika* |
| LABIATACEAE | *Ocimum gratissimum* | *Romba* |
| LABIATACEAE | *Spermacoce flagelliformis* | *Bemokony* |
| LAMIACEAE | *Leonotis nepetaefolia* | *Belohalika* |
| LAURACEAE | *Cryptocarya* cf *lucida* | *Tavolo* |

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TABLE A1 (Continued)

| Family | Scientific name | Vernacular name |
|---|---|---|
| LILIACEAE | *Aloe saccotrina* | - |
| LILIACEAE | *Asparagus bambusiterme* | *Hazonoely* |
| LILIACEAE | *Dianella ensifolia* | *Vilo* |
| LOGANIACEAE | *Anthocleista madagascariensis* | *Dendemy* |
| LOGANIACEAE | *Buddleia madagascariensis* | *Seva fotsy* |
| LOGANIACEAE | *Nuxia capitata* | *Lambinana* |
| LOGANIACEAE | *Nuxia verticillata* | *Lambinana* |
| LOMARIOPSIDACEAE | *Elaphoglossum* sp. | *Apangamainty* |
| MAESACEAE | *Maesa lanceolata* | *Voarafy* |
| MALPIGHIACEAE | *Acridocarpus excelsus* | *Vahimavo 2* |
| MALVACEAE | *Dombeya* sp. | *Sarinambera* |
| MALVACEAE | *Hibiscus diversifolius* | *Rohibe* |
| MALVACEAE | *Hibiscus lobatus* | *Sarimbomanga* |
| MALVACEAE | *Malvastrum* sp. | *Malvastrum* |
| MALVACEAE | *Sida rhombifolia* | *Kisindahory* |
| MALVACEAE | *Sida vurens* | *Volomboasary* |
| MALVACEAE | *Urena lobata* | *Kiripitsa* |
| MARATTIACAE | *Marattia fraxinea* | - |
| MELASTOMATACEAE | *Clidemia hirta* | *Voatsikotrokala* |
| MELASTOMATACEAE | *Dichaetanthera cordifolium* | *Tsingotroka* |
| MELASTOMATACEAE | *Tristema virusanum* | *Tsikotroka, Voatsikotroka* |
| MENISPERMACEAE | *Cissampelos madagascariensis* | *Vahimbomanga* |
| MENISPERMACEAE | *Cissampelos* sp. | *Vahinovy* |
| MONIMIACEAE | *Tambourissa perrieri* | *Ambora* |
| MONIMIACEAE | *Tambourissa purpurea* | *Kibolahindreny* |
| MONIMIACEAE | *Tambourissa thouvenotii* | *Ambora mavo* |
| MORACEAE | *Ficus botryoides* | *Fompoha* |
| MORACEAE | *Ficus lutea* | *Amontana* |
| MORACEAE | *Ficus pachyclada* | *Kivozy* |
| MORACEAE | *Ficus politoria* | *Ampaly, Kivozy* |
| MORACEAE | *Ficus reflexa* | *Nonoka* |
| MORACEAE | *Ficus tiliifolia* | *Voara ou Ara* |
| MORACEAE | *Morus alba* | *Voaroy hazo* |
| MORACEAE | *Streblus dimepate* | *Mahanoro* |
| MUSACEAE | *Musa* sp. | *Akondro* |
| MYRICACEAE | *Myrica phyllireaefolia* | *Lakalaka* |
| MYRICACEAE | *Myrica* sp. | - |
| MYRISTICACEAE | *Brochoneura* sp. | *Ambanivoa* |
| MYRSINACEAE | *Embelia conccina* | *Kisira* |
| MYRSINACEAE | *Embelia* sp. | *Vahipisoro* |
| MYRSINACEAE | *Oncostemum botryoides* | *Kalafana* |
| MYRSINACEAE | *Oncostemum leprosum* | *Voamasomby* |
| MYRSINACEAE | *Oncostemum* sp. | *Hazotoa* |
| MYRTACEAE | *Eugenia emirnensis* | *Rotsy* |
| MYRTACEAE | *Psidium catleyanum* | *Goavitsinahy* |

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TABLE A1 (Continued)

| Family | Scientific name | Vernacular name |
|---|---|---|
| MYRTACEAE | *Psidium guayava* | *Goavy be* |
| MYRTACEAE | *Syzygium emirnense* | *Robary* |
| MYRTACEAE | *Syzygium jambosa* | *Zamborizano* |
| MYRTACEAE | *Syzygium* sp. | - |
| OENOTHERACEAE | *Jussiaea erecta* | *Malalia* |
| ORCHIDACEAE | *Cheirostylis gymnochiloïdes* | *Ariandro* |
| OSMUNDACEAE | *Osmunda regalis* | *Apanganamalona* |
| OXALIDACEAE | *Oxalis corniculata* | *Kimamimamy* |
| PASSIFLORACEAE | *Passiflora edulis* | *Garana gasy* |
| PASSIFLORACEAE | *Passiflora foetida* | *Garana vazaha* |
| PASSIFLORACEAE | *Passiflora* sp. | *Goreraka* |
| PHYTOLACCACEAE | *Lobelia serpens* | *Anambozaka* |
| PHYTOLACCACEAE | *Phytolacca dodecandra* | *Anambazaha* |
| PIPERACEAE | *Peperomia aff. blanda* | - |
| PIPERACEAE | *Piper pyrifolium* | *Sakavirombato* |
| POACEAE | *Aristida congeta* | *Kifafa* |
| POACEAE | *Cymbopogon rufus* | *Vero* |
| POACEAE | *Cynodon dactylon* | *Kidresy* |
| POACEAE | *Digitaria* sp. | *Kilanjibeventy* |
| POACEAE | *Eragrostis* sp. | - |
| POACEAE | *Eulalia villosa* | *Gebona* |
| POACEAE | *Hyparhenia rufa* | *Veromena* |
| POACEAE | *Hyparhenia* sp. | *Verofehy* |
| POACEAE | *Imperata cylindrica* | *Tegny* |
| POACEAE | *Melinis minutiflora* | *Menakapa* |
| POACEAE | *Panicum* cf. *malacotrichum* | *Kisapihafitra* |
| POACEAE | *Panicum* sp. | *Kiapody* |
| POACEAE | *Paspalum commersianum* | *Bozaka* |
| POACEAE | *Setaria* sp. | *Setaria* |
| POACEAE | *Sporobolus subulatus* | *Kilanjy* |
| POLYPODIACEAE | *Phymatosorus scolopendria* | *Apanganala* |
| PTERIDACEAE | *Adianthum* sp. | *Apangamainty* |
| PTERIDACEAE | *Pteridium aquilinum* | *Apanga* |
| RHAMNACEAE | *Gouania glandulosa* | - |
| ROSACEAE | *Amygdalus persica* | *Paiso* |
| ROSACEAE | *Eryobotria japonica* | *Pibasy* |
| ROSACEAE | *Prunus persica* | *Paiso* |
| ROSACEAE | *Rosia* sp. | - |
| ROSACEAE | *Rubus rosaefolius* | *Voarointsaka* |
| ROSACEAE | *Rubus* sp. | *Rohifotsy* |
| RUBIACEAE | *Anthospermum ibityense* | *Anjavidy be ravina* |
| RUBIACEAE | *Breonia cuspidata* | *Valopangady* |
| RUBIACEAE | *Canthium* sp. | *Fantsikahitra* |
| RUBIACEAE | *Danais cernua* | *Vahinofokorana* |
| RUBIACEAE | *Danais fragrans* | *Vahitamborimantsina* |

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TABLE A1 (Continued)

| Family | Scientific name | Vernacular name |
|---|---|---|
| RUBIACEAE | *Danais pubescens* | *Tamboro* |
| RUBIACEAE | *Danais* sp. | *Vatoninara* |
| RUBIACEAE | *Fernelia ambositrense* | *Voalahimavo* |
| RUBIACEAE | - | *Hazondrainona* |
| RUBIACEAE | *Lecomtea bojeriana* | *Tamborimantsy* |
| RUBIACEAE | *Mussaenda trichophlebia* | *Fatora* |
| RUBIACEAE | *Mussaenda vestita* | *Fatora* |
| RUBIACEAE | *Oldenlandia affinis* | *Talapia* |
| RUBIACEAE | *Psychotria* sp. | *Sarikafe* |
| RUBIACEAE | *Psychotria subcapitata* | *Voamasindreniolo* |
| RUBIACEAE | *Saldinia* sp. | - |
| RUBIACEAE | *Saldinia* sp. | *Tavaza* |
| RUBIACEAE | *Schismatoclada psychotrioides* | *Voananamboa* |
| POACEAE | *Melinis minutiflora* | *Menakapa* |
| POACEAE | *Panicum* cf. *malacotrichum* | *Kisapihafitra* |
| POACEAE | *Panicum* sp. | *Kiapody* |
| POACEAE | *Paspalum commersianum* | *Bozaka* |
| POACEAE | *Setaria* sp. | *Setaria* |
| POACEAE | *Sporobolus subulatus* | *Kilanjy* |
| POLYPODIACEAE | *Phymatosorus scolopendria* | *Apanganala* |
| PTERIDACEAE | *Adianthum* sp. | *Apangamainty* |
| PTERIDACEAE | *Pteridium aquilinum* | *Apanga* |
| RHAMNACEAE | *Gouania glandulosa* | - |
| ROSACEAE | *Amygdalus persica* | *Paiso* |
| ROSACEAE | *Eryobotria japonica* | *Pibasy* |
| ROSACEAE | *Prunus persica* | *Paiso* |
| ROSACEAE | *Rosia* sp. | - |
| ROSACEAE | *Rubus rosaefolius* | *Voarointsaka* |
| ROSACEAE | *Rubus* sp. | *Rohifotsy* |
| RUBIACEAE | *Anthospermum ibityense* | *Anjavidy be ravina* |
| RUBIACEAE | *Breonia cuspidata* | *Valopangady* |
| RUBIACEAE | *Canthium* sp. | *Fantsikahitra* |
| RUBIACEAE | *Danais cernua* | *Vahinofokorana* |
| RUBIACEAE | *Danais fragrans* | *Vahitamborimantsina* |
| RUBIACEAE | *Danais pubescens* | *Tamboro* |
| RUBIACEAE | *Danais* sp. | *Vatoninara* |
| RUBIACEAE | *Fernelia ambositrense* | *Voalahimavo* |
| RUBIACEAE | - | *Hazondrainona* |
| RUBIACEAE | *Lecomtea bojeriana* | *Tamborimantsy* |
| RUBIACEAE | *Mussaenda trichophlebia* | *Fatora* |
| RUBIACEAE | *Mussaenda vestita* | *Fatora* |
| RUBIACEAE | *Oldenlandia affinis* | *Talapia* |
| RUBIACEAE | *Psychotria* sp. | *Sarikafe* |
| RUBIACEAE | *Psychotria subcapitata* | *Voamasindreniolo* |
| RUBIACEAE | *Saldinia* sp. | - |

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TABLE A1 (Continued)

| Family | Scientific name | Vernacular name |
|---|---|---|
| RUBIACEAE | *Saldinia* sp. | *Tavaza* |
| RUBIACEAE | *Schismatoclada psychotrioides* | *Voananamboa* |
| RUBIACEAE | *Tricalysia cryptocalix* | *Tavaza* |
| RUTACEAE | *Evodia madagascariensis* | *Rebosa* |
| RUTACEAE | *Toddalia asiatica* | *Anakatsimba* |
| SALICACEAE | *Bembicia axillaris* | *Sely* |
| SALICACEAE | *Calantica cerasifolia* | *Fanazava* |
| SAPINDACEAE | *Deinbollia pervillei* | *Hazombato* |
| SAPINDACEAE | *Dodonea viscosa* | *Dingandahy* |
| SCROPHULARIACEAE | *Halleria ligustifolia* | *Tsetsoy* |
| SCROPHULARIACEAE | *Radamaea montana* | *Kimaintiloha* |
| SCROPHULARIACEAE | *Scrophularia* sp. | - |
| SCROPHULARIACEAE | *Stenotaphum dimiaiatum* | *Kidresivazaha* |
| SCROPHULARIACEAE | *Torenia stolonifera* | *Anatarika* |
| SELLAGINELACEAE | *Sellaginella* sp. | *Sellaginella* |
| SMILACACEAE | *Smilax kraussiana* | *Fandrikabidisa* |
| SOLANACEAE | *Physalis peruviana* | *Voanaka* |
| SOLANACEAE | *Solanum auriculatum* | *Seva* |
| SOLANACEAE | *Solanum nigrum* | *Anamamy* |
| SOLANACEAE | *Solanum* sp. | - |
| STERCULIACEAE | *Dombeya megaphylla* | *Hafotra* |
| TILIACEAE | *Trumpheta rhumboridae* | - |
| TILIACEAE | *Trumpheta* sp. | - |
| UMBELLIFERAE | *Phellolophium madagascariense* | *Tangina* |
| URTICACEAE | - | *Mia* |
| URTICACEAE | *Laportea amberana* | *Ambera* |
| URTICACEAE | *Obetia radula* | *Hafodrano* |
| VERBENACEAE | *Clerodendrum aucubifolium* | *Trotrokala* |
| VERBENACEAE | *Clerondendrum putre* | *Tsatsandroy* |
| VERBENACEAE | *Lantana camara* | *Taindelontsinoa* |
| VITACEAE | - | *Vahikisy* |
| VITACEAE | *Cyphostemma microdipterum* | *Kiripitsa* |
| XYRIDACEAE | *Xyris capensis* | - |
| | *Crinum* sp. | *Vahindrano* |

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