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ALTERNATIVE AU TAVY / RECHERCHE

Structural and cultural constraints on adopting *tsabo*-based agroforestry as an alternative to *tavy* around Betampona Reserve, Madagascar

Photos 1.
Transportation of bananas and people to the nearest market place, by foot (a) or by boat (b) which can be 5 to 15 km from their homes.
Photo D. R. Rakotondratandra.

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RESEARCH / AN ALTERNATIVE TO SLASH-AND-BURN

RÉSUMÉ

Obstacles structurels et culturels à l'adoption de l'agroforesterie à base de *tsabo* comme alternative au *tavy* autour de la Réserve de Betampona, Madagascar

Madagascar est reconnu dans le monde entier pour sa biodiversité exceptionnelle. Pourtant, la culture sur brûlis (*tavy*) est à l'origine de 80 à 95 % de la déforestation dans ce pays. Malgré des décennies d'efforts pour promouvoir l'agroforesterie basée sur le *tsabo* comme alternative soutenable, la pratique du *tavy* a converti 50 % de la surface initiale de la Réserve naturelle intégrale de Betampona (environ 1 200 ha) dans l'Est de Madagascar en terres cultivées ou en forêts secondaires. À l'aide d'une approche interdisciplinaire et d'un cadre théorique intégré, cette étude tente de saisir les contraintes qui pèsent sur l'adoption et l'extension de l'agroforesterie à base de *tsabo* comme alternative au *tavy* dans les petites exploitations agricoles de la zone tampon autour de cette aire protégée. Bien que l'agroforesterie à base de *tsabo* fournisse jusqu'à 67,6 % de leur revenu monétaire provenant de l'agriculture, 20 % à 43 % des ménages échantillonnés ne souhaitent plus établir de nouvelles parcelles agroforestières à base de *tsabo* ou étendre leurs parcelles existantes ; 40,6 % et 62,7 % des ménages poursuivent leurs pratiques de monoculture et de *tavy*, respectivement. Notre étude en conclut que les facteurs qui entravent l'établissement ou l'extension du mode *tsabo* dans la zone concernée comprennent des aspects structurels et culturels. D'une part, l'aggravation de l'isolement géographique, de l'insécurité rurale et de la pauvreté, associée à la désintégration des circuits de commercialisation de leurs produits agricoles, décourage les agriculteurs d'étendre leurs parcelles cultivées en mode *tsabo*. D'autre part, le riz fait partie de l'identité malgache et régit tous les aspects de la culture villageoise, mais les projets d'extension des cultures *tsabo* n'intègrent pas le riz dans les systèmes agroforestiers qu'ils proposent aux agriculteurs. Il est recommandé aux décideurs politiques et aux programmes de développement de prendre en compte ces facteurs structurels et culturels afin de concevoir des systèmes agroforestiers qui correspondent aux besoins des producteurs.

Mots-clés : *tsabo,* adoption de l'agroforesterie, persistance du *tavy*, Betampona, Madagascar.

ABSTRACT

Structural and cultural constraints on adopting *tsabo*-based agroforestry as an alternative to *tavy* around Betampona Reserve, Madagascar

Madagascar is known worldwide for its exceptional biodiversity. However, slash-and-burn cultivation (*tavy*) accounts for 80 to 95% of deforestation in this country. Despite decades of efforts to promote *tsabo*-based agroforestry as a sustainable alternative, the *tavy* agricultural technique has converted 50% of the original surface area of the Betampona Strict Nature Reserve (about 1,200 ha) in eastern Madagascar into cropland or secondary forests. Applying an interdisciplinary approach with an integrated theoretical framework, this study attempts to capture the constraints on the adoption and extension of *tsabo*-based agroforestry as an alternative to *tavy* on smallholder farms in the buffer zone around this protected area. Although *tsabo*-based agroforestry provides up to 67.6% of their cash income from farming, 20% to 43% of the households sampled no longer wish to establish new *tsabo*-based agroforestry plots or to extend their existing ones; 40.6% and 62.7% of households have continued the practices of monoculture and *tavy*, respectively. This article concludes that the factors impeding the establishment or extension of *tsabo*-based cultivation in the study area include structural as well as cultural dimensions. On the one hand, worsening geographic isolation, rural insecurity and poverty, together with the complete breakdown of marketing channels for their agricultural products, are discouraging farmers from extending their *tsabo* plots. On the other hand, even though rice is part of the Malagasy identity and governs all aspects of village culture, projects for *tsabo* extension have failed to integrate rice within the agroforestry systems they propose to farmers. It is recommended that policymakers and development programs take these structural and cultural factors into account in order to design agroforestry systems that correspond to the producers' needs.

Keywords: *tsabo,* adoption of agroforestry, persistence of *tavy*, Betampona, Madagascar.

RESUMEN

Limitaciones estructurales y culturales en la adopción de la agroforestería basada en el *tsabo* como alternativa al *tavy* en los alrededores de la Reserva de Betampona, Madagascar

Madagascar es mundialmente conocido por su excepcional biodiversidad. Sin embargo, el cultivo de tala y quema (*tavy*) representa entre el 80 y el 95 % de la deforestación en este país. A pesar de décadas de esfuerzos para promover la agroforestería basada en el *tsabo* como alternativa sostenible, la técnica agrícola del *tavy* ha convertido el 50 % de la superficie original de la Reserva Natural Integral de Betampona (unas 1 200 ha), en el este de Madagascar, en tierras de cultivo o bosques secundarios. Aplicando un enfoque interdisciplinar con un marco teórico integrado, este estudio trata de captar las limitaciones para la adopción y extensión de la agroforestería basada en el *tsabo* como alternativa al *tavy* en las explotaciones de pequeños agricultores de la zona tampón en torno a esta área protegida. Aunque la agroforestería basada en el *tsabo* proporciona hasta el 67,6 % de sus ingresos en efectivo procedentes de la agricultura, entre el 20 % y el 43 % de los hogares de la muestra ya no desean establecer nuevas parcelas agroforestales basadas en el *tsabo* ni ampliar las existentes; el 40,6 % y el 62,7 % de los hogares han continuado con las prácticas de monocultivo y *tavy*, respectivamente. Este artículo concluye que los factores que impiden el establecimiento o la extensión del cultivo basado en el *tsabo* en la zona estudiada incluyen dimensiones tanto estructurales como culturales. Por un lado, el empeoramiento del aislamiento geográfico, la inseguridad rural y la pobreza, junto con la completa ruptura de los canales de comercialización de sus productos agrícolas, desaniman a los agricultores para la ampliación de sus parcelas de *tsabo*. Por otra parte, aunque el arroz forma parte de la identidad malgache y rige todos los aspectos de la cultura del pueblo, los proyectos de extensión del *tsabo* no han conseguido integrar el arroz en los sistemas agroforestales que proponen a los campesinos. Se recomienda que los responsables políticos y los programas de desarrollo tengan en cuenta estos factores estructurales y culturales para diseñar sistemas agroforestales que respondan a las necesidades de los productores.

Palabras clave: *tsabo,* adopción de la agrosilvicultura, persistencia del *tavy*, Betampona, Madagascar.

Introduction

Madagascar has exceptional natural resources with an endemicity rate among the highest in the world: > 90% for vascular plants, > 50% for birds and > 98% for amphibians, reptiles and mammals (Ganzhorn *et al.*, 2001). However, 71.5% of the Malagasy people suffer from poverty and malnutrition (IMF, 2017), which are major drivers of deforestation. Between 2010 and 2014, about 99,000 ha of natural forests were lost yearly (Vieilledent *et al.*, 2018) due mainly to slush-and-burn agriculture (*tavy* or *tevy ala*) which is responsible for 80% to 95% of the conversion of Madagascar's natural forests into cropland (Freudenberger, 2010).

Two approaches have been adopted to resolve the problem of *tavy* in Madagascar (Rakotondratandra, 2021). First, the fence and fine paradigm was locally materialized by the French colonial administration through the creation of protected areas and the banning of *tavy*. However, this repressive and exclusive policy failed to stop deforestation, leading to the adoption of an integrated approach seeking to include adjacent inhabitants in the management of state-owned forests since the 1970s. In this second approach, agroforestry was promoted as an alternative to *tavy*, through Integrated Conservation and Development Projects (ICDPs) and then through mechanisms of Reduction of Emissions due to the Degradation and Deforestation (REDD) of forests as well as the Payment for Environmental Services (PES) (carbon credits).

Empirical investigations showed that agroforestry systems provide socioeconomic as well as environmental benefits ranging from local to global scales. At plot level, trees allow a more effective water utilization; reduce soil erosion; protect crops against wind damage; and reduce insect, pest and weed pressure, which increases yields (Kabwe, 2010; Quandt, 2017; Karlsson, 2018). Though not always suitable for mechanization, agroforestry is also adapted to the peasants' manual work (Berton *et al.*, 2012). At community level, the introduction of living fences reduced conflicts related to domestic animal divagation in Uganda (Kirabo *et al.* as cited by Karlsson, 2018) whereas the integration of food and tree crops helped maintain labour force locally and decrease rural exodus in Indonesia and Madagascar (Bing, 2015). At the global level, finally, agroforestry systems may help reduce deforestation thanks to the optimal use of the existing plots while providing food and timber to the producers, serve as habitats for indigenous animal and plant species that are partially dependent on natural forests, facilitate animal species migration along agroforestry corridors that connect distant isolated habitats, and stock carbon for climate change mitigation (Schroth *et al.*, 2004).

Despite the above-mentioned advantages, agroforestry adoption remains limited whereas *tavy* continues to shape Madagascar's forest landscapes (Freudenberger, 2010; Bureau National de Coordination REDD+, 2016). There is a lack of knowledge as to the factors constraining the large-scale adoption of agroforestry technologies as an alternative to *tavy* on smallholder farms adjacent to protected areas. Effectively, previous investigations (Styger *et al.*, 1999; Messerli, 2003; Nambena, 2004; Rakotomanandraisoa, 2004; Downey, 2012; Gay des Combes, 2017) used pure agronomic approaches and focused specifically on the on-plot performance of agroforestry technologies (namely the biomass production, crop yields, and income) in order to conceive systems that can improve or completely replace *tavy*. Despite an investigation carried out in the Andapa region to attempt to explain the persistence of smallholder farmers' self-provisioning from *tavy* (Laney and Turner, 2015), there is a lack of understanding as to the factors why farmers in Madagascar still practice this anthropic farming system instead of agroforestry. To complete this gap in the literature, this article focuses on the constraints to the establishment and extension of *tsabo*-based agroforestry as an alternative to *tavy* around Betampona Strict Nature Reserve (SNR), on the east coast of Madagascar. This agroforestry system includes export and fruit trees (clove, coffee, litchi, jackfruit, breadfruit, coconut and many other trees), lianas (yam, pepper and vanilla) and herbaceous plants (banana, taro, sugar cane) mixed in different ways, in space and time, with variable density and level of stratification as observed in other regions of the country (Mariel *et al.*, 2021). In Betampona region, *tsabo* trees are traditionally associated with food crops while established away from home and also with animal husbandry if settled as home garden. In order to best understand the factors impeding the adoption or extension of *tsabo*-based agroforestry as an alternative to *tavy* around Betampona SNR, this study mobilized an integrated theoretical framework as well as an interdisciplinary and multiscale approach (figure 2). Based on this theoretical framework (Rakotondratandra, 2021), four factors influencing agricultural technology adoption often advanced in the literature will be considered, namely:

- the socioeconomic characteristics of the potential adopters,
- the characteristics of the agricultural technology or practice to be promoted,
- the ways the target agricultural technology is communicated and diffused,
- the political, economic, social and cultural context into which the target agricultural technology is to be integrated.

Materials and methods

Description of the study site

The study area is located on the East coast of Madagascar where forests are among the country's most highly threatened and impacted formations (Ganzhorn *et al.*, 2001) and where multiple extension projects – such as *Bilan Écologique à Madagascar* (BEMA) and Eco-regional Initiative (ERI) – have promoted agroforestry to reduce the impacts of *tavy* on remaining forests since 1980s. Betampona is an evergreen lowland rainforest (around 500 m above sea level) located about 40 km Nord-West of Toamasina town, between latitudes 17°52'–17°56' south and lon-

gitudes 49°11'–49°15' east. Established as the first Strict Nature Reserve of Madagascar in 1927, with a surface area of 2,228 ha in 1966, Betampona plays ecological functions vital both to the wild species living within its core zone and to the livelihoods of the surrounding populations. As one of the rare primary lowland forest fragments still existing in Madagascar, in fact, it serves a refuge for animal and plant species of which more than 40 are unique in the reserve (Birkinshaw, 2002; Ghulam, 2014; Freeman *et al.*, 2014). It is also a source of water for the Ivoloina and Ifontsy rivers.

Despite its ecological importance, Betampona Reserve is highly vulnerable to natural and anthropic threats. On the one hand, it suffers from violent tropical cyclones which frequently destroy crops. This indirectly contributes to expanding deforestation as certain inhabitants, who rely entirely on agriculture for their living, progress their *tavy* deep inside Betampona's core zone in order to grow food crops as the neighbouring valleys are too small and hill slopes severely degraded from years of slash-and burn agriculture to provide them with sufficient food (Rakotondratandra, 2021). The Reserve is partially buffered by a 100 m wide Protection Zone (PZ) where *tavy* is not allowed but still practiced. Therefore, about 50% of its original surface area has been reduced to *tavy* fields and secondary forests (Armstrong *et al.*, 2018), which also increases the spread of invasive plant species in the core zone. According to Ghulam (2014), for instance, the Chinese goyavia (*Psidium cattleianum*), the Molucca raspberry (*Rubus molluccanus*) and the Madagascar cardamome (*Aframomum angustifolium*) already cover 9.5% (402.6 ha) of the Reserve's surface area and 44.5% (195.7 ha) of its PZ.

From a sociodemographic point of view, population settlements have long existed on Betampona's buffer zone since the late pre-colonial era, with the two surrounding Rural Communes (RC) counting for 20,832 inhabitants in 2017 (Monographie d'Ambodiriana, 2004 and 2017; Monographie de Sahambala, 2004 and 2017). Ambodiriana RC has nine *Fokontany* (the smallest administrative area, each composed of several villages), four of which (Analamangahazo, Antaranarina, Fontsimavo and Andratambe) are located at less than 10 km from the Betampona Reserve (figure 1). Sahambala RC is composed of 12 *Fokontany* only one of which (Ambodirafia) abounds the Reserve. Although their population density remains low (in 2017, 16.6 to 37.4 inhabitants per km^2 for Ambodiriana and Sahambala, respectively), the 5 *Fokontany* surrounding Betampona Reserve shared 19% of the population of the two RC (2017).

Data collection and analyses

To capture the complexity of the factors impeding the large-scale adoption of *tsabo*, we used an integrated theoretical framework (figure 2) in which agroforestry adoption is considered as an investment decision and strategy that producer-households take in a larger system context within which multiple factors (technical, socioeconomic, biogeographic, institutional, political and cultural) interrelate at different geographic scales (field, farm, household, regional, national and international) (Rakotondratandra, 2021). Therefore, a mixed method approach of data collection and analysis was used to best address the problem.

For the data collection, we first surveyed 212 households from the above mentioned five *Fokontany* adjacent to Betampona Reserve (figure 1) using a non-probabilistic sampling method in August 2018. Face-to-face discussions with household representatives (114 women and 98 men ranging in age between 17 to 86 years old) took place in/outdoor using paper questionnaires. The survey included

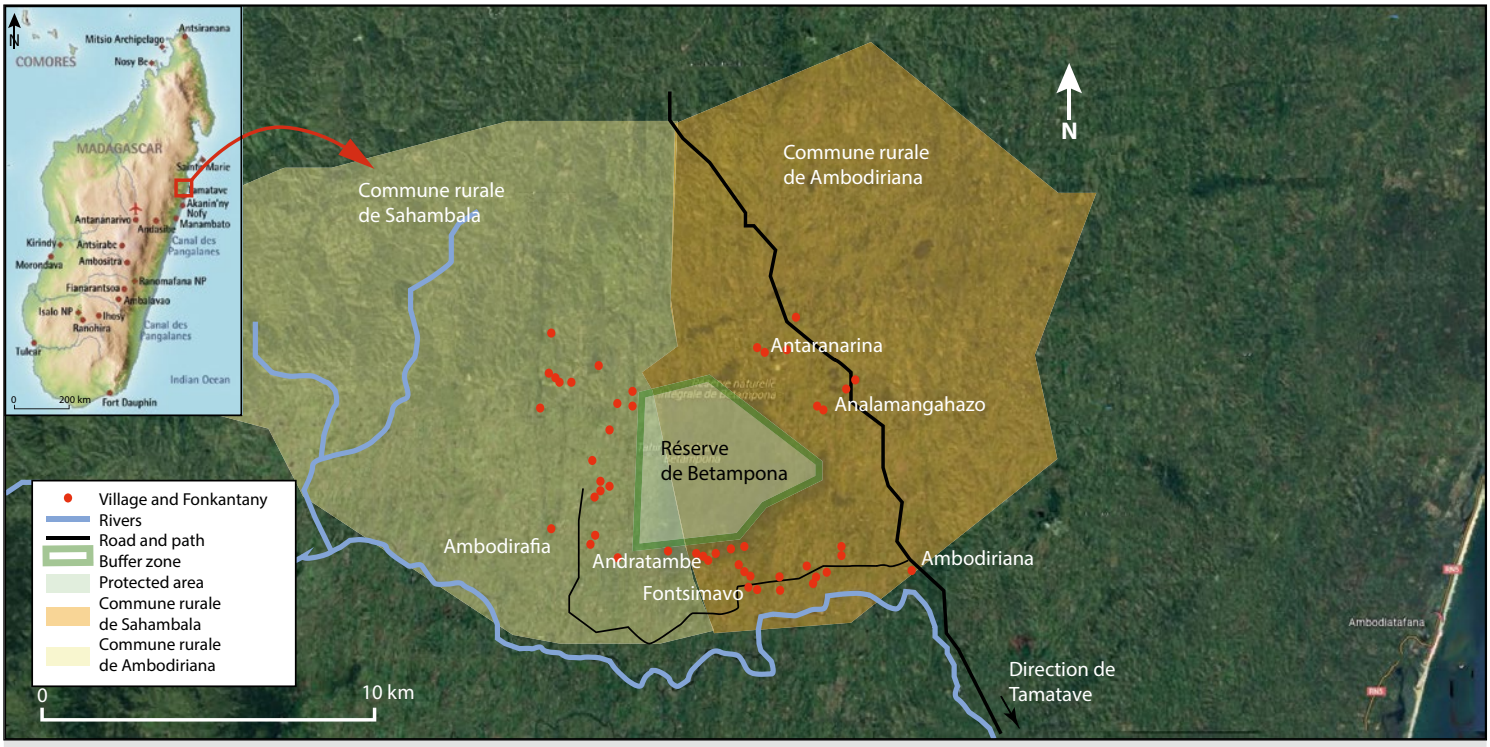

Figure 1.
Location of the study site. Source: adaptation of author from Rafilipo.

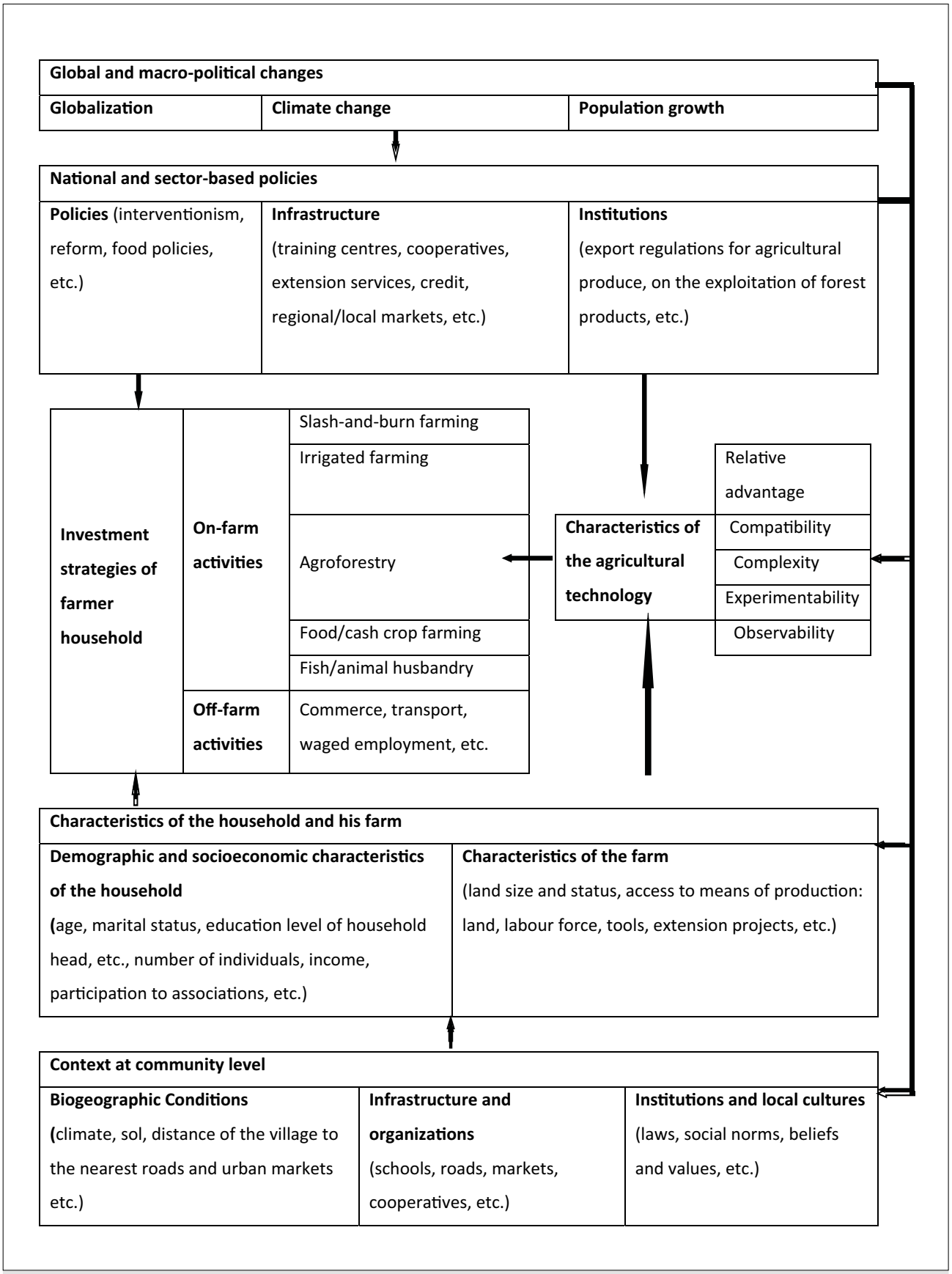

Figure 2.
Integrated theoretical framework showing the interactions between extrinsic variables which determine the farmer household investment strategies and agroforestry adoption. Source: author (for more information, see Rakotondratandra, 2021).

Photo 2.
Tavy field established on the edge of the primary forest of Antaranarina.
Photo D. R. Rakotondratandra.

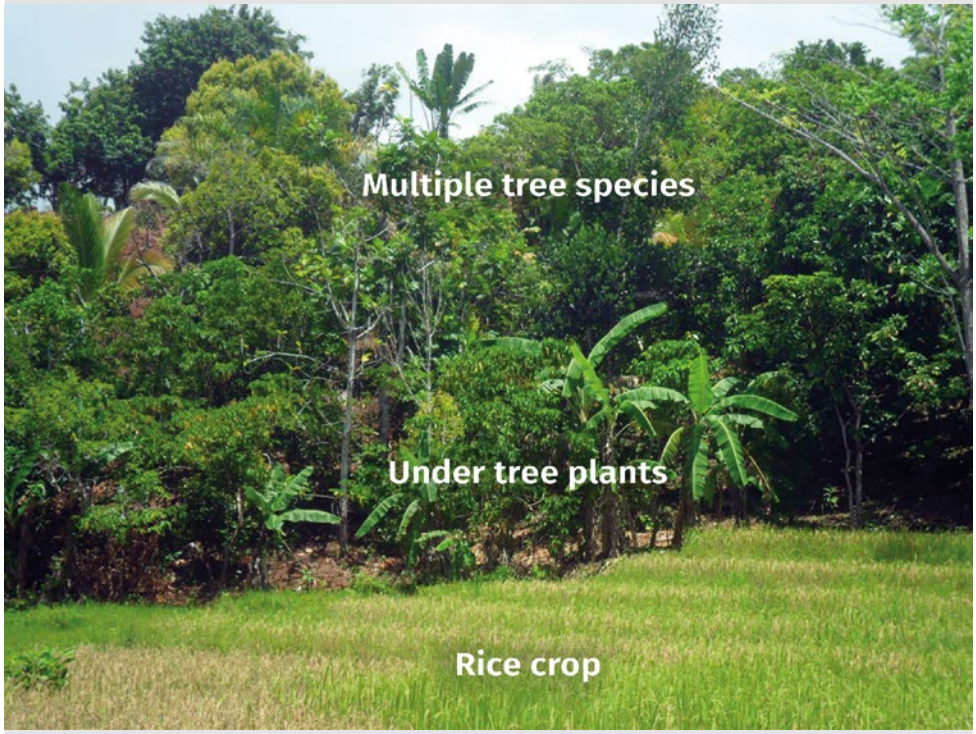

Photo 3.
Traditional *tsabo*-based agroforest.
Photo D. R. Rakotondratandra.

questions related to both the socioeconomic characteristics of the households (marital status, education level, main activity, participation to reforestation project, etc.) and their farms (total size of lands, total size of fields allocated to food crops other than rice, integration of trees with (pluri) annual crops, income generated from farming, etc.) as well as multiple-choice questions expressing constraints in establishing and/or scaling up each target *tsabo* tree species (i.e. clove, coffee, breadfruit, jackfruit, litchi, vanilla pole, and banana). Although different fruit trees (avocado, orange, etc.) are found around the Betampona Reserve, the above-mentioned tree species are the most used as *tsabo* components. Respondents could identify among the list of factors provided the ones that are most constraining to their own case, since the reasons why a household chose to invest or not in *tsabo* varied from one crop to another (Rakotondratandra, 2021). As woody fallows were usually reserved to *tavy*, only *tsabo* trees were considered as agroforestry trees in our study. In addition, four focus groups with representatives of local nurserymen (working for extension projects promoting agroforestry), local authorities and producers were carried out in December 2018. These focus groups covered different aspects of *tavy* and *tsabo*-based agroforestry farming systems (i.e. their histories, economic values, constraints, solutions, etc.) so as to get a full grasp of their representations, evolution and dynamics in the study area.

The quantitative data obtained from the surveys were compiled and analyzed with SPSS 25 to obtain descriptive statistics and to proceed to non-parametric tests so as to compare the differences in the number of trees within and between farms and *tsabo* fields according to several independent variables related to the households and farms characteristics. As the Kolmogor-

ov-Smirnov and Shapiro-Wilk tests of normality distribution indicated a $p < 0.05$ (i.e. $p = 0.000$), signalling an abnormality in the distribution of the number of trees, a Mann-Whitney test (U) was used to test the explanatory variables with two categories while a Kruskal-Wallis test (K-W) was employed for independent variables with more than two categories. To interpret the results from these tests, we relied to the following principles: a $p < 0.05$ indicates the presence of difference whereas a $p > 0.05$ tells the absence of difference in the number of *tsabo* trees grown on the farm according to the explanatory variables being considered.

The historical-anthropological data from the focus groups were analyzed using qualitative methods to account for the political and cultural aspects of the diffusion/adoption of *tsabo* as an alternative to *tavy* in the study area. A quantitative content analysis was applied to capture the representations of *tsabo* and *tavy* by five groups of nurserymen while a thematic analysis was favoured for the remaining and longer focus group interviews (Bernard, 2006).

Results

The influence of households and farms socioeconomic characteristics on the intensity of *tsabo* tree growing

The analysis of the survey interviews revealed that households have about four members on average and are generally male-headed. While 31% of the household heads (HHs) are illiterate, 50.5% attended primary school and only 17% went to secondary school. On average, the studied farms have 3.42 ha of surface area and are distinguished by their very low resort to mechanization and their diversity in terms of both the cropping techniques used (tilling, no tilling, cover crops, monoculture, polyculture, crop-livestock integration, etc.) and their productions (woods, fruits, food/cash crops, livestock, tubers, lianas, etc.). Food crops grown in mono- or polycultures (including rice, maize, cassava, beans, etc.) cover 45% (324.87 ha) of the total surface lands of the surveyed farms, of which 48% (155.8 ha) is devoted to *tavy* and 32% (104 ha) to irrigated paddy rice production. If lack of land is often advanced among the most important factors constraining *tsabo* extension, 21% of the lands in the sample farms are allocated to *tavy* while about 30% are left fallow. Therefore, the *tsabo* fields (with the number of trees varying from 1 to 1,529) represent only 25% of the farmlands although the products from *tsabo* (such as clove, coffee, breadfruit, jackfruit, litchi, vanilla, banana and big yam) provide the households with up to 67.6% of their cash income from farming. Because 52% of the households are rice insufficient, they mainly use their food crops and *tsabo* products (excepting vanilla and clove) for their own consumption. 85.4% of the surveyed households do animal husbandry (with 1,686 heads of poultry, 116 heads of pigs and 98 heads of cows) but this activity is practiced extensively and accounts for 18% of the annual farm incomes. On average, the households earn a yearly income of 414,109 Ariary (1 dollar = 3,160 Ariary in April 2017) from farming but 50% earn < 215,000 Ariary, which is largely insufficient for a decent life. Therefore, 46.7% and 6.6% of the household heads engage in a second or a third on/off/non-farm activity, respectively.

The extent of *tsabo* tree growing differs from one farm to the next, ranging from 1 to 1,529 trees. Table I shows that nine socioeconomic variables related to both households and farms characteristics have a significant influence on the number of trees grown on the farm.

Marital status of household heads (HHs)

The number of trees grown on the farm differs according to the marital status of the HH ($p = 0.014$). Farms belonging to single (male or female) HHs possess fewer trees (mean rank of 75) compared to those managed by HHs with partners (mean rank of 110).

Education level of household heads (HHs)

The difference in number of trees of HHs with secondary and above and without education is significant in a *post hoc* pairwise test ($p = 0.019$): mean rank of 121 compared to 89, respectively. More education may lead farmers to be more open to innovations or more actively seeking information to increase farm income. Because the differences are not statistically significant among the other categories of HHs, it can be inferred that the level of schooling of HHs does not fully influence the integration of trees in the farms of reference.

Main activity of household heads (HHs)

In a pairwise test, the main activity of the HHs showed a statistically significant difference between day labourers and small business owners in the number of trees ($p = 0.036$): mean rank of 52 and 140, respectively. Although full-time farmers tend to possess fewer trees (mean rank of 105) than small business owners, this difference is not statistically significant when a Bonferroni correction is applied ($p = 0.256$). Owing these results, it can be inferred that the main activity of the HHs does not fully explain the difference in the number of trees among the farms of reference.

Participation of household heads (HHs) to Betampona reforestation project

HHs who participate in the Betampona buffer zone reforestation project tend to possess more trees on their farms (mean rank of 120) than do non-participants (mean rank of 98); the difference is significant ($p = 0.009$).

Total size of lands on the farm (ha)

According to pairwise tests, growing trees differs in intensity according to the total size of lands on the farm ($p = 0.001$). The differences are statistically significant between farms with less than 2 ha of lands (mean rank of 70) and those with more than 5 ha (mean rank of 139), as well as between the latter and those having between 2 and 4.9 ha (mean rank of 103). This means that farms with more than 5 ha of lands tend not only to participate to Betampona reforestation project but also to grow more trees compared to those with less land.

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Table I.
Tree growing intensity according to the household and farm characteristics.

Explanatory variables	Categories	Number of households	Mean rank (a)	Median number of trees	Statistical results and significance
Sex of household head	Male	97	113	96	U = 4,895.500
	Female	115	101	85	Z = -1.533
					p = 0.125
Age of household head	Young (17-39 years)	91	108	86	KW = 460
	Old (40-59 years)	98	107	89	ddl = 2
	Very old (≥ 60 years)	23	98	80	p = 0.794
Marital status of household head	Without partner	21	75	66	U= 1,351.000
	With partner	191	110	90	Z = -2.453
					p = 0.014
Education level of household head	Illiterate	66	89	71	KW = 7.951
	Primary school	107	112	96	ddl = 2
	Secondary school and plus	39	121	116	p = 0.019
Number of household members	1-5	153	103	86	U = 4,040.000
	≥ 6	59	114	90	Z= -1.183
					p = 0.237
Number of household members who are working	1-3	190	107	87	U = 2,070.000
	≥ 4	22	106	80	Z = -0.070
					p = 0.944
Main activity of household head	Farmer	187	105	86	KW = 8.525
	Waged worker	5	119	258	ddl = 3
	Small business owner	15	140	144	p = 0.036
	Daily worker	5	52	52	
Adherence of household head to rural association	No membership	174	105	86	U = 3,065.500
	Membership	38	113	122	Z = -0.702
					p = 0.483
Participation of household head to Betampona reforestation project	Non-participant	129	98	80	U = 4,215.000
	Participant	83	120	116	Z = -2.612
					p = 0.009
Means of transportation of products to market place	Man's back	197	106	86	U = 1,313.500
	Bicycle	15	117	102	Z = -0.716
					p = 0.474
Total size of lands on the farm (ha)	< 2	15	70	37	KW = 14.803
	2 to 4.9	164	103	85	ddl = 2
	> 5	33	139	181	p = 0.001

Total size of fields allocated to food crops other than rice (ha)

The number of trees on the farms differs significantly according to the total size of fields the households allocate to food crops other than rice (p = 0.000). The differences are significant between households allocating land to only rice (mean rank of 43) and those growing less than 0.05 ha of food crop other than rice (mean rank of 111) as well as between the formers and households having 0.05 to 0.099 ha of this type of crop (mean rank of 117). Households without land allocated to non-rice food crops incorporate fewer trees on their farms (mean rank of 43) compared to those having 0.1 ha and more (mean rank of 94) but this difference is not significant after a Bonferroni correction is applied (p = 0.141). These results show that the intensity of tree farming does not fully depend on the size of fields allocated to non-rice food crops.

Explanatory variables	Categories	Number of households	Mean rank (a)	Median number of trees	Statistical results and significance
Total size of irrigated rice fields on the farm (ha)	Without	44	94	77	KW = 2.371
	< 1	129	109	89	ddl = 2
	≥ 1	39	112	102	p = 0. 306
Total size of pluvial rice fields (*tavy*) on the farm (ha)	Without	80	107	83	KW = 0.026
	< 1	38	107	96	ddl = 2
	≥ 1	94	106	86	p = 0.987
Total size of fields allocated to food crops other than rice (are)	Without	14	43	23	KW = 17.760
	< 5	142	111	89	ddl = 3
	5 to 9.9	37	117	120	p = 0.000
	≥ 10	19	94	72	
Total number of banana trees and yam plants	Without	08	29	7	KW = 31.291
	≤ 200	191	105	86	ddl = 2
	> 200	13	180	363	p = 0.000
Integration of trees with (multi)annual crops	No	31	51	36	U = 1,074.000
	Yes	181	116	102	Z = -5.487
					p = 0.000
Total number of poultry birds (head)	Without	40	87	74	KW = 5.856
	1 to 29	162	111	89	ddl = 2
	≥ 30	10	121	127	p = 0.053
Total number of livestock (head)	Without	119	102	86	KW = 1.688
	1- 4	84	111	88	ddl = 2
	≥ 5	9	121	121	p = 0.430
Household rice self-sufficiency	Selfsufficient	102	99	99	U = 4,838.500
	Non selfsufficient	110	114	75	Z = -1.729
					P = 0.084
Income generated from farming *(Ariary)*	Without	23	58	39	KW = 35.567
	< 400,000	122	98	82	ddl = 2
	≥ 400,000	67	139	169	p = 0.000
Distance to the place where firewood is collected (km)	< 2	114	101	80	U = 4,994.000
	≥ 2	98	112	102	Z = -1.329
					p = 0.184
Distance of the *Fokontany* to the communal market (km)	≤ 8	166	109	89	U = 3,387.500
	> 8	46	97	82	Z = -1.169
					P = 0.242

(a): number of trees on the family farm; Z: critical value of the Mann-Whitney test; U: Mann-Whitney test; KW: Kruskal-Wallis test; ddl: degree of liberty; p : p-value
Source: D. R. Rakotondratandra.

Total number of banana trees and yam plants

The number of trees on the farms increases with the number of banana trees and yam plants (p = 0.000). The differences are statistically significant between farms without banana trees and yam plants and those having ≤ 200, between the formers and farms having > 200 of such trees and plants as well as between those possessing ≤ 200 and those having > 200. These results indicate that tree farming differs in intensity according to the number of banana trees and yam plants the households grow on their individual lands.

Integration of trees with (pluri)annual crops

The number of trees on the farm varies according to whether the household does or does not associate trees with (multi)annual crops (p = 0.000). In fact, households who practise tree-crop integration also possess more trees on their farms (mean rank of 116) compared to those who

Table II.
Factors hindering the establishment/extension of *tsabo*[a] according to producers' perceptions.

List of factors[b]	Responses		Percentage of observations
	Effective	Percentage	
Problem of marketing	113	19.8%	42.6%
Problem of thievery	98	17.1%	37.0%
Lack of land	88	15.4%	33.2%
Problem of transportation	70	12.2%	26.4%
Difficulty to grow/care for crops[c]	58	10.1%	21.9%
Lack of seedlings	56	9.8%	21.1%
Other[d]	46	8.0%	17.4%
It takes years before one can get the first harvest	19	3.3%	7.2%
Fear of cyclone	17	3.0%	6.4%
Fear of bush fire	7	1.2%	2.6%
Total	**572**	**100.0%**	**N= 265[e]**

a. Coffee, clove, banana, big yam, vanilla, litchi, breadfruit, and moringa.
b. Group of dichotomies put in table at value 1.
c. Due to lack of time, of labour force, of technical knowledge or means (including the financial one).
d. Due to old age or the fact of already possessing trees on the farmland.
e. Sample size.
Source: D. R. Rakotondratandra.

Table III.
Representations of *tsabo* by 10 local nurserymen.

List of responses	Frequency	Percentage valid	Percentage accrued
Perennial crops/association of (export) crops	7	36.8	36.8
Source of cash/lasting livelihood	7	36.8	73.7
Source of food	5	26.3	100.0
Total	**19**	**100.0**	

Source: D. R. Rakotondratandra.

do not (mean rank of 51). This is explained by the fact that trees are often used to shade and support (multi)annual crops such as yam, pepper, vanilla, and pole beans, whereas fast growing crops like bananas are established to provide shade to young trees and provide income until those trees start producing.

Income generated from farming (Ariary)

The number of trees on the farm increases with the amount of income the household generates from farming ($p = 0.000$). Effectively, the differences from the pairwise test are statistically significant between farms without income from farming and those getting < 400,000 Ariary ($p = 0.020$), between the formers and farms earning ≥ 400,000 Ariary ($p = 0.000$) and between farms getting < 400,000 Ariary and those earning ≥ 400,000 Ariary ($p = 0.000$).

The influence of the local context on the producers' motives to establish and/ or extend *tsabo* tree numbers and species diversity

Statistical results shown in table II reveal six factors constraining producers from establishing or extending a sample of eight target *tsabo* species, namely: access to markets (19.8%), theft (17.1%), lack of land (15.4%), problem in transporting the produce to markets (12.2%), difficulty to establish/care for crops (10.1%), and lack of plant material (seeds and seedlings) (9.8%). However, factors related to the long-term nature of return on investment (3.3%), fear of cyclones (3%), and bushfires (1.2%) do not constrain producers. These results indicate that problems related to both crop evacuation and means of production as well as the local context are at play in *tsabo* establishment/extension.

The influence of *tsabo* socioeconomic characteristics on its adoption potential

The analysis of the focus group interviews revealed that, from the colonial era to the 1970s, different State-led programmes were implemented to diffuse the monoculture of cash crop species (like clove trees, coffee trees, litchi trees, pepper, banana, and vanilla, etc.) along Ivoloina valleys. However, the local producers have always associated these with food crops (i.e. chilli, big yam, vegetables, etc.) or/and with small animal husbandry (zebu, pork, and poultry). More than 80% of the sample households do *tsabo* agroforestry because it is very important to their existence. Group discussions with ten local nurserymen working for nongovernmental projects diffusing agroforestry as an alternative to *tavy* consider *tsabo* as a lasting source of cash/livelihood in 36.8% of their answers to our questions *fameloman-tena maharitra* (table III). Effectively, *tsabo*-based agroforestry contributes a lot to the economic and sociocultural lives of the local communities: as a place where children socialize to rural life when helping their parents with farming activities and as a source of useful materials (medicinal plants, firewoods, etc.), food (breadfruit, jackfruit, yam, vegetables, etc.) and cash income (allowing the producers to accomplish and maintain community customs including *tsaboraha*: a ritual where zebu is sacrificed and pieces of beef are offered to the dead ancestors while the living descendants share the rest of the carcass).

Thanks to their decades of existence in the Betampona landscapes, therefore, *tsabo*-based agroforestry is highly favourable to the local peasants' systems of production, for they are technically easy to understand, economically profitable and culturally compatible with the villagers' values (table IV). Despite these advantages, *tsabo* agroforestry adoption is not generalized and only practised on small parcels of less than one hectare, often on marginal, degraded land no longer suitable for *tavy*. Thus, many households no longer wish to establish a new *tsabo* field (20%) or to extend their old ones (43%), preferring monoculture cassava or rice growing (41%) with almost the two-thirds of households doing so using *tavy* methods.

Table IV.
Characteristics of *tsabo*-based agroforestry systems which may influence their rates of adoption.

Characteristics	*Tsabo*-based agroforestry systems
Relative advantage	- Because few cares are necessary in *tsabo* farming, producers can do other activities: one/two yearly weeding suffice and, except for vanilla farming, no other care is required before harvest - *Tsabo* serves as a lasting source of cash
Compatibility	- These agroforestry systems have been diffused and practised for more than 40 years - These agroforestry systems are embodied into the local values: a source of cash that allows farmer households to perpetuate ancestral customs without having to use rice from their granaries, a place where children socialize to rural life, and an accessible source of food during hard times
Complexity	These techniques are very easy to use: farmers are used to growing cash crops from their early childhood
Experimentability	It is obvious for a farmer to try one tree on the edge of his fields or yard before growing them on a large scale
Observability	No demonstration plot is needed as interested farmers can observe fields belonging to their neighbours

Source: D. R. Rakotondratandra.

The influence of diffusion strategies on *tsabo* adoption potential

The focus group interviews indicated that two distinct initiatives with differing strategies marked the history of *tsabo* diffusion in Betampona region (table V). State-led initiatives in the 1896-1990 period sought to fully organize cash crop planting and marketing by providing farmers with all technical supports they needed: on-farm training, distribution of seedlings, rehabilitation of paths/roads, creation of marketing cooperatives, and integration to international market agreements. Nongovernmental initiatives since 2000 used quite different diffusion strategies. First, they provided beneficiaries with theoretical training and limited seeds and seedlings, without following up their planting and management nor organizing the market for the produce. Second, these projects mainly promoted systems based on annual food crops grown in rotation or association but had little interest in diffusing tree-crop polyculture or small livestock husbandry. Third, the great majority of these initiatives only supported producers who were members of associations, disadvantaging those who were not.

The influence of historical and anthropological factors on farmers' willingness to abandon *tavy* for *tsabo*

The history of agricultural extension efforts in the study area shows that indigenous producers started to extend *tsabo* farming when the colonial farms collapsed in the 1940s due to the difficulty exporting products during World War II as well as the reprisals against the colonizers in 1947. Established as monoculture in the beginning, the four export crops (coffee, clove, banana and pepper) diffused as agroforestry orchards by State-led programmes since the 1970s are nowadays fully integrated into the farmers' systems of production. According to eyewitnesses, these crops covered more than 10 km wide along the rivers/roads before they collapsed in the 1980s, thus "hiding the sun underneath the forest-like *tsabo* trees". As State-led programmes did not provide extension and marketing services for food crops nor animal husbandry, producers relied on cash generated from *tsabo* to buy staple food. Our group interview with local nurserymen revealed that producers grew and valued cash crops more than rice in the 1970s for the latter was cheaper: clove was sold at 40-60 Ariary a kilogram, coffee at 24-40 Ariary and rice at 11 Ariary. However, our group interview with local producers revealed that people around the Betampona Reserve turned their *tsabo* fields into *tavy* mainly to produce rice when the price

Table V.
Initiatives aiming at diffusing *tsabo* in the Ivoloina valleys and buffer zone around Betampona Reserve.

Domains of intervention		Number out of three state-led initiatives (1896- 1990) [a]	Number out of eight non-governmental initiatives (2000- 2018) [b]
Technical supports	Theoretical training	3	3
	Demonstration plots	3	2
	On-field follow-up/control	3	3
	Distribution of seedlings	3	3
	Organization of the market for the produce	3	0
Types of agricultural systems diffused	Monoculture	2	0
	Food- cash crop tree polyculture	1	3
	Rice- cash crop tree polyculture	0	1
	Food crop rotation/association	0	4
	Small husbandry	0	2
Selection criteria of beneficiaries	Member of association	0	7
	Any household interested	3	1

[a] (1) Fonds de soutien du café et Caisse de stabilisation des prix du café de Madagascar et dépendances (1953-1960). (2) Opération banane d'exportation (1960-1980s). (3) Opération café-poivre-girofle et caisses de stabilisation des prix (1964-1980s).
[b] (1) NGO SAF/FJKM (2000/2017...). (2) NGO SECALINE (2006). (3) Eco-Regional Initiative - ERI (2007-2009). (4) Projet de soutien au développement rural - PSDR (2007-2010). (5) Projet de restauration forestière de Betampona (2007...). (6) Formation professionnelle et d'amélioration de la productivité agricole - FORMAPROD programme (2016-2021). (7) Save Our Species - SOS-LEMURS project (2007-2020). (8) Conservation of Key Threatened Endemic and Economically Valuable Species in Madagascar - COKETES project (2017-2021).
Source: D. R. Rakotondratandra.

of export crops collapsed and cyclones destroyed the crops in the 1980s. In fact, the farmers who already suffered from cyclones damages and the end of State-led programmes (which organized the planting and marketing of export products) were forced to find what to eat from day to day, so they converted their *tsabo* fields (which were invaded by *takoaka [Rubus molluccanus]* because no one cared for them) into *tavy*.

It comes out from our discussions with respondents that Betampona farmers acknowledge that *tavy* is neither environment-friendly nor economically viable but they insist on the unavailability of alternatives to explain why they keep practicing it. In fact, some producers noticed the widespread of insect pests destroying the rice plants due to the repetitive practice of bushfire and *tavy* while some others indicated on the economic disadvantages of these agricultural systems because people invest a lot of money and time for preparing, seeding and weeding the field, and also for harvesting but they harvest a very poor quantity of paddy.

According to Betampona producers' conception, "*a well-off farmer is the one who is producing a surplus of food, i.e. rice*". However, very few farmers produce a surplus: 52% of the households we interviewed are not rice self-sufficient. Consequently, Betampona producers qualify *tsabo* as lasting crops that future generations can inherit (*voly maharitra holovain'ny taranaka)* but they firmly stick to *tavy* rice production as it occupies a determinant place for their daily lives as well as for the *Betsimisaraka* cultural identities. More strikingly, 50% of the answers we got from the group of nurserymen identified *tavy* as a means for producing rice while one answer designed it as an "*alternative to irrigated rice*". In fact, Betampona producers think that "*clove [so are coffee, vanilla and cola nuts] cannot be served alone as a staple food as rice can, but it needs to be sold before one can buy food*". Or cash generated from *tsabo* does not suffice to provide households with all their needs: foods, hospital fees, children school fees, contribution to community events such as *tsaboraha ceremonials,* etc.

Discussion

Results from nonparametric tests (table I) reveal that *tsabo* tree growing varies in intensity according to nine variables: (1) marital status of HH, (2) level of education of HH, (3) main activity of HH, (4) participation of HH to Betampona reforestation project, (5) total size of lands on the farm, (6) total size of fields allocated to food crops other than rice, (7) total number of banana trees and yam plants, (8) integration of trees with (multi)annual crops**,** and (9) income generated from farming. Nevertheless, only variables (1) through (4) represent the HH's characteristics, the remaining variables relating to those of the farms. Or, if HHs without partners (variable 1) only count for 10% of the

sample, the pairwise tests showed that variables (2) and (3) do not fully explain the differences in number of trees grown on-farm, which is inconsistent with other findings (Sood, 2005). Sole variable (4) is statistically significant because participants to Betampona reforestation project (39.1% of the sample) benefited from material/technical advantages (training, seeds/seedlings/tools, etc.), which allowed them to invest more in tree growing. Therefore, the statistical tests reject the factor (1) related to the characteristics of adopters but support the influence of those of the farms on the intensity of tree growing (Sood, 2005) (i.e. variables 5 through 9).

We saw previously that *tsabo*-based agroforestry is highly compatible with the local way of life, hence factor (2) related to *tsabo* characteristics cannot explain why producers are not scaling them up as an alternative to *tavy*. This reinforces the role of the following exogenous factors as some *tsabo* crops (vanila, clove, peper) are not consumed locally (or minimally), and have to be marketed to earn money to buy subsistence food. In absence of markets and transportation (to get cash crops out, and rice in), it is more economical and logical to focus on growing one's own food crops first.

Three main points are worth noting from the history of *tsabo* diffusion in Ivoloina valleys (Rakotondratandra, 2021). Firstly, state-led initiatives took all measures (i.e. on-farm technical training and follow-up, road rehabilitation, creation of marketing cooperatives, and integration to foreign market agreements) (table V) to better organize the planting and marketing of the aforementioned four cash crops since the 1950s. Consequently, these crops shaped the landscapes around Betampona Reserve. Secondly, three conjunctural factors led to the collapse of *tsabo* farming in the Ivoloina and Ifontsy valleys since the 1980s. At the international level, prices of export crops from the African, Caribbean, and Pacific (ACP) countries tended to decrease (Ranarivony, 1999). At the national level, the political decision of the Malagasy State (under pressure of the International Monetary Fund, World Bank and international lenders) to liberalize the agricultural sector as part of the 1980-90s Structural Adjustment Programs (SAP) provoked a rural crisis in remote areas like Ivoloina, i.e. a worsening of geographical isolation, insecurity and poverty, and a total disorganization of marketing channels for agricultural products (Rakotondratandra, 2021). As a result of State budget deficits (Hugon, 1988), in fact, roads lacked maintenance and rural isolation increased, which gave less room for producers to negotiate the price of their produce while allowing middlemen from getting high profit margins (Razafimandimby, 1997). At the local level, finally, frequent cyclones destroyed *tsabo* plantations as well as damaged roads and bridges, further weakening the farmers who already suffered from the end of the State-led agricultural extension initiatives within the framework of the SAP (Rakotondratandra, 2021). Thirdly, non-governmental programmes (2000s to 2018) which substituted for the State ones privileged members of associations and the diffusion of *tsabo* but had little interest in promoting animal- or rice-based agroforestry and they made no attempt to organize the marketing of agricultural products (table V). Moreover, some projects' stakeholders fear for the spread of potentially invasive *tsabo* species if producers plant them within or close to the Reserve's PZ. Such strategies did not encourage the scaling up of *tsabo* farming as an alternative to *tavy*. Faced with the aforementioned rurality crisis, in fact, the price of imported rice from Toamasina market continued to increase whereas that of *tsabo* produce from Betampona region dropped enormously. As a result, many Betampona producers converted their *tsabo* fields into *tavy* mainly for rice production. Indeed, respondents who no longer wish to establish new *tsabo* fields or scale up their existing ones cited the problems of marketing (19.8% of answers) and transportation (12.2% of answers) as their limiting factors (table II). In 2018, for instance, green vanilla beans were sold 10,000 Ariary (about 3 dollars) a kilogram on farms while the price of dried vanilla reached 600 dollars in Europe (Rakotondratandra, 2021). In this context, Betampona producers continued practicing *tavy* as the surrounding valleys were too small to allow them to extend irrigated rice farming at a large scale. More than 62% of the sample households relied on *tavy* to produce rice which covered up to 21% of the total surface area of farms, i.e. 60% of that of the sample rice fields (Rakotondratandra, 2021). This was unfavourable to the large-scale adoption of *tsabo*, for farmers voluntarily left the available hills *tanety* and slopes lie fallow until the next cycle of *tavy*. Despite the availability of *tanety*, 15.3% of the answers provided by respondents who no longer wished to establish/extend *tsabo* farming considered the lack of land as a constraining factor (table II).

Previous investigations carried out in African countries (Russel and Franzel, 2004) and also in Colombia (Heath and Binswanger, 1996) insisted on the importance of political decisions, absence or lack of development of markets and infrastructure in encouraging or discouraging farmers to adopt agroforestry technologies. In line with these findings, our research focusing on the Betampona context confirms the initial factor (3) according to which the ways the target agricultural technology is communicated and diffused as well as the factor (4) advancing that the context in which this technology is integrated during the diffusion process impacts the producers' decision to adopt it or not.

Since our results show that economic reasoning is not enough to explain why Betampona farmers resist abandoning *tavy*, an anthropological one may help do so. The *Betsimisaraka* are the dominant ethnic group in this region and considers *tavy* a part of its cultural identity (Hume, 2006). Despite its ban since the promulgation of the code of 305 articles in 1881, rainfed-rice and *tavy* – introduced to Madagascar during the first millennia AD by Austronesian immigrants (Beaujard, 2011) – are still widespread nowadays for it expresses more than a farming technique, incorporating religious meanings symbolizing farmers' relation to God, to the deceased ancestors and to all the spirits inhabiting the landscape (Vicariot, 1970). Rice farmed on *tavy* involves cults, taboos and offerings to the spirits at different stages of the production, i.e. before clearing, burning and seeding the land, before harvesting ears, and finally before trans-

porting paddy to the village (Fanony, 1975; Hume, 2005). Such rituals are not practised and required for irrigated rice. This makes *tavy* elimination very difficult because, for a *Betsimisaraka* farmer, abandoning this lifestyle also means giving up a part of his identity (Hume, 2006). This is why, despite the mediocrity of the yield, Betampona producers continue *tavy* for their psychological consolation to get rice, a product that allows them to honour their cultural values and ancestors, and which consumers want (Rakotondratandra, 2021). Over time, rice became both the Malagasy staple food and an essential ingredient used for the accomplishment of some *Betsimisaraka* community rituals, namely the *laza* (circoncision) and the *tsaboraha* described previously (Lahady, 1979). Owing to the importance of rice in the cultural and daily life of the *Betsimisaraka*, its availability also determines *tsabo*-based agroforestry dynamics. Research in different locations in Madagascar help confirm this thesis.

Osterhoudt (2017) concluded that Imorona producers in Northern Madagascar care very much for their vanilla-based agroforestry. Each field has sacred sites (tomb, big rocks, etc.) which connect the owner's family members with the spirits and their deceased ancestors; their family histories are traced through daily works on the field (weeding, harvest, etc.). Besides, vanilla agroforestry allows the owners to meet their needs (including the purchasing of both rice and children's toys) while insuring their descendants' access to resources, namely land and vanilla vines, thanks to their prestige in society. For these reasons, Imorona producers never turn their vanilla agroforestry to *tavy* for paddy production, hence only 3% of the total surface area of this county are occupied by upland rice against 29% for agroforestry, 13% for secondary forests and 19% for natural forests.

While focusing on Andapa producers in Northeastern Madagascar, Laney and Turner (2015) noticed that farmers continue doing *tavy* for rice production even though commercial crops (clove, vanilla and coffee) are much more profitable in terms of income generation. To explain this dual persistence, these authors advanced the social relations of property hypothesis according to which the utilization of rice is socially controlled while that of liquidity is not. In fact, rice constitutes a solid capital that is difficult to access whereas cash generated from export crops can easily be expended for the daily needs of the farmer household, for the caring of extended family members during hard times and for unwise utilization just to show one's social prestige. Our results confirm Laney and Turner's findings as rice availability effectively influences Betampona farmers' attitude toward *tsabo*-based agroforestry. In other words, they reserve their lands to *tsabo* plantations only if they have access to rice. So, unless projects promoting the large-scale extension of *tsabo*-based agroforestry as a substitution to *tavy* are able to both resolve the above-mentioned rurality crisis and ensure a steady and ample supply of rice, they would fail. Instead, we recommend the diffusion of *tavy boka* which is an innovative agroforestry system that can associate *tsabo* trees with rice farming without using fire.

Conclusion

This research shows that 63% of respondents from villages located in the buffer zone around Betampona Reserve still do *tavy* for rice production, and 20% to 43% of them no longer wish to establish a new *tsabo*-based agroforestry nor to extend their old ones. It concludes that the impediments to the large-scale adoption of *tsabo* as an alternative to *tavy* have structural as well as cultural dimensions. A series of unfavourable historical events, political decisions, and diffusion strategies provoked a rurality crisis (geographic isolation, increased insecurity and poverty, complete disorganization of market channels for agricultural produce) that discourages farmers from extending their *tsabo*. As *tavy* and rainfed rice define the local cultural identity, farmer prioritize rice production by this method to ensure subsistence and livelihoods.

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Data access
In application of the FAIR principle, the sources of the data used in my article are freely accessible via the DOI :
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It is hoped that the author will be informed and cited at the time of use, and that the article and dataset will be cited.

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