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Characterisation of the metabolism of two rural territories in Madagascar: case of the Fokontanys of Miarinarivo and Malaza, district of Betafo

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Photographs on the cover were taken by Jonathan Vayssières, May 2023.

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Glossary

Description of the studied region and stakeholders

AVSF: Agronomes et Vétérinaires Sans Frontières. NGO present in the studied territories with projects regarding nutrition.

CEFFEL: Farmer organisation present in villages near the studied areas.

Leucofruit : Local vegetable processing company, working through contractual agriculture.

Malto : Local brewing company, working through contractual agriculture.

Socolait : Local milk processing company, collecting most of the milk in the region.

Vakinankaratra : administrative region of studied areas, of which the capital is Antsirabe.

Betafo: rural city near the studied areas. It is the main town of the district of the same name.

Mandritsara: name of the commune of the studied areas. Commune is an administrative delimitation grouping several villages.

Milk triangle: Geographical region situated between Tsiroanomandidy (West), Manjakandriana (East) and Ambalavao Tsienimparihy (South) where milk production activities have developed. The studied areas are at the heart of the milk triangle.

Kizozi: *Pennisetum purpureum*. Perennial cultivated fodder.

List of other abbreviations

CIRAD : Centre International de Recherche pour l'Agriculture et le Développement.

DINAAMICC : Démarches INtégrées et Accompagnement pour une Agriculture familiale à Madagascar Innovante et résiliente aux Changements Climatiques (Research project).

HCPC : Hierarchical Clustering on Principal Components (Statistical tool).

PCA : Principal Components Analysis (Statistical tool).

TLU : Tropical Livestock Unit.

Malagasy words used in the text

Cantina : farmer unit, which can contain 4kg of paddy rice.

Entana: farmer unit representing a maximum amount which can be carried on one's head

Fokontany: administrative delimitation, assimilated to a village

Kapoaka: 220mL can, used as a unit for grain products such as rice.

Sobika: Baskets used for carrying products. Their size ranges from a volume of 10 to 30L.

Tanimbary: irrigated field

Tanimboly: non-irrigated field

Tanimkazo: wood plantation

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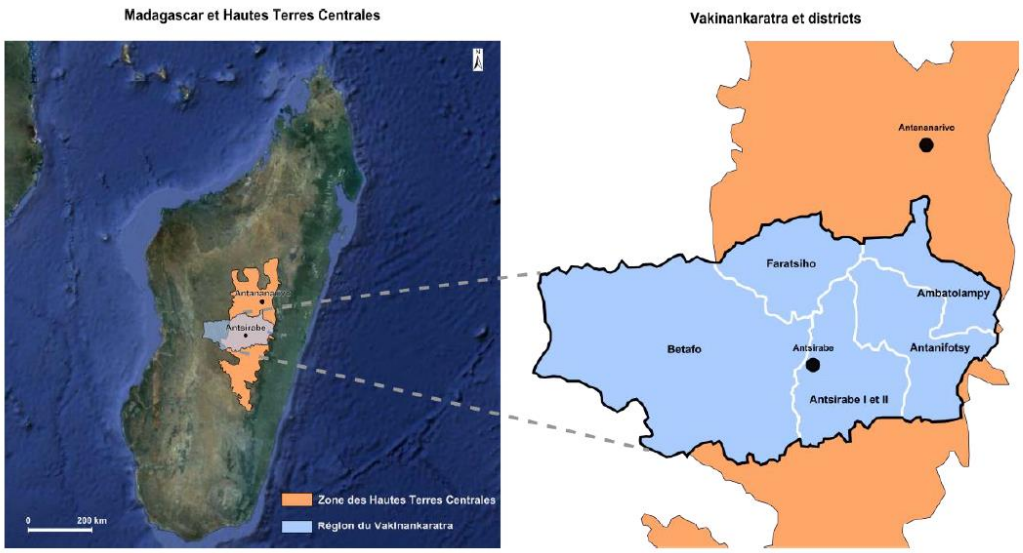

Figure 1: Location of the district of Betafo. In orange, the Malagasy highlands, in blue the Vakinankaratra region (Alvarez, 2012).

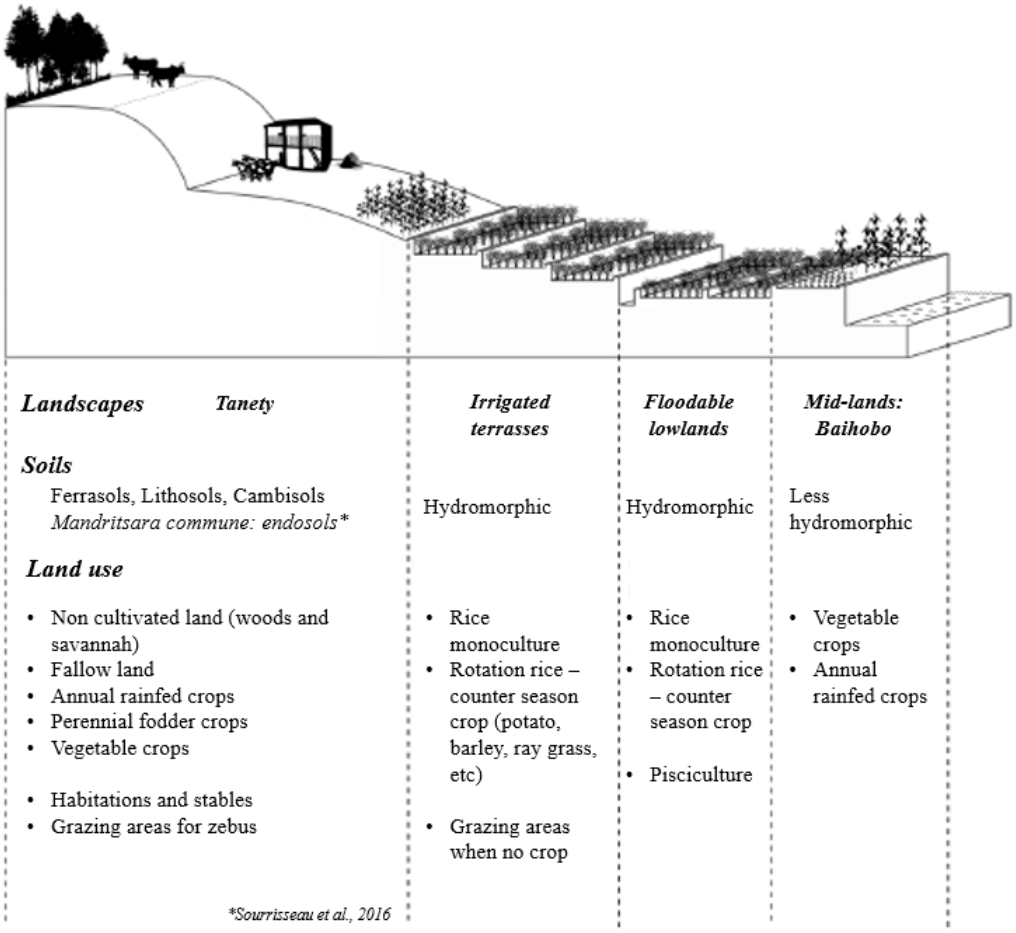

Figure 2: Agricultural landscape organisation in Malagasy highlands (adapted from Alvarez, 2012).

I. Introduction

1. Context of study

1.1 Situation of Madagascar

Madagascar is a big island country, located south-east of the African continent, under the tropics. It presents a large variety of climates and soil types, associated to a diversity of agricultural production systems. As most countries in the Indian Ocean, it is vulnerable to extreme climatic events such as droughts and cyclones. It is also vulnerable to climate change, especially given the extreme poverty striking the island.

With a GDP of 505 USD per capita and 80,7% of the population living below the poverty threshold (World Bank, 2023), Madagascar is among the poorest countries in the world. 64,9% of the population is in a situation of food insecurity, and 38% of children under 5 years old suffer from malnutrition (Faostat, 2023). At the same time, the country presents high population growth, with a population which has almost doubled in the last 20 years (World Bank, 2023).

Given these stakes and knowing that 60,8% of the population lives in rural areas (Faostat, 2023) practicing smallholder farming, actions in favour of agroecological development are more than needed in order to reduce the vulnerability of smallholders to food insecurity, economic fluctuations and climate change.

1.2 Madagascar uplands: geophysical context

The district of Betafo is situated in the Vakinankaratra region, in the Malagasy highlands (Fig. 1; Table 1). It is a mountainous region, characterised by a high-altitude tropical climate. Most of the highlands have an altitude comprised between 1200 and 1800 meters (Braun et al., 1997). The seasons are split in a warm and humid summer (October to April) and a cold and dry winter (April to October), with a mean annual temperature inferior to 20°C (Sourisseau et al., 2016).

The region has an agro-pastoral vocation, with landscapes highly anthropized. Due to deforestation correlated to high population density, little forest cover is left (Sourisseau et al., 2016). The landscapes are schematically organised along the topographic sequence shown in figure 2, depending on soil type and water availability. They present a continuous alternation of hills and valleys, with different land uses depending on the season.

Vakinankaratra is known as one of the most productive regions of Madagascar regarding agriculture, with a wide range of productions such as rice, milk, vegetables, and temperate fruits. The soils are fertile, and the know-how of the farmers is well renowned (Sourisseau et al., 2016). Products are sent throughout the country and abroad.

Table 1: Administrative delimitations for the two studied territories (1) and (2)

	Studied area
Region	Vakinankaratra
District	Betafo
Commune	Mandritsara
Fokontany	Miarinarivo (1) and Malaza (2)

Administrative delimitations in Madagascar are ranked as such (from larger to smaller scale): regions, districts, communes and fokontanys.

Table 2: Average number of livestock per farm in Vakinankaratra and Madagascar (Sourisseau et al., 2016)

	Cattle	Pigs	Small ruminants	Poultry
Madagascar	5,58	0,50	0,80	12,94
Province Antananarivo	2,63	0,87	0,06	10,97
Région Vakinankaratra	2,14	0,89	0,04	8,55
Betafo	2,85	1,22	0,01	10,84
Ambatolampy	1,47	0,91	0,06	9,48
Antanifotsy	2,08	1,16	0,13	11,12
Faratsiho	2,54	0,53	0,02	14,05
Antsirabe	1,82	0,54	0,00	8,24

Source : MPARA, 1988c et calcul des auteurs

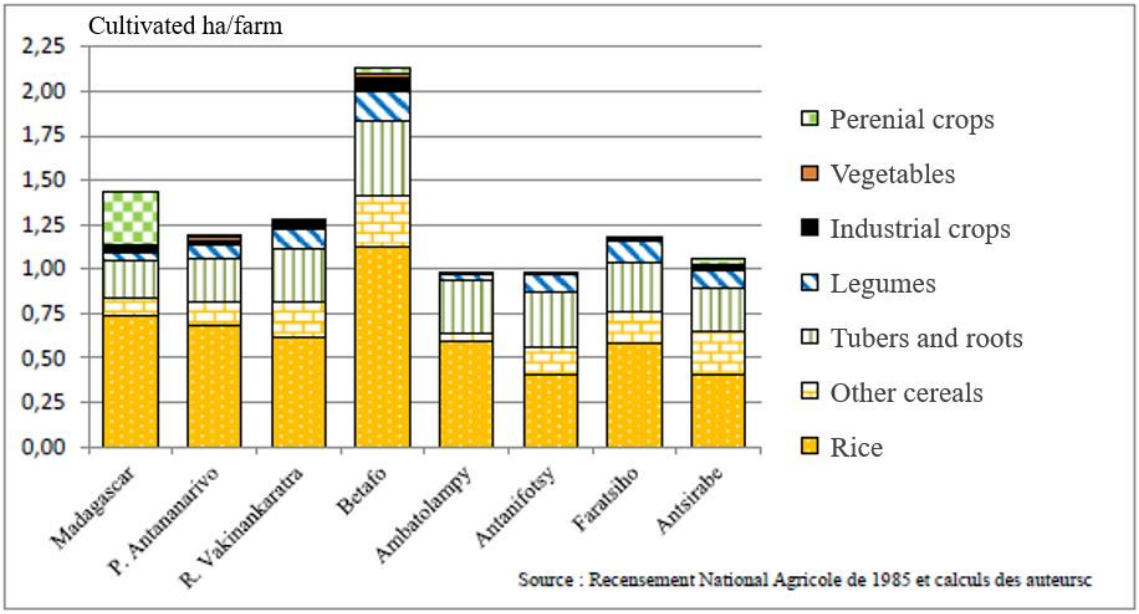

Figure 3: Average crop distribution per farm in Vakinankaratra and Madagascar (Sourisseau et al., 2016)

1.3 District of Betafo: crop-livestock integration within smallholder farming

The district of Betafo has several specificities contributing to its productivity: the soils are volcanic fertile soils with high organic matter content (Bied-Charreton, 1970), the water management is particularly well handled, allowing large shares of irrigated land (Bouayad-Agha et al., 1995) and crop-livestock integration is highly represented (Alvarez, 2012).

The two most important productions in the region are rice and milk. Rice is culturally the basis of Malagasy diet (Rakoto Ramiarantsoa, 1995), and is cultivated both for self-consumption and sales. Milk is the most distinctive production of the region, with 45% of milk produced within the so-called "milk triangle" being produced in Vakinankaratra (Bélières and Lançon, 2020). Milk would be the fourth agricultural product of the country (Andriamanalina, 2007).

The farms in the district of Betafo are small and diversified, with mean cultivated area of 1 ha per household and a mean of 2,85 cattle per household (Sourisseau et al., 2016). In Vakinankaratra, it is near Betafo that we found the more irrigated lands (used for rice culture) and the more cows per household (Table 2). Productions are diversified: rice, other cereals, tubers, legumes, and vegetables (Fig. 3) and the access to markets is facilitated through the presence of the cities of Betafo and Antsirabe, both big agricultural outlets.

Livestock plays an important role in these farming systems, agronomically, economically, and culturally. Zebus are used as draft cattle and capitalisation of financial resources, while milking cows and monogastric animals provide a regular income to households. Crop-livestock integration is at the basis of both soil fertility and livestock feed (Alvarez, 2012). Most of the culture residues, such as rice straw, are used for animal feed or bedding. Therefore, there is a huge pressure on all types of biomasses produced which can be used for livestock (Alvarez, 2012).

Despite these advantages, the food needs are not met, rice production covering on average 4 months of the consumption of the households (Sourisseau et al., 2016). Moreover, Vakinankaratra is one of the regions where the malnutrition rate is the highest (Sourisseau et al., 2016), suggesting that other factors than food production are influencing the household diets.

2. Co-conception of collective solutions at territorial scale, based on agroecology and circularity concepts.

Agroecology is a polysemic term, with principles that can be applied at different scales. Considering a territory scale, it has to do with the ecology of food systems (Wezel et al., 2009), and is therefore incorporating general concepts such as circularity (FAO, 2018; HLPE, 2019).

Given the context and stakes in Betafo district, the application of general agroecological principles for the development of the region is primordial. The farms need to strengthen their resiliency towards climate change and economic fluctuations, through activity diversification and virtuous practices which would guarantee their food autonomy in the long run. In theory, the less a territory depends on external markets for its subsistence, the more resilient it is and the more sustainable the practices since they must be based on local resources. The circularity paradigm implies reducing dependency to external inputs, enhancing nutrient efficiency use and reducing any form of nutrient losses, for nutrient cycles to be closed as much as possible (Kleinpeter et al., 2023).

Again, according to agroecological concepts, the stakeholders of the territory must be involved for transitions and evolutions to occur and be implemented in the long run, through co-creation and knowledge sharing (FAO, 2018). When all interests are considered and the actions coming from actors already implemented who know well their territory, it is more likely that systemic and coherent innovations emerge.

This work is part of the initial phase of the DINAAMICC research project, whose aim is to develop collective solutions at farm and territory scale in the highlands of Madagascar.

The project « Démarches INtégrées et Accompagnement pour une Agriculture familiale à Madagascar Innovante et résiliente aux Changements Climatiques » (DINAAMICC) conducted by the CIRAD in partnership with multiple local actors of research and development has for main goal to contribute to reduce poverty and food and nutritional insecurity of the rural communities in the central highlands of Madagascar. It articulates itself around 4 products:

- In-depth knowledge about situations and constraints endured by smallholders due to climate evolutions and anthropic pressure.
- Co-development of practices enabling smallholders to be more resilient and sustainable within their natural environment (with farmers, farmer organisations and development actors).
- Promotion of relevant innovations among a large share of smallholders and organisations.
- Reinforcement of the capacities of farmer organisations and development actors to help in adapting to climate and environmental evolutions.

The work hereby conducted is part of the first product of the project in the Vakinankaratra region, which should serve as a basis for the 3 other products. It can be considered as a first diagnosis of the studied region and might be used in other projects as well who have the same region of action.

3. Use of the concept of territorial metabolism for a territorial diagnosis

To answer the goals presented above, in-depth knowledge about the general functioning of the territories, especially regarding autonomy and dependencies, are needed. Therefore, the notion of territorial metabolism was mobilised in order to provide a synthetic and systemic view of the studied territories.

3.1 Territorial metabolism: definition

The concept of territorial metabolism is based on an analogy between the functioning of societies and the biological definition of metabolism (Modotti, 2013). It deals with the way territories use and transform matter and energy, how they mobilise biosphere resources and return them or not (Barles, 2010). Territories depend on these resources and modify their environment by the use they make of them. Therefore this notion helps characterising interactions between society and nature, in a systemic way (Barles, 2010; Madelrieux et al., 2017). It makes visible how the flows circulate within territories, and the losses and/or environmental footprints associated (Haberl et al, 2019).

Territorial metabolism represents the flows of matter and energy. It can be put in a social and spatial frame, which will then be called territorial ecology. This implies having the knowledge of the governance of the flows, meaning how they result of political, economic, social and technical choices (Barles, 2010). This frame is necessary to understand and analyse the flows.

Metabolism approaches come in various forms, at different organisation scales (Grillot, 2021). Here focus will be made on what is called proto-metabolism, which analyses the raw matter flows. It allows to visualise the nature and intensity of the needs of a territory, without going in the details of biogeochemical cycles (Bonaudo et al, 2016; Grillot, 2021). Basically, it comes down to the collection of data allowing the quantification of productions and flows within the territory (Grillot, 2021).

3.2 Interest of territorial metabolism in this context

Therefore, using metabolic approaches seems particularly appropriate for getting a synthetic and systemic picture of the studied territory. Madelrieux and Redlingshöfer (2023) assert that they are particularly relevant for studying competitions in agricultural biomass uses between different sectors, such as agriculture, alimentation, health, and energy. It is precisely the subject of concern of the Dinaamiic project in Vakinankaratra. They say they make visible the negative effect of policies who do not consider the material and energetic resources of our societies, which is also relevant in our study case.

The methodology for obtaining a metabolism diagram means capturing different kind of information: the different components of the territory, which will be the pool of flows, and the flows in themselves which must be quantified (Grillot, 2021). For proto-metabolism, the construction of the diagram focuses on flows from agricultural production to its first transformation, in or out of the territory. It should be enough to identify dependencies and interrelations between stakeholders (Grillot, 2021). Having the different components means having identified the different stakeholders and the different kind of spaces, including different types of farms if relevant (Aubron et al, 2021). All this information has to be collected directly on the field, and will help creating references for further steps of the project.

Moreover, since the aim is to co-conceive solutions with different local stakeholders, producing a synthetic, schematic view of the territory makes the diagnosis more accessible to all types of actors. Indeed, local stakeholders need to appropriate themselves the results if true co-conception is to happen.

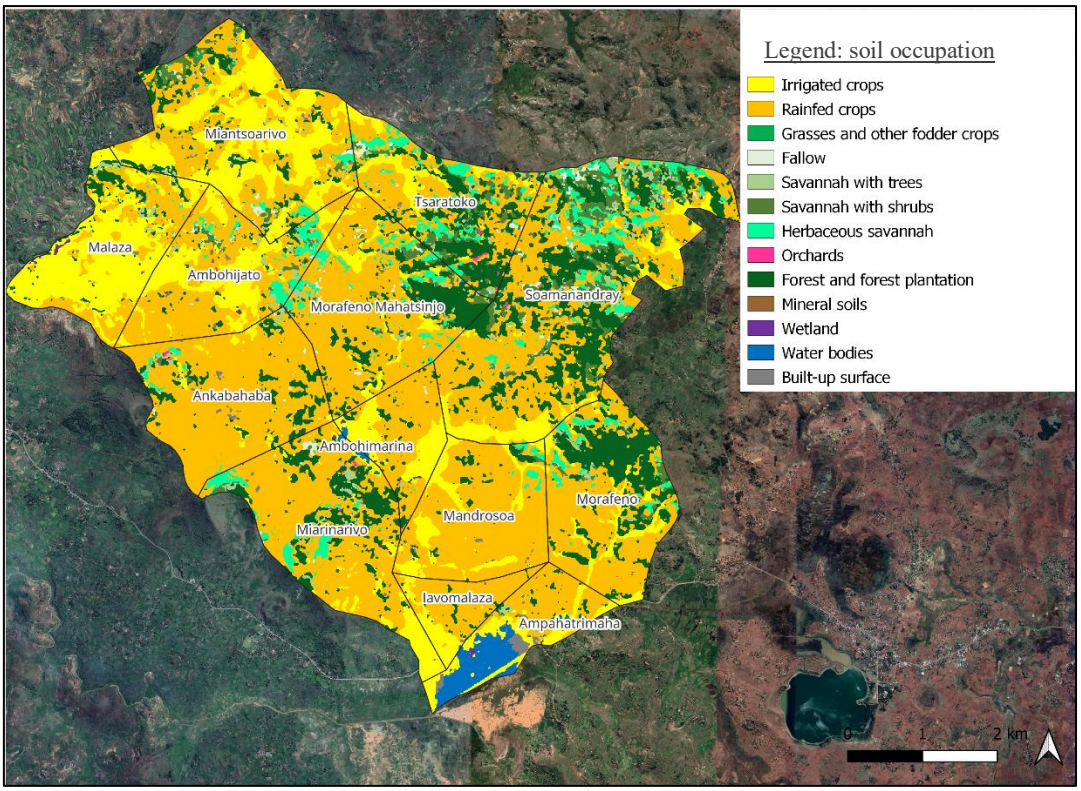

Figure 4: Soil occupation in the commune of Mandritsara, district of Betafo, with fokontany borders (based on the work of Lebourgeois et al., 2017)

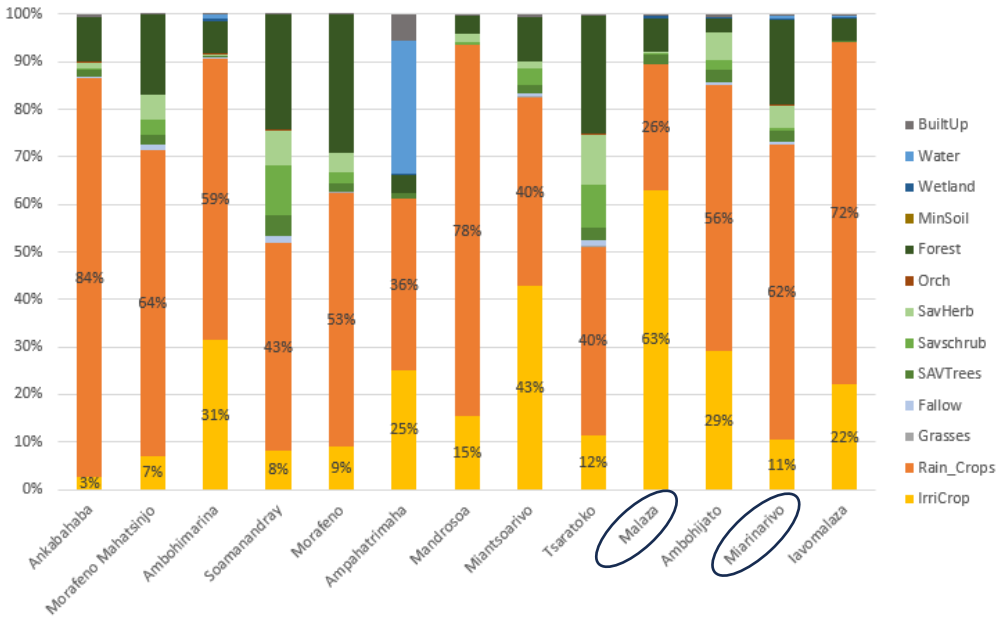

Figure 5: Soil occupation profile per fokontany in the commune of Mandritsara, and selected fokontanys (based on the work of Lebourgeois et al., 2017)

4. Aim of this study and selection of studied territories

The aim of this study is to provide a diagnosis at territory scale of biomass flows in two fokontanys (villages) of the district of Betafo. Focus was made on biomass flows, in order to provide a proto-metabolism diagram for each fokontany, which in light of what has been exposed before would answer the following questions:

- How are biomass flows organised at the scale of both these territories?
- Does this organisation reveal pressures, competitions in uses or main drivers of the flows?
- Does it reveal constraints and/or potential levers for optimisation of biomass circularity within the territories?

The studied scale was selected following two hypotheses: (1) Since the fokontany is a small administrative scale in which decisions and actions can be taken, it must be a territory the stakeholders appropriated themselves as their common zone of action. Biomass flows are therefore organised at this village scale. (2) Heterogeneity exists among fokontanys, with different levers and constraints on biomass flows. It is the reason why two areas of study were selected, with the aim of comparing and analysing the main differences between them.

Since there are few references studying territories at this scale, the design of a metabolism diagram was the result of the collection of data directly on the field, through different means. The hereby report presents the methodology used, the results in the form of diagrams of biomass flows at village scale, and a discussion based on these diagrams and observations from the field.

II. Material and methods

1. Selection of the studied areas

The intervention zone is within the district of Betafo. Focus was made on the commune of Mandritsara, situated between Antsirabe and Betafo, which is divided into 13 fokontanys.

Following the two hypotheses stated in introduction, the selection of the studied area was based on the visible differences between fokontanys. Some major differences reside in land uses, for which hypothesis was made that they are one main driver of the types of biomasses produced. Using the map of the soil occupation provided (Fig. 4), the soil occupation profile per fokontany was determined (Fig. 5) and two different fokontanys were selected:

- Malaza, a village very close to Betafo (30-minute walk), dominated by irrigated lands (63% of total area). This is very specific to some fokontanys of the region of Betafo, in which irrigation is very well handled (Bouayad-Agha et al., 1995).
- Miarinarivo, situated near mount Iavoko, a volcano crater. Cultivated lands are dominated by pluvial cultures (62% of total area), and a large share of the land is uncultivated savannah and shrubs. This fokontany is more representative of the others in the commune regarding land uses, and easily accessible compared to others further from the road between Antsirabe and Betafo.

Figure 6: Irrigated terraces in Malaza (left), natural areas and rainfed crops in Miarinarivo (right) (*Jonathan Vayssières, May 2023*).

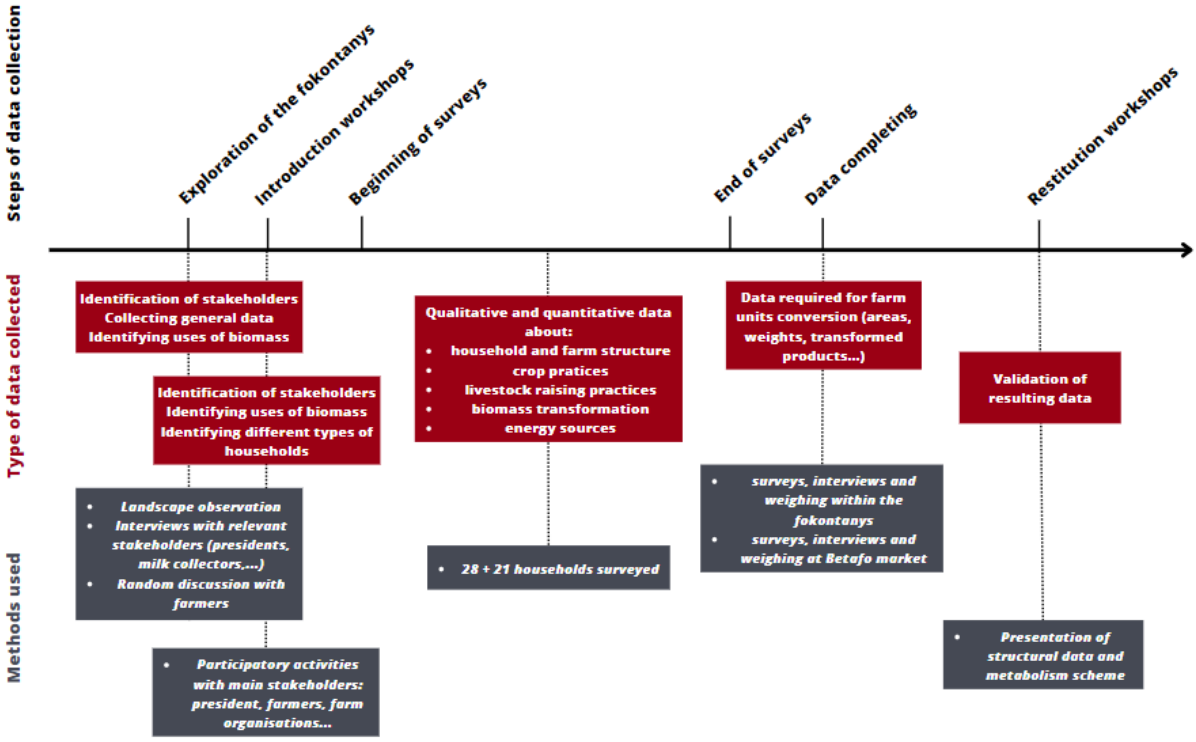

Figure 7: Description of the different steps of data collection, with type of data and method used.

Since the map used is dated from 2017 and given the quick evolutions which can occur in the region, it was important to check the validity of the soil occupation profile. 199 dots have been randomly sampled on the soil occupation map of Mandritsara and compared to a satellite image recently obtained (on-going internal works). As a result, 83% of the dots are validated over Mandritsara, 94% in Malaza and 50% in Miarinarivo. This big difference in Miarinarivo is either due to an error during the mapping process or some deforestation and previously cultivated land, now appearing as herbaceous savannah. It means the percentage of natural areas (27%) is probably underestimated in Miarinarivo but does not affect the selection.

2. Application of territorial metabolism

2.1 Elaboration of the structure of the metabolism diagram

Identification of the different components of the territory

As a basis for metabolism diagram, the pools of flows must be defined as different sub-systems. These pools were identified through observation (Fig. 6), discussion with the inhabitants and during the surveys, as progressively the different stakeholders and uses of spaces were more and more understood (first steps in figure 7).

Basically, 4 primary components have been defined: the crop system, the livestock system, the households, and the natural areas. The crop system is divided between irrigated land (*Tanimbary*), rainfed land (*Tanimboly*), field borders and cultivated woods (*Tanimkazo*). The livestock system is in reality several systems specific to each animal type. Natural areas can be defined as any non-cultivated space, from woods to very small areas within the village or cultures. In addition, some retailers and raw product processors are present in the fokontanys and have been added as a pool of flows. A more precise description of the existing pools of flows and categorisation is provided in annex I.

Typology of households

Since the flows must be driven by the households and the farm structure, another way of presenting the metabolism diagram is to differentiate types of households as different components of the diagram to visualize the flows between them. Therefore, attempts to get a typology of the households in each fokontany have been made in two different ways:

- Typology a priori, based on stakeholders' knowledge

During the introduction workshop (Fig. 7), a sequence was dedicated to categorising households. A typology made at Vakinankaratra's scale issued from on-going study in Dinaamicc project was presented, but the participants didn't recognize themselves in it. Following the main categories of this typology, the participants were asked to re-scale or modify it for it to suit what they know of their village. The typologies obtained for each fokontany are in annex II. Given the degree of interaction and participation, a good confidence level is accorded to the one from Miarinarivo but quite low for the one from Malaza.

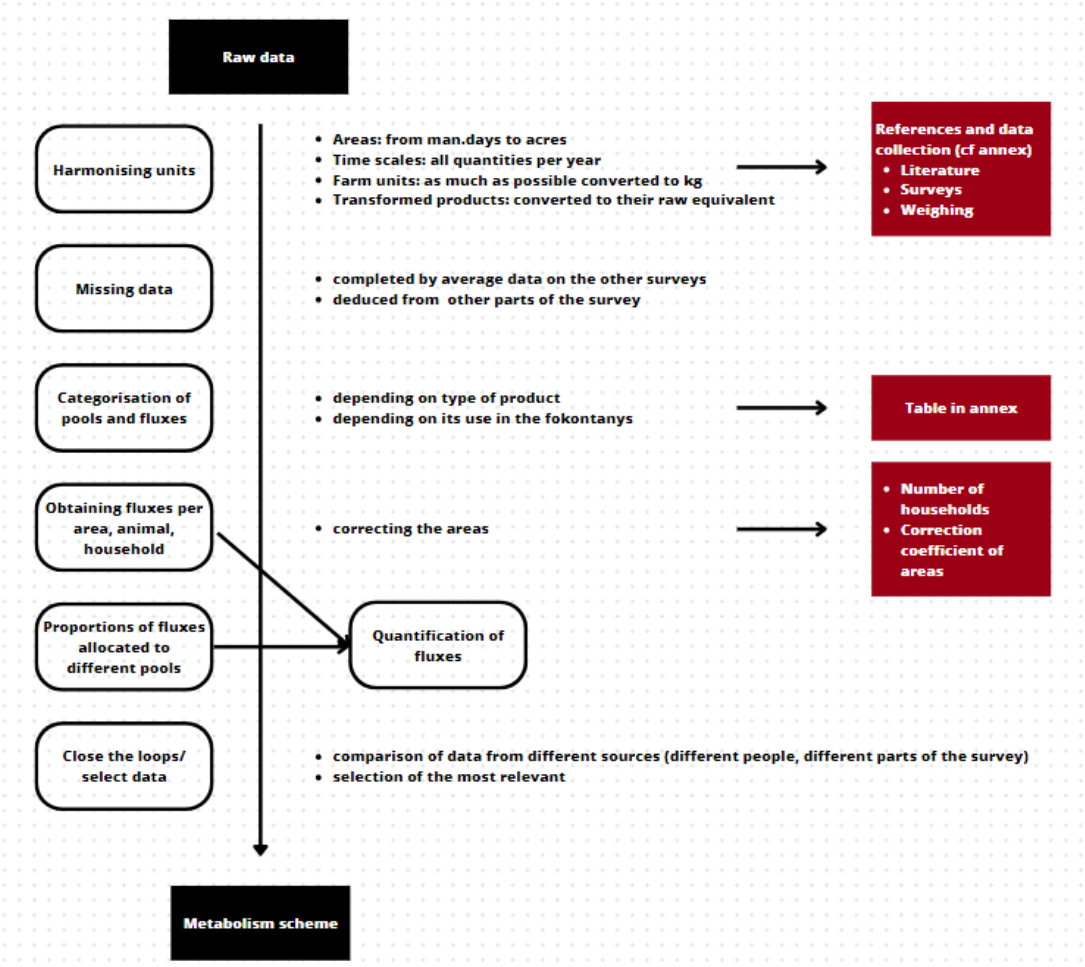

Figure 8: Relevant steps of data analysis and added data needed.

- Statistical typology, based on structural and functioning data

Once all the data was collected, it became possible to classify the households thanks to the data about the farm structure. Using statistical tools, i.e. PCA and HCPC, a new typology was established for each fokontany. Variables linked to flows were added as supplementary, to determine how they could be linked to this classification. In the end, the typologies used for categorising the households are presented in the results part and details are in annex III.

2.2 Data needed for the biomass flows' characterisation

Type of data collected

To establish the flows, different types of data are to be collected. Some structural data about the fokontany and households such as the number of households and people, the cultivated area, the number of animals. This will then be used to define the system and pools, and to extrapolate the data obtained from surveys at the fokontany scale.

Then for each production system, quantitative data is collected about all the entering and exiting flows. This means data is collected per crop, per animal production, per household needs. The data comes in various units and time scales, which is why it has to be harmonized afterwards. A certain number of steps and supplementary data were required throughout the data analysis (Fig. 8).

Given the multiple approximations and conversions which had to occur at all steps of data collection and analysis, the precision of the quantification of flows presented in the results is low. These numbers must be considered as an order of magnitude.

Conversions

For the proper representation of the flows and comparison to be possible, all the biomass quantities had to be converted to a common unity. Different types of conversions had to be done:

- Area units: estimating the size of the fields is tough for some farmers. In that case they usually give a surface in man-day. The conversion used was 1 man-day = 0,5 acre.
- Conversion from farm unit to standard unit: the conversions used appear in annex IV.
- Conversion between raw products and transformed products, such as paddy and white rice (annex IV.2)
- Quantities had to all be given per year.

Categorisation of flows

Biomass has been categorised according to its type and use, as observed on the field. These categories may hide some specificities regarding the types of biomasses used, which is why for each flow the proportions of different types of biomasses have been checked and specified when relevant. For example, a flow of cereals might be half rice and half barley, which have two completely different uses. The different categories and examples of the biomasses within appear in annex V.

Data corrections and extrapolation at fokontany scale

The number of households used for the quantification was deduced from the count of people registered on the official list and the average number of people in the surveyed households (273 households in Malaza and 288 in Miarinarivo).

The areas given by farmers are unreliable. But since the flows are calculated partly based on crop practices, it was important to have areas as close to reality as possible. When comparing to the areas estimated on the soil occupation map, it appeared they were clearly underestimated by the farmers. Based on the expected yield for irrigated rice in the region of Betafo (43 kg/acre, source from on-going study within Dinaamicc project), a correction coefficient of 1,6 has been applied to all estimated areas. It led to yields coherent with literature and total areas much closer to the ones estimated by satellite.

Extrapolation at fokontany scale was based on the number of households. The total numbers of animals and cultivated areas were directly extrapolated from the surveys, by multiplying by the number of households divided by the number of surveys. These numbers were then used to calculate the flows at fokontany scale, from quantities of biomass obtained per acre, per animal or per household from the surveys. They were then weighted by the proportions of these biomasses allocated to different pools, allowing to obtain proper flows from one territory component to another.

3. Data collection

3.1 First exploration of the two Fokontanys

As a first approach, 3-4 days were spent in each Fokontany to get a better understanding of the general context and practices around biomass. It was a way of getting familiar with the functioning of the fokontanys, through observation and informal discussion with inhabitants. This information has been used to confirm the hypotheses made when selecting the study area, to select specific stakeholders in the village which could be interviewed (milk collectors, butchers, rice huskers…), and to elaborate a first metabolism diagram.

The presidents of the fokontanys were both met, firstly to introduce the project and study and make sure they give their approval and support. Secondly for them to provide official information on the village, such as the number of households. Thirdly to organise the introduction workshop and invite relevant stakeholders.

3.2 Introduction workshops

Two introduction workshops were organised, one in each fokontany. The people invited were inhabitants, chosen by the president to be representative of household diversity and well-aware of the situation of the fokontany, the representative of the commune, and representatives of organisations already working in the villages (AVSF, CEFFEL). In total, about 15 persons were present at each workshop.

The aims of the workshop were the following:

- Introduce the DINAAMICC project on the territory, making sure the inhabitants understand the goals and timescale.
- Introduce the surveys which will be conducted in the next few months.
- Verify the hypotheses made for the selection of the areas of study.
- Get the actors involved in the project.
- Identify relevant stakeholders on the territory and try obtaining a typology of the households as different households may constitute different pools of the metabolism diagram.

The workshops followed 3 sequences: (1) the introduction of the project and of the hereby work by describing a simple biomass flows diagram. (2) providing examples of co-conception based on this diagram and participants' suggestions. (3) the establishment of a typology of households following stakeholders' sayings (described above).

3.3 Surveys

Surveys were conducted among households for two months. The aim was to get an image of the structure of the households/farms and of all the associated flows, in order to extrapolate at the fokontany scale.

Sample constitution

The household sample was selected at first from the list of inhabitants provided by the presidents. In Malaza, a list of 40 people has been randomly selected out of the 1083 people registered. In Miarinarivo, since a typology of the households has been established during the workshop, it was used to reduce the size of the sample. A list of people has been randomly picked out of the 1300 names registered, out of which were selected 30 people, 3 from class 3, 8 from class 2 and 19 from class 1, according to the president.

But in practice, the people selected could not always be found easily. Some were not available, others had rather their children answer the survey. When people on the list could not be found, if people around were willing to answer the survey they were welcomed. Moreover, the surveys lasted longer than expected, forcing the reduction of the sample size.

In the end, the samples were constituted of both people picked out of the fokontany lists and people randomly met during the ground phase. In Malaza, 26 households have been completely surveyed (out of 273 households, meaning 9,5%). 2 households have been partly surveyed, with only structural data which could be collected and was incorporated in the results. In Miarinarivo, 21 households have been surveyed (out of 288 households, meaning 7,3%), with proportions supposed to represent household diversity (according to the typology established by the participants to the first workshop).

Survey guide (annex VI)

The survey is constituted of several parts:

- Farm structure (household, fields and crops, livestock…)
- Technical itinerary and production per field
- Feed and production per livestock type
- Production of organic amendments
- Energy used.

Each question was asked orally and adapted to each household depending on the practices. With the translation, the survey would take 2 to 4 hours, requiring sometimes two sessions, or asking more general questions to save time. In these cases, the average numbers collected were used to extrapolate and complete the survey.

Unit conversion

During the surveys, the quantities and numbers given by the farmers come in various units, for which no official comparison charts exist. Therefore, it was needed to find a way to convert all the data in standard units, kilograms most of the time. Data had to be collected directly on the field, through the surveys or by weighting the biomasses we could find (annex IV).

The level of confidence accorded to these conversions depends on the type of unit, on the source of information (farm survey, weighing, market survey…) and on the type of product. For example, 1 bag of grass can weigh from 8 to 20 kg according to the weighing done, depending on the size of the bag and how dry the grass is. But 1kg of white rice is always 3,5 kapoaka, this was confirmed by retailers and farmers, as kapoaka is a constant unity (220mL can).

3.4 Data validation

Once the data from the surveys was analysed and results formalised, restitution workshops were organised in each fokontany. All surveyed people were invited, as well as relevant stakeholders such as the president or the milk collectors. During these workshops, the diagram resulting from the surveys was presented, and each number presented in accessible terms (quantities per household most of the time), discussed and submitted to validation by the people present. This allowed to take a step back regarding some of the data, given the big approximations which had to be made during the surveys and conversions.

Other ways of validating the data were by comparing the results with global numbers obtained through discussion with stakeholders during the initial phase. For example in Malaza, from the beginning the 3 milk collectors were met and each one of them said they collected 300L of milk per day in average. These numbers allowed to have an order of magnitude on what to expect from the results.

Table 3: Structural data for each studied fokontany (area from figure 5 data, herds from survey data)

	Malaza	**Miarinarivo**
Number of households	**273**	**288**
Total area (km²)	**3,17**	**4,26**
Share of irrigated crops	*63,7*	*10,8*
Share of rainfed crops	*26,5*	*63,4*
Share of natural areas	*9,8*	*25,8*
Herd (TLU)	**533**	**457**
Share of milk cattle	*57,7*	*54,7*
Share of draft cattle	*27,4*	*21,0*
Share of poultry	*8,6*	*8,8*
Share of pigs	*6,3*	*15,5*

Table 4: Main productions in Malaza, main outlets and becoming of by-products

PRODUCT	QUANTITY PRODUCED IN FOKONTANY PER YEAR	MAIN PRODUCTION SEASON	BECOMING OF PRODUCTION	BY-PRODUCTS	BECOMING OF BY-PRODUCTS
PADDY	458 T	Rainy season	71% household consumption	Straw	Cattle feed
KIZOZI	324 T	Rainy season	100% cow feed		
SOYBEAN	40 T	Rainy season	100% collectors	Straw, pods	Fuel
MAIZE	23 T	Rainy season	Household consumption and animal feed	Straw, envelops, cobs	Fuel, compost
POTATO	139 T	Inter season	73% collectors	Leaf tops	Animal feed, compost
VEGETABLES	161 T	Inter season	64% market and collectors	Leaf tops, others	Animal feed, compost
RAY GRAS	192 T	Counter season	100% cow feed		
BARLEY	129 T	Counter season	92% Malto	Straw	Animal feed and litter, manure
MILK	548 T	All year	100% milk collectors	Veals, Manure	Reproduction, meat, crop amendment
PORK	162 pigs	All year	85% market	Manure	Fertilizer
CHICKEN	12 600 chickens	All year	63% market	Chicken dung	Fertilizer

Table 5: Main productions in Miarinarivo, main outlets and becoming of by-products

PRODUCT	QUANTITY PRODUCED IN FOKONTANY PER YEAR	MAIN PRODUCTION SEASON	BECOMING OF PRODUCTION	BY-PRODUCTS	BECOMING OF BY-PRODUCTS
PADDY	170 T	Rainy season	92% household consumption	Straw	Cattle feed
KIZOZI	175 T	Rainy season	100% cow feed		
SOYBEAN	70 T	Rainy season	86% collectors	Straw, pods	Fuel
MAIZE	151 T	Rainy season	Household consumption and animal feed	Straw, envelops, cobs	Cattle feed, fuel, compost
BEAN	43 T	Rainy season	81% collectors	Straw, pods	Fuel
SWEET POTATO	150 T	All year	68% household consumption	Leafs and vines	Animal feed, seedlings
POTATO	123 T	Inter season	90% collectors	Leaf tops	Animal feed, compost
VEGETABLES	95 T	Inter season	50% market and collectors	Leaf tops, others	Animal feed, compost
MILK	353 T	All year	100% milk collectors	Veals, Manure	Reproduction, meat, crop amendment
PORK	220 pigs	All year	69% market and fokontany vendors	Manure	Fertilizer
CHICKEN	10 000 chickens	All year	61% market	Chicken dung	Fertilizer

Finally, to complete the data validation, the same information was sometimes obtained in different parts of the surveys, through different questions. This was meant to close the cycles of flows, with for example amounts of biomass leaving the crop system towards the livestock system being equal to the amount the livestock systems receive from crop systems. After the corrections, it was the case for most flows. When it was not, as for cultivated fodder, choices were made depending on what was thought to be the most viable information obtained during the surveys: for cultivated fodder, it is what is needed to cover animals' daily needs which is represented, as the numbers given on a daily basis matched better what was expected of animal needs.

III. Results

1. Deeper description of the fokontanys

1.1 Structural data

As expected, the two fokontanys are quite different regarding main structural points, described in table 3. Malaza is a fokontany with high share of irrigated land and cattle, while Miarinarivo has a high share of rainfed land and natural areas, and a higher share of pigs. Resulting from both observation and the surveys, description of the main productions, the relevant stakeholders and mapping of the fokontanys in space has been produced.

1.2 Main productions per fokontany and biomass management practices

The tables 4 and 5 show the main productions in each fokontany, along with their main outlet and the becoming of by-products. They show the diversity of productions throughout the year, the diversity of outlets depending on the product and the diversity of uses of by-products, which represent a considerable amount of biomass represented in the metabolism diagram.

Illustrations of farming practices and biomass management are provided in annex VII.

1.3 Mapping of the two fokontanys

In order to better visualize and understand the geographical situation of the fokontanys, a handmade map was created and annoted throughout the field work, with the names of the different locations surveyed people were referring to (annex VIII).

The two fokontanys are organised in small neighbourhoods, regrouping about 40-50 households each. But the households have fields all over the fokontany, sometimes even in other fokontanys. All households have a farming activity. The fokontany borders had to be reconsidered, as the ones available on the soil occupation map are not precise enough. It has implications on the precision of total estimated areas and share of land presented in table 3.

Table 6: Livestock repartition and productivity in Malaza

	Total number of animals in fokontany	% of households owning at least 1 animal	Number of animals per household (having at least 1)	Productivity
Milk cows	308 TLU 210 milking cows	65%	1,7 TLU 1,2 milking cows	7,1L/cow/day
Draft cattle	146 TLU	20%	2,8 TLU	4 out of 10 are used for paid activities
Pigs	168 pigs*	50%	1,2 pigs	1,2 pig/household/year
Chicken	4650 chickens	99%	17 chickens 3,5 hens	45 chicken/household/year

**According to the restitution workshop, this number is underestimated, as well as the amount of pork consumed by households*

Table 7: Livestock repartition and productivity in Miarinarivo

	Total number of animals in fokontany	% of households owning at least 1 animal	Number of animals per household (having at least 1)	Productivity
Milk cows	250 TLU 179 milking cows	50%	1,7 TLU 1,2 milking cows	5,4L/cow/day
Draft cattle	96 TLU	20%	1,7 TLU	8 out of 10 are used for paid activities
Pigs	357 pigs	50%	2,5 pigs	1,5 pig/household/year
Chicken	4000 chickens	99%	16 chickens 2,8 hens	36 chicken/household/year

Given the intense use of biomass throughout all the fokontany, it is relevant to specify the different types of uses and agreements over the different areas:

- Fields are separated between irrigated land and non-irrigated land. They are households' property, and the production belongs to the people who cultivate the field. Sometimes, crop residues can be collected by other households if the landlord is not using them. When the field isn't cultivated, anyone can use the naturally occurring biomass (grazing or mowing).
- The same rule applies to field edges. If cultivated, the production belongs to the cultivator. Otherwise, anyone can collect the grass if there is some.
- Woods can be cultivated plots on private property, which are in theory unavailable to other households, or trees growing naturally in common areas. In that case, anyone can collect wood from these trees.
- Grazing and mowing areas are most of the time common spaces. As long as there is no culture or defending sign, anyone can use the grass from natural areas or fallowed fields.

It must also be noted that a share of cultivated land does not belong to inhabitants of the fokontany, even though it is cultivated by them. In Malaza, about 16% of the land is rented or under sharecropping conditions, which usually means the landlord does not live in the village. In these cases, there is often a part of the production which is sent to the landlord. In Miarinarivo, this share is of 7,5%.

1.4 Description of households

Structural data

In Malaza there are 273 households of about 4 to 5 persons, cultivating in average **45 acres of irrigated land and 23 acres of rainfed land**. Almost all of them raise chickens, 65% have milking cows, 20% have draft cattle and half of them have pigs (table 6).

In Miarinarivo there are 288 households of about 4 to 5 persons, cultivating in average **14,5 acres of irrigated land and 55,5 acres of rainfed land**. Almost all of them raise chickens, half of them have milking cows, 20% have draft cattle and half of them have pigs (table 7).

The main differences between the two fokontanys seem to lie more in the proportion of irrigated land cultivated and in the productivity of the livestock systems. Overall, animal productions are much more intensive in Malaza were there are less natural areas and a higher share of irrigated lands, with an animal load of **168 tropical livestock units/ha**, whereas in Miarinarivo where the animal production relies more on natural areas the animal load is of **107 tropical livestock units/ha.**

Table 8: Description of household categories according to statistical typology in Malaza

Class with share of households within	Class 1 (29%)	Class 2 (64%)	Class 3 (7%)
No. of people active	2 – 6	2 – 6	2 - 5
No. of people dependant	0 – 5	0 – 3	0 – 2
Total cultivated area	8 – 36 acres (23)	1,5 – 154 acres (40)	159 – 330 acres (**245**)
Area irrigated land	2 – 15 acres (8)	1 – 90 acres (**26**)	**122 – 300 acres**
Area rainfed land	5 – 22 acres (**15**)	0 – 67 acres (14)	30 – 37 acres
No. of milk cattle	0 – 3 (0,8)	0 – 4 (1,2)	**8 – 9**
No. of draft cattle	0	0 – 2 (0,4)	**2 - 4**
No. of pigs	0 – 2 (0,5)	0 – 3 (0,5)	**6 - 18**
No. of chicken	0 – 19 (8)	0 – 67 (20)	7 - 51

The numbers between brackets ( ) are the mean within the category.

Table 9: Description of household categories according to statistical typology in Miarinarivo

Class with share of households within	Class 1 (62%)	Class 2 (24%)	Class 3 (14%)
No. of people active	1-2	2-5	2-4
No. of people dependant	0-4	1-3	0-1
Total cultivated area	1-76 acres (18)	25-265 acres (**128**)	20-105 acres (66)
Area irrigated land	0-10 acres (4)	5-92 acres (30)	6-15 acres (12)
Area rainfed land	0 – 68 acres (13)	19 – 173 acres (98)	5 – 90 acres (55)
No. of milk cattle	0 - 2 (0,5)	0 – 2 (0,5)	1,4 – 5,6 (**3,2**)
No. of draft cattle	0 – 2 (0,2)	0 – 2 (0,4)	0 – 5 (**2,3**)
No. of pigs	0 – 2 (0,6)	1 – 6 (**3,2**)	0 – 2 (0,6)
No. of chicken	0 – 25 (6)	12 – 29 (18)	24 – 60 (**39**)

The numbers between brackets ( ) are the mean within the category

Typology results

The typologies obtained through statistical analysis (Table 8 and 9) show a distribution of households along different criteria in the two fokontanys.

In Malaza, the 3 categories are characterised by the size of farms (cultivated area and number of animals) as well as by the proportions of irrigated and rainfed land cultivated: class 1 has 38% of total area as irrigated land, when class 2 has 76%. Meaning from class 1 to 3, households have more and more access to irrigated lands, i.e. the possibility to cultivate rice, barley and fodder crops.

In Miarinarivo, the 3 categories are also characterized by the size of the farms, which seems even more distinctive (cultivated area). But the type of livestock present on the farm seems to play an important role here, as class 2 who has the biggest cultivated area is the one having the more pigs on the farm (mean of 3,2 per household), while class 3 which has half less in cultivated area is the class having the more cattle (both milking cows and draft cattle).

2. Metabolism diagrams

2.1 Malaza: biomass flows oriented towards market exportations

MALAZA (Fig. 9)

- Seeds and seedlings

In Malaza, 12T of seeds are self-produced, 1,6T are exchanged between farmers and 4,7T are imported. These seeds are mainly rice, barley, soybean and maize. Most of the rice, soybean and maize seeds are self-produced, while a higher share of barley seeds are distributed by Malto, a local brewing company, main transformer of barley in the region.

For seedlings, 22T are self-produced, 5T are exchanged and 6,6T are imported. They concern potato, sweet potato and watercress. People produce as much as they can their own seedlings, except for watercress which is more often coming from other farmers in the village.

- Treatments

Only a very small number of people use natural treatments on their crops. The treatment index (number of treatments/number of plots) is of 0,46, meaning that almost half of the plots have received at least one chemical treatment throughout the year. Treatments are mainly used on potato, green beans, beans, barley, and ray grass.

- Fertilizers and manure

1770T of manures are used in the fokontany, out of which 200T are exchanged between farmers. All of it comes from the livestock systems within the fokontany. They are mostly cow manures, used fresh or composted. It is mostly used on rice, barley, potato and ray gras, all irrigated land crops.

In addition, 32,5T of chemical fertilizers are brought from the market: NPK, urea, sulphate. They are mainly used on barley, rice, ray grass, and potato.

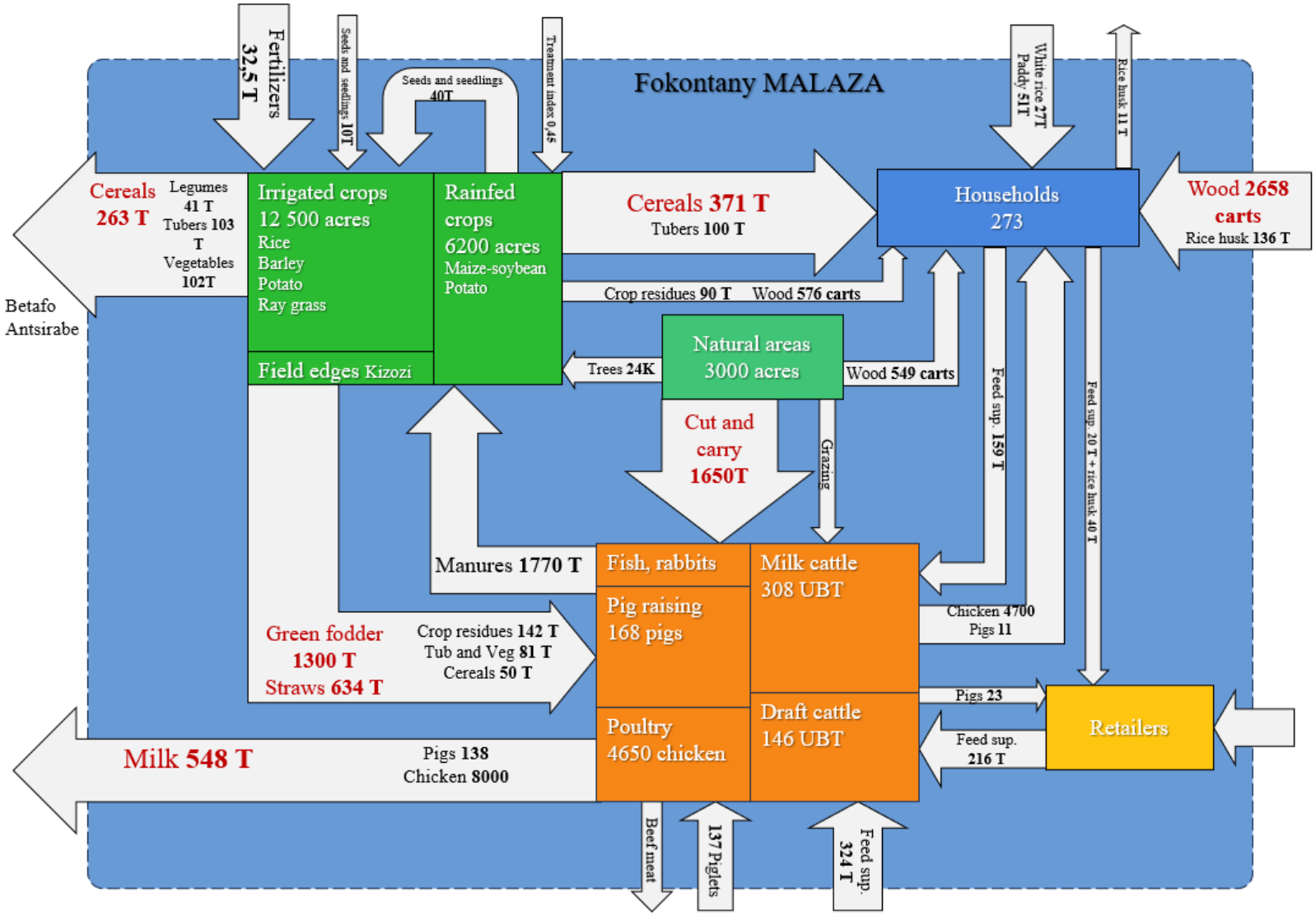

Figure 9: Organisation and quantification diagram of biomass flows within Malaza fokontany over a year

Considering the nitrogen in manures is usually about 4 mg/kg (Rasoamihamina, 2020), the nitrogen brought on the crops through manure is about 7T per year, whereas the nitrogen brought through chemicals is 11T. When confronted to these facts during the workshop, the farmers argued that the manures had more of an amendment value than a fertilizing value.

- Crop production and household consumption

371T of cereals are directly consumed by the households, mostly rice (paddy). They also consume 100T of potato and sweet potato and buy the equivalent of 89T of paddy rice. It seems these products constitute the basis of alimentation, and very few other vegetal products are added to the diets. Reported per person, it represents 750g of white rice/person/day and 220g of tubers/person/day.

As cash crops, 263T of cereals are sold (half paddy rice, half barley), 41T of soybean, 103T of potato and 102T of vegetables. These crops are produced especially for external markets, sometimes even through contractual forms (barley, green beans).

The third main outlet for crop productions are the livestock systems, as feed or litter. Some productions are purposely cultivated for animal feed, others are simple by-products. In any case, they represent a considerable share of animal feed.

- Animal feed

Cattle fodder comes from both cultivated land and natural areas. Only draft cattle graze, and often the grazing areas are out of the fokontany. The milking cows stay in the stables, and are given half natural herbs, a third of cultivated fodder, and the rest as straws and crop residues. Sometimes some feed supplements are given, such as potatoes, sweet potatoes, carrots, or distiller grains bought at the market.

Pigs feed on rice bran and crop residues, sometimes formulated feed bought at the market. Poultry is given a little bit of maize or rice, and out foraging all day.

- Animal production

Over the year, 548T of milk are produced, mostly for Socolait, the major milk industry in the region. It is a very important production on the territory, with cows producing in average 7,1L/day.

The fokontany is also producing a lot of pigs which are being sold on the market (138), although the number of pigs consumed by households is said to be underestimated. There is no piglet production within the fokontany, so most of them come from the nearby market.

- Energy

One cart of wood was approximated to 180kg of wood. It is a big approximation, which is why wood was kept in cart units in the flow diagrams.

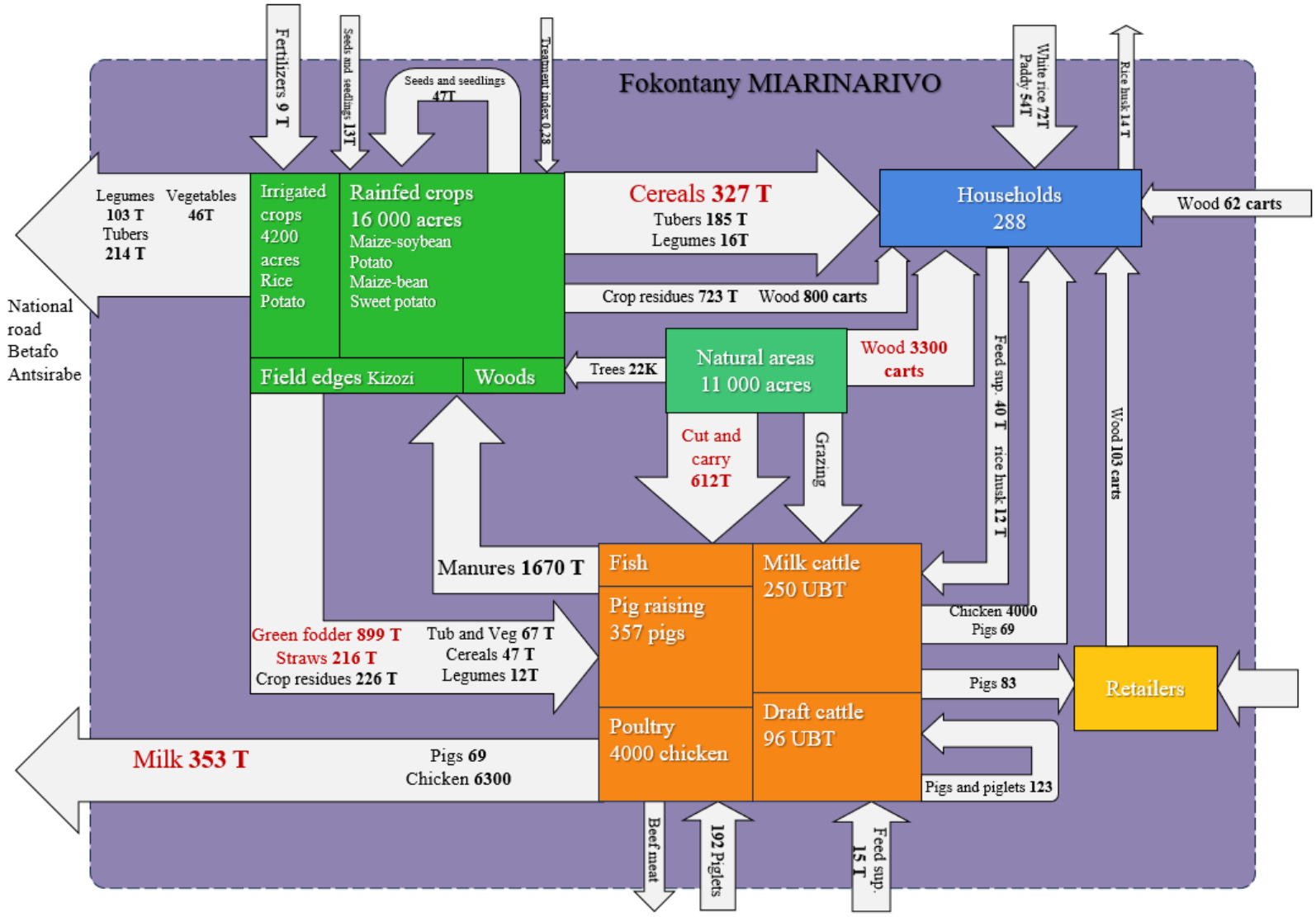

Figure 10: Organisation and quantification diagram of biomass flows within Miarinarivo fokontany over a year

Most of the energy needs of the fokontany are covered through wood combustion. The households collect 1126 carts on field and in cultivated areas and buy about 2670 carts from itinerant vendors. They also use crop residues from soybean and maize crops, and rice husk which are not negligible. In energy terms, the wood used corresponds to 13 000 GJ, the rice husk to 3000 GJ and the crop residues to 1400 GJ. Conversions follow the high heating values presented in annex IV.3.

People are planting 24 000 trees a year on their fields. Most of the plants are transplanted from natural areas.

2.2 Miarinarivo: biomass flows more subsistence-oriented

MIARINARIVO (Fig. 10)

- Seeds and seedlings

In Miarinarivo too, a large share of seeds and seedlings are self-produced. There are 20T of seeds self-produced, 2,5T exchanged between farmers and 7T imported. Mainly soybean, maize and bean seeds. For seedlings, 20T are self-produced as well, 4,7T exchanged and 6T imported, mainly potato, sweet potato and manioc.

- Treatments

The treatment index is 0,28, meaning less than 1 field out of 3 receives a treatment during the year. It is inferior to the one in Malaza, and treatments are used on the same type of cultures: potato, green beans, barley. These crops are less cultivated in Miarinarivo.

- Fertilizers and manures

1670T of manures are used within the fokontany, integrally coming from livestock systems. Out of it, 190T are exchanged among farmers. In the same way as in Malaza, the manures can be used fresh or composted, and there is a diversity of practices in the way they are managed. They are used mostly for potato, maize-bean, and maize-soybean crops.

Chemical fertilizers are bought out of the fokontany, up to 9T of NPK, urea and sulphate. They are mostly used for potato, barley and ray grass.

Converted to nitrogen amounts, the manures represent 7T of the nitrogen brought on fields, whereas fertilizers represent only 3T.

- Crop production and household consumption

The households consume 305T of cereals from their fields, half of it being paddy rice, the other half maize. They also buy the equivalent of 154T of paddy, meaning half of their rice consumption is imported. They consume 185T of tubers such as potato, sweet potato and manioc, as well as 16T of beans, all from their own production. Therefore, the diets seem much more balanced, with 450g of white rice, 300g of maize, 400g of tubers and 34g of beans per person and per day as vegetal products.

In contrast to Malaza, cereals do not represent important cash crops. The products sold are 214T of potatoes and sweet potatoes, 103T of soybean and bean and 46T of vegetables. They are mainly sold to the so-called collectors, itinerary merchants.

Products used as animal feed are detailed in the next section.

- Animal feed

For cattle raising, fodder comes both from cultivated crops and natural areas. A much larger share of cattle are actually grazing in Miarinarivo, even if most of the milking cows still stay in the stable. 612T of herbs are collected in natural areas, while 899T of kizozi and ray grass are produced. A small share of these fodders is exchanged (65T). The ration is completed by rice straws and maize straws, and some tubers and vegetables as supplements. Much less feed supplements are bought from the outside, only maize, rice bran and rice husks are fed to the animals.

Pigs feed on rice bran, tubers, and vegetables. A larger number of piglets are produced within the fokontany than in Malaza. Also, it is to be noted there is a high mortality rate: among the 344 pigs, 137 die of diseases before slaughtering age.

- Energy

As expected, most of the energy comes from wood combustion too, with this time a larger share coming from natural areas. Also, crop residues (soybean and maize straws) play a more important role: when converted in calorific terms, wood represents 14500 GJ of energy used whereas crop residues represent 11000 GJ.

IV. Discussion

If the flows presented answer to the questions of the uses of biomass and how they are circulating within the territory, multiple questions can arise from them about circularity, competition of uses, governance of the flows and the existence and influence of different stakeholders. Moreover, the representation of the flows at territory scale may hide significant diversity within the fokontanys, which is relevant when coming to the question of drivers of the flows. The present discussion is meant to provide insight on the questions of the autonomy of territories, the drivers of the organisation of biomass flows and diversity within fokontanys.

1. Territories' autonomy and relations to external markets

1.1 Crop-livestock integration

Crop-livestock integration is one main indicator of territories' autonomy. In our case, both territories have a strong crop-livestock integration, with about half of livestock feed depending on crop products and manure representing 1/3 and 3/4 of crop fertilization. They both have different types of livestock, and one territory is much more productive than the other. But they also both have very different types of livestock systems among the different households, especially regarding milking cows and pig raising.

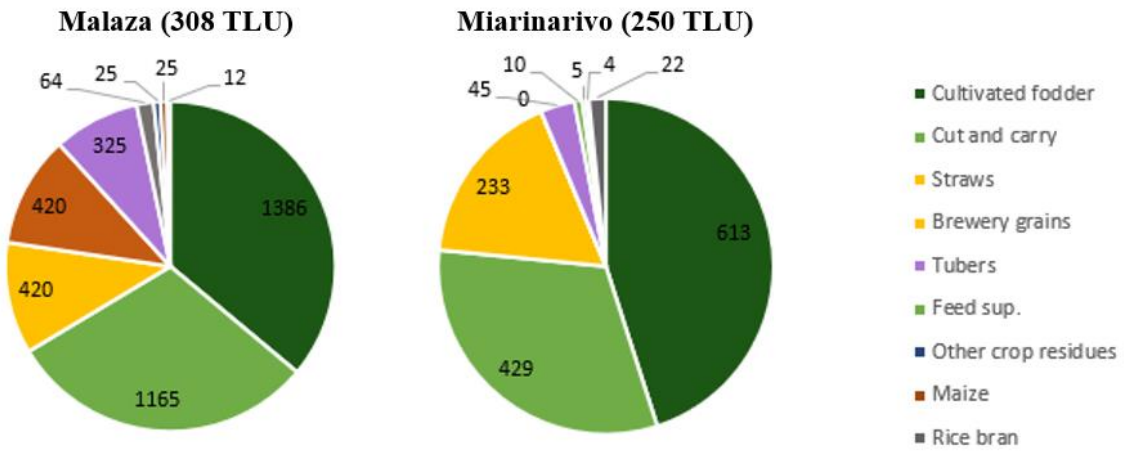

Figure 11: Cow feed amounts in Malaza and Miarinarivo (T/year)

MILKING COWS

There is a big difference in milking cows' productivity between the two fokontanys: 5,4L/cow/day in Miarinarivo and 7,1L/cow/day in Malaza. One of the reasons for this gap, alongside the cows' inbreeding, is the amount and quality of feed given to the cows (Fig. 11). This feed depends on the accessible resources for each household and territory.

In a territory such as Malaza, the amount of natural areas does not allow for much grazing, and all available space for grass production seems to be exploited at its fullest through cut and carry, as it is still the basis of cow feed. Compensating for the lack of natural fodder, kizozi and ray grass are cultivated on irrigated fields and field edges. These good quality forages are one of the reasons for the high production of milk in Malaza, but have the downside of needing chemical fertilizers such as urea and NPK. A considerable amount of feed also comes from crop residues, being intensively used for cow feed and revealing the dependency of cattle raising to cultivated crops in such territories. Another factor of productivity is the amount of feed supplements coming from external markets, such as brewery grains or formulated feed. Households in Malaza seem to have both the financial resources and the proximity to market needed for a good market accessibility. This intensive use of external resources is what allows the milk productivity to be so high in Malaza, but it also creates dependency to market and pressure on natural and cultivated space.

Surprisingly, the amount of cut and carry in Miarinarivo is less than in Malaza, despite the much bigger savannah area. The milking cows still depend a lot on cultivated forage and crop residues. And the amount of feed imported from the market is negligeable compared to Malaza. This shows feed systems which depend mostly on crop residues, and therefore are much more autonomous. The counterbalance is a much lower productivity of course, but also less dependency to external inputs.

Moreover, different types of systems exist within the territories. Firstly by the size of the herd, as we can see in the typologies (table 8 and 9), but also by the feeding systems and intensity of feeding practices. These practices have implications regarding the uses of different types of spaces and the pressure exerted on them.

PIG RAISING

The same kind of considerations can be discussed about the pig feeding systems, excepted that the lack of forage makes them simpler: all types of systems exist, from the one were pigs are fed only with crop residues (rice bran often being the basis of feed) to the one depending only on formulated feed bought at the market. It is rare to see crops only dedicated to pig feeding, and pigs seem to have little pressure on natural areas regarding collection of biomass. Two types of feeding systems were identified: one based on crop-residues and participating to crop-livestock integration (with feed such as rice bran, taro leaves and tubers, organic wastes), and the other based on imported feed from the market (formulated feed, rice bran), simplified but much less autonomous.

Table 10: Diversity of practices regarding manure management

	Malaza	Miarinarivo
Quantity of manure produced	1770T	1650T
Share in piles	52%	71%
Share in pits	48%	29%
Share covered	12,5%	29%
Share composted*	20%	19%
Average composting time	1 – 3 months	0,5 – 2 months

**composted means other material than animal wastes and bedding have been added in significant amounts*

Most of the animal productions are leaving the territory, being sold to collectors or on external markets: milk is mostly collected by Socolait and meat is sold on markets or collected. Even if the households do consume some chicken and pork, this situation contributes to the fact that livestock raising inserts itself in a logic of profitability. Much more than a way to valorise crop residues and natural areas, it is seen by the households as the farming activity generating the most income. Which explains why animal productions can become so intensive.

MANURES AND FERTILITY MANAGEMENT

Regarding the importance of manures in crop fertilization, one could expect they are well managed to take as much as possible advantage of this major by-product. In practice, there are several different practices (table 10), but overall no great care is taken of these resources.

Given these conditions, one can wonder about the true fertilising value of these products. In Malaza, people during the workshop seemed to think manures could not be considered as a real fertilizer, they said they used it only to enhance soil quality. There is true potential for adding to the fertilizing value of manures, and therefore for the fokontanys to gain in autonomy.

Moreover, if some exchanges do occur between farmers (about 11,5% of manures used on crops come from another farmer), big cattle raisers who have a lot of manure available tend to use it all on their crops, while farmers without a breeding activity will be much more cautious about the manure they can get, managing it into a compost and using it parsimoniously.

1.2 Importance of cash crops

Both fokontanys are growing cash crops, though in different proportions: mainly barley, rice, soybean, vegetables, and potato. These productions depend of course on the possibilities offered by the land types and the water management practices, but also on the opportunities offered by the different outlets for these productions.

- Contractual farming: some forms of contractual farming, with companies providing inputs and promise of buying the products, exist for barley and green beans (Malto, Leucofruit).
- Collectors for soybean and potatoes are visiting the villages during harvest season. People usually sell to the one who can offer the best price.
- Markets in Betafo and Antsirabe are both outlets for other products such as vegetables. When they have some, farmers would usually go to the closest market to sell their products.

These outlets each have their own specificities, and drive the flows in different ways. Together they are responsible for the flow of products leaving the studied territories, which both have a good accessibility to markets.

This intensive production of cash crops has strong implications within the territories. If the main production leaves the fokontany, they still produce interesting by-products which find their use in various ways:

- Rice straws and barley straws are used within livestock systems. They represent a source of forage or bedding which can be stored. Farmers in Malaza do feed their cows in average 4 kg of straw/UBT/day, every day, and will give more in moments when green fodders are lacking. Interestingly, practices around barley straw vary among farmers: apparently it is less appetising to the cows, so it is mixed with rice straws or used only as bedding. Rice and barley straws are less produced in Miarinarivo, where they use maize straws instead, and in smaller amounts (less than 2 kg/UBT/day).
- Potato and vegetable leaf tops are used for animal feed too, if not too many treatments were applied on the crop. Small potatoes which could not be sold are often cooked and given to the animals. They represent a significant amount of animal feed, and a possibility for farmers to adjust to the animal's needs depending on the availability of other feed resources.
- Soybean straws are stored and kept as fuel for cooking. They are of little importance in Malaza, but they are an important energy source in Miarinarivo, representing 8% of energy used by households. Since soybean isn't consumed within households or even livestock systems, the soybean outlet finds its importance in energy production. Moreover, it is often grown in association with maize, which is the other energy source from crops.

All these by-products find their place within the fokontanys' circularity. It must be taken into account when considering cash crops, that they do not only represent a product output and a financial income, but also an important production of biomass as by-products, with different uses within the territory.

When comparing both territories, it is interesting to note the impact the production and sales of cash crops seem to have on household diets. The more the fokontany is market-oriented, the more people will sell their products instead of consummating them. In Malaza, where all vegetables, legumes, and half of the rice are sold, it seems very little is kept for the households' self-consumption (less than 2kg of vegetables/household/year). Households feed only on rice, potato and sweet potato, fruits (which are not part of the products sold) and chicken meat. On the contrary, in Miarinarivo where productions are more subsistence-oriented, households feed on a larger variety of products: rice, maize, potato, sweet potato, manioc, beans, fruits, vegetables, chicken and pork. This implies a negative impact of cash crops on diets, and on the circularity of flows within territories, since selling the products outside the fokontany means buying some back in other forms or at another time of the year.

Table 11: Main crops per season per fokontany

	Rainy season		**Inter season and counter season**	
	Main crop	**By-products**	**Main crop**	**By-products**
Malaza	Rice	*Straw, rice bran, rice husk*	Barley	*Straw*
			Ray grass	
	Kizozi		Potato	*Leaf tops, small potatoes*
	Vegetables	*Leaf tops*		
			Vegetables	*Leaf tops*
Miarinarivo	Rice	*Straw, rice bran, rice husk*	Vegetables	*Leaf tops*
	Maize-soybean	*Maize straw, envelops, cobs, Soybean straw*		
		Bean stalks		
	Bean			

1.3 A large share of outputs in both territories

As discussed above, a large share of products leaves the fokontany in the form of milk, rice, barley, potato, vegetables, soybean, pork, and chicken. On a global scale, this means these flows must be balanced in some way for the system to be viable. Different forms of inputs have been identified on the fokontanys:

- Chemical fertilizers and treatments
- Rice bought by the households
- Wood for energy consumption in Malaza
- Feed supplements balancing the high productivity of animals in Malaza

No mention was made of the input of other biomasses such as straws or manures who might have come from other fokontanys nearby. It is difficult to assess the durability of such a situation without studying the substance flows and fertility management within the territories, but it is worth saying that the compensation of output flows by chemical and wood inputs seems unsatisfactory from a sustainability point of view.

2. Organisation of biomass flows within territories.

The proto-metabolism diagrams show how biomass flows circulate within the territory over a year, grouped per category of biomass. But they also hide some aspects of the organisation of the flows, related to biomass availability and uses.

2.1 Seasonality

The production of biomass is strongly related to the seasons, during which different crops are grown. Three different seasons can be identified: rainy season, inter season and counter season (Table 11).

Seasonality brings a variability in the availability of the products and is one main factor of the flows' organisation. Indeed, some of the flows represent day to day needs while others only happen once in a year. For example:

- Most of cash crops products such as barley, potatoes, soybean are all sold in one go, at harvesting season. They leave behind a high amount of by-products, which can be stored like straws, or are perishable like potato residues. It implies that at some time of the year, maybe a week, a lot of potato residues are available for food and feed. It probably is the reason why the unsold potatoes are given to animals and not kept for human consumption, as they cannot be stored for a long time.
- Much less fodder is available during counter season: usually people would gather twice as much grass from natural areas when it is rainy season, and compensate with straws during counter season.
- Some crops could be considered as adjustment variables. For example sweet potatoes are used both for human and animal consumption, and the vines can be used as fodder for the cows. It is a crop which can stay a long time at field and to which one can turn when needed, i.e. when other biomasses are not available.
- Seasonality also exists for animal productions. Piglets for instance are often bought right after the rainy season harvest, as a financial investment.
- Since crop residues can be an important source of energy, there might be a season during which wood is less needed when the availability of alternatives is high.

Table 12: Retailers and raw product transformers present in the studied fokontanys

	Malaza	Miarinarivo
Rice huskers	2	0
Butchers	1	1
Milk collectors	3	Not from the fokontany
Grocery stores	4 at least	4 at least

- Manures are not a constant need. They are mainly used during plantation time, at the beginning of the seasons. People can anticipate their use of manure, and prepare it adequately to the crops they want to use it on.

Moreover, there must be a difference between the two fokontanys regarding the biomass flows depending on the season, since the uses of irrigated land and rainfed land are not the same throughout the year either. A lot of rainfed lands are left to fallow during dry season, the weather being too dry. On the contrary, a lot of irrigated land can stand two cropping seasons, depending on how flooded it is. This is also one of the main reasons why Malaza is being so productive.

It also highlights the importance of stored biomasses: straws, paddy rice, maize, productions which can be kept at field such as manioc, etc. Storage is one issue for a lot of biomasses and is one driver of the flows. If products could be stored better or processed, they might be kept a bit longer within the fokontany and consumed by the households instead of being sold.

2.2 Role of the stakeholders within the fokontany

In the fokontanys, there are different stakeholders grouped under the term “retailers” (Table 12).

Besides being good sources of information, they tend to be active people involved in several activities. And these activities are concentrating some of the flows and can participate in their circulation within the territory. For instance, in Malaza there are 2 rice huskers who must husk about half of the rice consumed by the households. These rice huskers collect the rice husk and sell it afterwards to people in the village. None of the products leave the village. On the contrary, in Miarinarivo there is no rice husker. Either the people will husk their rice by themselves, at home, or they will go to another fokontany, and it is more likely the rice bran and rice husk will stay there and be used by others.

These stakeholders mainly have a role to play in the availability of the products. For example the butchers make pork meat available to households, and encourage meat consumption (the pork consumed by the households in Malaza is said to be underestimated in the surveys). But some of them are missing for the fokontanys to gain in autonomy:

- There are no piglet producers in Malaza, which is regretted by many pig raisers. If it could be developed, this production would definitely be a gain in autonomy. But there are also many constraints: in Miarinarivo where some piglets are produced, there is also a very high mortality rate (38% of pigs die before slaughtering age). Farmers may need training for developing this production.
- Rice huskers are lacking in Miarinarivo. People go to other fokontanys nearby or husk the rice by themselves.
- Many seeds and seedlings are produced within the fokontany, by the farmers themselves. But they are also demanding for new varieties, as they feel threatened by climate change. If there were local seed producers, they might provide the fokontanys with good quality and well-adapted seeds.
- Storage is an important issue for most biomasses. One could imagine collective barns in which products could be stored for the time needed.

Table 13: Energetic equivalences for different fuels used in the fokontanys

	Malaza	Miarinarivo
Total energy from biomasses	17400 GJ	25500 GJ
Wood	13000 GJ	14500 GJ
Rice husk	3000 GJ	
Maize straws	1000 GJ	9000 GJ
Soybean straws	400 GJ	2000 GJ

Conversions presented in annex IV.3.

All these issues were debated during the restitution workshops. The participants were interested and active regarding the suggestions made, and often had their own thoughts on the matter. They showed that a true dynamic around co-conception and co-organisation is possible within these fokontanys.

2.1 High pressure over energy sources

Both studied territories depend energyly on wood (for cooking essentially). Wood comes from trees growing spontaneously in natural areas or planted on owned land. It is a scarce resource for which few alternatives exist locally. Therefore, high pressure is exerted on natural areas for wood consumption and production. In Malaza where natural areas are scarce, most of the wood is bought, probably coming from fokontanys further away where there is more forest cover. It is interesting they do not buy much charcoal, which can be found at the market nearby. It means Malaza depends on another territory, relatively close, for its energy use. On the contrary, Miarinarivo uses wood produced within the territory, and seems to be able to cover its own needs. But the inhabitants are concerned about energy issues. In Miarinarivo, 48% of surveyed households plant trees on their fields, sometimes on field edges, sometimes as an entire wood plantation. They also say they feel pressure from the other fokontanys, with outsiders buying land exclusively for wood production. Which is coherent with the dynamics in Malaza, were a few wealthy households buy large areas of wood (50 to 200 acres) in other fokontanys. In Malaza too trees are planted on field edges (31% of households), even though the available area is limited. The tree plants are mostly spontaneous plants growing in natural areas and replanted, even if some are bought at the market or distributed by companies (Leucofruit).

The existing alternatives to wood are crop residues: mainly rice husk, maize straws, and soybean straws. They are not the same in the two fokontanys, but represent a considerable amount of energy (Table 13).

In Malaza people buy rice husk from the market especially for using as fuel. It is particularly appreciated, especially for brick making. In Miarinarivo it is less used, for two reasons: it seems there is less brick making, and the availability of the two other main residues used as fuel is much greater. Maize and soybean straws together cover 43% of the energy needs of the fokontany. They obviously participate in reducing the pressures over forests, and this use could be a driver in the choice of crops grown in the area. It also means there is no room for other uses of these biomasses, such as cow feed or compost making.

3. Household diversity

3.1 Different accessibility to resources

During the surveys, it appeared obvious that there is a diversity of households within the fokontanys, which has a strong influence on the accessibility to resources and biomass flows. Some households have very little resources, with only a few acres of land available, while others have land, animals, and additional activities. At household scale, it means the biomass flows are more or less significant and diversified. It is the reason why typologies of households were made by two means, to try to capture household diversity through different categories.

TYPOLOGY BASED ON STAKEHOLDERS' SAYINGS

This first typology was relevant for multiple points. It allowed to have from the beginning an idea of the diversity of households and of the main criteria differentiating them, before even making the sample of households to be surveyed. And it allowed the stakeholders to be involved from the beginning, to take the point of view of people who know their territory into account.

They revealed inequalities within households, especially in the size of the farming systems and in the main sources of income. In Miarinarivo, the president already had his own idea of the categorisation of households: for him there are the vulnerable, the non-self-sufficient and the self-sufficient, based on how wealthy the households are (annex II). There was no such thing pre-existent in Malaza, but for both fokontanys the farms were said to have different areas of cultivated land and associated it to more or less livestock. Meaning the amount of livestock per farm depends on the size of the available cultivated area, but no differentiation of the types of livestock owned in the different categories of households could be made, unlike in the typology at Vakinankaratra's scale. But one main key of differentiation which appeared was the sources of income. Households with not enough land would work as employees for others who have more land. The average household would live on its own land. And the wealthier are the ones having other revenues, such as schoolteachers or former militaries. This representation of households reveals how strong the inequalities are, and how the different categories may interact with each other: employees and employers for instance.

TYPOLOGY BASED ON THE SURVEYS

The typology based on the surveys completes the typologies obtained through the workshops, since the main keys of differentiation are slightly different. In addition, they are not the same in the two fokontanys:

- In Malaza, there is still no distinction made between the types of livestock systems, only by their size: the bigger the cultivated area, the bigger the number of animals. But a clear distinction appears regarding the main type of land cultivated: when in category 1 only 38% of cultivated land is irrigated, this percentage is of 76% in category 2. This is obviously of major influence over the biomass flows and probably the financial resources of the household, since most cash crops are grown on irrigated land. The fact that it does not affect that much the type of livestock reveals the flows from crops to livestock systems do not vary that much depending on the main type of land cultivated, meaning it has probably a stronger impact on the flows from crops to external markets. It is also probable that the products coming from irrigated land intended for livestock systems flow from category 2 to category 1.
- In Miarinarivo, the most relevant distinction keys appear to be the area cultivated and the type of livestock. Here there is a correlation between the size of the farm and the type of livestock, which was not the one expected: category 2 describes farms with a large area of cultivated land, associated to a large number of pigs raised within the farm. The farms with more cattle seem to have half less cultivated area (category 3). Again, this represents different types of biomass flows within the households. For example, there might be flows of cattle feed from category 2 to category 3, and it is probable the households from category 2 are more market oriented. They have a large surface area

on which they can grow cash crops, and invest the money earned at harvest season in pig raising.

Beyond the interest both these typologies had for the description of the studied territories and of the biomass flows within, it is noticeable they are different from one another, and from the one obtained at region scale through previous works. They reveal the diversity existing not only within the fokontanys, but also within the whole region, and this diversity must be considered when studying at small territory scales.

V. Conclusion

The study of the metabolism of these two fokontanys revealed the intensity of biomass uses through all their forms, as well as the diversity of strategies at farm and territory scale. Indeed, all produced biomass finds a use in household consumption, market sales, livestock production, energy consumption or fertility management. This participates greatly to the autonomy of the territory. But it may also lead to competition in uses, and unbalances at territory scale, since a lot of biomass is exported as cash crops or animal products.

- Two territories with different issues regarding autonomy

Malaza is market oriented. Miarinarivo is subsistence oriented, with developing market opportunities. Despite their geographical proximity and their similarities in the general structure of flows, they present two different types of metabolism. Malaza is a very productive territory, and the market opportunities are making it more and more intensive. The pressure over all types of land is high, and even though crop-livestock integration enhances circularity within the fokontany, the input/output balance seems unbalanced. Miarinarivo is also very productive, but much less intensive. The external markets do not represent as great a pressure on the territory, allowing the households to produce for themselves before thinking of selling outside. The fokontany's biomass flows are organised upon a strong autonomy, in which livestock plays a preponderant part.

Further works including conversion of biomass flows to substance flows (N, P) should allow to reconsider these questions with a more precise vision of the flows and especially the calculations of indicators of circularity, autonomy and sustainability.

- Multiple potential drivers of flows

The question of the governance of the flows must be answered to place the metabolism diagrams in the frame of territorial ecology. The results obtained through this preliminary work provide a few hints regarding the major drivers of the flows:

- The main land uses and resource accessibility. It was one of the main hypotheses in this work, and was verified: the different land uses lead to various accessibility to biomasses, therefore different flows within the fokontanys and within the households.

- The accessibility and relation to external markets. Both fokontanys were chosen to be easily accessible from the road, meaning also accessibility to markets. And it showed an implication in the orientation of the flows. But the differences noted between the two territories may also be in the relation and vision the stakeholders have from the markets, resulting in different dynamics: profit-seeking or simple income complement.
- The knowledge of potential levers. Through surveys and workshops, it seemed the farmers had different techniques, different education levels and different involvement in community. These lead to differences in the possibilities the households have of improving their systems, therefore on their management of biomasses.

By assessing in a more precise way the diversity of households and stakeholders, a more precise socio-economic context will be settled in further works, and allow to verify and understand better these drivers of flows.

➢ Possible extrapolation to larger scales?

The chosen study cases have their own specificities, but they were selected to represent at best the diversity of fokontanys within the commune of Mandritsara. Except for the accessibility bias, it is probable that other fokontanys in the region function in similar ways, especially the ones presenting a similar distribution of soil occupation. Others with more natural areas or less accessibility to markets may present less intensive forms of agriculture and different types of metabolisms. Therefore, with more precise diagrams taking into account household diversity and substance flows, and the identification of the drivers of flows, it should be possible to extrapolate these works to some communes around Betafo, providing precise data for these regions which are still lacking references.

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Annex I: Description and categorisation of pools of flows at two precision levels (with abbreviations used)

Pool 1	Pool 2	Abreviation description pool 2	Description pool 1 (components used for flow diagrams)	Description pool 2
AAF	VF	*vendeurs fokontany*	**Others stakeholders of the fokontany** *Autres acteurs fokontany*	retailers
	DF	*décortiqueurs fokontany*		rice huskers
Cultures	BF	*bas-fonds*	**Crop systems within fokontany** *Cultures dans le fokontany*	irrigated lands
	TB	*tanimboly*		rainfed lands
	BC	*bords de champs*		field edges
	B	*bois*		wood plantations
Elevage	EA	*élevage autre*	**Animal systems within fokontany** *Elevage dans le fokontany*	other animal systems
	EV	*élevage volailles*		poultry systems
	EB	*élevage bovins*		cattle systems
	EP	*élevage porcs*		pig raising systems
	EBL	*élevage bovins lait*		milk cattle systems
	EBT	*élevage bovins trait*		draft cattle systems
HF	LFM	*Leucofruit - Malto*	**Pools out of the fokontany** *Hors fokontany*	agricultural companies
	MA	*marché Antsirabe*		Antsirabe market
	MB	*marché Betafo*		Betafo market
	PHF	*paysan hors fokontany*		farmer from another fokontany
	VHF	*vendeurs hors fokontany*		retailers out of fokontany
	VRN	*vendeurs route nationale*		retailers on the main road
	BFHF	*bas fond hors fokontany*		irrigated lands out of the fokontany
	TBHF	*tanimboly hors fokontany*		rainfed lands out of the fokontany
	BCHF	*bords de champs hors fokontany*		field edges out of the fokontany
	BHF	*bois hors fokontany*		wood plantations out of the fokontany
	CF	*collecteurs fokontany*		collectors within fokontany
	CHF	*collecteurs hors fokontany*		collectors out of the fokontany
	PP	*propriétaire parcelle*		field landlord
	DHF	*décortiqueurs hors fokontany*		rice huskers out of the fokontany
	vol	*vol*		robbery
	PCF	*pré collecteur fokontany*		pre-collector within the fokontany
Menage	C	*combustible*	**Household** *Ménage*	fuel
	repas	*repas*		meals
	cons	*construction*		construction materials
MO	MO	*matières organiques*	**Biomass transformation and management** *Matières organiques transformées*	biomass transformation
	Fum	*fumiers*		manures and composts
	BioP	*biopesticides*		biopesticides
	L	*litière*		animal bedding
PF	PF	*paysan fokontany*	**Other farmer in Fokontany** *Paysan du fokontany*	other farmer from the fokontany
RF	RF	*ramassage fokontany*	**Collected biomass within fokontany** *Ramassage dans le fokontany*	gathering within fokontany
	BCF	*bord de champ fokontany*		gathering on field edges within the fokontany
	Dom	*domicile*		gathering near the house
	ENF	*espaces naturels fokontany*		gathering in natural areas of the fokontany

Annex II: Typologies a priori, based on workshop participants' knowledge.

Typology of households in Malaza established during the introduction workshop (low confidence level), ranked from small to big farms

	1	**2**	**3**	**4**
Cultivated area	< 50 acres	< 50 acres	> 50 acres	> 50 acres
Type of livestock	Pigs Poultry	Milking cows Pigs Poultry	2 – 3 milking cows Pigs Poultry Draft cattle	More than 3 milking cows Pigs Poultry Draft cattle
Proportion within fokontany	35%	40%	20%	5%
Number present at the workshop	1	9	1	0

Typology of households in Miarinarivo established during the introduction workshop (good confidence level), ranked from small to big farms

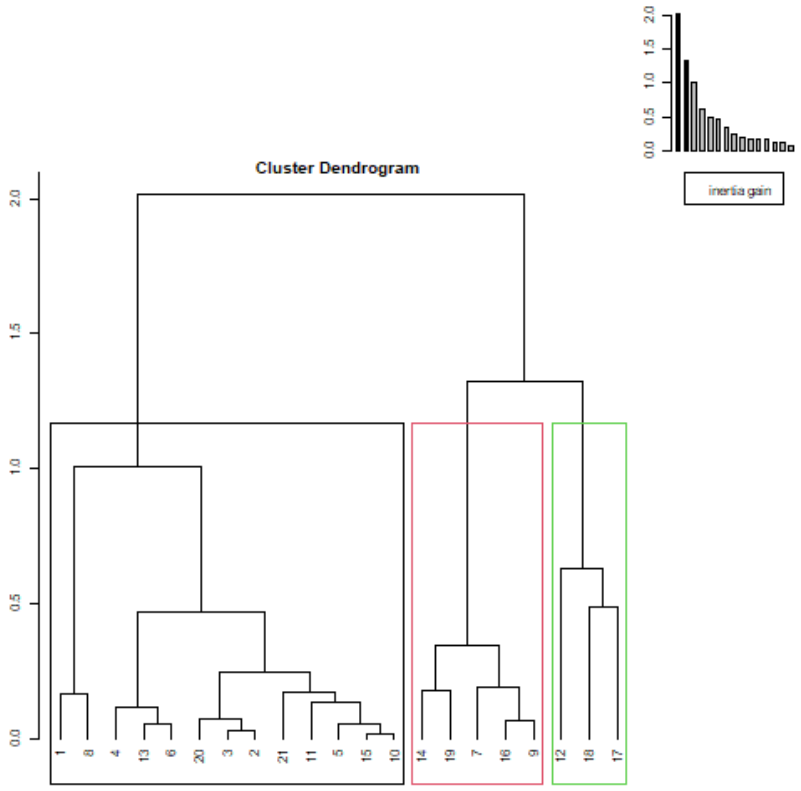
	1	**2**	**3**
Rice self-sufficiency	"vulnerable"	"not self-sufficient"	"self-sufficient"
Cultivated area	0 – 2 acres	5 – 10 acres	10 -150 acres
Type of livestock	Pigs or cattle (loaned)	Draft cattle Milking cows Pigs Poultry	Draft cattle Milking cows Pigs Poultry
Source of income	Agricultural wage-earning	Agricultural wage-earning (with renting of draft cattle) Counter season crops	Other activities (public servants, retailers) Farming revenues
Proportion within the fokontany	60 – 70%	20 – 25%	5 – 10%
Number present at the workshop	2	6	0

Observations and comments:

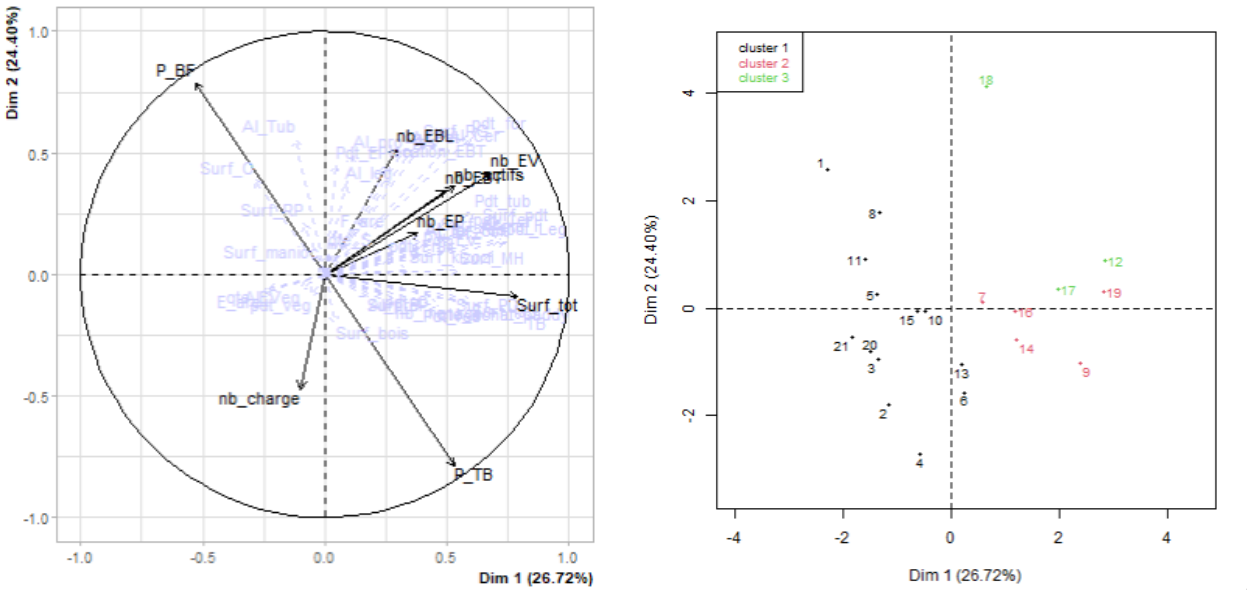
- *Participants have difficulties estimating the area of land in acres.*
- *Not all categories were represented at the workshop, meaning the people present were not representative of the diversity of households.*

Annex III: Statistical typologies, details.

- Typology in Miarinarivo

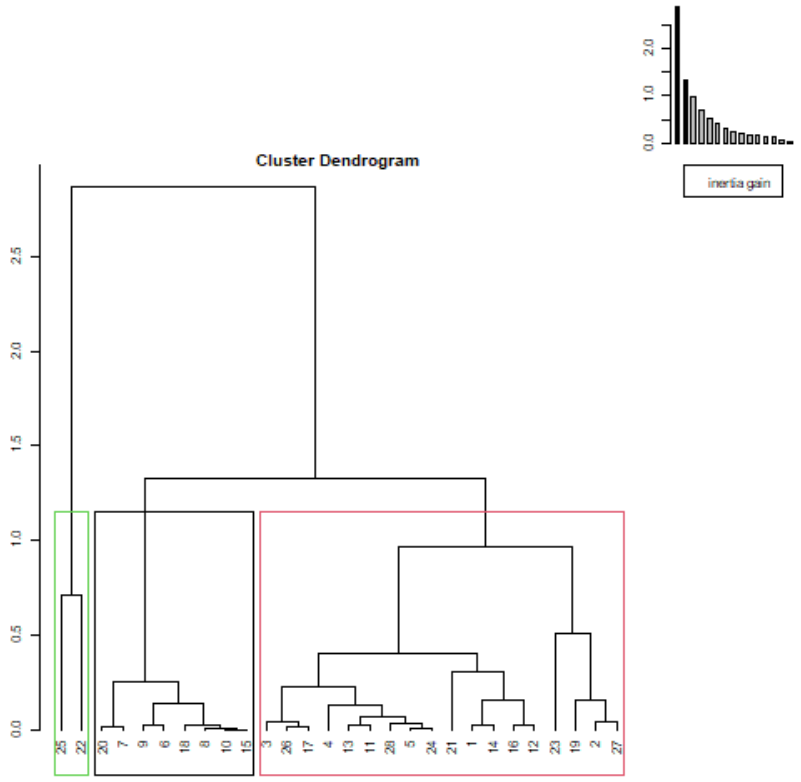


Classification tree resulting from HCPC on strucural variables of 21 farms in Miarinarivo

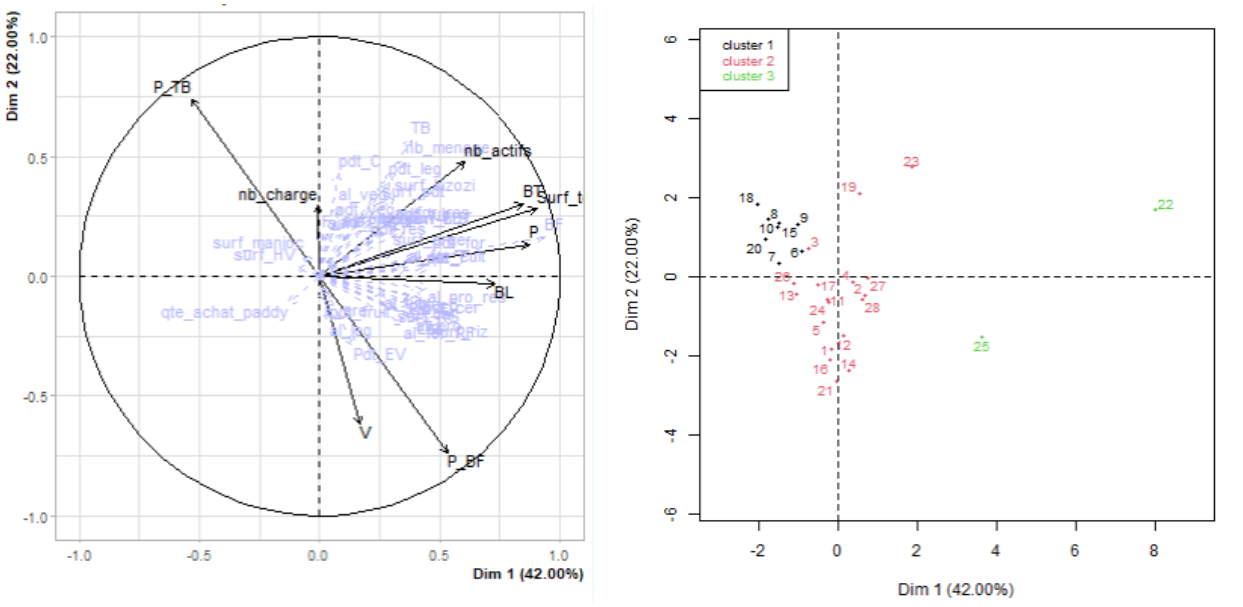


Variables and individual plots of PCA on sstructural varaibles of 21 farms in Miarinarivo, and associated clusters

➢ Typology in Malaza



Classification tree resulting from HCPC on structural variables of 28 farms in Malaza



Variables and individuals plots of PCA on structural variables of 28 farms in Malaza, and associated clusters

Main variables used for typology and description of categories

	Description of variables
Active quantitative variables	
Nb_actif	Number of active people within the household
Nb_charge	Number of people at charge within the household
P_BF	Share of irrigated land cultivated
P_TB	Share of rainfed land cultivated
Nb_BL	Number of milk cattle (TLU)
Nb_BT	Number of draft cattle (TLU)
Nb_P	Number of pigs
Nb_V	Number of poultry
Suplementary quantitative variables	
BF	Area of irrigated land (acres)
TB	Area of rainfed land (acres)
Qte_achat_paddy	Quantity of paddy rice bought throughout the year (kg)
Qte_E	Quantity of chemical fertilizers used (kg)
Qte_F	Quantity of manures used (kg)
Qte_S	Quantity of seeds used (kg)
Pdt_C	Quantity of biomass fuels produced (kg)
Pdt_cer	Quantity of cereals produced (kg)
[…]	[more quantities related to produced biomass]
Lait	Quantity of milk produced (L)
Location_EBT	Number of draft cattle put to rent
Pdt_P	Number of pigs produced
Pdt_V	Number of poultry produced
Suplementary qualitative variables	
Ilot	House location within the fokontany
Ac_HA	Other non-agricultural activities (yes/no)
S_agri	Working as farming employees (yes/no)
MO_ext	Type of labor employed (4 modalities)

Annex IV: Conversion rates used.

IV.1 Farmer units

For estimating quantities, several farmer units have been used. Often they can be assimilated to their volume, as estimated in the table below. The volume varies, depending on the type of product, and the weight varies even more. This table is given only as an indication, but the conversions used in practice might vary depending on the different sources of information collected regarding the biomass type (surveys, weighing, literature). Direct sources such as surveys in markets regarding one specific product have been privileged.

Conversion ranges used for different types of products

Farmer unit	Volume (L)	Variability	Small seeds (kg)	Vegetables (kg)	Dry grains (kg)	Straws (kg)	Green fodder (kg)	Wood (carts)	Tubers (kg)	Feed sup. (kg)	Manures (kg)
bag		high		21 - 35	30 - 90		11 - 30		50		
bag 50	45	med			30 - 45		11			50	
bag 250	90	low			70 - 90		22		90		
cantina	4	low			4 - 5				3 - 3,5		2,5
sobika	15	high		9 - 20	14 - 20	4	4 - 9		13,5 - 17,5		10 - 20
kapoaka	0,22	low	0,22		0,25 - 0,29						
spoon	0,015	med	0,015								
entana	45	high		18 - 25		6 - 16	11 - 52	5 - 7,5	50		
cart	360	high			400	165 - 270	170 - 430		560 - 700		250 - 375
bale		high		1		0,4					
litre	1	low								0,7 - 0,9	

The different types of units are the following:

- Bags can be any bag, but depending on the product the farmer is speaking of he/she would usually refer to more or less the same size of bag (small ones for cut and carry, big ones for paddy rice, etc).
- Bag 50 are bags initially used for 50kg of animal feed
- Bag 250 are bags which can contain 250kg of white rice, which are generally used for selling products.
- Cantina is a farmer unit which contains 4kg of paddy rice.
- Sobika are baskets used for all types of products, which come in various sizes.
- Kapoaka is a 220 mL can used for selling grains.
- Entana is the appellation for the amount of product one can carry on their head. It varies a lot depending on the product.
- Carts transport variable volumes and weights of products, since depending on the product and whether it is in bags or not the cart can be more or less charged.
- Bale is a handful of straw or grass.

One entana of straw

Sobika of potatoes

Bags "250"

Different farmer units encountered (*personal pictures, April 2023*)

IV.2 Other equivalences used (source: surveys and discussion with rice huskers)

Raw to transformed product coefficients used

Raw product (1)	Transformed product (2)	Amount of (1) for obtaining 1kg of (2)
Paddy rice	White rice	1,4
Paddy rice	Rice bran	5,8
Paddy rice	Rice husk	8,5
Maize ears	Maize grain	5

IV.3 Energetic conversions

Experimental high heating values of rice straw, rice husk and wood (source: Jenkins and Ebeling, 1985; adapted from Kargbo et al., 2010)

Biomass	**High heating value (MJ/kg)**
Rice straw	15,3
Rice husk	17,5
Wood	19

All crop residues used as fuel other than rice husk were assimilated to straws for this calculation.

Annex V: List of biomass categories

Abreviation used	Category	Biomass examples
Anx	Animals	Fish from piscicultures
Bois	Wood	
Cer	Cereals	Rice, barley, wheat, maize, etc
E	Fertilizers	NPK, urea, sulphates
Fum	Manures	Cow manure, composts
For	Forages	Cut and carry forages, kizozi, ray grass, etc
Fruit	Fruits	
Leg	Legumes	Soybean, dry and fresh beans
P	Seedlings (kg)	Potato, sweet potato, watercress seedlings
P_unit	Seedlings (per unit)	Tree, kizozi, manioc seedlings
Paille	Straws	Rice straws, barley straws, maize straws
Pat	Grazing	
Pro	Feed sup.	Formulated feed, brewery grains, rice bran
Res	Crop residues	Bean straws, leaf tops
S	Seeds	Rice seeds, vegetable seeds, soybean seeds
T	Treatments	D6, insecticides
Tub	Tubers	Potato, sweet potato, manioc
Veg	Vegetables	Leaf vegetables, watercress, carots, squash

Annex VI: Survey guide (in French)

ID ENQUETE : **DATE :**

Contact	**Localisation**	**Accessibilité**
Nom CE/Nom d'use : Tel : Nom personne enquêtée : Relation au CE :	Fokontany : Ilot : Geolocalisation domicile :	Accès charrettes : oui/non

Caractéristiques socio-économiques

Nb de personnes composant le ménage :

Nb d'actifs : Hommes
Femmes
Enfants

Achat riz : riz blanc/paddy/non si oui, qté :
provenance :

	M	J	J	A	S	O	N	D	J	F	M	A
Achat												

Activités hors agricole : oui/non

Salariat agricole : oui/non

Principales sources de revenus :

Main d'œuvre extérieure

Type (travaux)	Présence/absence	Provenance (in/out fkt)	S : Salariée E : échange de services P : échange de produits	Location bœufs (oui/non)	Provenance bœufs (MO :Avec MO P : Leurs propres anx A : autres in/out fkt)
Permanente					
Travail sol					
Implantation/repiquage					
Entretien					
Récolte					
Transports					

Cheptel

Quels types d'élevage sur l'exploitation (sur l'année) ? ☐ Bovin lait ☐ Bovin trait ☐ Porcin ☐ Poulets ☐ Autres :

Quels sont les animaux présents actuellement sur l'exploitation ?

	Présents sur l'exploitation	Race	Nb	Propriété (Propre, Confiage)	Pour VL, Porcs, Truies, Poulets : Production/unité de tps
BOVINS	Bœufs trait				
	Vaches laitières				
	Génisses				
	Veaux				
PORCS	Porcs en engraissement				
	Truies				
	Porcelets				
VOLAILLES	Poulets total				
	Poules mères				
	Coqs				
AUTRES Poissons, canards, lapins etc					

Possèdent-ils des animaux en dehors de l'exploitation ?

In/out fkt

Espèce : Nombre :

Selon quelles modalités de confiage ?

Produits perçus et qté :

Si anx confiés, selon quelles modalités :

Sur l'année passée, achat/vente d'anx : oui/non lesquels :

Naissances/morts : oui/non lesquels :

Font-ils de la rizi-pisciculture ? oui/non

Parcellaire

Surface totale cultivée (ares) : Parcelles toutes in-fkt : oui/non

Nb de parcelles cultivées (en propre, louées ou métayées) : Nb de parcelles non cultivées (en propre) : Nb parcelles confiées à d'autres :

N°	Localisation (îlot ou fkt)	Distance au domicile (tps de marche)	Type BF : Bas fond T : Tanety etc	Surface (ares)	Use saison des pluies (Culture, repos)	Use contre-saison (Culture, repos)	Uses autres (bords de parcelle, prélèvements anx, etc)	Propriété P : Propriétaire L : Locataire M : Métayage

Pratiques culturales similaires pour différentes parcelles ? Rotations culturales : oui/non Parcelles pépinières :___

Parcelles confiées : In/hors fkt Modalités métayage : Produits de ces parcelles :

Fiche par parcelle

N° parcelle : ☐ Cultures ☐ Pâturage/Coupes d'herbes ☐ Kizozi ☐ Bois ☐ Rizi-pisciculture

2022-2023	Mai	Juin	Juillet	Aout	Sept	Oct	Nov	Dec	Jan	Fev	Mars	Avril
Saison pluies												
Contre saison												

Si jachère, nb d'années : __

Si arbres, nb plants/unité de tps :__ provenance plants :___ année dbt plantation :____ production de bois : oui/non

Si oui, qté :____

Semences et plants : période, qté, provenance
Engrais : type, qté/provenance
Traitements : type, provenance

Produits : qté/destination
Co-pdts : qté/destination
Autres : période de pâturage/ramassage herbes, par qui ?

***Provenances** : AP Autoproduit ; PF Paysan du fkt ; PHF Paysan hors fkt ; EF Eleveur du fkt ; EHF Eleveur hors fkt ; VF Vendeur du fkt ; VHF Vendeur hors-fkt ; MB Marché Betafo ; MA Marché Antsirabe ; EN ramassage sur espaces naturels ; BC ramassage en bords de champ ; PF ramassage sur parcelles du fkt ; Malto ; LF Leucofruit*

***Destinations** : AC Autoconsommation humaine ; AB Alimentation bovins ; AP Alimentation porcs ; Lit Litière anx ; MO transformation de Mat Org ; C Combustible ; S Semences ; PF Paysan du fkt ; PHF Paysan hors fkt ; EF Eleveur du fkt ; EHF Eleveur hors fkt ; VF Vendeur du fkt ; VHF Vendeur hors-fkt ; MB Marché Betafo ; MA Marché Antsirabe ; PCF Pré-collecteur du fkt ; CF Collecteur du fkt ; CHF Collecteur hors fkt ; DF Décortiqueur du fkt ; DHF Décortiqueur hors-fkt*

Fiche élevage (bovin lait)

2022-2023		Mai	Juin	Juillet	Aout	Sept	Oct	Nov	Dec	Jan	Fev	Mars	Avril
Fourrages verts	*Lesquels* *Qté/j* *Provenance*												
Fourrages stockés	*Lesquels* *Qté/j* *Provenance* *Stock suffisant ?*												
Compléments/Autres	*Lesquels* *Uniquement VL ?* *Qté/j* *Provenance*												
Pâturage	*Tps/j* *Lieu* *Si parcelle n°*												
Entrées/sorties animaux	*Naissances/* *Morts* *Achats/ventes* *A qui ?*												
Production lait	*Prod moy/j* *Pic* *Collecte par qui ?*												

Devenir des veaux *(Pour qui ; dans quel objectif):* Mâles : Femelles :

TYPE MO :

Fumiers bovin *(sortie bâtiment)*
(sortie bâtiment)
Tps passé au bâtiment/jour :
Litière : oui/non
Fréquence raclage :
Qté raclée :
Qté vendue :

Fumiers porc
Tps passé au bâtiment/jour :
Litière : oui/non
Fréquence raclage :
Qté raclée :
Qté vendue :

Composition litière	Qté ajoutée/unité de tps	Provenance

Transformation matières solides (fumiers, composts)
Infrastructure stockage : tas/fosse abris/sans abri
Couverture : oui/non quoi, qté :
Stockage : durée min __ durée max __
Qté produite/unité de tps : Qté vendue :

Composition	Qté ajoutée/unité de tps	Provenance

Transformation matières liquides (biopesticides)

Fréquence de production :

Composition	Qté ajoutée/unité de tps	Provenance

Bois et sources d'énergie

Combustible	Origine A :Autoproduit /R :Ramassage/ P :Achat paysan/ R :Achat revendeur /M : Achat marché	in/out fkt si autoproduit, n° parcelle	Use (cuisson, autre)	Qté consommée/unité de temps

Devenir des cendres :

Est-ce qu'ils consomment des carburants ? Oui/non

Pour quels uses ? Véhicules : Machines : Autres : Quelle qté ?

Est-ce qu'ils ont accès à l'électricité ? Oui/non Panneaux solaires :

Pours quels uses ? Quelle qté ?

Décorticage et devenir des produits/co-produits (riz)

Lieu décorticage :
Fréquence décorticage :
Qté décortiquée :
Vente paddy : oui/non

Produits	Qté/Devenir des produits	Propriété
Paddy		
Paille		
Son		
Balle		

Annex VII: Illustrations of farming practices within fokontanys.

Photographs: Jonathan Vayssières, May 2023

Draft cattle ploughing in Malaza

Milking cows in stables

Women handling manure for crop fertilisation

A cart of rice straw ready to be discharged and stored

Milk pre-collector in Miarinarivo

Cattle coming down from grazing on mount Iavoko

Annex VIII: Handmade maps of the fokontanys of Miarinarivo and Malaza.

Corresponding locations indicated by inhabitants

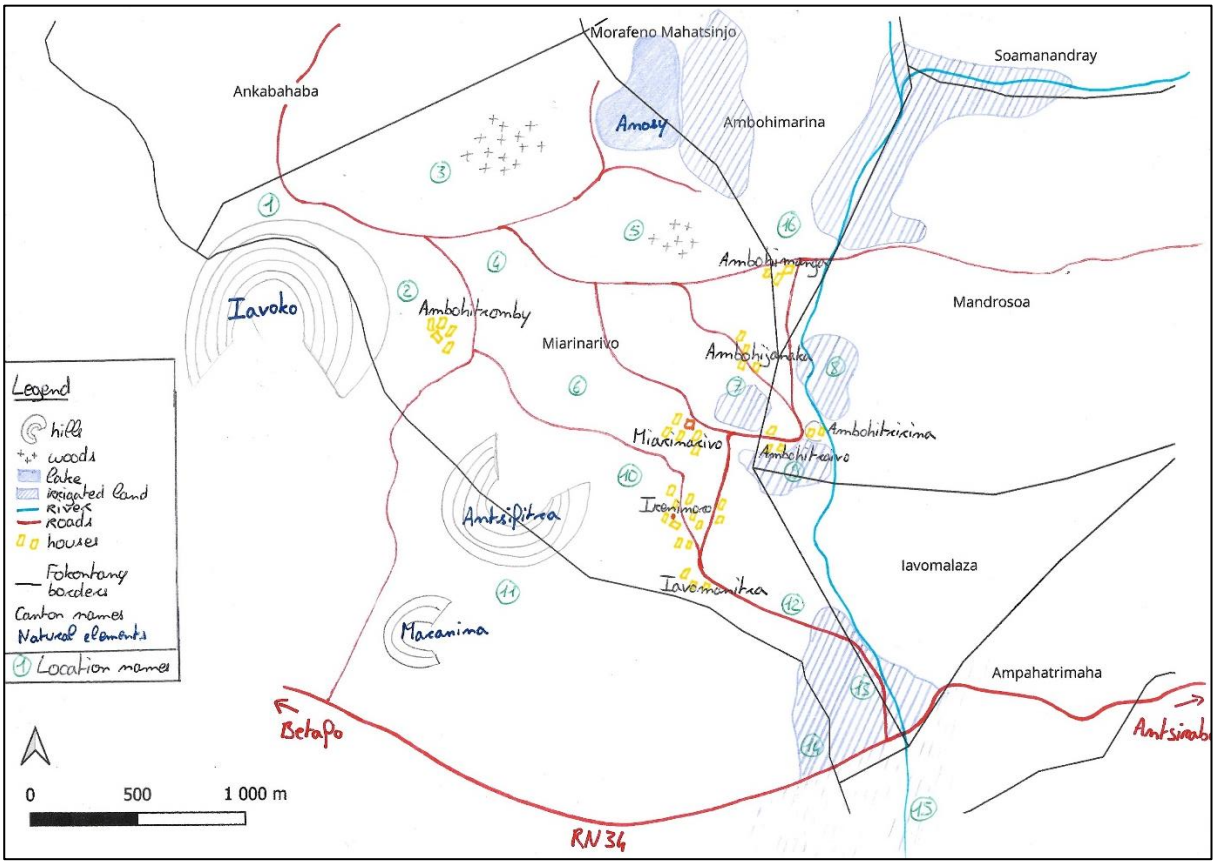
Miarinarivo		**Malaza**	
1	Amparihy	1	Ankasobe
2	Ampototry Iavoko	2	Amperifery
3	Ankilabe	3	Amparihy
4	Andrafipena	4	Ankadimena
5	Anativato	5	Andombiry
6	Andrepodehibe	6	Ankaditapaka
7	Andranoro	7	Anatisa
8	Lazaina	8	Ankady
9	Atsilola	9	Andrefana Ampasimbe
10	Soamatamana	10	Bezavona
11	Antsahabe	11	Antanifotsy
12	Atsimo maronjaka		
13	Antsimony Iavomandroso		
14	Filaona		
15	Ampasina		
16	Soafierenana		

List of neighbourhoods within fokontanys (in black handwriting on the maps)

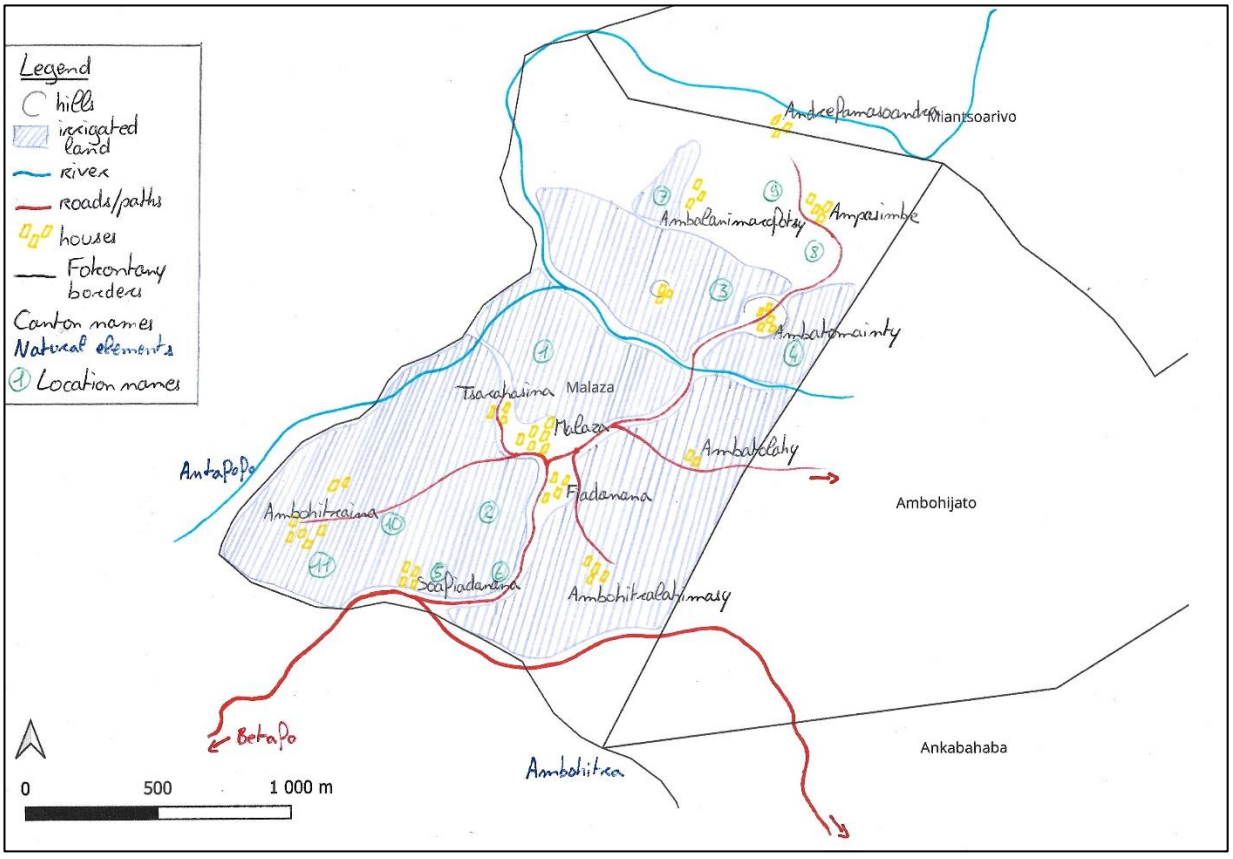
Miarinarivo	**Malaza**
Ambohijanaka	Ambalanimarofotsy
Ambohimanga	Ambatolahy
Ambohitraivo	Ambatomainty
Ambohitririna	Ambohitraina
Ambohitromby	Ambohitralahimasy
Iavomanitra	Ampasimbe
Ireninoro	Andrefamasoandra
Miarinarivo	Fiadanana
	Malaza
	Soafiadanana
	Tsarahasina

Note about fokontany borders

The fokontany borders showing on the maps are the ones from Lebourgeois et al. (2017). They lack precision and true borders are better represented by natural elements (rivers, lake, hills).



Localisation in space of different geographical elements in Miarinarivo



Localisation in space of different geographical elements in Malaza

L'INSTITUT agro Rennes Angers	Diplôme : Ingénieur Spécialité : Agronomie Spécialisation / option : Agroecology Enseignant référent : Anne-Lise Jacquot

Auteur(s) : Marie Hooker Date de naissance : 18/12/1999	Organisme d'accueil : CIRAD Adresse : 42 rue Scheffer, 75116 Paris
Nb pages : 25 Annexe(s) : 8	
Année de soutenance : 2023	Maître de stage : Mathieu Vigne

Titre français : Caractérisation du métabolisme de deux territoires ruraux à Madagascar : Cas des Fokontanys de Miarinarivo et Malaza, district de Betafo.

Titre anglais : Characterisation of the metabolism of two rural territories in Madagascar: case of the Fokontanys of Miarinarivo and Malaza, district of Betafo.

Résumé (1600 caractères maximum) :

Madagascar est un pays qui fait face à de nombreux enjeux de durabilité. Parmi eux : l'augmentation de la circularité dans les systèmes agri-alimentaires. Le concept d'écologie industrielle territoriale offre un cadre d'analyse pertinent pour étudier la circularité des territoires, à travers l'étude des interactions entre les sociétés et leur environnement. Il peut s'appliquer à travers la notion de métabolisme territorial, une représentation de la structure des flux de matières et d'énergie au sein des territoires.

Ces concepts ont été appliqués à deux territoires ruraux des hautes terres malgaches, dans le district de Betafo, à travers l'étude des flux de biomasses à l'échelle du village. Ces territoires peu référencés et reposant majoritairement sur des activités agricoles ont été étudiés via de l'observation participante, des ateliers participatifs et des enquêtes auprès des ménages. Deux schémas de flux ont ainsi été obtenus, révélant l'use intensif des biomasses et l'implication des différentes composantes du territoire.

Les deux villages ont montré deux types de métabolisme et des niveaux d'autonomie différents vis-à-vis des biomasses : l'un est tourné vers les marchés extérieurs, l'autre encore vers la subsistance des ménages même si des opportunités de marché se sont développées. Ces différences majeures créent différents types de pressions sur les systèmes de culture, d'élevage, sur les ménages et sur les espaces naturels, lié à l'accessibilité des ressources. Dans ce contexte, identifier des leviers pour la circularité sera spécifique à chaque type de territoire.

Abstract (1600 caractères maximum) :

Madagascar is a developing country facing multiple challenges regarding sustainability. One of them is increasing circularity within food systems. A relevant analysis framework for circularity is found in the concept of territorial and industrial ecology, through the studying of interactions between societies and their environment. It leads to the application of territorial metabolism, a representation of the structure of matter and energy flows within territories.

Application of these concepts was done in two rural territories in the highlands of Madagascar, in Betafo district, through the studying of biomass flows at village scale. These territories based mainly on agricultural activities and poorly referenced were studied through observation, participatory activities, and household surveys. Diagrams of biomass flows have been obtained for both villages, revealing the intense uses of biomass and the ways in which different components of the territory are involved.

The two territories showed different metabolisms and levels of autonomy regarding biomass: one is completely market-oriented, while the other is still partially subsistence-oriented despite market opportunities. These major differences create different types of pressure on crops, livestock, natural areas, and households, related to the accessibility to resources. Therefore, identifying levers for circularity will be specific to each territory.

Mots-clés : Madagascar, métabolisme territorial, biomasses
Key Words: Madagascar, territorial metabolism, biomass