ProINTENSAFRICA INITIATIVE

For a sustainable intensification of African agriculture

A CASE STUDY IN MADAGASCAR

SUMMARY REPORT

AGRICULTURAL INTENSIFICATION IN MADAGASCAR: PUBLIC POLICIES AND PATHWAYS OF FARMS IN THE VAKINANKARATRA REGION

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PREAMBLE

In 2015, the University of Wageningen, FARA (Forum for Agricultural Research in Africa) and CIRAD received Horizon 2020 funding from the European programme for research and development, to conduct a two-year project with the aim to build the foundations of a major research program, between Europe and Africa, on sustainable intensification of African agriculture.
The two continents are consulting about the best way forward for the future of their agricultural and agrifood systems. In Europe, within the context of the Common Agricultural Policy reform and in Africa, within the framework of adopting an "agricultural development policy" program under the aegis of the African Union. In Africa, it will consist of a specific study on the improvement of agricultural sustainability, of food and nutrition security and of how to increase African farmers' incomes. New approaches will be required because sustainable intensification is not only the production of many more products, but also the prudent and efficient use of resources, ecosystem services, the social and economic impact, induced technological dependence, limits of natural resources and energy, etc., at different scales of time and space.

This initiative is called **ProIntensAfrica (ProIA)**.

The work program envisaged case studies in several African countries to anchor the analysis in the reality in the field (Burkina Faso, Mali, Ivory Coast, Ghana, Kenya, Cameroon, Senegal and Madagascar).

The SPAD platform (dP SPAD) was chosen to coordinate the implementation of the case study in "Madagascar". The work began in late 2015, focusing on the Vakinankaratra region with three main activities: *(i)* exhaustive bibliographic review, *(ii)* field surveys of farms, and *(iii)* meetings/debates with representatives of different agricultural stakeholders of the Vakinankaratra region.

The work has mobilized many people including those responsible for the region, the decentralized technical services of the state, agricultural development, farmers' organizations, NGOs, private companies involved in agricultural production, upstream or downstream, funding agencies, farmers of Vakinankaratra, and researchers from partner institutions of the SPAD platform. Finally, young engineers freshly graduated from ESSA were mobilized to conduct field surveys, coordinate workshops, process and analyse data and finally participate in the drafting.

The coordination team wishes to thank all those who participated in some way in this study. Thank you for their time. Thank you for all the contributions that are either in the form of information, opinion, expertise or analysis, they have nourished the report presented here, in a rather synthetic way. The contribution of the SPAD platform to the **ProIntensAfrica** initiative is just one step in the search for the improvement of agricultural sustainability, the food and nutrition security of populations and increase in farmers' income in Africa and Madagascar.

INTRODUCTION

The **ProIntensAfrica** project is an initiative launched in 2013 to lay the foundations of a long term structural scientific partnership, between Europe and Africa in research and innovation. Currently, thirteen European countries and many African countries (including Madagascar) are involved in this project. This initiative is led by CIRAD, in partnership with the University of Wageningen and FARA (Forum for Agricultural Research in Africa) through funding, called Horizon 2020, from the European program for research and development. For European countries, this initiative may be one of the solutions to the economic crisis while for African countries, this will help to open the debate on the possible ways of intensification and their effects in the long-term in the economic and environmental fields, and especially on the food security problem.

For Madagascar, the SPAD[1] platform was selected to coordinate the project in the Vakinankaratra region, in the highlands of Madagascar. In the case of Madagascar, the objective is firstly to identify agricultural intensification dynamics in the Vakinankaratra region following the agricultural policies implemented, and secondly to characterize the driving forces of changes in family farms in order to be able to analyse the process of intensification of agriculture among smallholders.

The increasing world population brings into question food long term security. If in the northern countries production has managed to follow population increase, in the southern countries, particularly in Africa, it can barely keep pace with increasing demand. The success of the industrialized countries in terms of agricultural productivity is based primarily on agricultural policies, which favoured an intensification based on the extensive use of inputs (mineral fertilizers, pesticides, mechanization and fossil energy, etc.), farm size increase and gradual reduction of the agricultural working population. This form of intensification is described as conventional. In many African countries, agricultural production is the result of small family farms, which are generally less productive.

Madagascar is one of those countries where productivity remains low and even seems to be in decline, while it is an agricultural country. During the last decades, Madagascar has faced a food security problem that is accompanied by increasingly higher poverty rate (90% of the population live on less than US $ 2/day). The increase in agricultural production is a priority in Madagascar's public policies. With a sharp increase in population and a continued degradation of natural resources, questions arise about the best pathways to follow in order to promote a continuous and sustainable intensification. Within the framework of the **ProIA** initiative and with the aim to provide answers to the questions on the best ways of intensification to promote, a program was developed and implemented in three distinct steps:

(i) The first part of the work consisted of a bibliographic analysis combined with interviews of agricultural development participants in Madagascar. This part of the work was carried out from November 2015 to February 2016. It enabled the analysis of the location of intensification in agricultural policies over the last 20 years (1995-2015), in Madagascar and in the Vakinankaratra region;

(ii) The second part of the work consisted of very detailed field surveys, on 24 farms, carried out by a team of agricultural engineers from December 2015 to March 2016. This part allowed the illustration of the methods of intensification and makes available real cases of farm development;

(iii) The last part is a series of five workshops with the representatives of different stakeholders in the agricultural community of the region. These workshops were held from April to June 2016. On the one hand, they allowed discussion among all stakeholders, of the different concepts of agricultural intensification by confronting them with illustrations of all the pathways observed on farms, and on the other hand, the identification of the main constraints and the possible ways of intensification for the region and Madagascar.

[1] Platform in partnership for research and training - Highland production systems and sustainability.

This report is put together according to the different stages of the work performed. Thus, three distinct parts constitute the document:

- The first part summarizes the results of the bibliographical study with an analysis of the different types of intensification in Madagascar;
- The second part is a synthetic version of the different pathways observed across the 24 surveyed farms;
- The third part presents the perception of different stakeholders in agricultural development, the constraints to intensification and the propositions to address these constraints.

1. AGRICULTURAL INTENSIFICATION IN PUBLIC POLICIES IN MADAGASCAR AND THE VAKINANKARATRA REGION

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1.1. Agricultural intensification: basic concepts and global context

1.1.1. Basic concepts

The terms "intensive agriculture" and "intensive breeding" are often understood as highly mechanized production activities and which use high levels of inputs purchased on the market, such as: fertilizers, pesticides, fossil energy, seeds, feed, medicines, etc. (Tirel, 1987). However, there are many meanings for the term "intensity" or "intensification" in the agricultural sector (Bonnieux, 1986). Bonny (2010) distinguishes three ways of intensification qualified as: *(i)* conventional, *(ii)* systemic and *(iii)* ecological.

Conventional intensification is associated with the notion of productivity. We seek to increase the productivity of a factor, usually the one which is considered the limiting factor. Thus, "a factor is exploited intensively when combined, to a given quantity of this factor a large dose of other factors" (Tirel, 1987). For example, in a context where land is a limiting factor, we seek to increase its productivity by combining with significant amounts of labour (labour-intensive) and/or capital (capital-intensive). In a practical framework, FAO (2004) associated agricultural intensification to productivity and defined it as an increase in production per unit of inputs: manpower, agricultural surface area, fertilizer, seeds, fodder, capital, etc.

Systemic intensification proposes a better optimization of inputs used on the basis of the concept of substitution of production factors (Bonnieux, 1986). According to FAO (2004), there is agricultural intensification when the total production increases thanks to a strong use of inputs; or when production is maintained while inputs decrease. The approach is systemic: agricultural production depends on the combined use of various factors (Bonny, 2010) such as manpower/capital, energy, traditional or scientific knowledge, information, as well as ecosystem services (photosynthesis, water supply, action of auxiliaries, processes of interaction, symbioses, regulation, etc.). So, looking for a better match between different productions is another way to intensify (Dugué *et al.*, 2012). This type of intensification refers to the concepts of technical assistance, and crop, livestock and production systems.

Ecological intensification is a process that uses at best, or intensifies, ecosystem functions and/or ecological processes (Griffon, 2013; Bonny, 2010). Dugué *et al.* (2012) distinguish two major schools of thought in this area:

- The first one, associated with the English term "*sustainable intensification*", aims to limit the negative external factors of agricultural systems on the environment, while continuing to increase yield. This definition makes little reference to the means but much more to the purpose of sustainable development with the notion of sustainable agriculture (Landais, 1998). This approach corresponds to a "weak" form of ecological modernization according to Duru *et al.* (2014);
- The second one gives more importance to the mobilization of natural mechanisms and their environmental services as production factors that can substitute, at least partially, mineral inputs and equipment which consumes fossil energy. This approach corresponds to a stronger form of ecological modernization (Duru *et al.*, 2014), leading to a change of paradigm in agricultural production.

1.1.2. World context

The thesis of Malthus[2] states that the population increases exponentially or geometrically while resources only grow arithmetically, hence the inevitability of demographic disasters, unless population growth is limited. In opposition, the thesis of Boserup[3] which states that the increase in population density is a necessary condition for agricultural intensification and the analyses of Mazoyer show that agricultural production has increased slightly faster than population. In fact, at the peak of the demographic explosion (in the second half of the twentieth century), the world population multiplied by 2.4 while the global agricultural and food production experienced a faster progression (x 2.6) and was greater in the past fifty years than it had been before in the previous 10 000 years of agricultural history (Mazoyer, 2008). This productivity growth is due to agricultural intensification.

Despite this strong growth, agricultural production has been insufficient, and above all it has been distributed unequally, to meet the needs of all humanity. In fact, while the average yield more than doubled in most industrialized countries, emerging countries and some developing countries, in other regions, and particularly in the least developed countries, the average yield has increased only a little or not at all. In a century, the productivity gap has not ceased to increase among those countries, changing from 1 - 5 W/AWU[4] in the middle of the nineteenth century to 1-2000 W/AWU in the twentieth century (Mazoyer, 2001; Mazoyer, 2008; Figure 1).

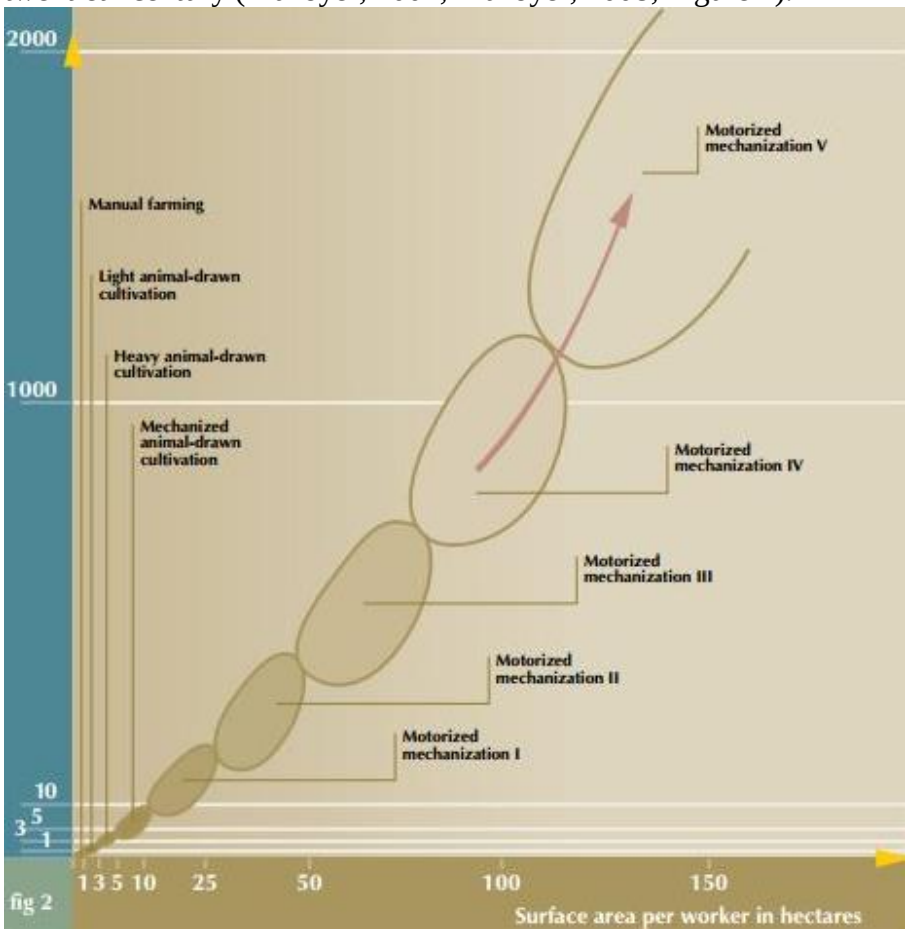


Figure 1: Development of productivity inequalities in cereal crops worldwide during the second half of the twentieth century (source: Mazoyer, 2001; Mazoyer, 2009; Mazoyer and Roudart, 2009)

[2] Thomas Robert Malthus (1766 – 1834), demographer, formulated his "principle of population" in 1798, in his "Trial on the principle of population" thus providing the kick-off to a debate on population issues (Rutherford, 2007).

[3] Ester Boserup (1910 – 1999), economist, considers in his book "The conditions of agricultural growth" (1965), that in non-industrialized countries, the increase of the rural population is a favourable factor for agricultural intensification and, under these conditions, it is unrealistic to expect an intensification of agricultural production if population density is low (Jouve, 2004).

[4] AWU: Annual Work Unit, unit of measure of the amount of human work done on farms. This unit is equivalent to the work of one person working full time for a year.

From the 60s, farmers in developing countries, supported by public policies, engaged in the modernization of agriculture following the principles of the Green Revolution (Bazlul, 1986), a variant of the productivist model, but generally deprived of large motor-mechanization (Mazoyer, 2008; Mazoyer, 2009). Thus, in many Asian countries, rice yield, which rarely exceeded 2 t/ha during the last 40 years, nowadays reaches 10 t/ha in a single harvest (up to 20 tonnes when hydraulic development allows two or three crops a year). In Africa, the Green Revolution has not achieved the same results due to the poor development of irrigation and where the rain fed farming systems, dependent on weather conditions, (Dugué *et al.*, 2012) and the weakness of agricultural policies (Sumberg, 2002) make the process of intensification difficult.

This productivist agricultural model has led to strong criticism, related in particular to the economic inefficiency of growth, acceleration of the exodus from agriculture, destruction of small farms and polluting effects on the environment (Malassis, 1997). In fact, this agricultural revolution has been accompanied by a sharp decline in real agricultural prices, and thus a reduction in income in small and medium-sized farms that do not have the means to invest sufficiently to compensate for the effects. This led to the gradual disappearance of small farms in developed countries, or to their exclusion in the least developed countries (Mazoyer and Roudart, 2009). This productivist model also has negative impacts in ecological terms, affecting "environmental" capital.

Thoughts were then directed towards the development of sustainable agriculture. Thus, the concept of "sustainable development", defined for the first time in 1987 (Brundtland's report)[5] has emerged and was adopted by the international community in the 90s. It led to a rethinking of agricultural production models and their relationship with society, orientated towards ecological intensification models.

In 2007-2008, a global food crisis was generated by the sharp rise in prices of basic foodstuffs. Several countries in sub-Saharan Africa have been severely affected, having suffered from "hunger riots" in some major cities (Janin, 2009) and about 75 million people who fell into malnutrition status (Mazoyer, 2009). This crisis brought the issue of hunger and food security in the world to the agenda with the central role of agriculture for world food supply. Within this context, from the point of view of policy makers, it seemed more efficient to promote the Green Revolution model, which is easier to implement and with the possibility of rapid increase in production (Dugué *et al.*, 2012).

1.2. Agricultural intensification and public policies in Madagascar

1.2.1. Issues and challenges for Madagascar

Madagascar is ranked among the poorest countries in the world with 80% of the population living on less than $1.25 PPP[6] per day and 92% with less than $2.0 PPP/day in 2010 (World Bank, 2014). Agriculture is the livelihood for 81% of the active population (INSTAT, 2011); a much higher rate than the average for sub-Saharan Africa which is 60% (World Bank, 2011). However, the agricultural sector contributes only 30% of the total GDP, a proportion that has fluctuated only slightly over the last 30 years.

Thus, the increase in agricultural productivity is a major challenge for Madagascar which is translated by this "vision" mentioned in the 2016-2020 Programme for Agriculture, Livestock and Fishing sectors: "Madagascar in 2025, will be based on a competitive and sustainable agricultural production, integrating family farms and modernized processing units to ensure food security and conquer export markets" (MinAgri, MRHP and MinEL 2015). However, to achieve these goals, the challenges are substantial and associated with little-favoured backgrounds.

[5] Brundtland report (1987) refers to a publication entitled "Our Common Future" by the World Commission on Environment and Development of the United Nations, chaired by G. H. Brundtland. http://www.diplomatie.gouv.fr/fr/sites/odyssee-developpement-durable/files/5/rapport_brundtland.pdf

[6] Purchasing Power Parity (PPP) is a monetary conversion rate used to express in a common unit the purchasing power of different currencies. It may differ from the exchange rate (http://www.insee.fr/fr/methodes/).

The demographic transition process remains slow and the growth rate is still at a high level of 2.8% for the 2010-2015 period according to UNDP projection (United Nations Development Programme, 2014). Even if this growth rate has slowed slightly (3.0% in the 90s), the population continues to grow rapidly (with a population doubling every 18 years), and in 2015 it will be nearly 700,000 people.

There is a high concentration of the population in certain production areas with very small farms and 70% of farm households cultivate an area of less than 1.5 ha, over 50% have less than 1.0 ha (INSTAT, 2011), which seems paradoxical compared to the reserves of arable land undeveloped[7].

Madagascar has suffered, for several years, a sharp deterioration of its natural resources and global environment. According to an estimation by the World Bank, the annual cost of environmental degradation (natural resources and infrastructures) represents 9 to 10% of the 2005 GDP (MEF, 2012), from which about 75% come from deforestation, 15% from decreased productivity of agricultural and pastoral lands due to erosion, and about 10% from the increase in operating costs and the reduction of the lifetime of infrastructures according to UNDP data in 2003.

Regarding the degradation of soil resources, according to the EPM surveys carried out by INSTAT in 2001, over 50% of households believe that *tanety*'s fertility has deteriorated in a space of 10 years, with more than a quarter saying that degradation was significantly more pronounced among the poorest households (Minten and Ralison, 2003). According to FAO figures from 2004, 53% of the Malagasy population lived in areas with a high proportion of degraded lands (World Bank, 2013). This degradation makes agricultural intensification efforts increasingly difficult at the farm level.

Madagascar is ranked among the countries with "high to extreme" risk in terms of vulnerability to climate change. Agriculture in Madagascar is already particularly vulnerable to climate hazards (World Bank, 2011). Considering the limited means of irrigation, agricultural production in Madagascar is highly dependent on the amount and distribution of rainfall (FAO and WFP, 2014).

The country is clearly under-equipped in terms of infrastructures, with a direct impact on agricultural services and marketing channels. This difficulty limits the modernization of agriculture. There is a general lack of roads to facilitate exchanges, which is also observed in the main agricultural areas.

Thus, in such contexts that already make the achievement of food security difficult, the ambition to conquer export markets appears very difficult without profound changes that will allow the increase, over time, of agricultural production. How to achieve a virtuous circle of increased production? Could we increase the agricultural area rapidly in a country where available land still exists, and how to manage such a dynamic? How to help farmers to achieve sustainable intensification? Agricultural and rural development policies implemented in Madagascar have failed to activate the virtuous circle of agricultural intensification.

1.2.2. Intensification within agricultural development policies

Madagascar's agricultural policies have evolved according to different periods characterized by break points related to international references, as well as according to the national political and socio-economic context. Since independence, the political environment of the Malagasy State, as for many other developing countries, is marked by three major periods: *(i)* the interventionist period, *(ii)* the structural adjustment program, and *(iii)* the policy of poverty reduction and sustainable development (Figure 2).

[7] In Madagascar, there are 40 million hectares (Mha) of agricultural land of which 10 Mha are cultivable, but only 3.5 Mha are cultivated and which could be clearly be a far superior cultivated area (Bélières *et al.*, 2016).

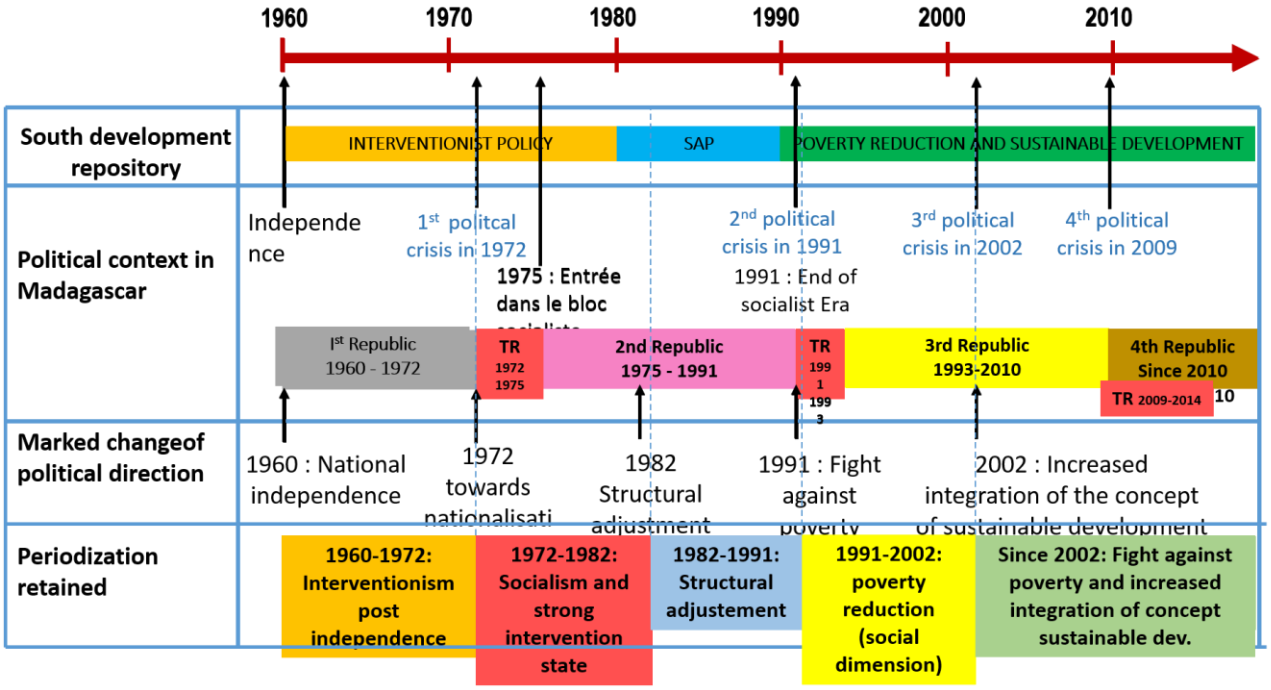


Figure 2: Periodization of public policies in Madagascar (Raharison, 2014)

The last 20 years have been marked by particular reference to poverty reduction and sustainable development. Three major principles have generated quite contrasting directions in terms of development and agricultural intensification:

- the continued disengagement of the state, notably to reduce public expenditure and to allow a market economy develop with private participants (companies and NGOs);
- the need to produce more to ensure food security and to open up to the outside market;
- the growing importance of environmental aspects along with the integration of the concept of sustainable development.

This period was marked by a succession of political crises and economic reframing, leading to changes in the country's general policy guidelines. The political guidelines that influenced the actions in terms of support to agricultural intensification can be separated into five periods:

From 1990 to 2000: The economic policy focused on the disengagement of the state, with the liberalization of prices and the transfer of responsibilities to private sectors and producers (law 90-016). Actions were undertaken to facilitate and promote the participation of civil society organizations (farmers' organizations, NGOs, etc.) and farmers in the economy. The actions for poverty reduction and the support to intensification were mainly carried out with co-financing from donors through NGOs and other development operators.

From 2000 to 2005: Poverty Reduction Strategy (DSRP 1 and 2) was the general policy framework. The agricultural sector was considered as a vital sector and emphasis was placed on the importance of supporting the rural population. The concept of sustainable development was integrated into the general program. The state continued its disengagement process relative to the productive sector and focused on the establishment of a socio-economic environment favourable for private sector development. Various rural development projects/ programs were carried out with the improvement of agricultural practices, increase in agricultural yields and farmers' incomes, but also with crop diversification to reduce the vulnerability of farms.

From 2005 to 2009: The vision "Madagascar, naturally", a framework document based on the Madagascar Action Plan (MAP) in 2007, was established to achieve the objectives of sustainable development and fight against poverty. Agriculture was defined as a priority sector with the vision of

a Green Revolution, but sustainable. The development of farmers' organizations to take over the functions neglected by the state was one of the principles stated in the public policies. The development of chains of values was also a major guideline of the public policies (MAP, 2007) with the objective of facilitating the access to market by farms in their territory.
The state also engaged in a National Decentralisation and Deconcentration Programme to strengthen land-use planning policies (within this context, the 2004-001 law has divided the country into 22 regions). Direct support to intensification was carried out (provision of agricultural inputs especially fertilizers, construction and rehabilitation of hydro-agricultural infrastructures, "small agricultural equipment" campaign (ploughs, cultivators, weeders, etc.).

From 2009 to 2014: This period was marked by the political and socio-economic crisis. The political direction remained unclear between the desire for a split relative to the directions of the previous regime and the continuation of the actions implemented. Connected to the international political sanctions, some donors stopped their funding, including that for agricultural intensification programs. Other projects, already underway or implemented, continued.
Initiated under the previous regime, the strategies for farm counselling were finalized in 2009. The projects/programs have increasingly integrated counselling approaches to family farms, contrary to what was previously done with the extension of simple technical packages. Agricultural Service Centres (CSA) were set up in each district of Madagascar to provide information about the market, the access to inputs, and the opportunities and to provide technical economic advice to farms (SACSA/MINAGRI, 2009).

Since 2014: It was considered as a period of economic recovery. In the area of support to agricultural intensification, this relaunch was based on the PSAEP program (Programme for Agriculture, Livestock and Fishery Sectors). It aims to achieve a greater integration of farms in the markets through the development of contract farming, the organization of the agricultural profession and the commitment of the private sector to ensure the commercialization and the development of agroindustry to process agricultural products (National Pact PSAEP/CAADP, 2014). The overall guidance document of PSAEP was signed in 2014. The action strategy is still being developed. Implementation in the field is still limited and marked by the continuation of the actions already undertaken (improvement of agricultural services, support for agricultural intensification through the support of IMFs and projects/programs, etc.).

Table 1 is a fairly detailed presentation, for each period, of the changes in the policies implemented: from the general policy guidelines, down to the measures of agricultural intensification in the major projects/programs financed by donors, distinguishing the direct actions of the State and the actions implemented by the private sector.

Table 1: Application of rural development policies and agricultural intensification at different levels

Period	1995-2000	2000-2005	2005-2009	2009-2014	Since 2014
Global context and general policy guidance	Progressive disengagement of the State and beginning the concept of sustainable development	State disengagement and reinforcement of the concept of sustainable development	Back to the concept of the Green Revolution with an ecological vision of agricultural production at the same time	Crisis context, lower general investment in the agricultural sector	Relaunch of support for agricultural production
Policy framework document	DCPE (Economy Policy Framework Document)	DSRP (Strategic document for the reduction of poverty)	MAP (Madagascar Action Plan)	PGE (State General Policy) and MAP suspension	PND (National Development Plan)
Action plan, rural development policies	1994: Rural Development Policy	2001: Action Plan for Rural Development (PADR) and the Regional Programme for Rural Development (PRDR)	2005: National Rural Development Programme (PNDR) 2008: Agricultural Sectoral Programme (PSA)	Attempt at alignment of Sector Programme for Agriculture Livestock and Fishing Sectors to CAADP (Regional Initiative)	PSAEP alignment to CAADP
Agricultural policy measures and global orientation in terms of intensification	Privatisation of the financial sector (agricultural funding) Reduced spending by the Ministry of Agriculture	Liberalization and privatization by applying true prices for all products (inputs and products)	Liberalization, improvement, of production environment and services according to farmers decentralization process Direct intervention of the State on the development of inputs	Liberalization, service improvement according to farmers. Overall decline in agricultural investment (from 13% of the State budget to 4%)	Improved services according to farmers. Relaunch support in the agricultural sector (min 10% of the state budget according to the PSAEP/CAADP)
Role of the state	Orientation towards the direct improvement of the production environment from the 2000s in particular with the development/drafting of political documents, political letters, national strategies (global or sub-sectoral) following various processes integrating the different participants.				
Political documents to improve the environment of production	1996: Adoption of a law allowing the transfer of natural resource management responsibilities to local communities	2000: Agricultural and Food Policy 2004: Master Plan for the Development of Rural Economy	2005: National Action Plan for Development of Food Security/ 2007: Action Plan for the Sustainable Green Revolution/ 2009: Framework of Service Strategy to Farmers	2012: National Strategy for Agricultural and Rural Training 2013: Alignment of the ASP on the COMESA regional priorities within the framework of CAADP	2015: Policy Letter for Agricultural Development

Political letters or sub-sector national strategies (improvement of production environment)	1994: Policy statement for the development of irrigated subsector 1996: Various laws (AUE Water Users Association, community management, at the village, of natural resources known by the name GELOSE law, adopted in 1996), seed producers' associations, breeders' associations	2001: Livestock Sector Development Policy Letter 2004: Rice Development Policy 2003: Director Plan for Fishing 2004: Milk sector and dairy policy in Madagascar 2004: National Microfinance Strategy (NMFS, 2004-2007)	2005: Letter of Land Policy/Food Security Policy Letter 2006: Policy Letter for development of BVPI/Letter of Food Security Policy/ National Strategy for the Adaptation of sugar sector in Madagascar/National Strategy for development of fertilizer use 2008: National Seed Policy Document/National Rice Development Strategy/National Microfinance Strategy	2008: Integration in the CARD[8] country group with the development of mechanization subsector 2009: Farmers services development; 2010: Rice development/Policy Letter for development of cassava industry 2013: National Strategy for Financial Inclusion	2015: National Strategy for the Mechanization of the rice sector
	Despite the progressive disengagement of the State, some direct operations were conducted by the State depending on the period. Policy tools were also implemented by the State to support the process of agricultural intensification				
Direct actions by the state to support agricultural intensification	ODR 2: Rural Development Operation PNVA: National Agricultural Extension Programme	Reform to secure the rights of farmers on land that they enhance in drafting land policy letter in 2005.	National Program BVPI[9] Service strategy with farmers (SACSA in 2009). Decentralization of actions to support producers	Establishment of Agricultural Service Centres. « Coup de pouce »[10] operation « Révolution verte durable »[11] operation	During the 2009-2010 campaign, the "Opération Labour" was conducted to promote agricultural mechanization
	Increased involvement of the Civil Society (private, NGO ...), favoured by the support of donors				
Actions managed by the Civil Society (in cooperation with the State)	Rural microfinance systems[12] in order to support agricultural development	Diversification of rural micro finance offers/Miscellaneous Projects/Programs (fight against poverty, food security, crop diversification, small irrigated areas, etc.) Early dissemination actions of agroecological practices	Various donors supporting Projects/Programs (fight against poverty, crop diversification, food security, agricultural intensification, small irrigated areas, etc.) Dissemination actions of agroecological practices strengthened and diversified players	Scarcity of donors supporting projects/agricultural development programs Dissemination actions of agroecological practices continued	Reopening of support funds (fight against poverty, food security, crop diversification, agricultural intensification, small irrigated areas, etc.)

[8]CARD or Coalition for African Rice Development: it is a regional initiative (Africa) which aims to double rice production in Sub Saharan Africa.
[9] PNBVPI: National Programme of Watersheds and irrigated perimeters created and institutionalized by decree N° 2006 – 644.
[10] "Coup de pouce" Operation: Operation managed by the State to purchase transport of improved seeds, fertilizers and pesticides to support intensification.
[11] « Révolution verte durable ou doublement de la production » Operation → Recruitment of agricultural extension workers referred to as "Volunteers of Agricultural Development" (VDA), Transport and/or mission of DRDR technicians, purchase of agricultural inputs, technical support by NGOs.
[12]Following a relay difficulty in agricultural financing with the new private banks, the State with the support of donors (IMF, World Bank, EU and AFD) and specialized NGOs (CIDR, IRAM, FERT, etc.) has institutionalized the Decentralized Financial Systems (DFS) in 1990, in particular AECA created by CIDR in 1990, CECAM created by FERT in 1993, OTIV created by DID in 1994 (Guignand and Weiszrock, 2006).

Among the main projects/programs supervised by the Ministry of Agriculture, Livestock and Fisheries (non-exhaustive list):

- 1997-2006: PADANE – North-east Agricultural Improvement and Development Project
- 2001-2013: PSDR - Project to Support Rural Development
- 2005-2012: PPRR - Rural Income Promotion Programme
- 2008-2016: AROPA - *Andrin'ny Rafitra Ombom-Pamokatra ny Ambanivohitra*
- 2011-2021: FORMAPROD – Training and Improving Agricultural Productivity Programme
- 2013-2018: PRIASO – South-west Region Agricultural Infrastructure Rehabilitation Project

1.2.3. Evolution of the level of agricultural intensification in Madagascar

It is difficult to specify the impact of policies at the national level because they have been very diversified (improvement of production environment, planning of productive infrastructures, commodity chain approaches, geographical approaches, support to agricultural holdings, etc.) of a different nature (state or private, actions of donors, NGO initiatives, etc.) and in different periods of time.
Three aspects have been retained to analyse the effects and present the general evolution of agricultural intensification in Madagascar: *(i)* the evolution of the structure of agricultural holdings and their productivity, *(ii)* the evolution in various aspects of intensification, and *(iii)* the evolution of major productions at national level.

1.2.3.1. Evolution of the structure of agricultural holdings and their productivity

Statistics on the evolution of agricultural holdings are few and relatively old, with the results of the two-agricultural census of 1984/85 and 2004/05. From the evolutionary rates between the two census, a projection of the situation for 2014/15 has been proposed (MAEP, 2007) and then the calculation of averages at the level of the agricultural holdings has been made (Sourisseau *et al.*, 2016; Table 2).

Table 2: Global evolution of structure and productivity at the level of the average Malagasy farm

Variables	RNA	RNA	Previsions	Average per farm		
	1984/85	2004/05	2014/15	1984/85	2004/05	2014/15
Agricultural population	8,265,972	13,315,725	16,900,528	5.67	5.48	5.39
Farm's workforce	1,458,835	2,428,492	3,133,300	1	1	1
Number of plots	6,314,329	10,071,126	12,718,923	4.33	4.15	4.06
Physical area (ha)	1,755,707	2,083,590	2,269,794	1.20	0.86	0.72
Rice cultivated area (ha)	1,088,452	1,250,842	1,158,773	0.75	0.52	0.37
Rice average yield (T/ha)*	1.84	2.44	2.77	1.84	2.44	2.77
Rice yield (kg/farm)	1.380	1.260	1.020	1.380	1.260	1.020
Bovines (Stock numbers)	8,148,984	9,500,139	10,257,540	5.59	3.91	3.27
Pigs (Stock numbers)	736,027	1,247,043	1,623,212	0.50	0.51	0.52
Sheep (Stock numbers)	429,136	695,229	884,900	0.29	0.29	0.28
Goats (Stock numbers)	744,768	1,218,848	1,559,243	0.51	0.50	0.50

* The evolution of rice yield was calculated through the national production statistics from 1980 to 2013 (2014/2015 yield being that of 2013).

The average values at the level of the farm indicate a severe degradation of productive capacities in particular regarding the availability of land and animals (physical areas of farms and those cultivated under rice, the same for cattle). In 1985, the average area was 1.2 ha, and it dropped to 0.86 ha in 2005, a reduction of almost 30% in 20 years, linked to the sharing of farms during the transfer of inheritance between generations. The number of cattle decreased from 6 to 4 head/farm. The extrapolation of the trends showed a very difficult situation in 2014/15 with greatly reduced production capacities (only 0.72 ha of the physical area, 0.37 ha cultivated annually with rice and only 3.27 head of cattle). Even if it is difficult to make comparisons, this situation seems to be confirmed by the results of the periodic household survey (PHS) carried out in 2010 (INSTAT, 2011).
Despite the positive evolution of rice yield during the last thirty years, the strong decrease in agricultural land per farm induces a progressive decrease in production per farm, and thus a

reduction in the overall productivity of Malagasy farms, even if the physical productivity of rice increases. By evaluating the two, the number of workers per farm, rice productivity of farms, the productivity of rice on farms and by approximating productivity of cereals, would it should now be 500 kg/worker. According to the work of Mazoyer, there would be a productivity gap from 1 to 4,000 compared to farmers in developed countries.

Public policies do not seem able to address the constraints of agricultural development, considered by some as a demo-economic impasse caused by the combination of a strong increase in the rural population and the immutability of agrarian structures (Dabat *et al.*, 2008). While the population doubles in a generation, secondary and tertiary sectors stagnate and are unable to absorb the additional annual young entrants into active life. It is the agricultural sector that has absorbed most of the population growth. But due to the low labour productivity (Bockel and Dabat, 2001) and a very limited area extension, the sector now appears to have run out of steam.

1.2.3.2. Evolution of some components of the intensification process

1.2.3.2.1. Non-successful Green Revolution

Agricultural intensification following the conventional approach of the Green Revolution[13] has been promoted for a long time in Malagasy agricultural policies and especially since 2005. Even if the statistics are largely missing, some indicators converge to conclude that agricultural intensification of Green Revolution type has made little progress in Madagascar.

- ✓ **Very low use of improved seed varieties**

Diffusion of improved varieties (or improved breeds) has always figured prominently in the objectives and measures of agricultural policy. However, according to assessments, the use of improved varieties is very low in Madagascar compared to other countries. The 2005 General Agricultural Census estimated that only 1.3% of the irrigated rice areas used improved seeds. Currently, only 20 percent of the area under rice cultivation in Madagascar would be planted with modern varieties (World Bank, 2014b).

- ✓ **The management of water, a model in crisis**

In Madagascar, the management of water in the lowlands and low slopes for rice cultivation is one of the main concerns of agricultural development in Madagascar. Irrigation on the uplands (*tanety*) remains a very limited practice.

With the structural adjustment policies in the late 1980s, the state has disconnected from the irrigation sector. Over the past 20 years, interventions have focused on the rehabilitation of the existing equipment and/or the construction and rehabilitation of small and micro rice-growing areas. Along with this public support, many management transfer actions were carried out under the 1996 law on the creation of various types of association, including the Water User Association (AUE). But, the technical, organizational and financial capacities of AUE would not be sufficient to ensure an effective maintenance and management of hydraulic networks (Minten *et al.*, 2006). The regulations on the management and distribution of water are not respected within these associations (Bédoucha and Sabatier, 2013) resulting in an increase of badly-irrigated rice crops or poor control of water, and therefore losses of rice yields.

- ✓ **The limited use of effective techniques**

Effective techniques have always been important thematic guidelines for public policies in terms of extension or farm advice to deal with low agricultural productivity (in 1995 with the National Agricultural Extension Programme - PNVA, and later through the actions of projects/programs and NGOs). It should be noted that the evaluation of projects always shows

[13] The five pillars of the Green Revolution which are: *(i)* use of improved seeds, *(ii)* water control, *(iii)* use of effective techniques, *(iv)* use of modern and efficient agricultural equipment, and *(v)* use of fertilizers, have always been promoted in various policies in Madagascar. However, the term "Green Revolution" has been used more often since 2005.

either the non-adoption of the systems or the gaps between what is proposed and what is actually applied. This phenomenon of technical adaptation is explained by some authors as inherent in farmers' innovation process (Penot *et al.*, 2015).
Malagasy farmers are resistant to many technical changes especially because of their strong aversion to risk, understandable considering the regular shocks that they have to face. The passage from random rice transplantation to rice transplantation in lines took forty years for 90% of the farms studied in a rural commune (case of Ampitatafika Commune) in the Highlands (Gannon and Sandron, 2006).
In the case of the System of Rice Intensification (SRI), an innovation that seemed promising within the context of small family farms with small areas of rice production, with the possibility of considerable increase in yield with little external inputs (Moser and Barrett, 2002), the adoption rate for this system remains too low and represents only 0.18% of the national rice cultivation area (Dabat *et al*., 2008), even with cases that dropped out (Minten *et al.*, 2006). However, for some researchers, if SRI had a great media and political success in Madagascar, but a low adoption in the field, we must look for the causes in the mechanisms accompanying the "political implementation" rather than in the farmers' inertia (Serpantié, 2013; Serpantié and Rakotondramanana, 2013).

- ✓ **A low mechanization level**

Mechanization (tractors, small engines, draft animals, agricultural equipment, etc.) is also part of the option of public policies for increasing agricultural productivity. In the 80s, operations for promoting mechanization were carried out but they did not produce the desired results. In the mid-2000s, the state initiated the following operations: diffusion of tractors (imported from India), "Plough" operation, directly by the state or within the framework of projects, donations of small implements (through projects/programs and NGOs).
According to the 2000 figures, cited in the National Rice Mechanisation Strategy in 2015, only 0.2% of farmers use a tractor and its equipment. The rate is 0.1% for the use of tiller with accessories. The use of an ox-plough is of 33%, ox-harrow is 29% and rotary hoe (weeding) is 14%. The vast majority of farmers use manual tools: 97%, use the "*angady*", shovel, pickaxe and 92% the sickle and machete.

- ✓ **A very low level of use of fertilizers and pesticides**

The use of fertilizers and pesticides has always been an important part of the Green Revolution promoted in Madagascar with public policies that include measures of support through direct actions of provision or improvement of access and use. However, fertilizer use stagnated at a very low level. According to the World Bank, the use of fertilizers changed from 2.1 kg/ha in 2002 to 3.9 kg/ha in 2013 (http://donnees.banquemondiale.org/). This use would be in the order of 6 to 8 kg per hectare in rice cultivation (Randrianarisoa, 2000). This rate is below the average of African countries which was 9 kg/ha in 1995 (Yanggen *et al.*, 1998).
The use of fertilizers in Madagascar is well below of that of Indonesia (290 kg/ha) and has decreased in recent years (FAOSTAT, 2009), a country that had success in its Green Revolution. It should be noted that according to some surveys, the dose used on plots receiving mineral fertilizers is around 75 - 85 kg/ha which indicates that only 5-6% of the plots receive mineral fertilizers in Madagascar (Randrianarisoa and Minten, 2003; Minten and Ralison, 2003).
Regarding the use of pesticides, the level of use also remains very low in Madagascar, fluctuating from 100 to 700 grams of active ingredient per hectare. For reference, this rate is 5.4 kg/ha in France (in 3rd place at the European level).

1.2.3.2.2. Ecological intensification, a model still in an embryonic state

In Madagascar, the first experiments on ecological intensification date from the 90s. They have been heavily focused on the model of Direct Seeding Mulch-based Cropping systems (DMC),

also known as Conservation Agriculture (CA) that FAO defines as a model of agro-ecological practices based on three principles: *(i)* minimum soil disturbance, *(ii)* association and crop rotation, and *(iii)* permanent soil cover (http://www.fao.org/ag/ca/fr/).
Extension campaigns with farmers in Madagascar started in the early 2000s as part of projects that aimed to enhance and protect Watersheds and Irrigated Perimeters (BVPI) with an approach designed to protect the infrastructures within the perimeters of irrigated areas. Later, the actions were extended throughout Madagascar through food security projects/programs, adaptation to climate change, management/mitigation of risks and natural disasters, and protection of protected areas.
The adoption of DMC techniques remains limited despite the efforts to support it over the past fifteen years. We should note that the AC, with its three combined principles, induces practices quite complex to implement on farms. In recent years, other ecological intensification routes have also been promoted (management of organic matter, crop-livestock integration, etc.).
In 2013/14, it was estimated that a little more than 20,000 farms used ecological intensification practices. This level is still far below the 3 million farms across the country (only 0.7%). Thus, the dissemination of these practices is still embryonic and its contribution to the evolution of national productivity remains negligible.

1.2.3.2.3. Evolution of systemic intensification

The figures on the systemic agricultural intensification (optimization of the use of resources and production factors at the level of cropping systems and production systems, crop-livestock integration, management of crop rotation) are very rare across Madagascar. The existing statistical data are often per sector and per commodity chain, and do not allow the analysis in terms of a systemic approach.
These are the forms of intensification that seem the most widespread at the farm level as shown by the work carried out on intensification pathways carried out on the farms of the Vakinankaratra region, within the framework of **ProIntensAfrica** program.

1.2.3.3. Evolution of principal productions

Analysis of the national statistics available, shows that trends in the evolution of agricultural production varies according to the period of the policies, with similar trends for the principal food crops, within each period.
The period from1995 to 2000 was marked by the progressive disengagement of the State, with the privatization of the financial sector (agricultural funding). This period was also marked by the creation of a law on the transfer of management (establishing various types of association). During this period, agricultural production changed little (a trend towards stabilization).
From 2000 to 2005, the disengagement of the state was strengthened with economic liberalization in all sectors and the application of the "true price" for all products. This period was also marked by the initiation of actions to improve the production environment. NGOs and the private sector took over in the implementation of development activities. The evolution of food crops experienced variable trends.
From 2005 to 2009, the state has engaged in Green Revolution policies. The initiative was reinforced by the 2008 food crisis, with the return, at the international level, to investment in agriculture. The State has implemented many operations to improve access to fertilizers, improved seed varieties and pesticides. With decentralization, actions were carried out within the 22 regions (controlled by DRDR). Agricultural policies promoted agricultural intensification and small family farms have responded positively to incentives (Sourisseau *et al.*, 2016). The production of the main food crops increased during that period.

From 2009 to 2014, Madagascar was affected by political, economic and social crisis. Within this context, investments in the agricultural sector were revised downwards (from 13% during 2005-2009 to 4% during the transitional period according to UPDR). The actions of the State have been limited to a minimum with the introduction of a new organization of agricultural services (operation programmed during the previous period) in 2008/09. The effects of the actions carried out from 2005 to 2009 continued for a few years but in the second half of this period food production declined.

1.2.4. Partial conclusion

Despite the political orientations adopted and the efforts made to promote agricultural intensification over the past 20 years, the results are not as expected. Agricultural holdings have suffered a deterioration in their productive capacity and productivity. The Green Revolution has not been successful and ecological intensification remains at a very low level, with an impact that is not yet visible at the national level. The net production index per person reflects the productivity of Malagasy farmers (Figure 3). Over the long term, the trend is a decline in farm productivity. This trend continued during the last 20 years. In the years 2003-2004, policy measures have resulted in improved income and growth of global production that helped to stop the decline. A slight increase in the index was recorded in 2005, followed by stagnation in the following years. It should be noted that due to population growth, the overall increase in production was only sufficient to maintain the production per person.

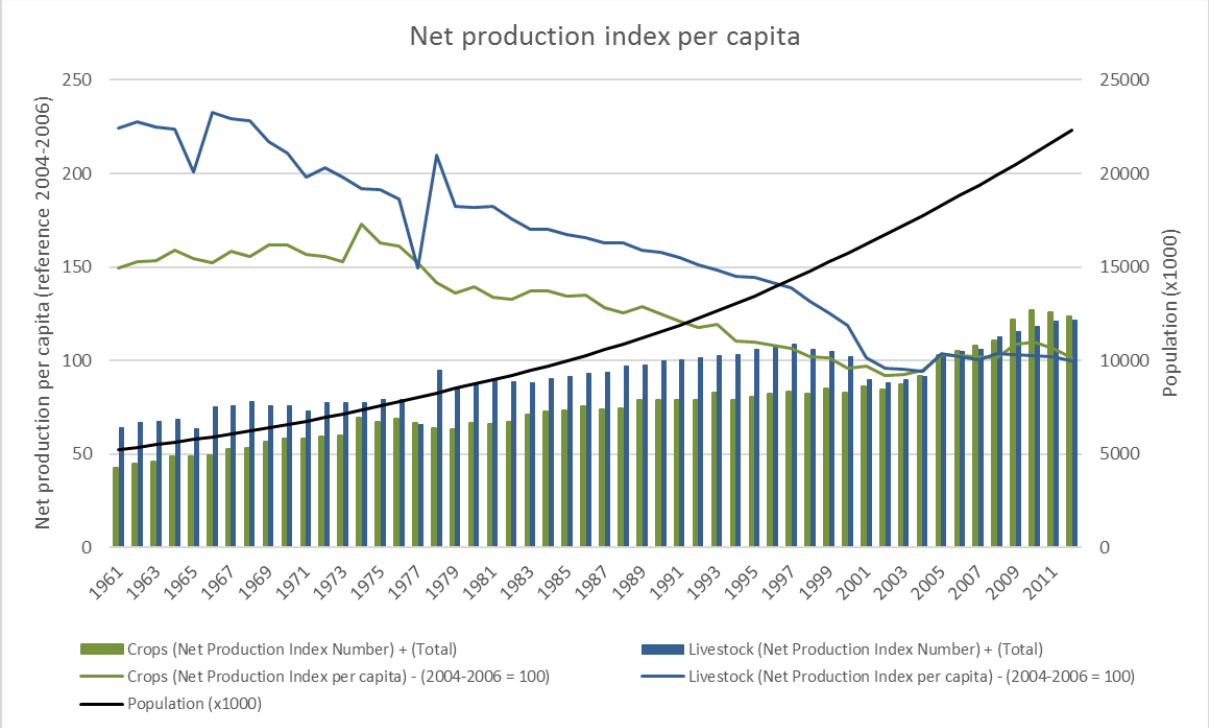


Figure 3: Net production index per person in terms of food crop production and livestock production

The evolution of agricultural production cannot follow population increase. Like rice cultivation, the emblematic crop of Malagasy agriculture for centuries, practiced by a large majority of farms, yields and agricultural production have stagnated, causing declining availability per capita and promoting import competition from Asian countries. Low productivity contributes to the inertia of rural areas.

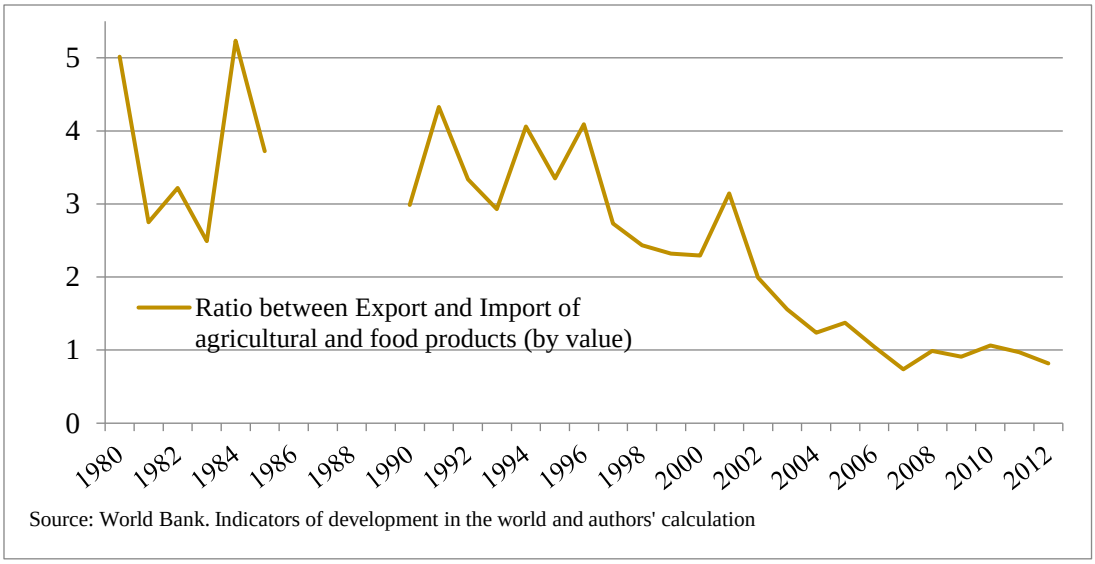


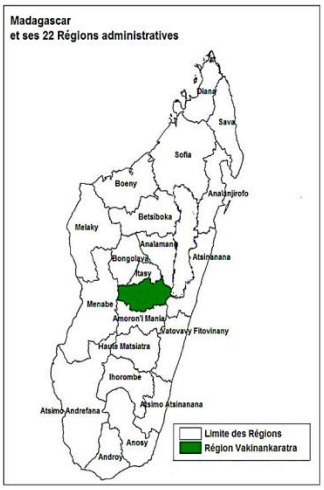
Figure 4: Evolution of the ratio between export and import of agricultural and food products

If the current political vision is to ensure food security and conquer the export market in 2025 (Republic of Madagascar 2015; MinAgri, MRHP, and MinEL 2015), the trends do not clearly reinforce this vision. The ratio of value between exports and imports of agricultural products deteriorated sharply over the past 20 years, with a value less than 1 from 2006 to 2007 (Figure 4).
This situation is very worrying for an agricultural country and where 81% of the active population works in the agricultural sector. The challenges of sustainable agricultural intensification are of major importance for the Malagasy state and for the country as a whole.

1.3. Agricultural intensification in the Vakinankaratra region

The region of Vakinankaratra was selected for a more detailed analysis in terms of agricultural intensification in Madagascar by observing its transformation during the last 10 years (2005-2015). This region was chosen because of its diversity of production systems under agricultural intensification but also due to its strong potential in terms of the improvement of agricultural productivity.

1.3.1. Vakinankaratra region



Located in the southern part of the central highlands of Madagascar, (Figure 5), Vakinankaratra region is characterized by a high-altitude tropical climate with summer rainfall. Its surface area is 126,473 ha and is the second most populous region of Madagascar (1,803,300 inhabitants with a density of 108.6 inhabitants per km², estimated by INSTAT 2013).
It currently comprises seven districts including two urban districts (Antsirabe I and Ambatolampy) and five rural districts (Antanifotsy, Faratsiho, Antsirabe II, Betafo and Mandoto); of 90 communes and 1,002 fokontany (Sourisseau et al, 2016).

Figure 5: Map of location of the Vakinankaratra region

1.3.1.1. Diversity of production systems

Vakinankaratra is a region with a vocation of crop-livestock farming and a predominance of food crop cultivation. Rice cultivation has a decisive place in the organization of space (irrigated rice and increasingly upland rice).
The population of the region increased from 1.541 million people (9.28% of the national population) in 2003 to 1,803,000 (8.3% of Malagasy population) in 2013. This population is very unequally distributed, with a higher population density in the East and in the Centre and which decreases towards the West (Figure 6). However, this density is relatively high compared to the national average because with less than 3% of the country, the region contains more than 8% of the population.

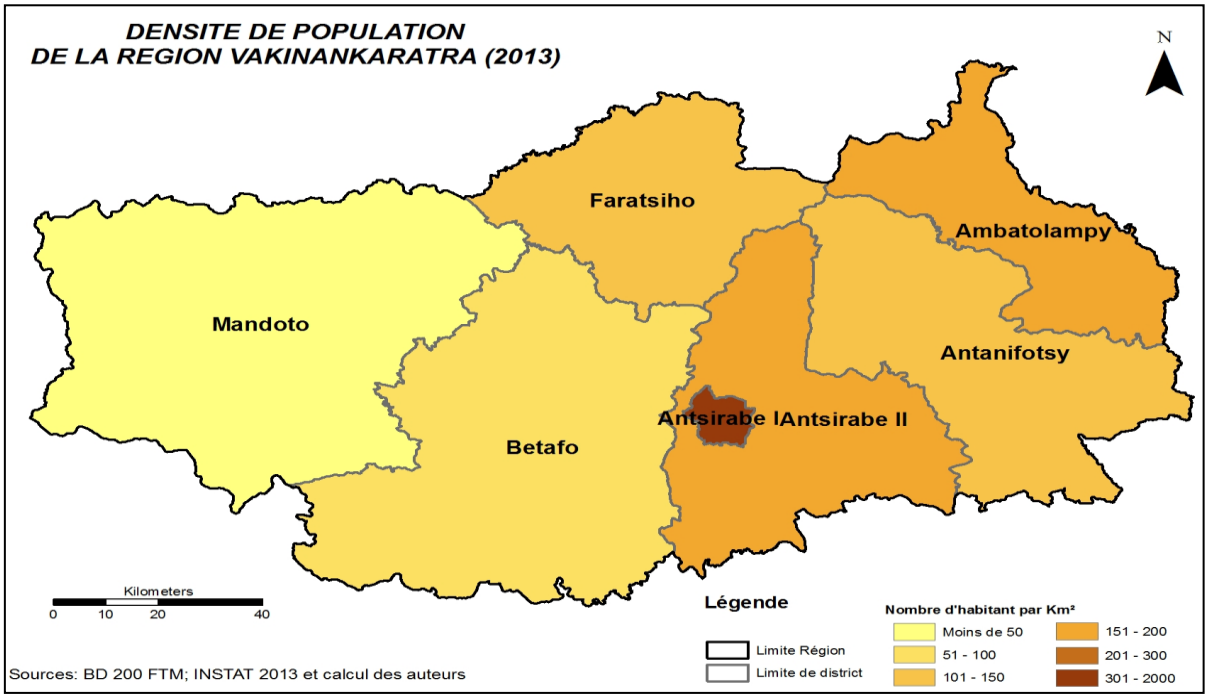


Figure 6: Population density map per district of Vakinankaratra region in 2013

The agricultural area is vast, but on one hand there are areas with relatively fertile soils (volcanic areas of Ankaratra and Betafo and the Great Plains from Ambohibary to Antsirabe) and on the other hand, over half of the surface area, have leached, ferralitic soils. The altitude varies from 600 to 2,600 m. Soils and microclimates are the source of some agroecological diversity with some more or less specific production systems (Figure 7):

- high altitude areas (over 1,600 m) characterized by cold temperatures, high rainfall (> 1,500 mm/year), rugged geography and medium land pressure, that are favourable for crops of temperate conditions, especially fruit trees (peach, plum, apple, pear, etc.), as well as fruit and vegetables (potatoes, carrots, etc.);
- medium altitude areas (1,200 to 1,600 m) with moderate temperatures, high rainfall (> 1,200 mm/year), a relief with relatively wide alluvial plains and high land pressure due to high population density are favourable to temperate crops and dairy farming of improved breeds. The region of Vakinankaratra lies at the heart of the "dairy triangle" (main zone of milk production in Madagascar);
- low altitude areas (<1,200 m) of the Midwest with warmer temperatures, a slightly lower but still substantial rainfall (<1,500 mm/year), peneplains with narrow valleys and a low

population density (this is an immigration area) are favourable for tropical crops and are an extensive livestock farming area.

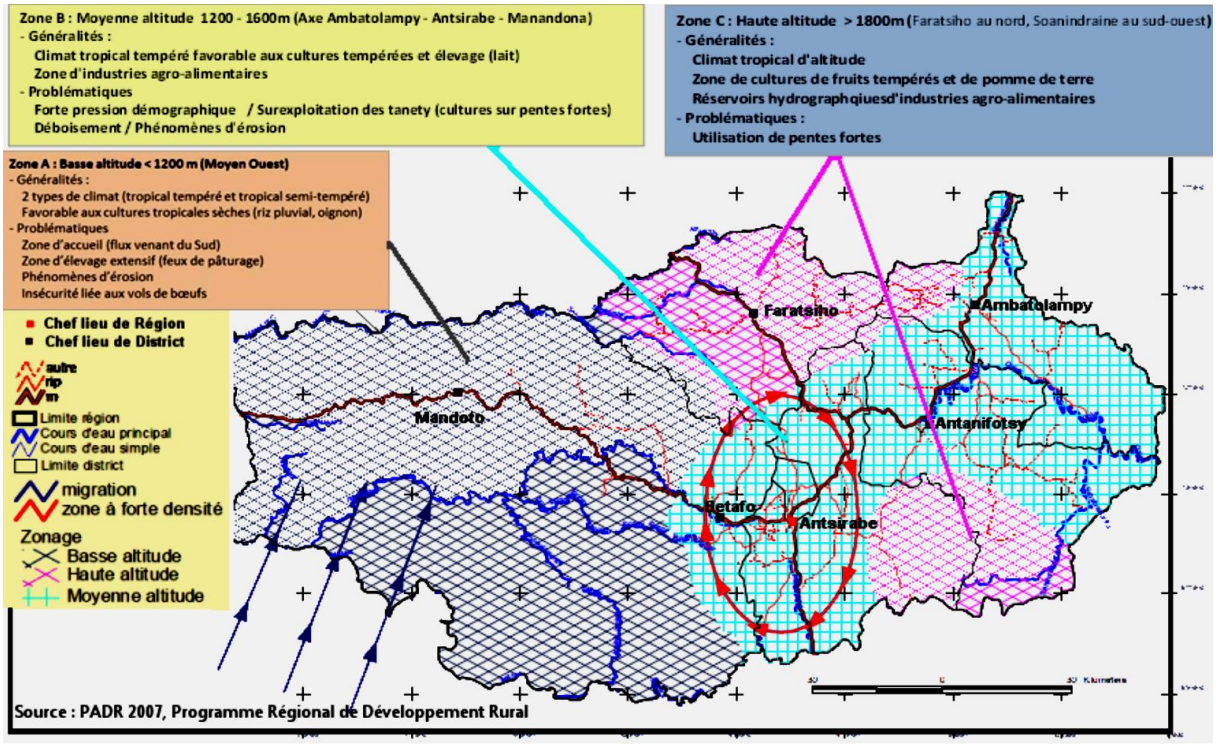


Figure 7: Agro-ecological zoning of the Vakinankaratra region (PADR, 2007)

1.3.1.2. A region with strong potential

Its geographical position, near the capital Antananarivo and not far - on the scale of Madagascar - from the main port of the country, gives this region significant benefits in terms of access to domestic and international markets. Adjacent to seven other regions, it is at the heart of economic exchanges in the south of the country. When comparing the number of busy days in the markets we can observe that the economy of the region is more commercial than most other regions (CREAM, 2013).

High tropical climate and fertile soils permits a great diversity of crop-livestock systems that farmers manage with real knowledge. Production systems are partially oriented towards the commercialisation of products (milk, fruits, vegetables, cassava, rice, leguminous plants, maize, etc.).

Mineral resources (precious metal, precious and semiprecious stones) are important, as well as water resources that could be mobilized for agriculture, hydro-electricity production and, more generally, the development of industry.

Compared to other regions, the secondary sector is relatively well developed with the presence of industries in several sectors: textiles and clothing, agrifood (dairies, beverage industries, mills, etc.), tobacco, essential oil processing, etc. Finally, the service sector including tourism is evolving.

In 2003, the Ministry of Agriculture, Livestock and Fisheries estimated the area that could be cultivated at 344,000 ha, which means 22% of the total area, of which only 52% was cultivated. In 2014, the Regional Directorate for Agricultural Development estimated the area that could be cultivated to be more than 600,000 ha, of which only 56.5% were cultivated. Thus,

Vakinankaratra region still has potential for agricultural extension, especially in the Middle East. However, farms are of a medium size and with a very low production capacity. The poverty level in 2010 was very high, 75.8% (INSTAT 2011), even if it was slightly below the national average (76.5%). Considering the few job opportunities in other sectors, the very significant place of the agricultural population and high population growth, the question that arises is the need to increase available agricultural land in order to allow the installation of new family farms.
The dynamism of the region, the biophysical conditions favourable for agricultural production, the diversity of production systems, the availability of agricultural land and the know-how of farmers constitute a large part of the potential for development. But, the expression of this potential requires the intensification and increase of agricultural productivity, particularly in the areas where population density and land pressure are already high.

1.3.2. Policies and programs implemented

The rural development policies of the Vakinankaratra region followed the national policies of the agriculture sector. For the last decade, they fit into the frame of fight against poverty and sustainable development and can be characterized according to three periods (Table 3).

Table 3: Periodization of rural development policies in the Vakinankaratra region from 2005 to 2015

Period	2005-2009	2009-2014	Since 2014
National political contexts (agriculture sector)	Improving production environment and return to the concept of Green Revolution (strong and direct involvement of the state in agricultural intensification)	Crisis context → Decline in agricultural investment Unclear guidance (objective to change but overall continuation of actions initiated)	Relaunch of support for agricultural production (land-use planning and agricultural intensification)
Agricultural policy and regional priority	Integrated Growth Pole, land-use planning (AIZ), agribusiness, commodity chain support, support of sustainable Green Revolution, land tenure reform	Commodity chain support Strengthening agricultural services	Growth Pole (AIZ), Commodity chain support Agribusiness Enhancement of territory Strengthening agricultural services

1.3.2.1. From 2005 to 2009: return to concept of the Green Revolution

The agricultural intensification policy adopted from 2005 to 2009 followed the concept of the Green Revolution with strong state involvement. With its agricultural potential, the Vakinankaratra region was able to obtain specific support from the state for improving agricultural productivity and land use planning (agricultural extension). Among the programs implemented the following should be mentioned:
The choice of Antsirabe as one of the three Integrated Growth Poles[14]**:** which allowed the region to benefit from the construction and improvement of infrastructures, institutional capacity building, development of its financial sector, as well as support of the development of agriculture and industry (CREAM, 2013). The overall vision of the program was to provide the services to improve quality and competitiveness to the different participants of the target sectors.

[14] PIC project (Integrated Growth Poles) is a project of the Government of Madagascar launched in 2004/2005 and supported by the World Bank. This project aims to raise economic growth over a broad social base in the poles identified by supporting promising sectors. Three IGP were chosen in Madagascar: Antsirabe/Vakinankaratra, Nosy-Be/Diana and Taolagnaro/Anosy.

Land-tenure reform for securing property rights in 2005: the objective was to promote agricultural investment through land-tenure security by establishing local services (land offices supported by MCA project - *Millenium Challenge Account*) and the allocation of documents guaranteeing land-tenure security.
Specific initiative for land-use planning and agricultural extension: this program aimed to facilitate access to land ownership and its exploitation. Within this context, since 2005, the region has promoted Agricultural Investment Zones (ZIA)[15] in different areas including the Middle East/Mandoto, the plain Onive aval/Antanifotsy, Manapa/Betafo and Soavinandriana/Faratsiho (EPP PADR and GTDR Vakinankaratra, 2007).
Professionalization of agricultural production with the following objectives: *(i)* encourage foreign direct investment (preferential regime, legal security including land tenure, simplification of administrative procedures), *(ii)* promote the installation of agro-industry in relation to small producers (quality support, extension, production management and purchase to producers), *(iii)* direct traditional small farming towards organic the agriculture sector which supplies the international market of organic fruit and vegetables, *(iv)* improve access to financial services to encourage agricultural intensification through micro-finance institutions.
Improving access to agricultural information (Agricultural Marketing): establishment of a market information centre, combined with additional surveys carried out on farms (establishment of Network of Rural Observatories).
Direct actions to support agricultural intensification: some were conducted with the direct intervention of the State. In the Vakinankaratra region, the priority sectors (defined within the framework of PRDR) were rice, fruit and vegetables, dairy and fish farming. Within the framework of the implementation of the Green Revolution, the "Voucher" system (provision of fertilizers at subsidized prices and reimbursement at harvest) was used to promote agricultural intensification by using mineral fertilizers. In parallel, the Ministry of Agriculture has encouraged the promotion of small machines (plough, harrow, rotary hoe, etc.).
We must note that several projects/programs and agricultural research organizations have accompanied this policy for sustainable farm management and their territories.

1.3.2.2. From 2009 to 2014: reduction of agricultural investments

The 2009 political crisis in Madagascar had the effect of abruptly ending some programs while continuing others.
Breaking the intensification dynamic: the actions which were strongly supported by the previous regime, with more or less political links or requiring a lot of public expenditure, and the actions supported by donors who boycotted the new regime, have been put on standby. We can mention some examples:

- Agricultural Investment Zone project on standby mode because a lot of companies stopped their activities;
- Reduction of support (reduction of State resources) in the implementation of the Green Revolution;
- Putting on standby the land-tenure security program due to cessation of funding by the US government through MCA (the transfer of the land offices to decentralized communities encountered technical and financial problems);
- Closure of TIKO Group belonging to the former President and very important to dairy sector (processing, collection, financing of production, etc.). Many crop-livestock

[15] The Agricultural Investment Zones (ZIA) are land reserves intended for farming. They were created by a decree issued by the Minister in charge of land following a request made by the Minister of the sector concerned or the Chief Executive of decentralized authorities according to the procedure outlined by the law 2008.014 of 23 July 2008 on the private domain of the State and its implementing decree.

farmers have been affected and restructuring actions have been carried out by participants in this sector.

Limited continuation of actions to support agricultural intensification: Especially micro-finance support, restructuring of priority sectors, support of certain initiatives for ecological intensification. However, the dynamics have been weakened by the crisis and the reduction of resources (both state and private).

Improving access to agricultural services[16]**:** a new strategy for facilitating farmers' access to agricultural services was undertaken with the creation of the Agricultural Services Centre (CSA) in the region (SACSA/MinAgri, 2009) in connection with the FRDA (Regional Agricultural Development Fund) which provides financial support for certain actions. Within this framework, farmers or groups of farmers have benefited from training, infrastructure support, financing of small items of agricultural equipment, as well as support in terms of farm structuring.

1.3.2.3. From 2014: Relaunch of support for agricultural production

In national policies, for many people, the relaunch is based on the implementation of the PSAEP program. The support of agricultural intensification, already underway, have continued in particular those that contributed to the improvement of the production environment (agricultural credit, land-tenure security, professionalization of farmers, access to agricultural services, etc.), and those that accompany agricultural intensification (productivity improvement projects/ programs, agricultural research, etc.). In this context, the region had some actions that it considered to be a priority:

- Strengthening of community grain stores to reduce producers' vulnerability to climate and economic hazards, etc.;
- The establishment of an agricultural science park, with a phase of studies launched by the PIC in 2007 - 2008;
- Supporting commercialization (awareness of commercialisation quality) with the establishment of wholesale markets and export goals and to supply the national market;
- Supporting structuring farmers' organisations, always with the aim to improve marketing channels;
- Sanitisation of commodity chains of the leading products of the region (dairy and apple industries) with the establishment of fixed and itinerant analytical laboratories.

For the Vakinankaratra region, relaunch is also marked by the strengthening of partnership with the private sector and by the enhancement of available lands, having as a priority investment, employment, and promotion of agricultural sectors.

1.3.3. Devices for implementation of public policies

Vakinankaratra is one of the few regions in Madagascar where the structuring of rural areas is relatively advanced. The region benefits from a territorial governance and more or less well-structured sectors with different public and private participants.

Administrative structures: Vakinankaratra region has many territorial and decentralized services (STD), some of which accompanied agricultural intensification. The Decentralized Territorial Collectivities (CTD) namely the Region and the Communes also provide services in this field.

Research centres and organizations: research organizations are numerous in the region and play an important role in the support of agricultural intensification.

[16] This action is the result of strategic discussions held before the crisis, even if the implementation began after the 2009 crisis (finalizing SACSA strategy in 2009 and then implementation of CSA and FRDA).

NGOs and Civil Society: the private sector, in particular NGOs, are involved in the implementation of rural development actions. CREAM inventoried forty NGOs working in the Vakinankaratra region, where a great part is connected to agriculture. Over 85% of these NGOs are concentrated in Antsirabe (CREAM, 2013).
Economic operators: they are among the main partners of farmers in terms of agricultural intensification. Compared to other regions, Vakinankaratra has many economic operators in different segments (exporters, distribution companies, collectors of agricultural products, agro-processing industries, manufacturers and traders of agricultural equipment, service providers, etc.).
Interprofessions and support centres for building up commodity chains: the development of commodity chains is one of the main orientations of the policies of Vakinankaratra region, targeting the most promising sectors: fruits and vegetables and dairy industry. Various interprofessional centres, technical centres, and platforms targeting priority sectors are actively involved in the improvement of agricultural productivity (target sectors).
Farmers' Organisations: with the aim to professionalize producers, farmers' organizations have been strongly promoted by various institutions (public and private). Thus, this region hosts a significant number of farmers' organizations. CREAM inventoried more than 3,170 farmers' groups.
Finance organizations and microfinance: they were set up to finance agricultural development. The first Micro Finance Institutions were installed in rural areas in the early 90s with a large extension of networks from 1996.
Development projects and programs: it is through them that key actions are carried out in terms of agricultural intensification. Their lifetime is variable, as well as the means that they mobilize.
Centres for support and supervision of agricultural mechanization: Vakinankaratra region has some organizations specialized in the development of mechanization and small agricultural equipment.
Agricultural Service Centres (CSA): these centres have been installed as part of the national program under the guidance of the Ministry of Agriculture and Livestock. They are independent structures with NGO status, driven by local participants to serve as a technical tool for the development of agricultural services. There is an ASC in each District.
Training centres (academic and professional) in the agricultural field: Vakinankaratra region has academic agricultural training centres and professional training centres on technical/agricultural advisement and in some cases farmers to implement and manage farms.

1.3.4. Agrarian system and agricultural intensification

It is difficult to comprehend the impact of the different intensification policies implemented. The following section provides an overview of agricultural intensification across the region from the available statistical data (which, it must be recalled, are scarce for many) and some survey results on intensification pathways of farms that were conducted within the framework of **ProIntensAfrica** program.

1.3.4.1. Evolution of intensification indicators

1.3.4.1.1. Productive capacity of farms

During the last ten years, surveys at farm level have been very limited and data are lacking to analyse productivity evolution across the region. To get information about farms in Vakinankaratra region we must consult both the agricultural censuses of 1984/85 and 2004/05. Based on these data, the productive capacity of farms in the Vakinankaratra region has clearly regressed in 20 years, since the average agricultural area per farm changed from 1.07 ha in 1984

to 0.55 ha/farm in 2004. This average area is low compared to the national average of 0.86 ha/farm in 2004.
The most recent data were obtained from the periodic survey of households carried out in 2010, (INSTAT 2011) which show that the average farmed surface area in the Vakinankaratra region is 0.5 ha (a much smaller area than the national average of 1.0 ha). The economic area[17] is on average 0.8 ha (median area is 0.4 ha) for Vakinankaratra region against an average of 1.4 ha (median area 1.0 ha) for the whole country, showing the very low farmed surface area per farm in this region. It is also noteworthy that the portion of small farms (<1.5 ha) is 84% in this region with a very small proportion of "large farms" with more than 4.0 ha (3.3%).
Household surveys conducted by the NRO from 2000 to 2013, in some villages in the Highlands of Vakinankaratra, show a declining trend in agricultural production per household. While the average yield remains at 2.8 ton/ha, the average production of paddy/household decreases with the downward trend in the average surface area cultivated with rice (Figure 8).

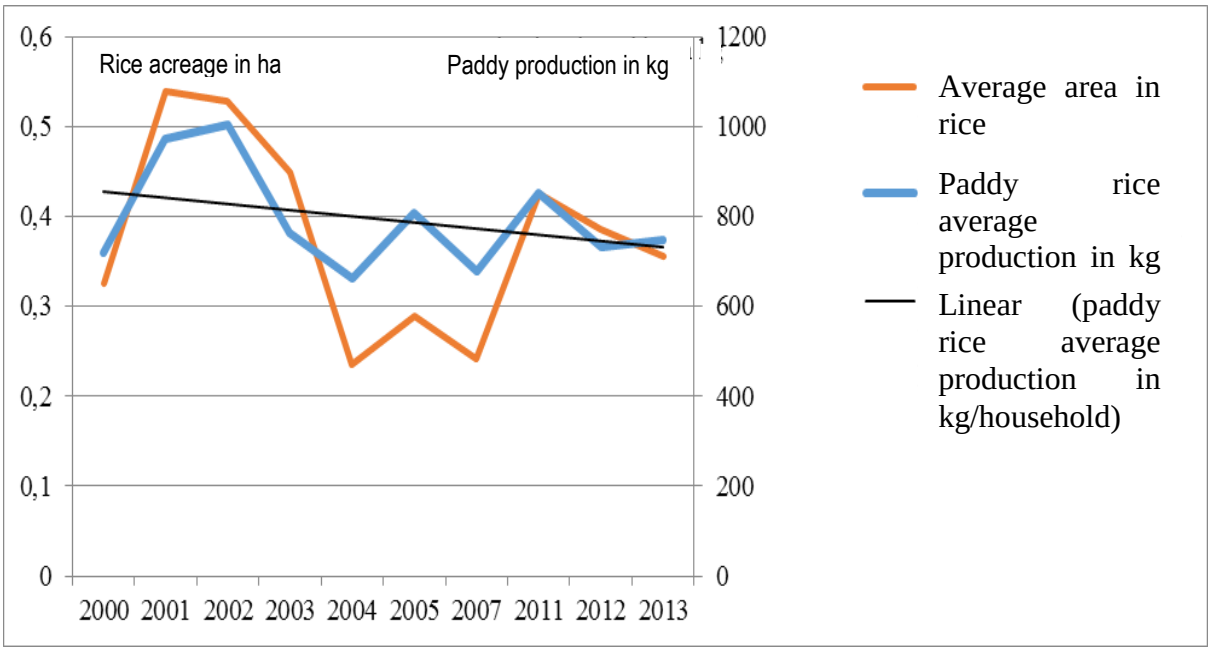


Figure 8: Evolution of surface area planted with rice and paddy production per household

1.3.4.1.2. Evolution of the components of conventional and ecological intensification

As for the national level, support for **conventional intensification** was conducted through the measures of the Green Revolution by promoting the use of: fertilizers and pesticides, improved seed varieties, agricultural mechanization, irrigation, and use of improved techniques, etc. As for the national level, the expected results were not attained (Gastineau *et al.*, 2010; CREAM 2013; Andrianantoandro and Bélières, 2015). This situation could be justified by:

- Very low use of improved seed varieties in cropping systems;
- Regression of mineral fertilizer use over the past 30 years, although 27% of the households in the Highlands use organic manure or mineral fertilizers, which is already better than the national average;
- Low mechanization of farms, with predominance of hand tools and traditional farming techniques;

[17]According to INSTAT, economic area is the physical surface area that is counted as many times that it is cultivated during the campaign. For a plot under double cropping the surface area is counted twice. However, the physical surface area corresponds to the surface area of the farm.

- Poor use of irrigation: 5% of the cultivable land and only 9% of the cultivated land is irrigated, which is low compared to national averages of 6.8% and 13%, respectively (Table 4).

Table 4: Rate of irrigated areas in the 7 districts of Vakinankaratra (CREAM 2013 and DRDA 2014)

Districts	Total cultivable	Cultivated/cultivable area	Irrigated/ cultivable area	Irrigated/cultivated area
Antsirabe I	7,500	83.9%	14.4%	17.2%
Antsirabe II	174,900	41.4%	5.0%	12.0%
Betafo-Mandoto	190,200	62.5%	3.9%	6.3%
Antanifotsy	84,500	65.2%	3.9%	6.0%
Faratsiho	37,700	58.1%	10.5%	18.0%
Ambatolampy	113,200	60.7%	5.7%	9.4%

With reference to rice cultivation, which for decades has been the priority of the state, 47% of farmers still used traditional rice growing techniques in the Highlands of Madagascar (ROR, 2013). As for the adoption of RIS techniques, it remains very low.

In terms of **ecological intensification,** the Vakinankaratra region was one of the privileged regions for the promotion of agro-ecological practices. The first actions of dissemination of CA techniques on-farm began in this region in the 2000s. Over the past 10 years, the dissemination actions have been intensified with the national agro-ecology project/GSDM in 2004 and BVPI project SE/HP in 2006.

In the Highlands, DMC systems with cover crops were abandoned in favour of forage production (BVPI SE/HP 2012). It is in the middle east that DMC systems were the most widespread, in response to low soil fertility but also to the development of Striga[18]. However, DMC adoption remains very limited in this zone with only 600 farmers applying it in 2015 in the middle east of Vakinankaratra (GSDM 2016). Moreover, the areas that adopted DMC systems tended to decline over recent years (Table 5).

Table 5: Evolution of DMC systems in the middle east during the last 10 years in ha

	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015
DMC based on *Stylosanthes*	5	129	398	703	391	373	601	467	116	
Fallow of Stylosanthes	0	4	99	408	808	276	141	165	23	54
Other systems	2	71	51	5	79	80	3	17	1	17
TOTAL (in ha)	**7**	**205**	**549**	**1,117**	**1,280**	**730**	**745**	**650**	**140**	**343**
Stylosanthes systems/total DMC tanety	**67%**	**65%**	**90%**	**99%**	**93%**	**89%**	**99%**	**97%**	**99%**	**94%**

Source: Database of FAFIALA, BVPI SE/HP and GSDM from 2005 to 2015

1.3.4.2. Intensification process at farm level

Due to increasing population pressure, productive resources are reduced and in most cases, no longer allow all families to meet their needs (Andrianantoandro and Bélières, 2015). Thus, to

[18]Striga (*Striga asiatica*): Hemiparasitic plant (cereals for the case of the Middle West of Madagascar). This plant has appeared in the Middle East in the 90s. It grows especially under conditions of decreased organic matter and soil fertility.

deal with food insecurity, households develop different strategies to intensify their production systems. This consists mainly of a systemic intensification.

1.3.4.2.1. Diversification at farm level

Land pressure in the region of Vakinankaratra influenced farmers in terms of production systems. Crop diversification was a widespread strategy to meet the low surface area available. This strategy, sometimes for survival, allowed farmers to enhance different types of land and depending on the different crop cycles of the year, to optimize the use of small areas with rotation or association of crops, to minimize risk-taking linked to specialization, and to meet their own consumption needs. Rice cultivation, practiced by 97% of the households according to ROR surveys carried out in 2013, remains the main crop, followed by maize, potatoes, beans and sweet potatoes. Rice, beans and sweet potatoes are mainly for home consumption, while a certain percentage of the maize and potato harvest is sold for cash income (EPP PADR and APB Consulting, 2009).

In the areas with high population density, as in the communes of Betafo District (volcanic area), plots are very fragmented and farmers can cultivate from 3 to 4 crops per year on the same plot: maize + beans, followed by potatoes once the beans are harvested and sometimes followed by off-season wheat, taking advantage of the last rains.

Similarly, diversification is the first lesson learned from data analysis of the 24 surveyed[19] farms, with three main reasons mentioned:

- It consists of an anti-risk/impact protection strategy;
- It allows better enhancement of production factors;
- It helps to meet the food requirements of the farmer's family.

Almost all the farms surveyed have diversified crops since their installation (Figure 9). The level of diversification is unique to each farm, but in general, crops are part of the most widespread speculation in the region.

[19] Following the discussions held at the 4th meeting of rural stakeholders in Vakinankaratra region that took place on the 2nd June 2016 at the Social Residence, in Antsirabe.

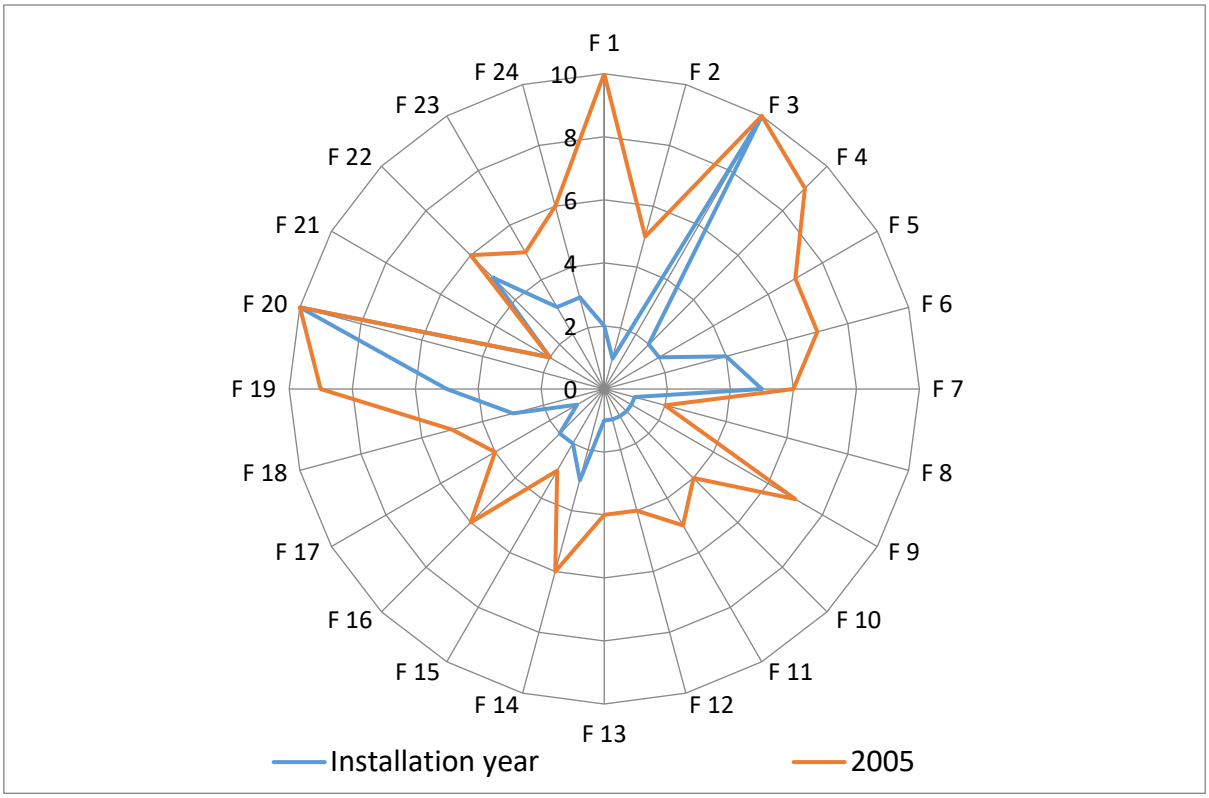


Figure 9: Number of species cultivated by farmers from their implementation until 2015

Diversification is related to the development of off-season crops. In the region, off-season crops are deeply-rooted in farmers' practices. They were promoted by the state, projects/programs and NGOs but also supported by those active in certain sectors (support through contract farming with input supply and purchase of crop products, and through the technical framework). Off-season crops are generally practiced in irrigated rice fields after rice cultivation during the rainy season (November to May). The practice of off-season crops is an example of successful intensification within a context of space saturation because rice benefits from the effect of off-season fertilizer input (Penot *et al.*, 2009; Gastineau *et al.*, 2010).

1.3.4.2.2. Strong expansion of upland rice on *tanety*

The lack of land for irrigated rice is a real problem for farms in Vakinankaratra. In the areas where ROR carried out surveys, a household has an average of 42.3 acres, i.e., less than 7 acres per person, 8% of farms have no lowlands and 62% have less than 50 acres (Andrianantoandro and Bélières, 2015). This situation has encouraged the development of upland rice on *tanety*, which is a method of adaptation to meet the growing demand for rice and the increased land pressure on flooded land (Dabat *et al.*, 2005).

In the Vakinankaratra region, a strong expansion of upland rice was observed during the last 10 years. According to DRDA, 27,000 ha of upland rice were identified and would increase by 30% between 2014 and 2015. This increase was facilitated by the extension services and the strong adoption rate of technology (10% in 2000, 30% in 2005, 71% in 2012 and 89% in 2014; Figure 10) according to the work of several authors. The last survey of Randriambololona, carried out in 2012, reported that the average surface area cultivated with upland rice was 5.5 acres/farm against 20 acres/farm of irrigated rice.

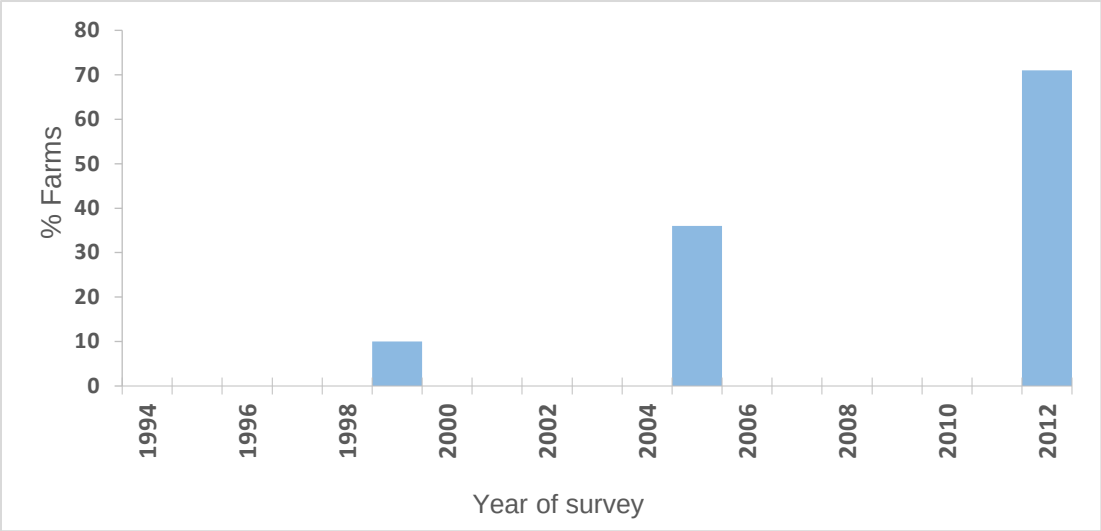


Figure 10: Evolution in percentage of farms practicing upland rice in the Highlands of Vakinankaratra

The development of upland rice is a kind of systemic intensification that was strongly supported by research (Breumier, 2015). In fact, in the mid-west, upland rice has been grown since the 60s especially with varieties from Brazil introduced through research. In the Highlands, the growing of upland rice was not possible before the development of the first improved varieties of upland rice adapted to low temperatures in 1995 resulting from research work (Raboin *et al.*, 2015).

1.3.4.2.3. Strong crop-livestock integration

In this region, mixed crop and livestock farming are widespread. According to NRO surveys carried out in 2013, cattle, pig and poultry farms are practiced by 71%, 64% and 81% of households, respectively. Crop-livestock integration is one of the components of production systems based on three pillars of interaction: *(i)* use of animal power, *(ii)* improvement of animal nutrition with agricultural products and by-products, and *(iii)* enhancement of effluents for crop fertilization. This practice was strongly supported and remains a priority in questions of research.

1.3.4.2.4. Adaptation of production systems within a crisis context

The 2009 crisis and the abrupt cessation of the TIKO group, which collected up to 45% of the milk produced in the region, strongly impacted dairy farms (Duba, 2010). With no outlet, crop-livestock farmers had to adapt, by seeking new outlets, reducing animal nutrition in order to reduce the purchase of external inputs, decapitalising with reduction of their dairy herd or by developing other activities. Some farmers, strongly committed to a conventional intensification process, have shifted towards a systemic and/or ecological intensification process in search of greater autonomy vis-à-vis input supply.
In certain farms, intensification is also supported by off-farm activities. Many farm managers have two jobs (ROR surveys in 2013). The search for off-farm activities is not a strategy of intensification itself, but it is a practice that can contribute to intensification by providing cash and financial resources to purchase inputs or to adopt techniques and equipment used for intensification.

1.3.4.3. Evolution of agricultural production in the Vakinankaratra region

There was a sharp increase in rice production from 2007 and potato production grew from the year 2010; Figure 11 and Figure 12). The other speculations tended to stagnate. The strong growth in rice production resulted from a combination of factors including: *(i)* the development

of upland rice cultivation (increase in surface area), *(ii)* development of "*vary aloha*" or first rice practiced in the off-season *(iii)* increasing yields by using improved seeds (produced through research), and *(iv)* also off-season practices, often heavily fertilized with organic matter, creating secondary effects on irrigated rice (Penot *et al.*, 2009). For the cultivation of potatoes, technical improvements (in large part thanks to the work of FIFAMANOR) have enhanced crop yields.

Thus, it can be concluded that the changes noted are partly related to agricultural policies that favoured the use of inputs (improved seeds, fertilizers, pesticides) and the development of off-season crops.

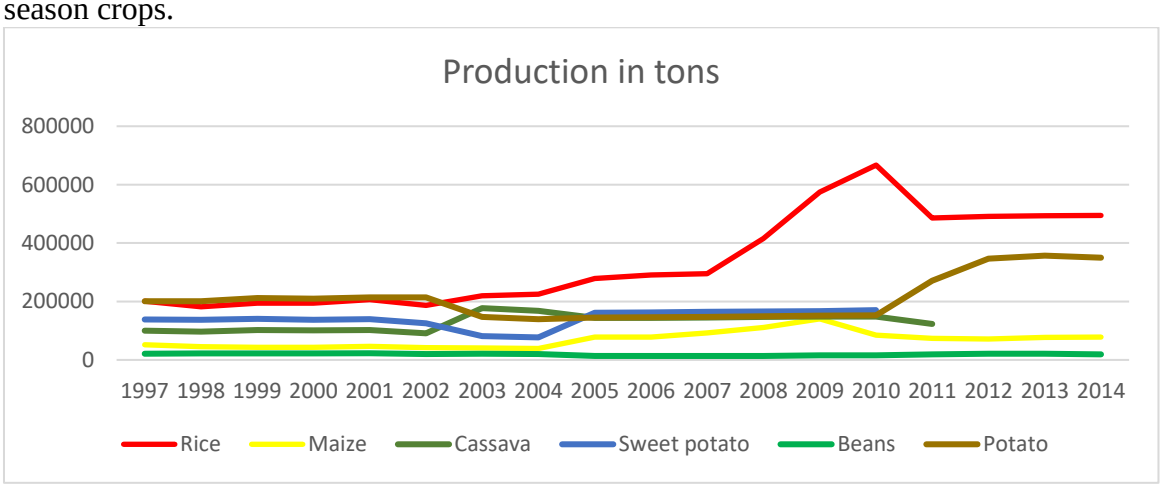


Figure 11: Evolution of the main productions in Vakinankaratra (DRDA)

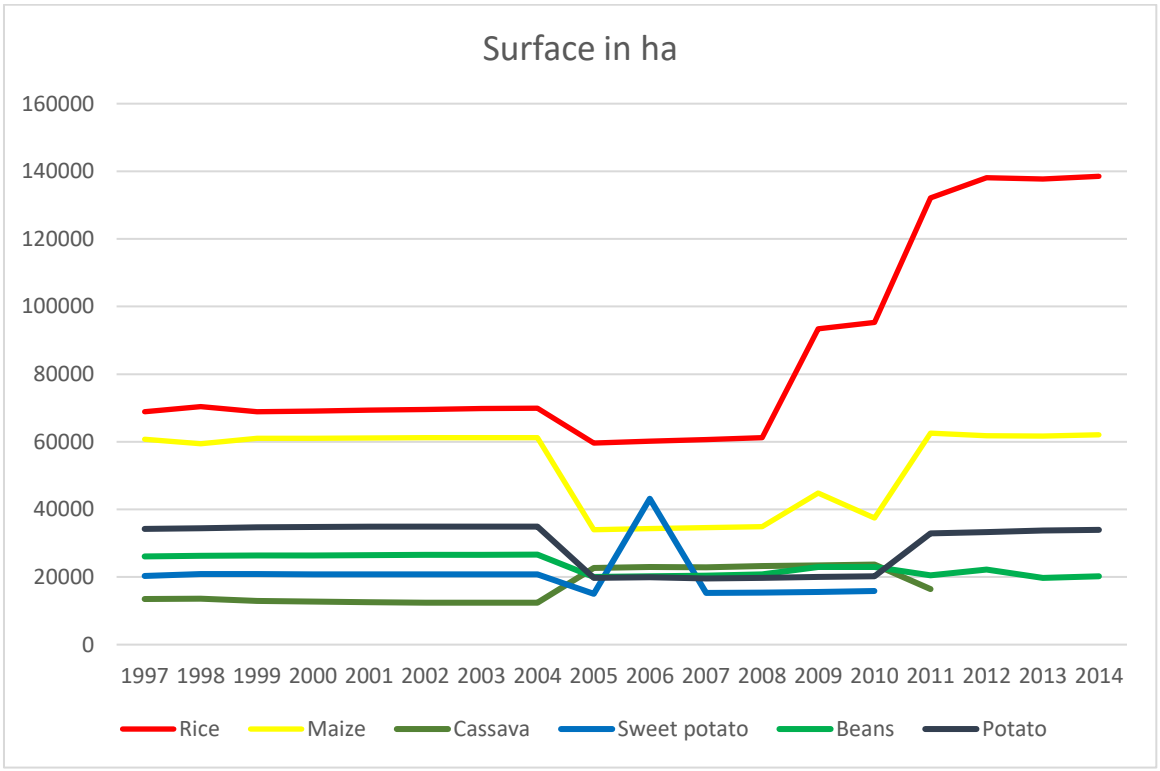


Figure 12: Evolution of the surface area of main productions (DRDA)

1.3.5. Partial conclusion

Agricultural development policies established in recent years have favoured the emergence of various forms of intensification in the region, but:

- They did not allow sustainable development of conventional intensification indicators and the ecological forms of intensification are still very limited;
- Farms have mostly adopted a form of integrated or systematic intensification;
- The increase in production cannot keep up with the increasing population and the productive capacity of farmers has tended to decrease;
- Major efforts are still needed to reverse this trend and to achieve a real sustainable intensification.

1.4. Challenges of a sustainable intensification

In some countries of East Asia (Taiwan, Korea, China, Thailand and Malaysia), agriculture has played a catalytic role in economic development with the increase of agricultural productivity during the Green Revolution (Bockel and Dabat, 2001).

In Madagascar, policies propose the vision of a competitive and sustainable agricultural production to ensure food security and conquer export markets by 2050 (MinAgri, MRHP and MinEL, 2015). In the light of past achievements, the challenge remains tough. Agricultural production is still characterized by very low productivity, one of the lowest in the world. And with less than 1.0 tonne in cereal equivalent per worker, it is characteristic of a manual agriculture according to Mazoyer (2008).

According to the bibliography mobilized in this part of the study, the situation continues to deteriorate particularly with the decline of the productive capacity of farms. This decrease is related to the increase of the active population, the transfer of inheritance between generations, the inability of other economic sectors to provide jobs to absorb the cohorts of young active people and the immutability of agrarian systems. At the macroeconomic level, the net production index per person is declining and the ratio of the value between exports and imports of agricultural and food products is deteriorating.

Public policies carried out so far have not reached a sustainable agricultural intensification. The Green Revolution policies from 2004 to 2009 were accompanied by an overall increase in major food crops. But over the long term, development is slower than population growth that is estimated today at 2.8% (i.e., a doubling of population every 18 years) according to the projections of UNDP in 2014. In the absence of consistent support policies, intensification remains limited. Farmers have mainly developed forms of systemic intensification by opting for the diversification of farming systems, mainly to avoid risks (or survival for the poorest) rather than to strongly increase productivity with increasing presence in the markets.

Studies showed that the barriers and constraints resulted from technical, environmental, social, economic, institutional and political factors.

In terms of the technical and environmental aspects, access to land remains a major constraint. Despite the small size of farms, Malagasy agriculture has both low land and labour productivity (Bockel and Dabat, 2001; Dabat and Jenn-Treyer, 2010). Thus, due to risk aversion, resistance to technical changes results in a low use of mineral fertilizers, limited mechanization and reduced diffusion of innovation (Dabat *et al.*, 2008). In addition, farms face a deficient production infrastructures which is also a major reason for low productivity (Morris and Razafintsalama 2010). The difficulties of access to improved varieties of seeds and agricultural inputs (limited availability and high cost) are due to the weak development of input distribution systems, high transport costs and the weakness of private sector (Morris and Razafintsalama, 2010; Randrianarisoa and Minten, 2003).

Farmers are faced with the degradation of natural resources (soils, watersheds, water resources, ecosystems, etc.) that generate a spiral of poverty and decreased agricultural productivity (Morris and Razafintsalama, 2010; Carret *et al.*, 2010; Minten and Ralison, 2003). To this is added frequent constraints (climatic hazards, insecurity, volatility of output prices, etc.).

Among social factors, land insecurity is often cited as an impediment to investment in productivity improvement (Dabat and Jenn-Treyer, 2010; Droy *et al.*, 2010; Morris and Razafintsalama, 2010). Human capital also influences the level of agricultural intensification according to some authors. The higher level of school education and financial security of the household manager (measured for example by the number of head of cattle per household) are favourable factors (Randrianarison, 2003). Finally, the reduction in the physical capacity of farmers (due to poor nutrition, inadequate health services) constitutes an intensification blocking factor (Morris and Razafintsalama, 2010).

For economic factors, several authors show the influence of agricultural prices on agricultural productivity (Randrianarisoa and Minten, 2003; Dabat and Jenn-Treyer, 2010; Droy *et al.*, 2010; Morris and Razafintsalama, 2010). The performance of Malagasy agricultural markets remains weak and is a real blocking factor for agricultural intensification. The unfavourable business environment discourages private investment and the majority of agricultural sector investors remain in the informal sector, which creates a vicious circle of low productivity (Morris and Razafintsalama, 2010). The low level of agricultural productivity is also linked to a very limited capacity of farmers to make productive agricultural investments. The market penetration rate of financial institutions in rural communities is only 20%, and only 10% of rural households have access to credit to finance agricultural production activities (AGEPMF in Morris and Razafintsalama, 2010). This low use of credit for production is associated to the lack of effective demand for bank financing and also an inappropriate offer of financial services (Morris and Razafintsalama, 2010) and that is expensive to users, even if borrowing rates are substantially higher.

Regarding the institutional and political factors, several studies have shown the link between poverty, low productivity of Malagasy farmers and remoteness of production areas, and consequently the isolation of farms (Razafindranovona *et al.*, 2001; Stifel *et al.*, 2003; Dabat and Jenn-Treyer, 2010; Morris and Razafintsalama, 2010). Morris and Razafintsalama indicate that in 2010 public institutions operating in the agricultural sector in Madagascar are fragmented, poorly provided with qualified personnel, and often managed incoherently. It was also shown that innovation is held back by an uncertain economic environment (Dabat *et al.*, 2008). Political crises have negative impacts on poverty. In addition, agricultural policy in Madagascar is sometimes under political influence, leading to opportunistic behaviours rather than the adoption of coherent measures to maximize social well-being and efficiency of the sector in the long term (Morris and Razafintsalama, 2010).

These elements partly explain the increased difficulties for the agricultural sector in Madagascar. The situation is very worrying and requires the performance of research work to improve agricultural productivity. This productivity improvement does not necessarily require a conventional type of intensification. Therefore, questions should be addressed on the types of intensification to develop and how to achieve sustainable intensification.

2. PATHWAYS FOR AGRICULTURAL INTENSIFICATION ON FARMS IN THE VAKINANKARATRA REGION

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In the previous section, the bibliographic study showed the important place that agricultural intensification has had in the policies implemented in Madagascar over the past 20 years. But it also showed the weakness of the results. Despite this, the increase in agricultural productivity and intensification seem to be required to face the economic and social development issues because of the driving role of agriculture: *(i)* at the macroeconomic level, to contribute to development and to fight against poverty, to provide employment to a growing population and to ensure food security, and *(ii)* at the microeconomic level, where agricultural activities constitute the main source of livelihood for the majority of households in the country, with 81% of the households in Madagascar practicing agricultural activities in 2010 (INSTAT 2011).
But, the relationship between policy measures at a national or regional level and the decisions made by producers on their farms are difficult to establish, and are not widely known. It was therefore relevant in the context of this study to better understand the place occupied by intensification in the strategies and practices implemented by farmers on their farms. From the analysis of long-term policies, the choice was made to understand changes over time, because the levels of productivity and intensification at a given moment for a given farm depend on the options taken previously. According to our approach, agricultural intensification is a process that is built over time at the mercy of decisions taken by producers; these decisions are related to: *(i)* the adopted strategies, *(ii)* the environment and its evolution (including policy measures, but especially in Madagascar the problems faced) and *(iii)* the interaction between the family and the farm, because farms are a family business.
To understand these processes and empirically illustrate the different pathways of agricultural intensification analysed in the context of the **ProIntensAfrica** initiative, extensive surveys were carried out among a small sample of farms in the Vakinankaratra region. This second part of the document presents the results of these specific surveys in three sections: *(i)* the methodology adopted, *(ii)* the results from the characterisation of pathways and their analysis, and finally *(iii)* the main lessons to be learned.

2.1. Methodology

2.1.1. Choice of farms and survey system

Within the framework of this case study, the main objective assigned to the field work was to collect some understanding of the implementation of the intensification process, over time, in the farms of Vakinankaratra, and not to have quantitative data more or less representative, to assess the level of intensification achieved by the different types of farms. With such an objective of comprehensive analysis, the approach developed could not be limited to speculation on very diversified farms in the region, but should also take into account the whole productive system (crop and livestock systems) related to other activities. Under these conditions, it should be carried out within a small sample of farms and reconstruct for each of them the pathways of intensification followed, by collecting, among the surveyed farmers, information on the reasons and motivations that "explain" this pathway and its possible changes. This kind of work could not be carried out by simple surveyors, it should utilize people with a

good training on agronomy, knowledge on the functioning of family farms, capacity to adapt questions to different pathways and communication skills to gain the trust of the farmers being surveyed.
With the means available and the expected time to do the job, the sample was limited to 24 farms (with a week of survey per farm in the field, then 2-3 weeks for formatting the data, control, treatment and writing up of each case) and surveys were carried out by four teams of two young agricultural engineers (i.e., six farms per team).
The selection of farms was decided on using the following criteria: *(*i) the farms involved, at a given moment of their existence, in intensification processes based on different types of production and localized in different environments and *(ii)* farms ready to receive a team of two young engineers and to give them the time and necessary trust to describe their journey. For this, different research teams involved in the SPAD platform (dP SPAD) and a few development organizations were asked to provide the names of farmers, as well as their location, being careful not to propose too "exceptional" cases. It was also necessary to have a few cases to represent the most common situation in the region with small farms, with few facilities to engage in intensification. This selection was made outside any research or development projects, in relation to local government officials (mayors and chiefs of *fokontany*).
A total of 24 farms were surveyed: 20 from the list established with Research and Development and four selected in conjunction with local communities. Table 6 shows the distribution of farms by their main activity assumed to be in the heart of the intensification process at the time of sample selection. The main agricultural systems of the region are represented. Farms with livestock activity (including fish farming) assumed to be strong in intensification process, represent more than half of farms (13 of 24), but all these farms also cultivate food crops. The work will show, only some rare exceptions (two cases), that there is no real specialization of the production system; the trend is the diversification of activities within the intensification processes carried out, most often by several production activities.

Table 6: Distribution of farms according to the main activity of the farming system

Main activity	**Number of farms**	**%**
Annual crops	6	25%
Annual Crops & DMC	2	8%
Traditional cattle farming	2	8%
Dairy farming	5	21%
Pig breeding	4	17%
Fruit and/or market gardening	3	13%
Rice-fish farming	2	8%
Grand total	24	100%

The design and preparation of the surveys needed a relatively long time due to the little experience available for this type of survey "pathway" in the region, and also because of the great diversity of situations needed to be taken into account. The survey was constructed with a first part that tracked the path of the farm itself, since it was started until the present day (2015), with the evolution of the available production factors, practices and techniques used, and finally to determine the results. In a second part, the questions were qualitative and open, and aimed to collect the opinion of farmers on the path followed, and especially the reasons that explained some decisions, but also on future projects for their farm and family, and the perception on agricultural policies implemented in the region. The collected data were entered into a common database built with ACCESS software. The treatments were performed with the software ACCESS, EXCEL and XLSTAT. For each farm surveyed, a specific report, with approximately 25 pages, describes in detail the intensification path followed and presents the results, especially with three sets of indicators (see below).

2.1.2. Sample of farms surveyed

The sample studied consists of 24 farms located in five of the seven districts of the Vakinankaratra region a with greater representation in the districts of Mandoto and Antsirabe II, where are located, at present, the main research fields of dP SPAD (Figure 13).

Figure 13: Location of farms monitored under the **ProIA** initiative

They are distributed over the three major agroecological zones defined within the framework of the Rural Development Regional Program (PADR, 2007; Table 7) *(i)* 42% in the mid-west corresponding to the district of Mandoto and part of the district of Betafo (low altitude <1,200 m, mild temperatures, importance of rainfed crops on *tanety*, extensive livestock farming, reception area), *(ii)* 50% in the mid-altitude zone (between 1,200 and 1,600 m, altitude tropical climate, importance of irrigation, dairy farming, fruit and vegetables, strong land pressure), and finally *(iii)* only 8% (the two farms of Faratsiho) in the high altitude zone (> 1,600 m, cold temperatures, hilly terrain, importance of irrigation, temperate fruits, medium land pressure). More than half of the surveyed farms are easy to access and are connected to power and water grids. Some farms are in difficult access areas (especially those of Faratsiho). Almost all surveyed farms have already benefited from the support of at least one development project.

Table 7: Distribution of farms by districts and ecological areas

Districts	Number of farms	%
Antsirabe I	3	13%
Antsirabe II	7	29%
Betafo	2	8%
Mandoto	10	42%
Faratsiho	2	8%
Total	**24**	**100%**

Agroecological areas	Number of farms	%
Medium altitude	12	50%
Middle West	10	42%
High altitude	2	8%
Total	**24**	**100%**

The head of the households that were surveyed were on average 53 years old (minimum 28 and maximum 69 years old), which is considered relatively old because in the rural areas of

Madagascar the average age of the head of the household is 42 years old (INSTAT, 2014a). Among these farm managers, there was only one woman, which is low compared to the 18.5% of households in rural areas that are headed up by women (INSTAT, 2011). Farm managers (FM) were on average 28 years old when they settled (minimum 18 and maximum 42 years old). The average age of farms (since the installation of the current farm manager) is 25 years old, but varies greatly, as the oldest installation dates back to 1975 and the most recent was in 2009. Logically, there is a positive linear relationship between the age of the farm and the age of its manager (correlation coefficient of + 0.74) and negative between the age of the farm and the age of its manager at his installation (coefficient correlation - 0.46).

2.1.3. Indicators used

Indicators were defined to assess economic performance in 2015 and to assess the levels of intensification and sustainability of the farm at the time of its installation and in 2015. These indicators were selected on the basis of bibliography and previous work in this area (Raharison, 2014; Briquel *et al*., 2001). With the aim to facilitate comparison and analysis, scores for each indicator were given from 0 to 10, according to predefined values. Scores were attributed according to a logic to qualify the levels of intensification: 0 is the lowest and 10 the highest level, indicating a very good level of intensification. All indicators were calculated from quantitative or qualitative values collected during the survey phase. They are presented in the tables below.

- ✓ ***Indicators of intensification***

In order to assess the level of intensification, 23 indicators were adopted (Table 8). They were grouped into five fields.

Table 8: Indicators of intensification

Field	Indicators of intensification
Productivity	Irrigated rice yield
	Rate of improved seeds
	Use of mineral fertilizers
	Number of bovine animals per forage surface area
	Rate of tanety utilisation
	Equipment (type: manual/animal/motorised)
	Animal performance
	Improved animal breeds
Viability	Surface area of irrigated rice field
	Rate of enhancement of rice fields
	Cattle herd size
	Pig herd size
	Poultry herd size
Resilience	Intercropping
	Number of crop species
	Number of animal species
Social area	Level of land ownership
	Improved crop farming techniques
	Improved animal farming techniques
	Surface area per family workforce
	Number of heads of animals per family workforce
Environmental scope	Use of manure
	Proportion of use of manure/mineral fertilizer

✓ ***Indicators of sustainability***

Regarding the indicators of sustainability, they are divided into three sectors, namely indicators of agroecological sustainability, economic and socio-territorial (Table 9). Moreover, some indicators of sustainability are common with the analysis of intensification. The analysis of sustainability allows the appreciation of the capacity of farms to continue in the long-term by preserving its resources.

Table 9: Indicators of sustainability

Field	Indicators of sustainability
Agroecological	Diversity of animal species
	Diversity of annual crops
	Diversity of perennial crops
	Distribution of different types of land
	Surface area affected by the improved rice cultivation techniques
	Ratios of irrigation
	Level of self-sufficiency in terms of organic fertilizers
Economic	UAA per person
	Number of pairs of zebu on cultivated area
	Number of livestock species commercialized
	Number of crop species commercialized
	Situation of equipment and material of the farm
	Land occupancy index
Socio-territorial	Market access
	Index of landlocked territory
	Proportion of commercialized agricultural products
	Education of adults in the household
	Sending young people to school
	Membership of farmers' organizations

✓ ***Economic indicators***

Finally, economic indicators measure performance in terms of land productivity, labour and capital but also with regard to poverty (Table 10). These indicators have been determined only for the present situation (2015), because it was impossible to reconstruct the initial period from the memories of surveyed farmers alone.

Table 10: Economic indicators

Field	Productivity indicators
Work productivity	Crop production income/family workers active in agriculture
	Livestock production income/family workers active in agriculture
	Farm income/family workers active in agriculture
	Total income/family workers active in agriculture
Land productivity	Agriculture Gross Margins/ha UAA
	Annual Work Unit of family farm/ha UAA
	Annual Work Unit of total farm/UAA (ha)
Capital productivity	Agricultural capital in million/AWU farm family
	Farm income/agricultural capital * 1,000
Level of poverty	Total income/person (compared to the poverty line)

To assess the level of poverty, the annual income per person in 2015 was compared to the 2012 poverty threshold which was Ar 535,603/person/year[20]. With this threshold, 71.5% of the population were classified as poor. To establish the scores, we also used: *(i)* the extreme poverty

[20] This threshold was evaluated with prices in the capital.

threshold (food basket threshold providing 2,133 kcal/day, estimated at Ar 374,941/person/year) with just over half (52.7 %) of the population living in extreme poverty and with a higher incidence in rural areas, *(ii)* the International monetary poverty threshold of $ 1.25 PPP[21] per person (corresponding to Ar 610,496/ person/year in 2012) and the threshold of $ 2.00 PPP per day or Ar 976,794/person/year) (INSTAT, 2014b).

2.1.4. Intermediate results

As already mentioned, each survey has given rise to the production of a specific report, so 24 reports with about 25 pages each, that present the quantitative data that characterizes the pathways, and the analysis made from the indicators.
Each report is structured as follows: *(i)* a general presentation of the farm (geographical location, main activities and main streams of development since the installation of the manager until 2015), *(ii)* a detailed description of the evolution of all the production factors of the farm, *(iii)* the major stages in the evolution of production practices (crop rotation, crop and livestock techniques, etc.), *(iv)* the results (yields, productivity and income in 2015), finally, the last part *(v)* shows the evolution of the level of agricultural intensification and sustainability of the farm by analysing the indicators. You will note that some items have been removed to prevent the identification of the farm.
The reports are complemented by a presentation of about 20 slides, used to lead discussions with development participants during the meetings with stakeholders (15 cases were presented and discussed). Finally, all the quantitative information that was used to prepare the reports was grouped in a database, used to conduct the analysis of pathways.

2.1.5. Limits and advantages of the methodology used

- ✓ ***Limitations and advantages of the method***

The main limit was related to the sample size: only 24 farms were studied and analysed, which excludes any representation in statistical terms, but also the diversity of situations in Vakinankaratra which is a region with great agricultural diversity. In addition, surveys were based on the statements of the farmers and their spouses. By using the memory of the farmers surveyed and by using the local units of measurement with conversion rates, there is a significant risk of inaccuracy.
But, this choice allows us to have common information over a long period for the 24 cases studied. Time and human resources allocated to each farm has allowed us to go over repeatedly the statements of the farmers surveyed and thus to reduce errors and inaccuracies. Only such a device was possible to illustrate a part of the diversity and understand the functioning and evolution. Moreover, the selection of farms was made in order to have information on the different agroecological zones and production systems characteristic of this area and the guidelines in terms of intensification (see above). Thus, even without representing the whole diversity, these case studies provide a broad overview of intensification situations and the information collected is unique and original in all the research work conducted in this area.

- ✓ ***Limitations related to indicators***

The first limitation, mentioned previously, is the lack of measurement and therefore the lack of "objective" data. The indicators are constructed from data declared by the surveyed persons. But, this limitation is inherent in this type of survey that complements in station and on-farm trials providing objective criteria because they were measured.

[21] The purchasing power parity (PPP) is a monetary conversion rate used to express in a common unit the purchasing power of different currencies. This rate represents the ratio of the amount of monetary units needed in different countries to obtain the same "basket" of goods and services. It may differ from the exchange rate (http://www.insee.fr/fr/methodes/)

The selection of indicators was made according to the available data and to adapt to systems with a great diversity of activities. Despite this option, some indicators could not be calculated or all the farms and for the two dates of comparison, because the farm did not practice any more or never practiced this activity. Hence the missing data for some indicators.
Finally, the indicators selected are designed to analyse three types of intensification, and in some cases, may have opposite meanings, for example, for conventional intensification, an indicator that increases at the same time as use the of inputs increases; and for agroecological intensification an indicator that measures the ratio of manure and mineral fertilizers that increases with the amount of manure but also with a limited use of mineral fertilizers.

- ✓ ***Relevance of considering the farm as a whole***

The methodology considered the family farm as a whole, that is to say, both aspects related to agricultural production and its use, but also non-agricultural activities and the relationship between family and farm. This methodological option allows you to better understand the choices made by the farmer, because as we shall see later, certain decisions that heavily impact the intensification process can be taken according to the family. There may be farm-decapitalization to deal with social problems, as well as the opposite, with agricultural investments made with the income from non-agricultural activities.

- ✓ ***Relevance of pathway analysis***

Finally, the results obtained allow us to describe agricultural intensification on a farm as a process for the long term with a situation at a time which depends on choices made earlier, confirms the relevance of the choice of method to track the pathways to analyse intensification.

2.2. Characterization of pathways

The surveys allowed us to track the evolution of the 24 farms, since the installation date until today (2015), by dividing it into three main parts: *(i)* changes in the farm structure (main production factors) and the activities carried out (including non-agricultural) which give an overview of the process of accumulation and evolution of the activity system, *(ii)* the evolution of the practices used in cropping and livestock systems with some performance indicators that provide an overview of the intensification process, and *(iii)* an assessment, for 2015, of the performances and productivity level achieved within the different activities. The results logically display a high diversity (methodological choice) and provide valuable lessons on the dynamics of intensification linked to the accumulation process.

2.2.1. Evolution of the structure and the activity system of farms

2.2.1.1. Number of persons and family workforce

On family farms the manpower available is related to the composition of the family that evolves over time. During installation, there are usually two active persons (parents), then the family is enlarged and the available workforce evolves and with it the capacity to intensify in terms of work in agricultural activities. However, the number of mouths to feed grows faster than family active workforce: consumption needs grow faster than workforce. To trace this pathway, we have grouped the farms according to their installation period (and therefore the age of farm) into four periods (Table 11) with average periods that range from 7 to 37 years. For the oldest farms, the period concerned approaches the duration of a farm life.

Table 11: Distribution of farms according to installation period

Installation period of the farm	Average age of the farm in 2015	Number of farms
From 1975 to 1984	37	7
From 1985 to 1994	27	9
From 1995 to 2004	16	6
Since 2005	7	2
Total	25	24

The evolution of the number of people on the farm, according to these four periods, is presented in Figure 14. The farms start with two or three people. The first curve corresponds to the longest cycle (40 years): the number of people increases during fifteen years to reach seven people, then stagnates at this level for ten years and then decreases to five people 40 years after the installation of the farm. We note that the departure of children is often partly compensated for by the arrival of young people, such as grand children or other family relatives, thus, the curve does not go down very low.
The other curves correspond to a part of this evolution. The curve for farms that settled during the 1985-1994 period reproduces the first two thirds of the cycle with a maximum of seven people. The curve of farms who settled between 1995 and 2004, seem to indicate a plateau with five people, and not seven as the previous ones, which could be interpreted as a slowdown in population growth, but the sample is very small and does not allow us to make such conclusions.

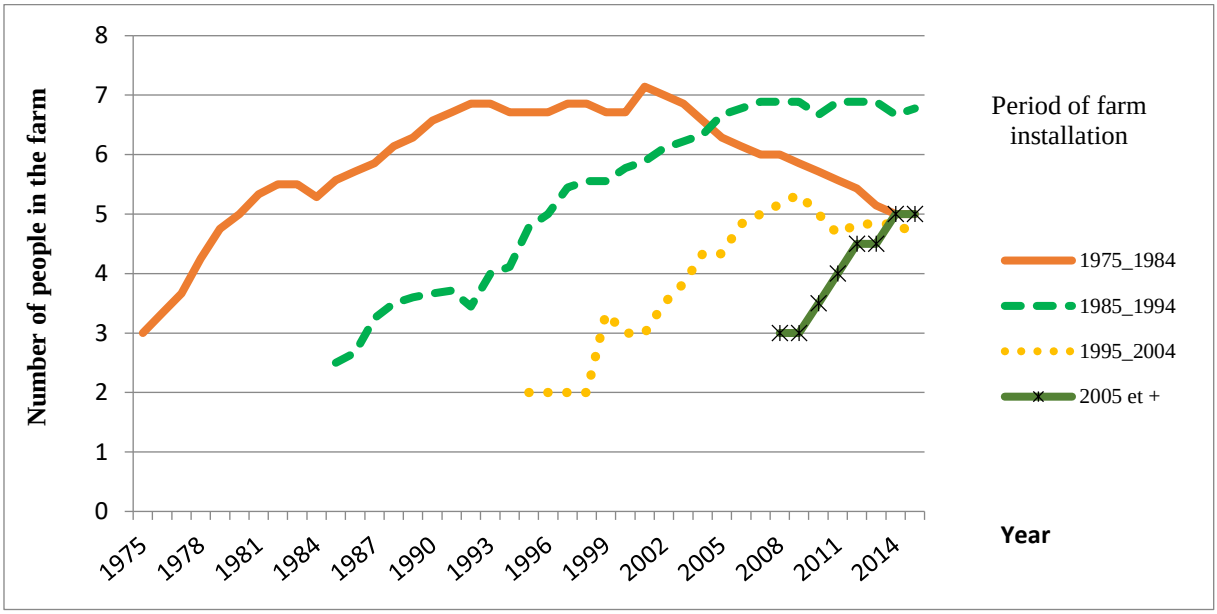

Figure 14: Evolution of the number of people per farm according to farm installation

The curves of evolution of the number of active family members have a slower growth (maximum 4.5 active people per farm) and slower (about 20 years to reach this maximum; Figure 15). The particular shape of the curve for farms installed after 2005 (only two farms), is related to the departure of one active person, which has reduced the average number of active persons on the farm.

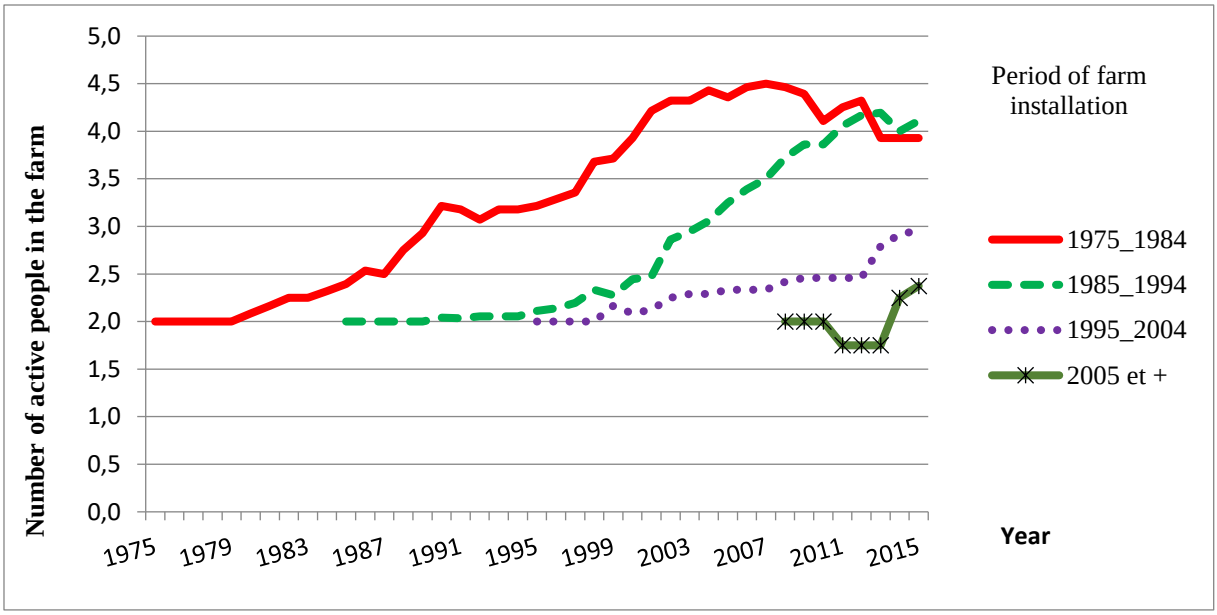

Figure 15: Evolution in number of family workers per farm according to installation period

Figure 16 shows the evolution of the number of family members and the number of workers on farms that have settled during the period 1975-1984. The farm began here with three people and two workers (the parents). There were very few mouths to feed. Then the number of people increased with the birth of children, but the number of family workers did not change. Then the older children reached working age (children often begin between 8 and 12 years) and participate increasingly in agricultural activities (and housework) growing the number of available family workforce. Even if they go to school, children participate in agricultural tasks during the holidays, at weekends and often in the morning before school or at night. Competition between school work and work on the farm may be stronger or weaker, depending on parental attitude and the importance that they give to academic education. This participation in agricultural tasks is also a form of learning this job. Then when they leave school, children become full-time workers, by increasing the available workforce if they stay on the farm. Finally, when the children leave, available workforce decreases. If these children settle in agriculture, they often treat the land and animals that their parents give them in advance, as their heritage. Thus, along with the family workforce diminution, the production factors of the parents' farm also decrease. In the Figure below, we can observe the gap created during the first 25 years, between the number of people on the farm, the number of mouths to feed, and the number of active people. It is an illustration of the evolution of the dependency ratio (ratio of inactive and active people calculated for a population) on a family farm. Farms may have recourse to the labour market to fill the gaps in the workforce (and also to mutual aid). Generally, in the region, they are doing it with temporary work, but some farms also hire permanent workers as we can note in Figure 16 (these are often large farms and/or dairy farmers).

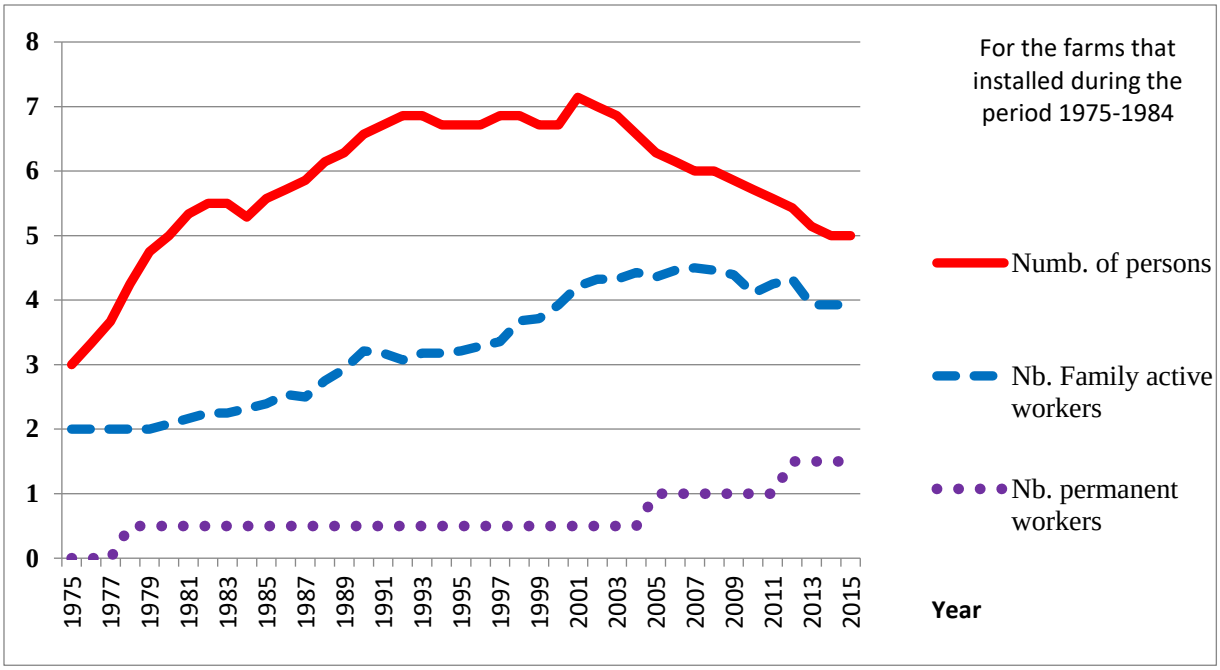

Figure 16: Evolution of the average number of people, of family active people and permanent hired workers in farms that started before 1985

The average evolution calculated on seven farms and represented in Figure 16, in reality can be much more brutal, such as farms n°7 and n°14. The case of farm n°14 is presented below (Figure 17). This farm started in 1991 with two active family members; and in a little over 10 years, the number of mouths to feed grew to eight, but the number of active people does not increase significantly. During this period the improvement in productivity was essential to meet growing consumption needs, with an intensification of factors other than family work (to intensify work it is necessary to hire external paid work). Then, 15 years after installation, the workforce grew very rapidly to reach over seven active people. In this case, to "occupy" these active people and allow them to generate income, a work intensification and/or a significant increase of production factors (land in particular) should happen. In the case of this farm, the available production factors have always been very limited to sustain the family and to occupy the family manpower. Thus, family workers that were under-occupied on the farm, had to sell their workforce outside the family farm, especially as agricultural workers. These temporary jobs are low paid and in the end, the total annual income per family is low. The two farms in this case have incomes per person far below the poverty line. We can evoke in this case, a situation of imbalance between production factors and in particular between land and family workforce.

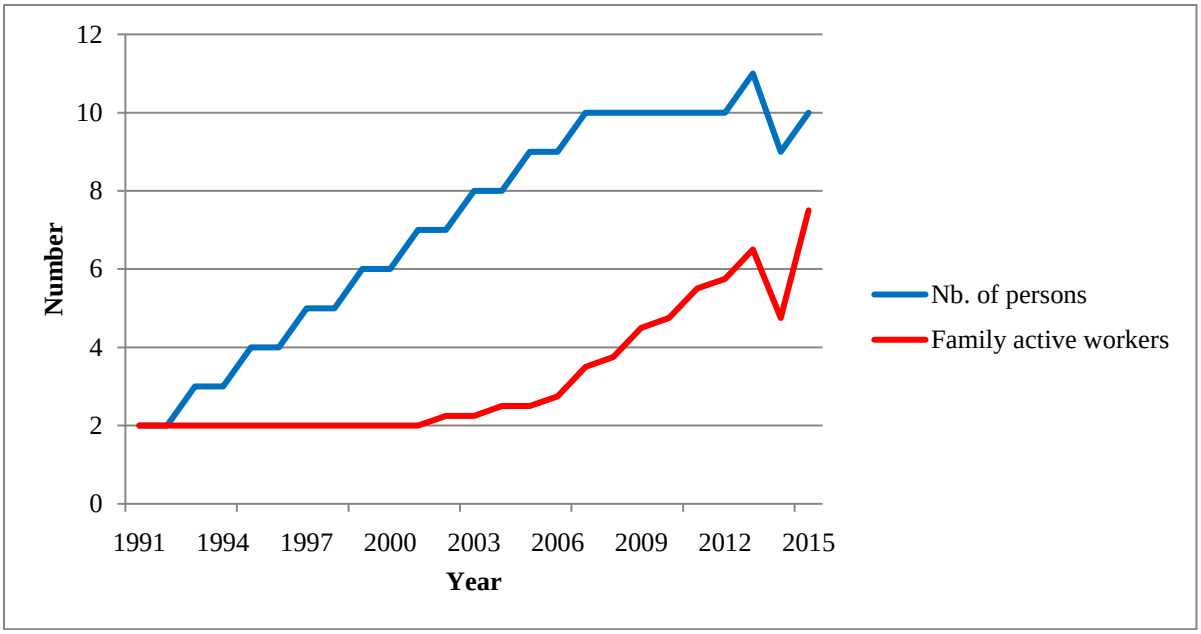

Figure 17: Evolution in the number of people and the family workforce on the farm n°14

In our sample, one farm is in the opposite situation, with a substantial number of family workers (five annual work units) but one UAA of about 11 ha. This farm hires nine permanent employees, mainly concerned with the maintenance and feeding of dairy cattle. Work intensification is made possible thanks to the significant land resources and a production system (milk) which demands a lot of labour.

2.2.1.2. Available land and cultivated areas

The land is certainly the main farm production factor and it often determines the evolution of other factors and intensification options taken by farm managers.

✓ ***Evolution of available surfaces acquisition modes***

In general, farm managers have installed with a relatively low available UAA (average 76 acres, 50 acres median, CV 98%). However, there are contrasting situations: a farm (n°10) began in 1990 only with pig breeding, and had its first plot in 1993; three farms have started with less than 10 acres, seven farms began with more than one hectare (3.1 ha maximum, making it a "great" farm in the region[22]). For many farms, increasing the land is a central element of the development strategy. Only one farm had, in 2015, an area smaller than that with which it began. All the others have increased the size of their land, but with many differences, as we can see in Figure 18.

[22] For Vakinankaratra region, the general census of agriculture of 2004-2005 gave an average farm size of 0.55 ha (MALF, 2007) and the periodic household survey carried out in 2010 showed that the median cultivated area per farm was only 0.50 ha, with 84% of farms that cultivated less than 1.4 ha per year (INSAT, 2011).

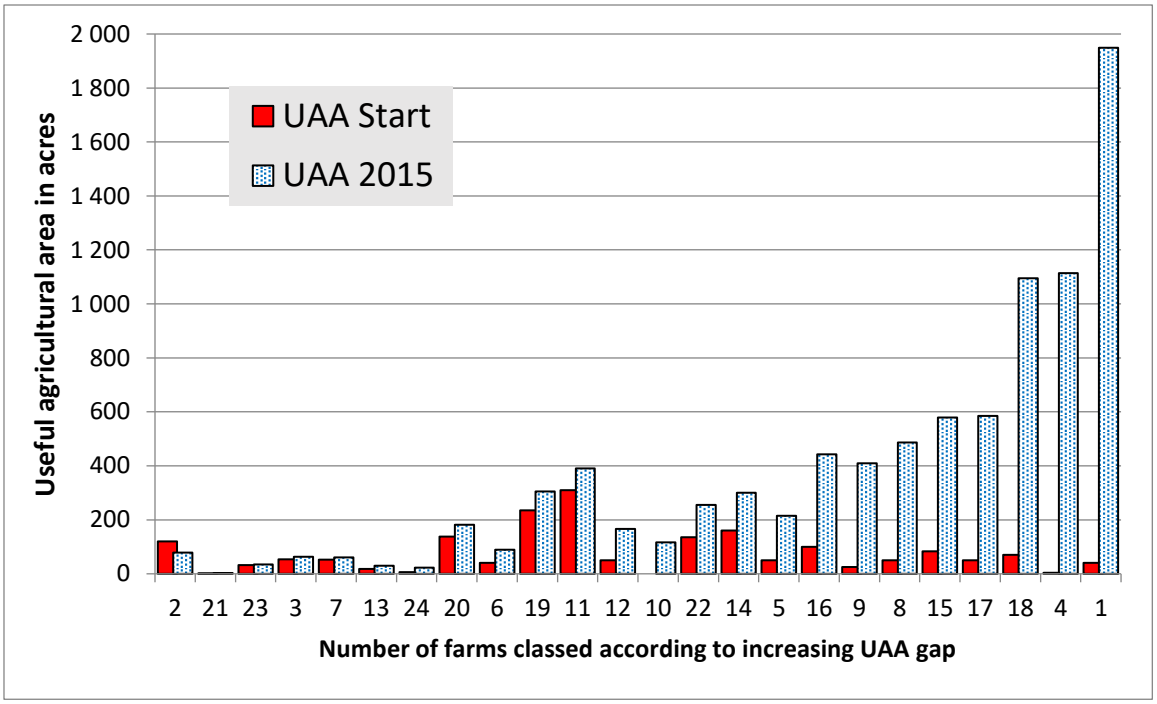

Figure 18: UAA available surface per farm at startup and in 2015

There is no direct relationship between the final size and surface area at the start, and farms that grew the most (in absolute value) which started with small areas: the three farms that have more than 10 ha of UAA in 2015, began with an average of 0.38 ha.
The case of farm n°1 is remarkable (Figure 19). This farmer started with a plot of 40 acres on *tanety*, bought in 1987, and he has today 22.7 ha, of which 4 ha is lowland. In addition, the farm is close to Antsirabe, in an area with strong land pressure. The acquisitions were all carried out by purchase. We note on the curve that there are two significant increases in 1990/91 and 2009/10, in times of political crisis. This farm was committed, with success, in a "conventional" intensification path until the 2009 crisis. Land investments were self-financed from the margins generated by the agricultural activity (mostly dairy production), but also and especially at the beginning, by a capital contribution from non-agricultural activities (teacher salary in a public college).

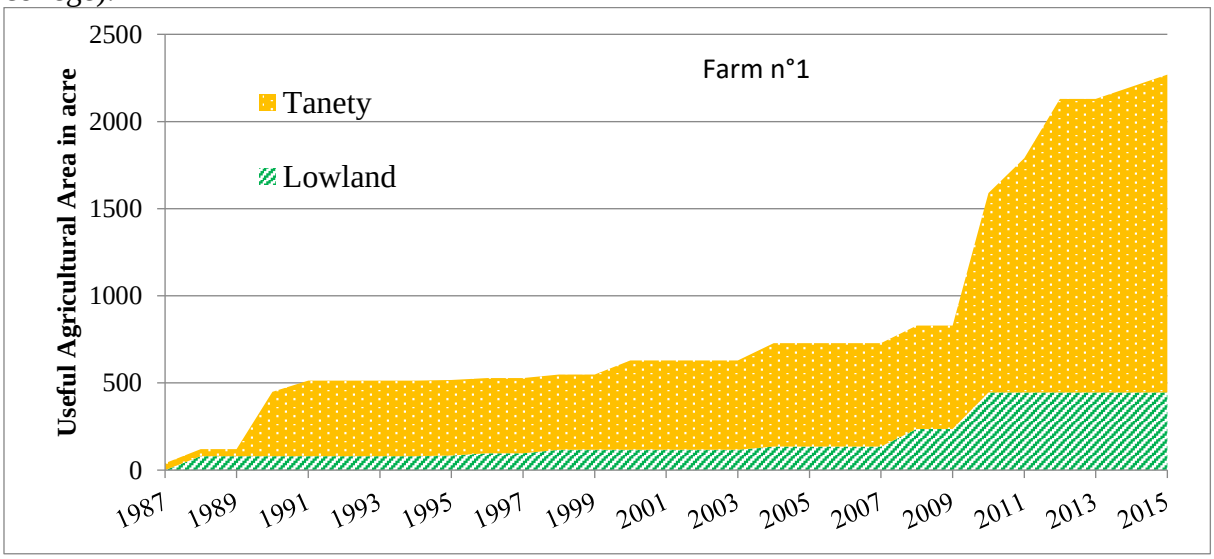

Figure 19: Evolution of land in farm n°1

The method of land acquisition available in 2015 is shown in Figure 20. Farms were grouped by size class. The situation varies greatly, a third of the farms have less than 1 ha and 17% of the farms have more than 10 ha. We find that the modes of acquisition per group are significantly different: large farms were formed mainly by purchasing land, since farms of over 10 ha, 72% of the land in 2015 was purchased and only 11% inherited.
In general, small farms have greater difficulties to increase their available land because they don't have the means to purchase or lease land. We can mention as an example farm n°24 which had a high level of agricultural intensification with the highest gross margin per hectare of our sample, but because of a very limited land surface (only 23 acres) it provides a survival income, and there is no possibility to generate enough cash to acquire land. For small farms, the average parcel of land that was purchased barely exceeds 20% of the available area, and it is the inherited land or land received as a donation that represents the most important part.

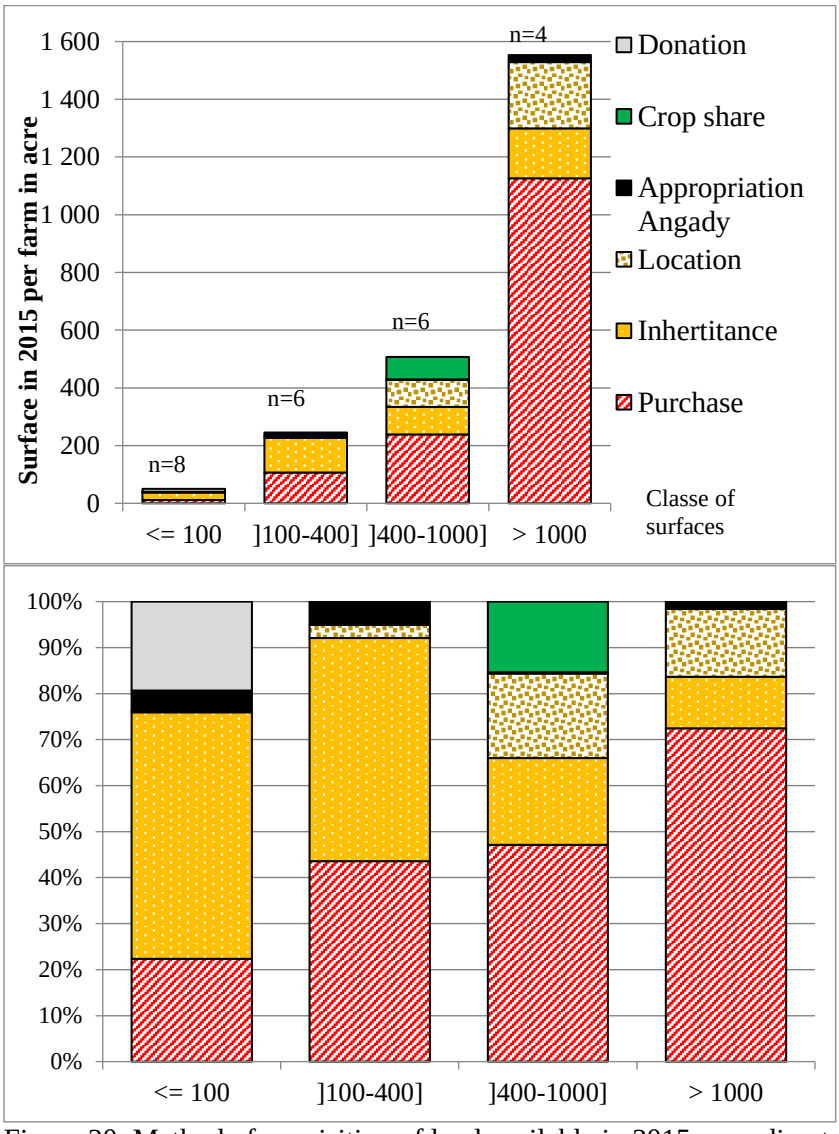

Figure 20: Method of acquisition of land available in 2015 according to surface area (in acres)

We note that the land acquired by clearing (by *angady*) represents very little, less than 2% of the total area inventoried. Thus, the opportunities for area expansion by clearing, appear very limited in the areas where the farms of our sample are located. But the mid-east of the Vakinankaratra region is a famous reception area, but these areas are far from the main road.

In our sample, there is no case of reproduction of a very large farm. Large farms have acquired most of the land on the land market. These acquisitions were made thanks to their capacity for self-financing, but also with loans from a bank, a microcredit or from a third party, and by taking risks with decapitalization to raise the funds necessary to purchase. Farm n°14 has, for example, sold its single pair of oxen and borrowed money from their family in order to buy the land that had been rented for ten years and was for sale. Later, the farmer was able to buy a pair of oxen and continues his intensification pathway.
Only one farm has less land in 2015 that when it started. Farm n°2 lost about 2/3 of its UAA, because the old farmer donated a part of his plots on *tanety* to his nephew and to his sons. We also identified another farm (n°21), that since its establishment, has only a very small amount of inherited land available, plus a very small rented plot. This is a farm that hardly developed its production factors because of its lack of means.
We will see later that there is a strong correlation between the economic performance of farms and the surface area available: a +0,87 coefficient between surface area and total gross margin of the farm (crops and livestock), 0.80 with the farm income per family worker, and 0.77 with the poverty index. While there is no correlation between surface area and gross margin per hectare. Total performance depends on the surface area available, but not on the productivity per surface unit.

✓ ***Types of land***

The characteristic landscape of the Vakinankaratra region, is that of very hilly valleys of varying sizes. The most popular are those of lowlands which are laid out with rice fields (Rabenandro *et al*., 2009). The land on the slopes and the summit plateau of the hills are called *tanety* and cultivated in the rainy season. The fertility of the ferralitic soils, the most widespread, is low, the volcanic soils are more fertile but confined to small areas in the west of the region (Radanielina, 2010). At the bottom of the slope, *baiboho* is a "facet of contact between lowland and *tanety*" (Blanc-Pamard, 1986). Composed of colluviums, this land is rich and cultivated in the rainy season, but is shallow, and crops can be irrigated. *Baiboho* land is scarce in some areas, particularly in the mid-east.
The farms generally have plots of two types of land and practice both upland and irrigated crops (Table 12). To have rice fields and upland plots (*tanety* or *baiboho*) seems to be an objective of land increase strategies.

Table 12: Distribution of farms according to the number of land types at installation and in 2015

	Number of land types	At installation			
		1	2	3	**Total**
In 2015	1	4%	0%	0%	4%
	2	29%	46%	0%	75%
	3	13%	4%	4%	21%
	Total	46%	50%	4%	100%

In our sample, eleven farms (46%) started with one type of land; in 2015, only one farm still has only one type of land (farm n°13, a migrant who settled in the Middle East, in 2003, by buying a plot of *tanety* and since then has not increased its land size. All the other farms have evolved and have two or three types of land. Thus, in 2015, 21% of farms have three types of land, whereas only one farm (4%) was in this situation at the time of installation. Only 50% of farms had two types of land at installation, in 2015 they represented 75% of the farms in our sample.
Table 13 includes the classes of surface area in 2015, used in the previous point. We note that these are the small and the large farms that in 2015 have a significantly less important lowland area (about 20%). We note that for the first two classes it is the lowlands that increased in

available land, changing from 15% to 21% for the smallest farms, and from 29% to 30% for the class with 100 to 400 acres, and this within a dynamic of increasing the total surface available. Only the class of very large farms has seen its share of lowland decrease due to a sharp increase of *tanety*; but if we reason in terms of surface, we note that the lowlands increased from 19 to 179 acres, almost 10 times (but at the same time *tanety* was multiplied by a coefficient of more than 70).

Table 13: Distribution of surface areas according to the type of land in 2015, and at installation, according to the classes of total surface area in 2015

Classes of surface area in 2015 (acres)	**<= 100**	**]100-400]**	**]400-1000]**	**> 1000**	**Total**
Workforce	8	6	6	4	24
Average surface area in 2015 (acres)	50.38	245.90	506.92	1,553.25	463.87
Lowland	21%	30%	32%	12%	20%
Baiboho	2%	7%	0%	0%	1%
Tanety	78%	63%	67%	88%	79%
Average surface area at installation (acres)	42.38	106.67	163.50	36.50	87.75
Lowland	15%	29%	32%	51%	29%
Baiboho	2%	0%	0%	0%	0%
Tanety	83%	71%	68%	49%	70%

Thus, we can conclude that the pathways followed by farms seem to indicate the search for available land composed of two main types of land, for upland and irrigated crops, aiming to have an equilibrium of about 30% of lowland and 70% of *tanety*. *Baiboho* lands are rare and represent a plus for farms that can acquire them.

2.2.1.3. Livestock

Livestock farming is a widespread activity on farms in the region; according to the Census of Agriculture, in 2004-2005, 90% of farms had at least a farm animal, and at least 51% a bovine[23]). Short-cycle livestock (poultry, rabbits and pigs to a lesser extent), which require relatively little investment, are widespread as they are often an easily saleable resource to deal with agricultural cash or consumption needs. Cattle production is the one that requires the most important investment and that can impact most strongly on intensification pathways by providing draft animals, organic fertilization and income.

Before starting the analysis, it should be noted that to facilitate comparisons we evaluated the value of animals in 2015. This assessment was made on the field with the farmer. The value of the animals at farm installation was also assessed using the 2015 price (an ox has the same value at installation and in 2015). Thus, a change in animal capital indicates an increase of the number of animals or the presence of a different type of animal.

In our sample, only one farm didn't have animals in 2015. This farm (n°21) is the smallest (3 acres of UAA) and practiced livestock production repeatedly. The manager of this farm installed in 2001 on an inherited plot, after living in Antananarivo for about ten years and where he had a small business. Upon his installation, he invested a part of the money that he had saved during his migration period, buying two chickens and two pigs. He sold the pigs two years later to invest in a house and the last chickens were sold at the birth of his daughter in 2005. Since

[23] Data from the general Census of Agriculture 2004-2005 (MALF, 2007b).

then, he had never had enough financial resources to reinvest in livestock. In 2010, his uncle gave him five young chickens, but unfortunately they died of illness in the same year. Thus, for the most disadvantaged people, to invest and maintain a small animal husbandry unit remains a difficult task.

The situations vary between farms, both at installation and in 2015, and unlike the land situation, we note that there is a significant relationship between the initial herd numbers and that of 2015, even if the coefficient is not very high (+0.70). This suggests that the herd at the moment of installation affects the orientation of the farm and the importance of livestock in the pathway.

In our sample, eleven farms (46%) had at least one bovine on the farm; eight already had a pair of oxen and three had a dairy cow. This is a very substantial initial capital that enabled the farmer to carry out the right choices of intensification after installation, which would have been difficult to achieve otherwise: improved labour productivity, organic fertilization, ploughing services off the farm to supplement farm income when needed. These animals were inherited (three farms) or purchased at the time of installation, often with funds from other activities practiced before or during installation.

In 2015, only three farms have no cattle (they are among the poorest), 14 farms have at least one pair of oxen (against nine at installation) and two farms have only one bovine. The acquisition of cattle, and particularly oxen, is certainly an important objective in the strategies of farmers. And this goal is sometimes achieved by grouping together with other farms. For example, farm n°2 has a pair of oxen and equipment for draft animals, in "co-ownership" with two brothers: cattle are kept in his house under his responsibility, and he benefits from the manure.

One farm (n°17), has three pairs of oxen, including a pair of young animals that are being trained. This farm has chosen a development strategy based on agriculture, and its herd (10 bovines) is mainly intended for manure production and renewal of draft animals.

During their installation, three farms already had a dairy cow (installation in the 70s and 80s). Two farms (n°1 and n°4) have really developed this activity, at the same time that they increased their available land (over 10 ha of UAA), one part by purchase and the other by inheritance and rent, to have in 2015, 18 and 15 dairy cows, respectively. These farms have feeding systems based on the production of fodder crops, innovation they have adopted a long time ago. They benefited from the support of FIFAMANOR, which has taught them a lot in terms of technique and livestock management. They increased their improved breeding herd and milk production by commercializing to TIKO company when it still functioned. In our sample, it is these two farms that generate the highest gross margins for livestock and for all agricultural activities.

Regarding the other farms, they are less important, at least in terms of capital. In our sample, six farms had one or two pigs at installation, mainly for fattening. In 2015, 15 farms had at least one pig but one single farm (n°9) had a substantial herd (20 fattening pigs) and three farms had a breeding stock (sows and boars). When we consider the pathways, at any given moment, 17 farms grew pigs and some have even begun to develop this activity by increasing the number of animals. But, the analysis of the pathways shows that pig farming is very risky because of diseases, including African Swine Fever (ASF), which can decimate the entire herd. This is what happened in 2014, to farms (n°15 and 16), located in the same fokontany, at Ivory, in the district of Mandoto. They lost their entire pig herd, including 10 head in farm n°16. Farm n°15 has faced this disease twice, the first time just a year after its installation, and then in 1999, where it lost 22 head. Since then, the farmer has carried on pig farming. Moreover, the loss of 22 pigs has severely disrupted the intensification pathway that he initiated.

These very high risks, explain why farmers do not engage much in this type of farming, even if considered profitable. They prefer to restrict the number of pigs fattened to one or two, thus limiting the risk of loss associated with diseases. As mentioned, only farm n°9 (installed since

1985) now has a large stock (20 pigs). The manager started production in 2010 with local pigs, and then he stopped due to the illness of his wife, and in 2013 he restarted with improved breeds of pigs.
Poultry farming is practiced by all the farms at least at one given moment in their pathway. This production is for home consumption, festive occasions, and for sale to overcome difficult times, so providing funds for especially urgent financial needs, for example, in the case of illness of a family member. Upon installation, the average number of poultry was low, with two chicken per farm; but nine farms do not have any poultry. In 2015, the average increased to 22 birds per farm, with three farms without poultry (n°2, 19 and 21). Farms n°1 and 5 have a large stock in 2015 compared to the average, with hundreds of poultry. Farm n°5 is the only one to produce another type of poultry, having thirty geese.
Poultry farming also faces many problems related to insecurity (poultry theft is frequent) and disease is common in some areas. Farm n°19, for example, located in the district of Betafo, was victim of avian influenza in 2015, eliminating all the poultry stock, which consisted of around ten birds.
In terms of capital "livestock", the total value (cash value in 2015) obtained in all 24 farms was estimated at about 26.6 million ariary[24] (Ar) at the time of installation; representing an average of about one million Ar or less than one ox (Figure 21). In 2015, the average age of farmers was 25 years. This value was multiplied by six, which means a herd estimated at about Ar 167.2 million. Some farms have invested more than others in livestock capital. Figure 21 shows the great variability in terms of livestock evolution. Farms n°1 and 4, which are "specialized" in dairy farming, have multiplied their initial capital by almost 8 (5 million to almost 40 million) and own almost half of the livestock capital of all farms together. While others, poorly supplied at the start, saw the number of animals decline (farms n°7 and 21).

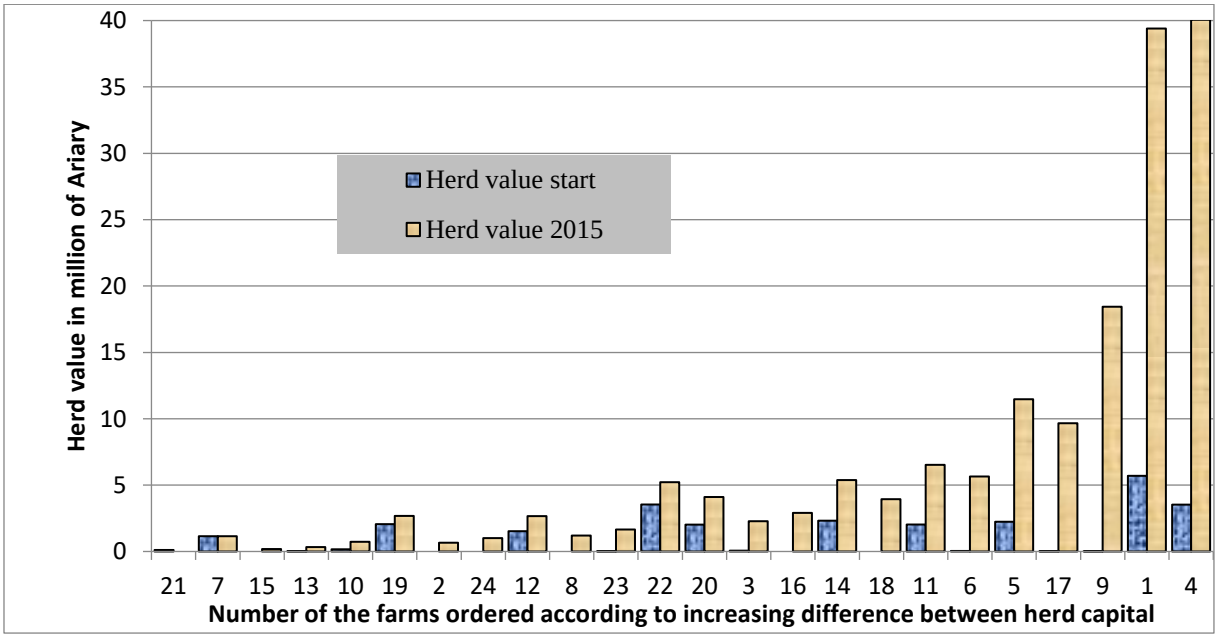

Figure 21: Evolution of livestock capital per farm from installation until 2015

With reference to the value of livestock capital of each farm in 2015, three classes of farms were created (Figure 22). There are five farms (8%) who have a livestock capital of over Ar 7.5 million and 51% of this capital consists of dairy cows, 17% draft cattle, 18% other cattle (bull, heifers and calves) to replace animals at culling, 18% pigs and 2% poultry. Therefore, cattle

[24] 1 euro (€) ~ 3,500 Ariary (MGA)

mobilize a relatively large capital in these big farms strongly oriented towards livestock farming, and particularly dairy farming. But these farms are those that have the biggest UAA (average of 854 acres).

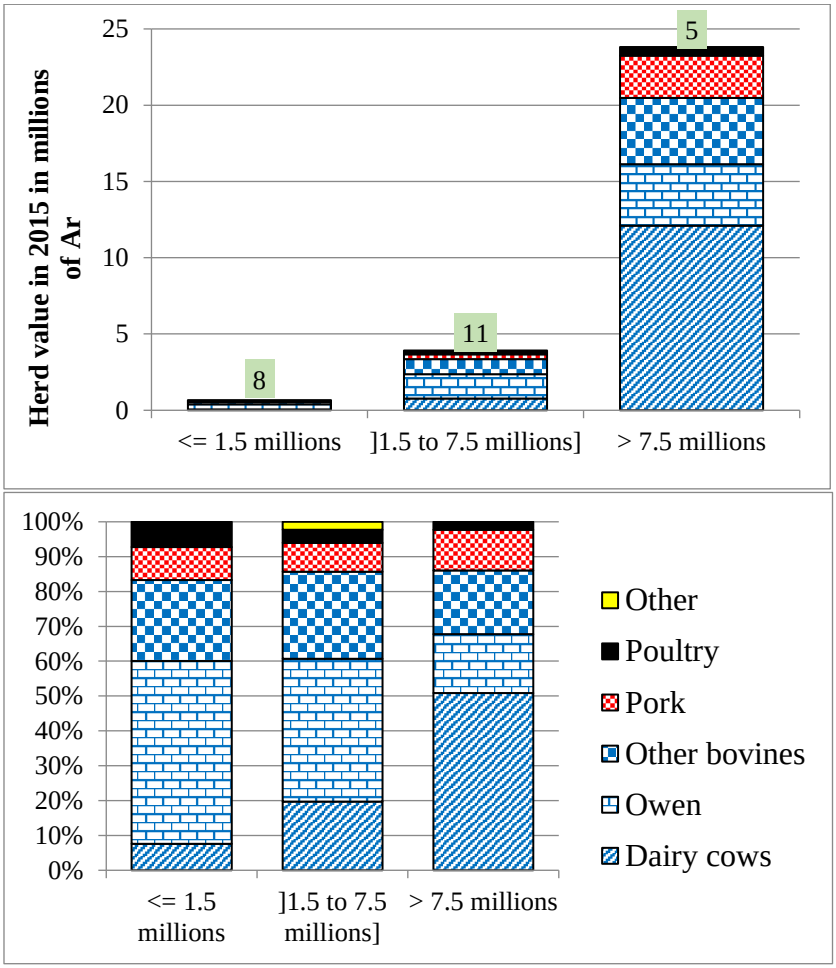

Figure 22: Composition of the herd according to the value classes of livestock capital

The second class brings together 11 farms (46%) with a livestock capital between 1.5 and Ar 7.5 million. This is the group of medium-sized farmers (average UAA of 302 acres) with several pairs of oxen (41% of the capital) and cattle (21%) for herd renewal. Some farmers who engaged in the development of livestock for milk production (20% of the herd), pork production (8%) or even fish or bee farming (2% of capital).

Finally, the last group comprises eight farms (33%), whose herd has a value lower than 1.5 million Ar. This is the group of small farmers (average UAA of 172 acres) that have difficulties to capitalize and to invest in livestock. The value of the herd is low and divided between the draft cattle (52%), other cattle (23%), pigs (9%), local or cross breed dairy cows (8%) and poultry that represent 7%. These farms clearly show the weakness of livestock capital. In this group, there are farms that never had the means to develop animal husbandry, but also farms that were committed at a given moment of their pathway to these activities, but who faced problems (illness, theft, etc.) and lost their animals or had to decapitalise.

Within this last example, we can mention farm n°2. Established since 1980, this farmer has shared since 1986, a pair of oxen with his brothers. In the early 2000s, he wanted to develop animal husbandry. He started with the purchase of two piglets that he fattened and sold. He restarted the following year. With the money from the sale of the pigs he bought a dairy breed heifer that gave birth to a calf in 2013. The livestock intensification process was on track. But

in 2014, a family member was sick and to cope with health costs, he sold the calf. In 2015, the cow got sick and had to be slaughtered and he sold the meat. Today, he thinks he can no longer re-engage in such a process of intensification.
The example of farm n°7 was also exemplary. At its installation in 1976, the farm had a local breed cow and a calf obtained by inheritance. He engaged in a process of capitalization by keeping the animals born on his farm. In 1980, he got his first pair of oxen after they have been trained. From 1976 to 2010, the number of cattle increased from two to eleven, including two oxen, four cows and five calves. In 2010, he lost 11 bovines due to theft. And although if in 2012 he was able to buy two oxen to replace those stolen in 2010, the dynamics of capitalization and intensification was broken.
In our sample, an important number of the farms that were engaged in the livestock development process were halted abruptly with the loss of animals because of disease, theft or decapitalisation to face a family problem (mostly to pay for health costs). These losses are severe for the farm concerned, but also affect the region's development dynamics.

2.2.1.4. Agricultural equipment and buildings

✓ ***Equipment***

In Madagascar, agricultural production is mainly based on manual labour; in 2004/05, there were an average of three manual tools per farm, a plough for four farms and a cart for six to seven farms. Vakinankaratra region is not better supplied than the rest of the country with 3.2 ha per ox plough (only 20% of farms are equipped) and 2.4 ha/harrow (national averages: 3.5 and 5.0, respectively) and if the number of manual tools per ha (5.5) is higher than the national average is because surface areas per farm are significantly smaller. There were only 43 tractors, eight rear tillers to more than 227,000 farms (MAEP, 2007c).
In 2005, our sample was much better equipped than other farms in the region. Already at their installation, half of the farms were equipped with draft animals plough and/or a harrow, obtained by inheritance or purchased at the time of installation. But only nine farms (38%) had a pair of oxen, five had a cart and two bicycles. The other farms began with only manual tools, and we observed that one farm (n°7) had no tools and has worked several years with borrowed tools lent by his parents (this is not rare in the region).
Over time, for the majority of farms, the level of equipment has improved. In 2015, two farms had a tractor, 16 farms (including the two motorized farms) were equipped with draft animals (67%), six of them had two or more pairs of oxen, but two farms shared a pair with other farms. Eight farms still had only manual tools for agricultural production.
But farms are equipped with other types of equipment: harvester (two farms), milking equipment, motorized harvester, sheller, feed grinding machine (one farm for each material), 14 farms had at least one bicycle, seven farms a motorcycle, two farms had a truck or van, and one farm had two cars.

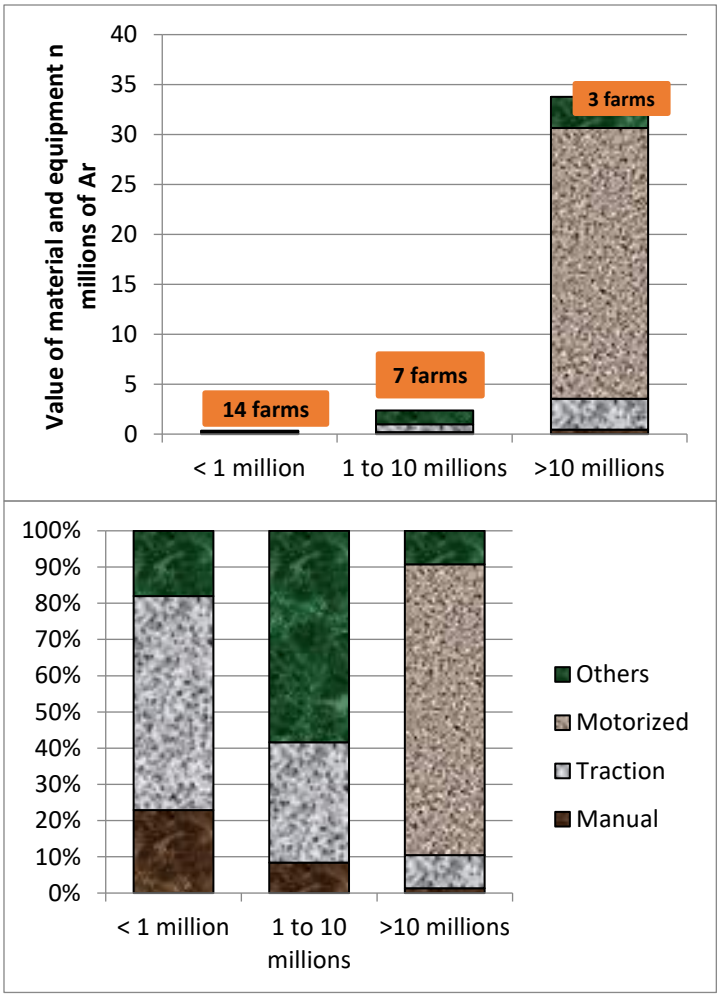

Figure 23: Average composition of equipment capital of farms according to the value of capital "agricultural equipment and material"

The value of materials and equipment was evaluated (residual value of the equipment was estimated from the buying value or from the mean value on the second-hand market; Figure 23). And as for animals, the differences between the farms are very important, from Ar 22,000 for the less equipped one (n°24) to over 66 million for the better equipped (n°1).

Three distribution classes were established according to the average value of "equipment and material" capital of farms: *(i)* less than Ar 1 million, *(ii)* between Ar 1 and 10 million and *(iii)* more than Ar 10 million. Through this distribution of farms, a more or less obvious correlation arises between "livestock" capital and "building" capital. More than half of the farms (58%) belong to the first group with an average of Ar 340,000 capital, but a median of only Ar 188,000. In this group, it is the draft animals which constitute most of the capital (59%). Manual tools (on average Ar 78,000 /farm) represent only 23% of the total value of capital.

In the other two groups, the value of traction equipment is decreasing: 33% for farms with Ar 1 to 10 million and only 9% for farms with more than 10 million. The third class is composed of only three farms (13%); these are the biggest farms in our sample. Two farms (n°1 and 4) followed a pathway of very strong agricultural intensification (dairy farming), rather conventional with substitution of labour for capital, and particularly with a tractor and a silage harvester, which allowed them to obtain very high labour productivity for feeding livestock. A farm (n°9) has mainly diversified its activities by investing in equipment (sheller, grinder and truck) to develop downstream production activities and that produce high added value (shelling,

feed production, trade of agricultural products). Three pathways that are certainly relatively rare in the region.
We note that in most cases, the value of the animals is considerably greater than the value of the equipment. Only four farms have an inverse ratio: the larger farm of the sample that has an exceptional amount of equipment for the region, a farm well-equipped in terms of draft animals (and especially with a cart) which limits its herd to oxen, and finally two poorly equipped farms but that have acquired motorcycles with funds from other activities.
Finally, the pathways studied do not all go in the direction of increasing the level of equipment. Two farms (n°6 and 19) that were equipped with draft animals returned to manual tools after facing problems or choosing other pathways. A farm lost an ox (mortality), and as in the same year he had the opportunity to buy a *tanety* plot, he sold the second ox. Since then, adequately supplied in terms of labour (working family members + permanent employee) he decided to orient his farm towards pig farming and milk production. The other farm had to sell its equipment (including a cart) to cope with health costs related to the manager's illness. The farm has never been able to reinvest in equipment.
There is a strong correlation (coefficient greater than 0.8) between material capital and the UAA available and the value of livestock, but also with the "building" capital. Thus, farm equipment is only one component of the intensification process that is part of the "balanced" development of all production factors. Within this framework, the transition to draft animal seems an unavoidable or necessary step of producers' strategies to increase labour productivity, but also soil productivity thanks to manure.

✓ ***Buildings***

At installation, only five farms had an agricultural building. Among them, the two major dairy farmers in 2015 (farm n°1 and 4), which had a stable (in bricks, and the other in wood), a farm have inherited a small pigsty and a stable, another a stable and finally a last farm had built a shelter for zebus. The other farms that had animals, usually housed them in the main house on the ground floor or in a shed.
With the development of livestock and acquisition of equipment, some farms have invested in farm buildings, mainly for livestock, sometimes in hard materials (brick and cement) but more often in wood or "feta" (adobe or mud) on the farms that are limited in their capacity to invest. In 2015, 71% of the farms built a stable and 67% a pigsty. Only "big" farms built a shed, garage or shop. Other farms prefer to store materials and agricultural products in their residential house (especially for safety). The value of these buildings varies enormously according to the size and materials used. The total estimated value of the inventoried buildings is low: Ar 27 million for 24 farms, on average 1.3 million, which represents 1/6 of the value of animals and slightly more than 1/4 of the value of materials. Finally, the distribution is extremely uneven, since the four biggest farms (n°1, 4, 5 and 9) hold 78% of this capital (in average 5.3 million).
Large farms orientated towards dairy farming (and farm with activities downstream of production) invested in buildings, mostly in hard materials, to ensure good control of animal husbandry, for easier maintenance, cleanliness, and secure storage. But for other farms, this type of investment does not seem a priority compared to the purchase of animals or the acquisition of equipment.

2.2.1.5. Other agricultural activities and non-agricultural incomes in the pathways

If rice cultivation still occupies an important place in agricultural production activities, they are very diverse (see below), some farms also have other agricultural activities on the farm (forestry, fish farming, and especially processing of agricultural products), outside the farm (agricultural wage labour, agricultural services, etc.) or non-agricultural activities. All these

activities combine to form the farming system. And even if these activities are often considered as "secondary" in the production system, they can play an important role in the livelihoods of families but also in pathway intensification.
Among the farms of our sample some have "secondary" agricultural activities: forest plantations, production and commercialisation of forest plants, fish farming, etc.

- ✓ **Forestry activities**

At installation, only two farms (8%) had areas planted with eucalyptus or pine trees (n°3 and 20). The total planted area was 2.65 ha and represented 58% of the total combined area of these two farms, more than the double of the UAA. In 2015, nine farms (36%) have areas with forest plantation or nursery activities. The area concerned represents 19% of the total area of all farms, but for the farms involved this represents 28% of this area. The total planted area has increased eightfold between installation and 2015, which reflects the real interest of farmers in this type of land that can be enhanced both as pasture and as a source of wood, but which constitutes perhaps also a form of land reserve and savings.
On two farms (n°9 and 20) forest areas are greater than the UAA and occupy respectively 76% and 58% of their total area. These plantations are exploited firstly for self-consumption, to supply the family with fire wood or for the construction of buildings or cattle shelters. But they can also be a source of income, directly exploited to produce and sell wood and charcoal, or the owner can sell the standing timber to a logger who will cut and sell the wood and/or charcoal. Thus, these plantations, which require little maintenance, are "savings" that the farm can mobilize when needed. But the risks, particularly of fire, are high. In our sample, only one farm states having improved some of its forest plantations in 2015 by selling the standing timber to a logger (Ar 200,000 for about 0.5 ha) without specific charge. Another farm (n°11) has stated expenses for planting and maintenance without product, resulting in a negative gross margin.
Three farms have forestry seedling production (n°1, 14 and 18), among them two also have plantations. This nursery activity (which involves a small area: 3-5 acres) was promoted by development actions, in particular by FAFIALA project. We note the presence in this activity of farm n°1, the largest milk producer, with production intended only for his plantations (3.24 ha)[25]. The other two farms sell their plants; income generated in 2015 was estimated at 1.0 million and 1.4 million and occupies an important place in the overall income: 9% and 37%, respectively.

- ✓ **Fish farming**

Three farms (n°11, 18 and 19) practice fish farming in managed ponds with respectively, 5, 25 and 8 acres. They are also experimenting rice-fish farming. These three farms have engaged in fish farming recently (one in 2010, and two in 2012), under the leadership and with the support of institutions specialized in this area (APDRA). The techniques are not yet well-mastered, hence, sometimes death rates among young fish can be high (up to 80% according to farm n°11). The gross margins obtained in 2015 with this activity ranged from Ar -180,000 and Ar + 900,000. The negative margin is explained by the fact that baby carp were transferred to another pond and that they still didn't sell anything.
These three farms have similar structural characteristics: the UAA varies from 3 to 10 hectares, the livestock value varies from 2.7 to 6.5 million. However, the performance of these three farms in their agricultural activities are very different. In 2015, annual agricultural income per family farm worker are Ar 5.2 million, 1.9 million and 0.8 million, respectively. One of the farms is facing many problems, and especially manager's health problems, thus, only a small portion of the UAA was cultivated in 2015.
The gross margins of fish farming still weigh very little in the total agricultural gross margin of farms (from -8% to + 13%). Despite these relatively weak results, the farmers felt that this is

[25] This activity has not been evaluated and therefore does not fit into the financial accounts of the farm. In all cases, the charges entailed by the nursery and the product represented by plants are very marginal when compared to economic results.

an activity with strong potential because the price of fish is interesting, the local market demand is high and production costs are low compared to other agricultural activities.
For the farms studied, fish farming appears as a diversification of activities in a systematic intensification and agroecological pathway. We note that one of these farms also adopted, in addition to traditional agricultural activities, beekeeping. Fish farming is therefore part of the already diversified activity systems and complements the livelihoods of families.

- ✓ **Beekeeping**

Only one farm practices beekeeping (n°18). It started this activity in 2007, after joining an association that is promoting it (*Taratra Miaradia*). Between 2007 and 2010, the number of hives (traditional) increased from one to five. In 2011 the apiary was devastated by the varroa mite. The farmer stopped the activity and restarted it in 2014 with a small swarm.
At present, this farm has two traditional hives. The net margin generated in 2015 by this activity is quite low (Ar 112,000) and its impact on the agricultural net margin is relatively low since it represents less than 2%.
As for the previous activities, beekeeping is an element of diversification in a systematic intensification and agroecological pathway.

- ✓ **First processing of agricultural products**

Two farms (n°9 and 20) have activities of first processing of agricultural products for commercialization purposes: for one it consists of rice milling and production of animal feed, and for the other yogurt manufacturing. Both farms are relatively big and the net margins of transformation increase farm income by 10 and 13%, and contributes to around 9% and 10% of the total revenue, respectively.
These processing activities reinforce the intensification pathways adopted by increasing the creation of added value produced on the farm.

- ✓ **Agricultural off-farm activities**

These agricultural activities conducted on other farms in the neighbourhood, are of two types: the ones performed with agricultural equipment and wage labour.
Two farms conduct mechanized service activities outside the farm: one (n°1) with the tractor and the truck (transport, tillage, silage) and the other (n°23) carries out tillage with its coupling. These services enable the use of agricultural equipment outside the farm and complement farm income.
In the case of farm n°1, the income from this service activity (and rent) are a very important part of the total annual income (42%). As analysed above, this farm has invested heavily in agricultural equipment in a conventional intensification process for dairy production. After the crisis of 2009, he changed his strategy and opted for a more systemic intensification with the search for more autonomy in its production system on its farm. The services with agricultural equipment and truck therefore appear both: *(i)* as a way to support this change of direction in the pathway of agricultural intensification, ensuring the profitability of investments made prior to this change of strategy, *(ii)* but also, since large investments in equipment have been made recently, as a rebalancing of production activities for the benefit of the provision of services in transportation and agricultural work.
Agricultural wage labour is widely used in the region. Many farms have not enough land to ensure adequate income and to occupy the family workers full-time. Family workers (including the manager) will then look for work outside, in other farms or in other sectors, where they are paid daily or per task. Generally speaking, salaries are low (between Ar 2,000 and 35,00/day) and workdays are relatively few over the year. Among the farms in our sample, six have agricultural wage labour activities (n°7, 12, 14, 21, 23, 24). The wages received in 2015 range between Ar 6,000 and Ar 520,000 and occupy an important place in the overall income of the two farms: 39% for farm n°21 and 26% for farm n°24. These two farms are part of the "smallest"

farms of the sample, with respectively 1 and 3 acres of UAA per person. But these agricultural wage labour activities occupy a very different place in the strategies of these two farms:

- For farm n°21, agriculture is only a secondary activity in the livelihoods that combine agricultural and non-agricultural wage and service activities. This farm has no real intensification strategy.
- For farm n°24, agriculture remains the main activity and the manager engaged in an efficient agricultural intensification pathway despite his very low resources. It has a very diverse agricultural production with food crops, fruits, vegetables, livestock and has good performances since it is the farm that has the best agricultural income (crop and livestock) per UAA surface. This farm has an income of more than Ar 5 million per ha of UAA. The problem is that its UAA surface is only 23 acres! In its intensification strategy, he even rents in off-season a part of his rice field (for Ar 35,000) which allows him to complement his income and to increase the productivity of his land. So, in this pathway, allowing the low farm income to be complemented with high physical productivity, agricultural wage labour is an essential part of a high-performance intensification pathway, more agroecological and systemic.

✓ **Agricultural rents**

In our sample, four farms (n°7, 10, 21 and 24) rent their agricultural land and therefore benefit from rental that ranged from Ar 35 000 to Ar 128,000 in 2015. As we have seen above, and paradoxically, it is not the biggest farms which rent their land, but the small farms (UAA area of these farms are respectively 61, 169, 3 and 23 acres).

Farm n°10 appears somewhat unusual with a land area which doubled in 2008 by inheritance and low workforce especially as the manager and his wife have non-agricultural salaried activities. Farm incomes are relatively low in the livelihood of the family. Renting out is a way to use the land in a farm which is not in a process of agricultural intensification.

For the other farms, the surface area available is so small that the product from the land use do not provide sufficient income. The members of the farm are forced to look for work elsewhere and in some cases, they prefer to rent a part of the land than to work it. We note the specific case of farm n°24 that rents in off-season, which consists in a dynamic of strong intensification of land.

✓ **Non-agricultural activities and other income**

Often, non-agricultural activities and other income is not taken into account in agricultural analysis, particularly in intensification analysis. However, several studied pathways show that revenues from non-agricultural activities strongly influence the process of agricultural intensification.

To do the analysis, we have grouped all the non- agricultural activities and sources of income: non-agricultural wage, income from commercial activities, crafts and liberal professions, pensions and retirement allowances, various transfers, as well as payments received as responsible for local authority or other organizations, etc. In total 71% of the farms are concerned with non-agricultural incomes in 2015, ranging between Ar 5,000 and Ar 7.2 million, with an overall average of 1.2 million, which represents on average 24% of the total income (with a minimum of 0% and a maximum of 77% with regard to farm n°10). For seven farms (29%), these revenues represent 50% or more of the total income, and thus, are very important in the livelihoods of these farms.

But the importance of intensification pathways is not limited to the share in the total income. These revenues are money and therefore constitute a treasury for the family, but sometimes they are also obtained from the agricultural activities on the farm that can be financed by non-farm incomes. Generally speaking, they bring autonomy to farms with this cash facility which can reserve their production to consumption, and are not obliged to borrow to finance the inputs

or the purchase of animals, and can maintain their agricultural production to sell at a better price.
Some examples of pathways clearly show the role played by non-farm incomes. For farmn°1, the monthly salary received by the manager as a teacher allowed him to finance, at least initially, its conventional intensification pathway with the acquisition of production factors (land, animals, inputs, material, etc.). In farm n°15, the manager was employed as a technician by an NGO until 2011 and had a small farm near Antsirabe, with a plot of 18 acres. In 2011, the NGO had problems and could not pay salaries. In 2012, the manager collected the wages for a single time, and looked for another technician working in the Middle East, where with his small available capital he was able to lease land on *tanety* then lowland. This capital injection enabled him to engage in a new pathway of intensification.

2.2.2. Evolution of the practices in crop and livestock systems

2.2.2.1. Evolution of the practices in cropping systems

Intensification can be read through the evolution of practices in cropping systems with green revolution type or conventional techniques and in particular the use of improved variety of seeds and inputs (fertilizers and pesticides), but also through intensification techniques more systematic and agro-ecological, with agro-biodiversity thanks to crop diversity, rotations and intercropping, and the use of organic fertilization.

At installation, the average cultural diversity for all the farms is three species, usually rice, maize and cassava (Table 14). Only 16 farms practiced irrigated rice and only one upland rice on *tanety* (sole cropping).

Table 14: Evolution of the number of farms for each agricultural practice observed

N=24		Installation	2015
Crop diversity (average number per farm)		3	6
Intercropping (number of farms)		9	10
Use of improved seed variety (number of farms)		1	18
Cultivation technique (rice): (number of farms)	TRS	10	2
	SRI	13	20
	DMC	0	2
Use of organic fertilizers		12	24
Use of mineral fertilizers		0	13

In 2015, the average number of crop species cultivated by farms has doubled. The number of farms growing upland rice has risen sharply to 19, and 21 for lowland rice cultivation. Intercropping, usually on *tanety*, was practiced by 38% of farms at installation. This practice has changed little because in 2015, 10 farms are concerned (42%). Among these farms, two (n°4 and n°23), increased the cultivated area with intercropping.

The traditional rice cultivation system (TRS), with crowd transplantation or "*ketsa-saritaka*" was used by 10 farms at their beginning against 13 farms with the improved rice system or IRS. According to farmers, this last system is characterized by the lining out by respecting the distance between the lines, without necessarily using mineral fertilizers. This technique facilitates the operations of hoeing and/or weed control and contributes to improve production.

In 2015, there are only two farms (n°14 and n°23) that still devote themselves to the traditional rice technique. Thus, the SRI technique is highly diffused, but only partly because farmers combine this technique with transplantation in lines.

Two farms (n°8 and 13) practice in 2015, the DMC (under upland with *Stylosanthes* or Mucuna as cover crop). They were initiated by FAFIALA project in the early 2000s. Only one farm (n°19) usually practices SRI (System of Rice Intensification) over a part of the irrigated rice, but this farm has not implemented this practice in 2015 because the farmer was seriously ill.

Regarding the improved seed varieties, only one farm used it at installation (farm n°3 which has settled in 2003). In 2015, 18 farms reported using improved varieties which, for some, contributed to an increase in rice production. However, the improved seeds in question are not necessarily certified seeds. Many producers have acquired seeds from other farms, mostly in the vicinity.

Manure is the basis of crop fertilization on all farms. The addition of mineral fertilizers has developed, especially on *tanety* plots but usually at very low doses compared to the recommendations. The farmers explained that the cost of mineral fertilizers is too high for them and they do not master their use (dosage, time and frequency of application). At installation, no farm used mineral fertilizers. In 2015, there were 13 farms which use it with an average dosage of 21 kg/ha. Half of the farms were using only organic fertilization, with an average dosage of 5.5 tonnes/ha of manure. In 2015, all the farms use organic fertilizer on their crops, but the dose has not really evolved. The stagnation of organic fertilizer input per hectare was due to the fact that manure production follows the increase of farm's UAA. In general, farms do not buy manure. They use only the manure that they produce.

Fallow can be read with a double entry: *(i)* vis-à-vis the intensification of land use, fallow indicates low intensification, and *(ii)* vis-à-vis agro-ecological intensification, the practice allows the reconstitution of soil fertility, so it can be considered as beneficial, even if other techniques also help improving fertility. In our sample, fallow practice increased since it concerned 21% of farms at installation and 46% today (Table 15).

Table 15: Evolution of fallow practice

	Installation	2015
With effective fallow	5	11
Average surface area with fallow (acres)	101,20	141,82
Average UAA (acres)	144,60	497,26
Average % (Fallow area/UAA)	60%	32%
Without effective fallow	19	13
Average UAA (acres)	58.47	271.15

In absolute terms, fallow surface area was multiplied by 3. But at the same time, UAA surface area was multiplied by 5. Thus, the average proportion of fallow on farms which have this practice has decreased from 60% to 32%.

We find that the farms that practice fallow have an average surface area significantly higher than the others (at installation: 144 acres against 58 acres for those which have no fallow, and in 2015: 497 against 271 acres). This development of fallow is related to the growth of farm size since installation. And practice is related to the size of the UAA.

2.2.2.2. Evolution of practices in livestock systems

The intensification of practices in livestock systems can be assessed from: *(i)* the number of dairy cattle per forage area, *(ii)* the high diversity of animal species, (iii) the percentage of improved breeds and finally (iv) the type of animal housing.

Only one farm (n°4) produced fodder crops to feed its dairy herd at the time of installation. At that time, it also had one dairy cow to a forage area of 4 acres, which was more than enough to feed it. In 2015, six farms have dairy cattle and grow forage to feed them. The average for the six farms is 15 head of dairy cattle per hectare of forage area. Animal stocking is very high and indicates a strong intensification. However, animal feed is produced from other sources, in particular by-products of crops, fodder purchased or collected on common land and the animals graze on grassland or forest plantations on *tanety*.

At installation, each farm had on average 1.46 species, but as shown in Table 16 the farms' situation was contrasting because five farms (21%) had no animals, while three farms (13%) had three species (cattle, pigs and poultry).

Table 16: Evolution of number of animal species in the farms (in %)

Number of animal species in 2015	Number of animal species at installation				
	0	1	2	3	Total
0			4%		4%
1	4%	4%			8%
2	13%	8%	8%		29%
3		13%	25%	13%	50%
4	4%		4%		8%
Total	21%	25%	42%	13%	100%

Farms with one species (25% of farms) have only poultry, farms with two species usually combine cattle and poultry (25%), and rarely pigs and poultry (8%) or beef and pigs (8%). Furthermore, only three farms (n°1, 4 and 5) had improved breeds: dairy cows.

In 2015, the average diversity of species increased to 2.5 per farm. The evolution is towards an increase in diversity, together with an increase in the number of animals (as we have already analysed). Farms without animals and with only one species became rare: only two farms have no animals (we note that these two farms had two species at their installation), and farms with two species decreased from 25% to 8%. In 2015, 50% of the farms have three animal species and 8% have four species (the fourth species is one of fish, bees or geese). Additionally, the number of farms rearing improved breed animals tripled (nine farms in 2015), with on average 90% of animals (cattle or pigs) which are of improved breeds. For poultry, no farms have improved breeds.

Regarding the method of animal housing, at installation about 75% of the farms had no stable. Only three farms had cattle shelters to accommodate their zebu at night and another farm supplies harvested fodder in addition. Only farm n°4 kept its dairy cow tethered in a cowshed along with feed supply. In 2015, the construction of livestock housing has led to the improvement in the method of animal housing. Only one farm (n°15) still breeds animals (poultry) free range, since it does not have a henhouse. The majority of farms keep their livestock in buildings and some provide feed. Five farms practicing dairy farming (seven) keep their cows in permanent housing along with feed supply.

2.2.2.3. Productivity of agricultural farms

- ✓ **Performance of crop production**

Agricultural gross margin of the farms has been determined only for 2015, calculated for each crop, and for each farm operating expenses and gross income (family work is not included in the charges). Fruit and forest areas could not all be evaluated (part of the fruit crop are grown at the edge of the fields). Unit prices for the evaluation are the average of the information provided by producers. The choice was made to evaluate forage crops and manure produced on the farm (self-supply), therefore, the amount of the gross income of fodder crops appears as a product in agriculture and as a charge in livestock. For manure, it was the opposite. Finally, to present the results, crops were grouped into large families (Table 17).

As already mentioned, rice occupies a very important place in the farm production systems in the region. All farms in our sample produce it. When we aggregate farm data we find that rice occupies more than a half of the cultivated area (evaluated). And lowland rice is the most important crop with 27% of the area and 29% of the gross income of crop production and the average gross margin (weighted by area) is the highest of the major crops. Upland rice, which also occupies an important part of the area (almost ¼), is less productive and its share in the gross income is much lower due to a margin per hectare among the lowest along with legumes.

Table 17: Proportion of different crops in the surface area and the cumulative gross income

Crops	Number of farms involved	Area*	% Surface area*	% Gross income	Average gross margin** in Ar/ha
Irrigated rice	21	19.49	27.2%	29.1%	1,823,013
Upland rice	19	17.73	24.8%	12.0%	720,193
Rice subtotal	24	37.22	52.05%	41.0%	1,297,607
Maize	18	11.09	15.50%	9.0%	1,118,290
Tubers	18	6.70	9.36%	6.7%	1,119,141
Legumes	15	6.50	9.09%	3.5%	683,924
Vegetables	6	0.60	0.84%	1.6%	3,085,500
Fodder	7	9.41	13.16%	31.7%	4,942,503
Fruit	8			6.3%	
Forestry	3			0.1%	

* The areas for fruit and forestry were not able to be evaluated for all farms

** Gross margin weighted by surface

Because of the importance of dairy farmers, fodder crops play an important role both in terms of surface area (13.2%) and as gross income (31.7%). This mode of representation clearly shows the strong agricultural productivity which is generated by dairy farming that can enhance forage production at very high prices and gross margins per unit of surface area that compete with market garden production.

The average yield of irrigated rice per farm is 4.1 t/ha. In 24% of farms it is less than 3 t/ha while in 30% of farms is 5 t/ha and more (Figure 24). There is a significant difference between the average per farm (4.11 t/ha) and the weighted average acreage (3.64 t/ha) which seems to indicate a better productivity for farms that cultivate small areas, however, the analysis of the correlations between yield and surface area indicates a negative factor but is not significant.

The gross margins of irrigated rice are also very different according to farms, but the average (Ar 1.8 million/ha) was significantly higher than for other upland crops (a little less than double).

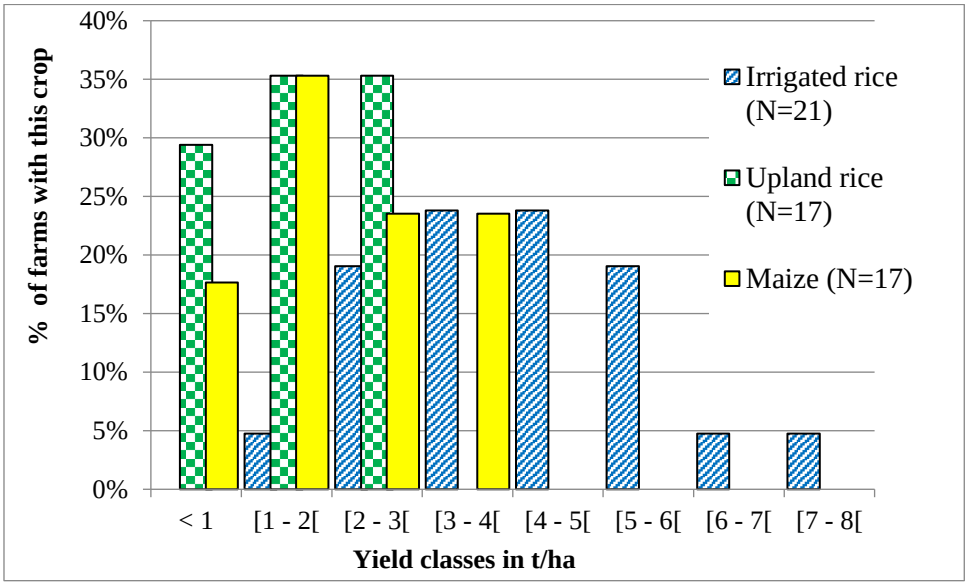

Figure 24: Distribution of farms according to yield classes for the three main crops

The upland rice yields are much lower: 1.5 t/ha on average per farm. The weighted average of the surface areas is identical. The gross margin (Ar 720,000/ha) is significantly lower than for irrigated rice and maize. Finally, the average maize yield with 1.8 t/ha is significantly higher than that of upland rice and allows a significant gross margin (Ar 1.3 million/ha) to be obtained. Because of the differences between the available area surface of UAA, gross margins are very different between farms. The Table and Figure below show the great differences between farms: eight farms (33%) have a gross margin of crop production of less than Ar 1 million (middle of the class of Ar 488,000) which represents only 3% of the total gross margin obtained by all the studied farms. In contrast, three farms (13%) have a gross margin of more than Ar 10 million (middle of the class Ar 25 million) which represents 58% of the total gross margin.

Classes agri GM in million Ar	Nb. Farms	Aver. surf. (acre)	Average GM Ar	GM per hectare (Ar/ha)
= 1M	8	36	487,978	1,362,590
]1M - 5M]	9	255	2,797,069	1,096,890
]5 - 10M]	4	521	6,522,488	1,252,518
> 10M	3	1 044	25,216,933	2,415,415
Total	24	325	5,450,758	1,677,909

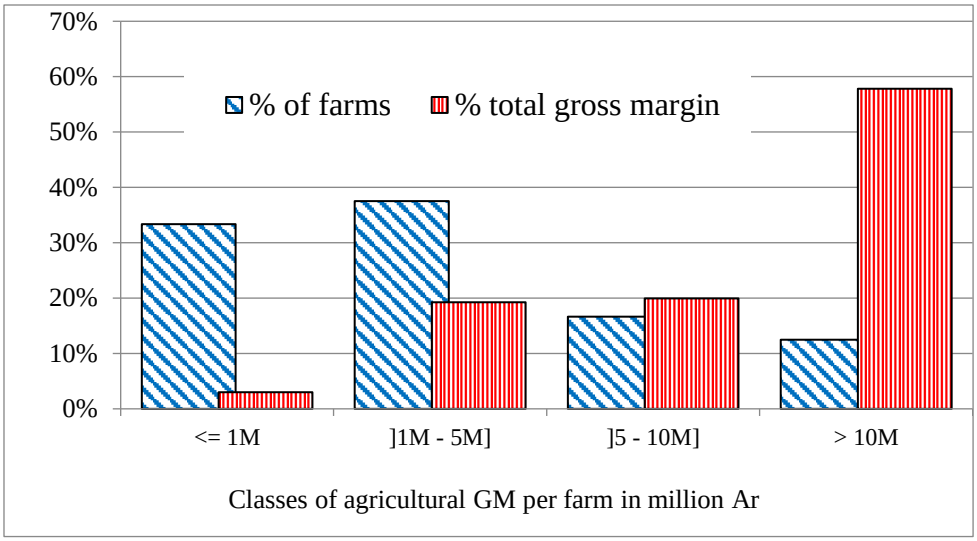

Figure 25: Distribution of farms and gross margin according to gross margin classes

The average gross margin per hectare of UAA is the highest for the three big farms (n°1, 4 and 9) with Ar 2.4 million on average per ha of UAA, this very high level is related to the presence of two big dairy farmers with a substantial forage area (forage constitutes nearly 55% of the total gross margin). In this group, irrigated rice occupies less than 10% of the gross margin, while in the other groups it represents 35% for smaller farms and nearly 63% for farms in the second group (1M to 5M). For the other three groups, we note that the margin per hectare is the highest for farms in the first group, that is to say, that the smallest farms (36 acres on average). Without seeking to determine if these differences are significant, we can conclude that the gross margins obtained by small farms are at least equivalent to those generated by larger sized farms.

In the years following installation, farms commercialized small amounts of crop products; production, was generally low and for own consumption. Some farms even bought foodstuffs to fulfil their family needs. In 2015, the share of commercialized products is very variable. Among the 24 farms, 19 commercialize over a third of their crop production, among them 5 farms sold more than half of this production. Rice is the main product sold (in any quantity) by farms with large areas. On small farms, rice is usually kept for home consumption and the most commercialized products are cassava, beans, maize, fruit and vegetables.

- ✓ **Performance of livestock production**

The assessment of livestock performance was made by major types of animals (Table 18). In some cases, gross margins are negative (common for draft cattle) because the farmer has costs without animal products. Farm n°5 has a negative gross margin in livestock production (approximately Ar 2 million), linked to the renewal of one ox and especially to their diet. Farm n°20 bought pigs to be fattened and in 2015 its margin was negative Ar 50,000.

The gross margins for livestock production are smaller compared to those of agricultural production. And again, there is a great variability with more than half of the farms which have an average margin of Ar 317,000 and always the three big farms (n°1, 4 and 9) which have an average margin of Ar 12.7 million. The first two are dairy farms and the third one developed pig farming.

Table 18: Breakdown of the average gross margin per farm

Gross margin class	<=1M	]1M - 10 M]	>10M	Total
Number of farms	13	8	3	24
Average gross margin/farm	317,465	2,305,025	12,658,087	2,522,563
Animal purchase	62%	33%	8%	14%
Imported feed	28%	36%	52%	49%
Animal health	8%	3%	1%	2%
Internal consumed feed	2%	28%	38%	35%
Total expenses	100%	100%	100%	100%
Milk	6%	58%	81%	73%
Meat	10%	13%	17%	15%
Animal sale	76%	27%	0%	9%
Manure sale	0%	0%	0%	0%
Internal consumed manure	7%	2%	2%	2%
Gross income	100%	100%	100%	100%
Milk cattle	29%	73%	61%	62%
Other cattle	23%	2%	3%	4%
Pigs	55%	14%	35%	30%
Poultry	-7%	2%	0%	0%
Other		8%		3%

The breakdown of expenses and incomes is different according to the gross margin class (Table 18). Farms with less than Ar 1 million of gross margin, have herds with few cattle and the margin is made up to 55% by pig farming. Thus, expenses (62%) consist mainly of the purchase of young poultry level (-7%), with small farms that have problems of theft and diseases, but also maybe an underestimation of consumption.

For the other two groups, the essential production target and the gross margins are the result of dairy farming (for margins of 73% and 61%, respectively). Expenses are made up by the purchase of outside feed and also by intra-fodder consumption (which constitutes 38% of the expenses for the group of the three big farms). We note the contribution of fish farming and beekeeping (others), representing 8% of the margin for medium farms.

Intra consumed manure represents only a small proportion of livestock products (2% for farms with more than Ar 1 M gross margin, and 7% for small farms).

In 2015, milk is the main livestock product commercialized on the farms in this sample. These farms have faced crisis years (2009-2010) with the ending of TIKO company which collected milk production. To cope, initially, these farms tried to sell milk or processed products (yogurt and cheese) directly, they reduced their production, and some have even given free milk to their neighbours. Today these farms sell their products to ROVA cooperative. For the farms that do not produce milk, pigs are the main commercialized products. Poultry, represent only a small share of sales.

- ✓ **Agricultural gross margin (livestock + crops)**

In general, crop production activities generate margins significantly higher than livestock on the vast majority of farms. And if we consider the gross margin as a specialization indicator,

then very few farms are specialized in livestock production; in Figure 26 we observe two farms n°4 and n°9, the first with dairy cattle and the second one with pig farming.

In farm n°1, which is nevertheless the biggest dairy farm, the livestock gross margin is well below the margin of crop production, this is explained by the effect given to the intensification pathway due to a search for autonomy and thus with significant forage production and medium milk yield, but, with very high margin rates.

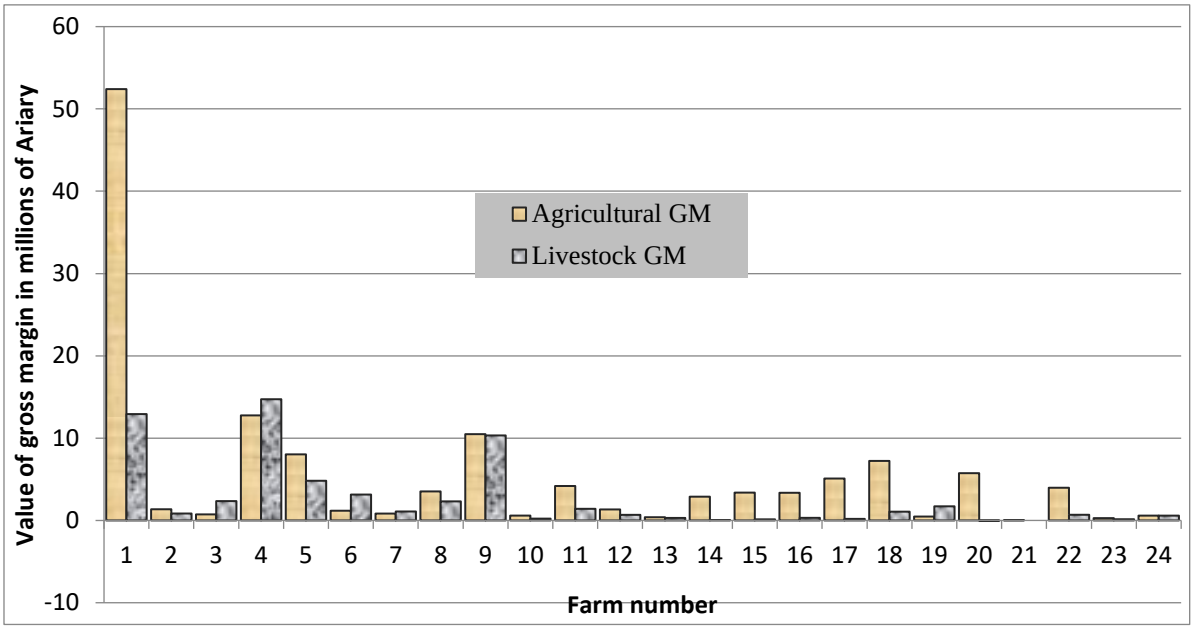

Figure 26: Gross margin of agriculture and livestock for each farm

Margin differences between farms are considerable as we can see in Figure 26, with the extremes farms n°1 and n°21. The gross margin of the farm is linked to the availability of land and the number of animals owned.

- ✓ **Agricultural income and total income of farms**

The costs of facilities specific to livestock production consist of costs related to the maintenance and repair of buildings; those specific to agriculture, are composed of the costs of renting agricultural land and the repair and maintenance costs of agricultural equipment.

The average facilities maintenance costs for all farms are estimated at Ar 1.5 million equitably divided between agricultural and livestock activities.

Non-agricultural and off-farm incomes were presented in the previous point. Five farms do not conduct non-agricultural activities and the one that has the highest non-agricultural income is still farm n°1, which alone represents over half of the total revenues generated by non-agricultural activities. For the other farms, farm income generally consists of salaries (daily or monthly), retirement pensions and others.

The average total income of the twenty-four farms surveyed is not significant because the farms are so different.

But the distribution of farms by income class illustrates the very high variability well and allows the analysis of the composition (Table 19). We created five classes with average incomes per class ranging from Ar 1.8 M to 42.0 M/farm. These discrepancies indicate very different farms in terms of available production factors and levels of intensification.

Table 19: Composition of the average total income of farms according to income classes

	<= 2.5	2.5 - 5	5 - 10	10 - 15	>15	Total
Number of farms	7	5	6	3	3	24
Global farm income	1,849,519	3,488,710	5,848,565	11,719,467	42,598,911	9,518,196
Income from crop production	33%	68%	45%	52%	48%	49%
Income from livestock production	32%	7%	22%	14%	20%	19%
Agricultural off-farm	10%	11%	2%	3%	32%	20%
Non-agricultural	24%	15%	31%	32%	1%	13%
Agricultural income/farm family worker	512,397	1,090,370	1,581,448	3,736,058	11,906,896	2,727,341
Global income/family worker	719,389	1,316,802	1,970,159	2,719,613	13,538,603	3,008,972

The breakdown of the total income according to its origin provides information which varies greatly from one group to another. But for all the farms together, the agricultural income is between 65 and 74% (crop + livestock). There are farms where non-agricultural income plays an important role, such as farms n°10, 21 and 23, where over 75% of their income is obtained from off-farm activities.

The income from crop production represents about half of the total income. It is on the poorest farms (with an average income Ar 1.8 million) that such income is the lowest (33%), as well as livestock income (32%). This is linked to land constraints (these farms have on average less than 1 ha) and therefore to intensification strategies that pass, for some of these farms through livestock production. We have seen before that livestock production is very risky (theft, illness), making small farms very vulnerable. It is also these farms that have the most important proportion of off-farm and non-agricultural incomes (34%). To compensate for the low farm income these farms sell their labour as agricultural workers and conduct non-agricultural activities. These activities are often poorly paid and the income per family worker is very low, less than half the minimum wage. The farms in this group are in poverty traps, with insufficient production factors to engage in an intensification process that would allow them to increase their income enough to escape poverty and on the other hand the off-farm activities are low paid, or at least insufficient to significantly increase their income. Finally, family labour productivity is too low to ensure a decent income.

For the group of farms with an income between Ar 2.5 and 5 million, we note the relative importance of crop production income (68%). These are farms with relatively large areas in the region (average 2.7 ha) and well-endowed with animal capital but less productive livestock. Income is still low, with a family work productivity lower than the minimum wage. For these farms, that have access to relatively substantial production factors, agricultural intensification could be a way of improving livelihoods.

For all the other classes, the average income per family worker is higher than the minimum wage, which reflects a relatively good productivity of family labour. We note that Class 5 at Ar 10 million of total income had an average animal capital lower than the previous class but this livestock activity is much more productive.

2.2.3. Evolution of indicators and type of pathways

2.2.3.1. Economic and social performance indicators in 2015

The selected economic indicators measure, for some, labour and capital productivity, and, for others, the levels of income received that we can consider as an assessment of profitable activity. This is a way of assessing the economic results of agricultural intensification. The

average score of the group of farms is close to the average (4.6 in 10) but with a fairly high variability between farms (coefficient of variation of 50%). We grouped the farms according to their average score in three groups:

- Farms with very low economic indicators: average score is less than 3;
- Farms with economic indicators of an intermediate level: score from 3 to 6;
- Farms with high level economic indicators: Average higher than 6.

The average for each indicator of the three groups is shown in Figure 27.

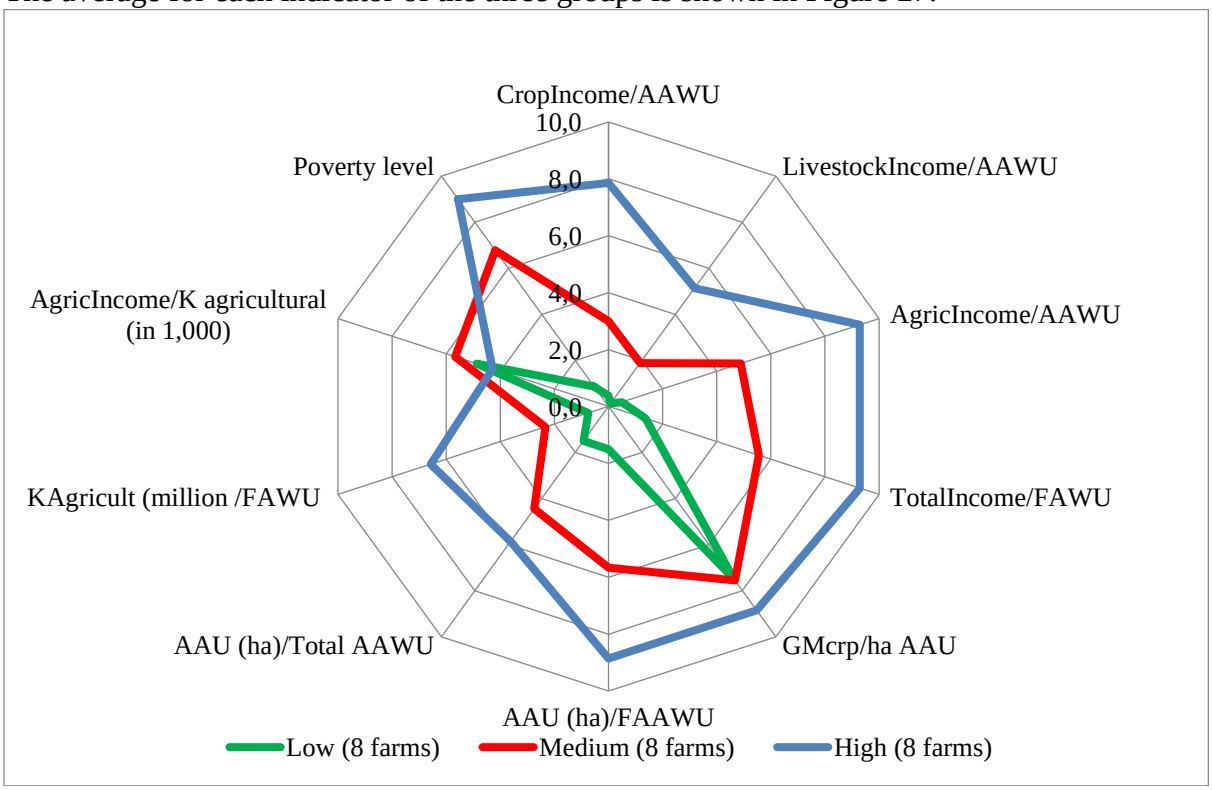

Figure 27: Average of economic and social performance indicators in 2015 by group

Farms are equitably distributed among the three groups.

For the group of farms with poor economic indicators, most of the average is composed of types of indicators that measure the productivity of agricultural activities per surface unit (gross margin of crop production per ha of cultivated UAA) and capital productivity (income from agricultural activities per million of agricultural capital invested (total estimated value of the land, equipment, animals and buildings). For this last indicator, the group's average is close to that of other groups, even higher than that of the group with the highest economic indicators because the investments are very poor and even if the income generated by the activities is also very low, once brought to the total value of the investment, productivity appears high. Regarding the gross margin of crop production per ha of cultivated UAA, the results obtained by this group are slightly higher than that of the group with average economic indicators. Following the same reasoning as before, the cultivated areas are poor and even if the gross margins are discounted for cropping activities are they very poor, once brought to the total value of the UAA, the productivity of agricultural activities also appears high. All the other indicators have very low scores, showing: *(i)* on one hand the weakness of farm resources compared to working family members (very little land available per family worker; the average UAA per family worker is less than 0.3 ha/family worker), *(ii)* on the other hand the weak labour

productivity (income per family[26] worker is less than Ar 300,000). Even the overall productivity of family labour measured by the overall farm income (which includes non-agricultural income) per family worker remains very low (less than Ar 600,000). Thus, for these farms, income from non-agricultural activities does not compensate the weakness of resources and farm incomes per family worker. The level of poverty is measured here by the global income per capita compared to the poverty line in Madagascar[27]. For these farms, the very low average score (close to 1) is close to the extreme poverty line. The intensification process, if it has occurred, has not resulted in economic results that ensure an acceptable living standard for the family farm. The efficiency of the intensification process depends of the productive resources to which the farm has access. If resources are very weak, agricultural intensification must be accompanied by a significant increase in resources.

Regarding the group of farms with economic indicators of an intermediate level (average between 3 and 6), the average income per capital invested (thousands of Ar) is significantly higher than the two other groups of farms (over Ar 600 of income for Ar 100 of capital). However, the invested capital is not very important for this group of farms (average score of 2 which corresponds to Ar 3.5 to 5.0 million of capital invested by agricultural family worker). The scores assigned to other economic indicators lie between those of the other two groups, with significant differences compared to that of farms of the group with high economic indicators: *(i)* on labour productivity, in terms of crop production income, total farm income and total farm productivity, *(ii)* on productive resources per family worker unit (UAA and agricultural capital per family AAWU), and finally *(iii)* on livestock productivity measured in terms of income per family worker. Despite these results being significantly lower than those of the group with the best performance, the score for the indicator of poverty level remains high (around 7), an income between Ar 926,000 and Ar 1,075,000 per person per year which is double of that of the poverty line. For these farms, agricultural intensification allowed them to reach a level of income far enough from the poverty line, allowing these farms to have a significant capacity to finance themselves.

For the group with good economic indicators, the average is higher than 7, with very high scores for labour productivity (agricultural and total incomes per family worker are 4.4 times higher than the minimum annual income), but also for land productivity (the average gross margin calculated per ha is of Ar 1.8 million) and land availability per family worker (higher than 3 ha/family worker). Livestock production income per family worker is medium (around Ar 1.4 million/family AAWU) representing a better contribution of crop activities compared to livestock activities for most of the farms of this group. However, we must remember the link between the two activities and the fact that in our assessment manure input was considered but that of draft animals was not taken into account. The average income per agricultural capital invested (in thousands of Ar) is significantly lower compared to the other two groups of farms (lower than Ar 300 of income for this group against more than Ar 600 for the third group for Ar 100 of capital). However, the capital invested is significantly higher for this group of farms (average score of 7 that corresponds to Ar 20-30 million of capital per agricultural family worker, against less than Ar 3 million for the group of farms with the lowest results). For this group of farms, the score of the poverty level indicator is very high (more than 9), which means that the income per person is more than three times higher than the poverty line. For these farms, agricultural intensification, often based on significant production resources, allows them to achieve a significant income with a family livelihood level far removed from poverty.

[26] Which is measured according to the annual minimum wage in Madagascar (Ar 1.6 million/year).

[27] Score 3 is attributed to an annual income per person from Ar 441,000 and 500,000 which integrates the poverty line in Madagascar in 2010 (Ar 468,800/person), score 0 is attributed to an annual income of Ar 330,000/person/year which corresponds approximately to the extreme poverty line in Madagascar (INSTAT, 2011).

2.2.3.2. *Analysis of agricultural intensification indicators*

The 23 indicators that characterize the intensification pathways adopted by the farms were divided into five principles of synthetic indicators. These principles regroup the indicators that have similar characteristics and can be assigned to one of the following criteria: *(i)* productivity, *(ii)* viability, *(iii)* resilience, *(iv)* social and *(v)* environmental. An analysis of the evolution of the principles of intensification from the moment of the farms' installation up to 2015 has been carried out (Figure 28). In one part, this analysis allows the grouping of farms that have the same evolution profile for each of the different intensification principles established, and in the other part to understand the possible correlations between the evolutions designed for each principle.

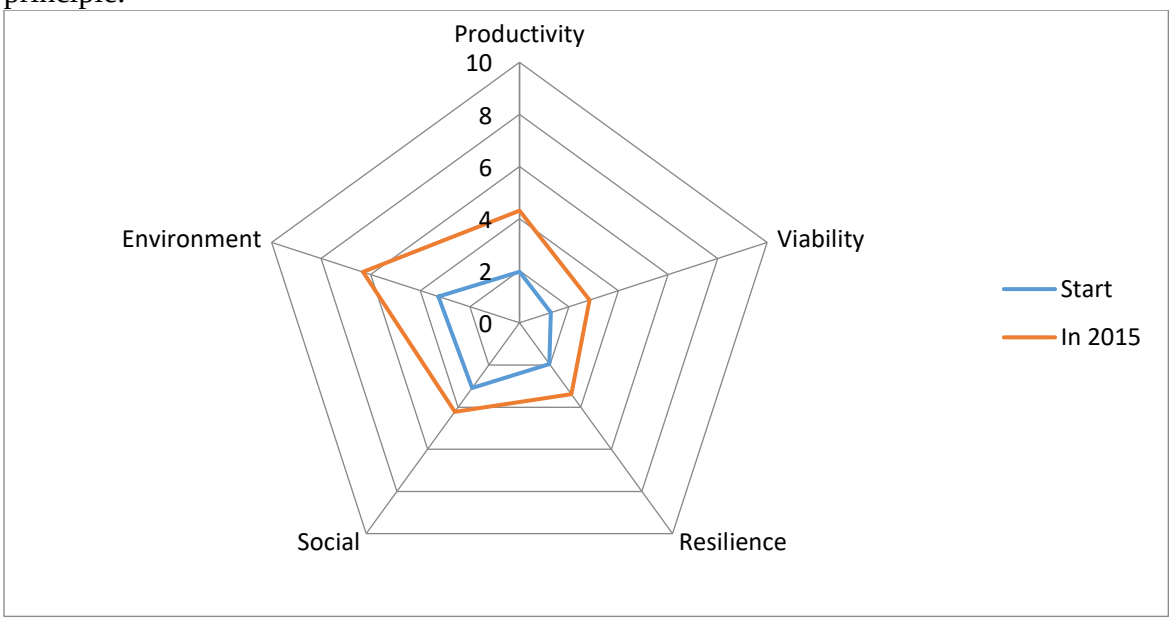

Figure 28: Evolution of intensification principles from the moment of farms' installation until 2015

To understand the level of global intensification better, the evolution of each principle, and eventually the evolution of each farm, a score from 0 to 10 was established for each intensification indicator. Figure 28 shows the global evolution of the level of intensification for all the farms through the five established principles.

Globally, our sample of farms has not made impressive progress in terms of agricultural intensification. The average score of intensification for all the 24 farms evolves lightly, changing from 2.3 to 4.2. This means that our sample is composed of farms where most of them start with very few production resources that remain at a low level in 2015. Among the five principles, environment is the one that made the most significant progress, with a score that changes from 3.3 at the beginning to 6.3 in 2015. However, even if the farms seem to start with few production factors, the evolution of each one of them is very diversified. If some farms did not achieve improvements to their intensification level, most of them obtained fairly satisfying results. Thus, according to the global average of the level of intensification attained, farms were classified in three categories: *(i)* class 1 that regroups farms that evolved weakly, with a score lower or equal to 3.5 in 10.0, *(ii)* class 2 that regroups farms characterized by relatively medium rate of evolution, with a score from 3.5 and 5.0, and *(iii)* class 3, that comprises farms that had a remarkable rate of evolution, with a score higher than 5.0 sur 10.0.

Class 1, that corresponds to 29% of the farms of our sample, has an average age which is quite low (23 years), except for two farms (n°2 and 7; Table 20). The low evolution of intensification principles observed at the level of these farms can be linked to the fact that these farms did not have enough time to progress.

Table 20: Age and level of intensification of class 1 farms

Number of farms	Age of farms (years)	Level of intensification in 2015
2	35	3.5
7	39	3.4
8	17	2.6
10	25	2.5
15	7	3.0
16	23	3.3
21	14	3.1

At the moment of installation, the farms of this class have very few production resources. In 2015, only "productivity" and "environment" principles show some evolution (Figure 29).

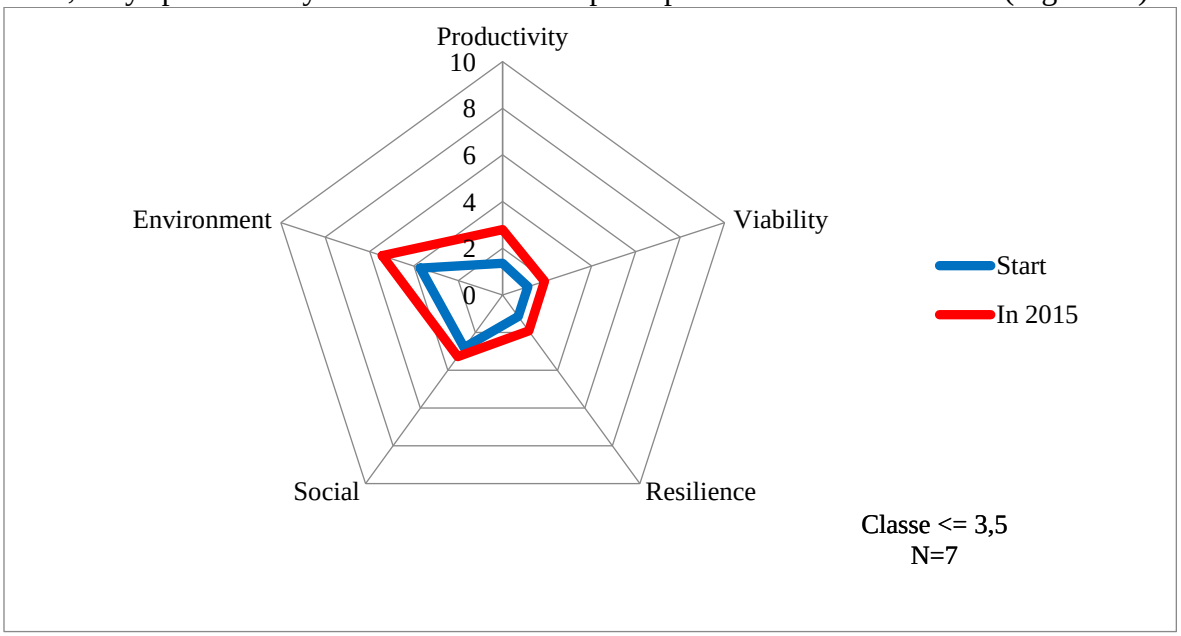

Figure 29: Evolution of intensification principles on farms with low levels of evolution

In terms of productivity, only one farm has equipment for draft animals, the others use only manual materials. In 2015, three farms still use manual equipment. They consist of farms that do not practice dairy farming. Resilience of the farms of this class is highly affected by the low diversity of crops (in average 3.6 species) and of animals (two species) associated to the fact that only one of these farms practices intercropping (3% of the UAA). Regarding the "social" principle, the level of land appropriation of the three farms has decreased: farm n°8 started to cultivate lands rented along with other members of the family and farms n°15 and 21 rented most of the land that they cultivate.

The average age of farms of class 2 is quite close to the average age of our sample (24 years old; Table 21). However, big differences in age were observed: in one part, we observe in this class the youngest farm (n°22; 6 years) and the oldest (n°9; 40 years). Thus, it seems that the factor "age" doesn’t have a major influence on the level of intensification attained by the farms.

Table 21: Age and level of intensification of farms of class 2

Number of farms	Age of farms (years)	Level of intensification in 2015
3	12	4.3
11	35	4.5
12	16	3.5
13	12	4.0
14	24	3.6
17	40	4.4
18	23	3.9
19	40	4.3
20	29	4.6
22	6	4.5
23	26	4.0
24	20	4.7

In this class, a stronger evolution is observed compared to the first one (Figure 30). The level of global intensification increases in two points, but still remains lower than the average, changing from 2.1 to 4.2. The "environment" principle has strongly improved and increased to a satisfying level. However, the other principles remain at a level lower than average.

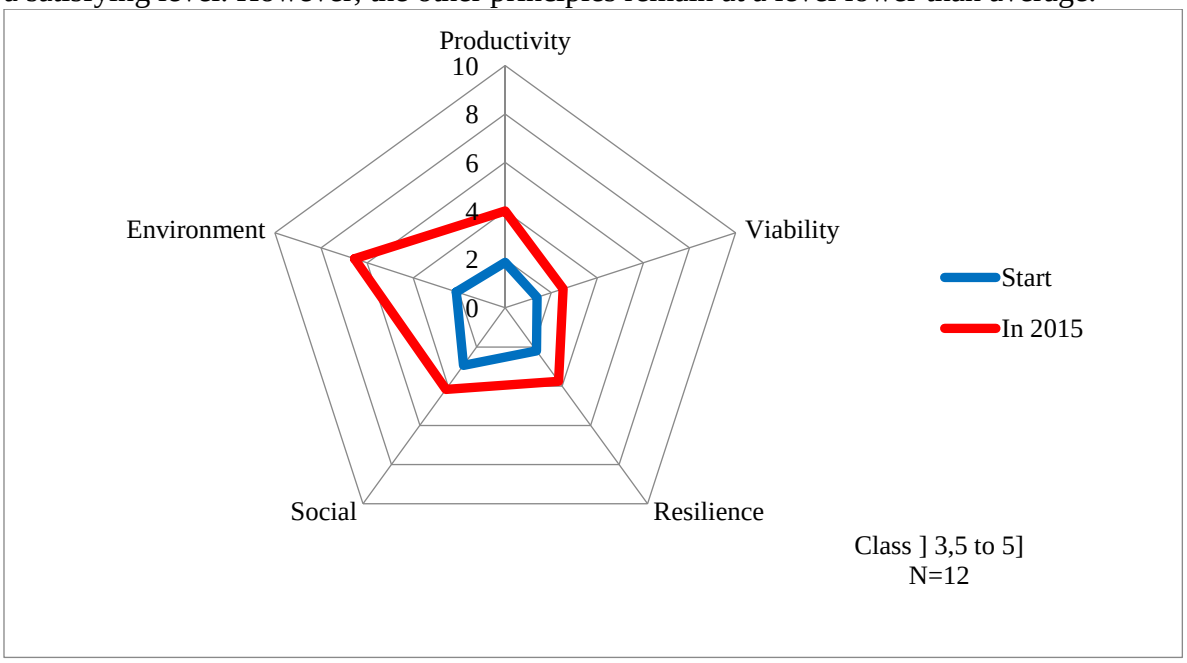

Figure 30: Evolution of the intensification principles on farms with medium levels of evolution

Here, we observe the farms that depend highly on the energy provided by oxen to carry out work on the land. Sixty-six percent of the farms in this class use draft animals. In addition, the average head count of cattle is high compared to the pig herds among all the farms, where most of them do not practice dairy farming. On average, one farm of this class has 3.6 head of cattle against 2 head of pig. In other part, these farms have a higher diversity of crops compared to the farms of class 1. With a higher number of oxen, the farms use manure to fertilize their fields. In this class, eight farms did not have access to manure when they started. In 2015, all the farms started to use manure at least to fertilize their crops, which allowed to improve the "environmental" principles on these farms.

Class 3 is characterised by a remarkable evolution of intensification principles compared to the previous classes. With a total score relatively low at the start, but much higher compared to those farms of the other classes, the level of global intensification of the farms of this class changed from 3.2 to 5.9. This progression is probably linked to the age of farms (Table 22). In this class, the youngest farm (n°1) was 28 years old and the oldest (n°5) was 37 years old. The average age of the farms of this class was 31 years old, which is significantly higher than the average of all the sample.

Table 22: Age and level of intensification of farms of class 3

Number of farms	Age of farms (years)	Level of intensification in 2015
1	28.0	5.1
4	31.0	5.7
5	37.0	5.7
6	30.0	5.9
9	30.0	6.9

The specificity of farms found in this class is related to the fact that these farms have strongly intensified their productivity and viability (Figure 31). We observe here the farms that have invested highly in livestock activity. Four of these farms were oriented towards dairy farming and one of the farms practices pork fattening with a stock of 20 head of pigs. The indicator related to zootechnical performance is highly favoured for this reason and contributes to the productive performance of the farms of this class. On the other hand, most farms have considerable infrastructures, including solidly built livestock buildings, where animals are stabled and efficient equipment (some motorized). All these factors induce a strong increase in the productivity of these farms. The other principles of intensification also improved and indicate a better balance of production factors.

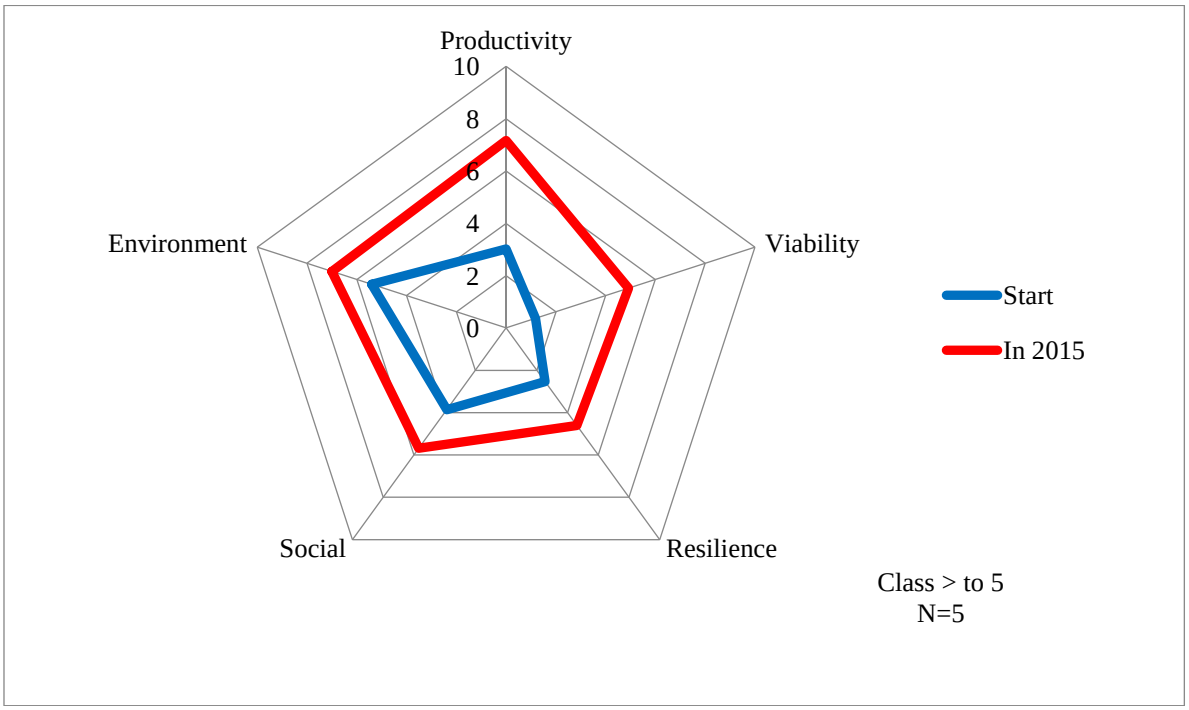

Figure 31: Evolution of intensification principles of farms with high levels of evolution

A classification of agricultural and total income generated by family workers was established to highlight the results of the activities carried out per unit of available labour (Figure 32). Thus, the values identified through the relationship between income and AAWU (family, internal and total) were reported for each of the three classes of evolution established.

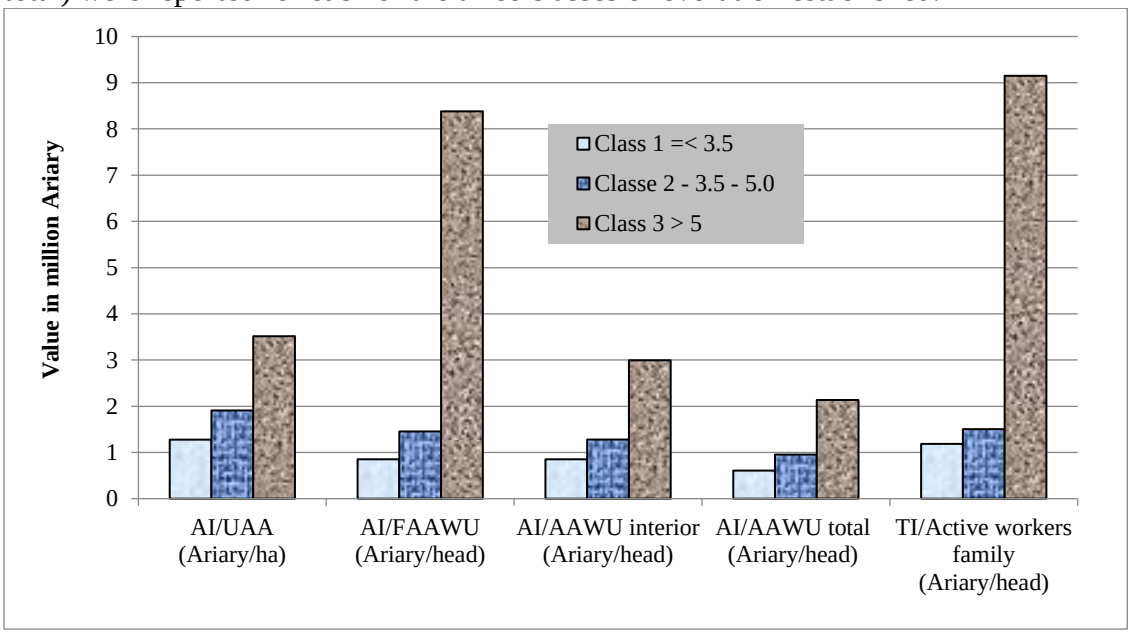

Figure 32: Classification of farm income per active worker

A general finding indicates that the most evolved farms are those that generate the highest income per active worker. The better balances of the different classes of farms are found among the farm income generated by the internal and total AAWU compared to those generated exclusively by family AAWU. It follows that the most developed farms are more dependent on external employees (daily and/or paid by task or even permanent employees) than the less evolved farms. Indeed, all the farms of class 3 employ a permanent workforce. The other farms generally do not have much financial capacity to cover workforce costs.

2.2.3.3. Evolution of sustainability indicators

To analyse the sustainability of farms, we calculated the average scores of the 20 indicators. Figure 33 shows the evolution of the average score of sustainability between the time of installation and 2015, for the 24 farms of our sample. All farms registered a positive development. The average score goes from 3.1 to 4.8, representing an increase of 1.7. The variability of the difference is not very high (40%) and the scores evolve between a minimum of 1.9 (at installation) and a maximum of 7.0 (in 2015).

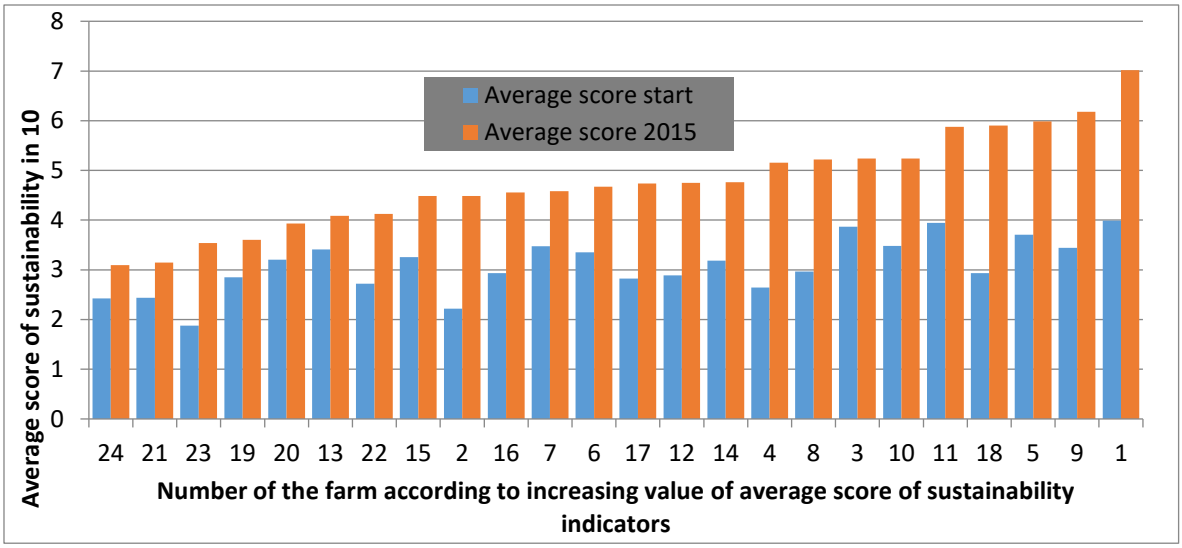

Figure 33: Evolution of the average score of sustainability for the 24 farms

To facilitate the analysis, indicators have been grouped according to the three principles of sustainability with eight indicators for "environment", and six "economic" and "social" indicators (or more precisely the socio-territorial indicators because the indicators of remoteness and market access are included here, see item 2.1.3). The average scores for each principle have been calculated for both periods (installation and 2015) and on the basis of the average evolution of scores of the three principles the 24 farms were grouped into three classes of evolution.

The first class contains five farms with a score of less than 4 in 2015. These are farms that had a very low score at installation (average 2.6) and have evolved little with an average increase of less than 1 point (average of 3.5 in 2015) and in particular with the score for "economy" stagnant (Figure 34). These farms started with very few production factors and could not increase them, these are the most deprived farms, the poorest of our study. Today, they are characterized by a very low level of equipment and AWU per person; their crop and livestock systems are poorly diversified and they sell very few agricultural products. Some are in isolated areas. Low income. The sustainability of these farms appears compromised particularly economically with insufficient production factors to engage in a process of intensification that would allow them to significantly improve their situation. And this is true for all forms of intensification, including an agroecological intensification because good indicators of diversity of annual and perennial crops, or animal species, access to different types of soil, irrigation allowance, manure production, etc. can only be obtained with a minimum of production factors. Access to production factors is a major constraint to agricultural intensification. The use of non-agricultural activities would certainly be an option for those farms but employment opportunities are very limited and, if conditions do not change, these pose the question of leaving agriculture and of exodus for their children.

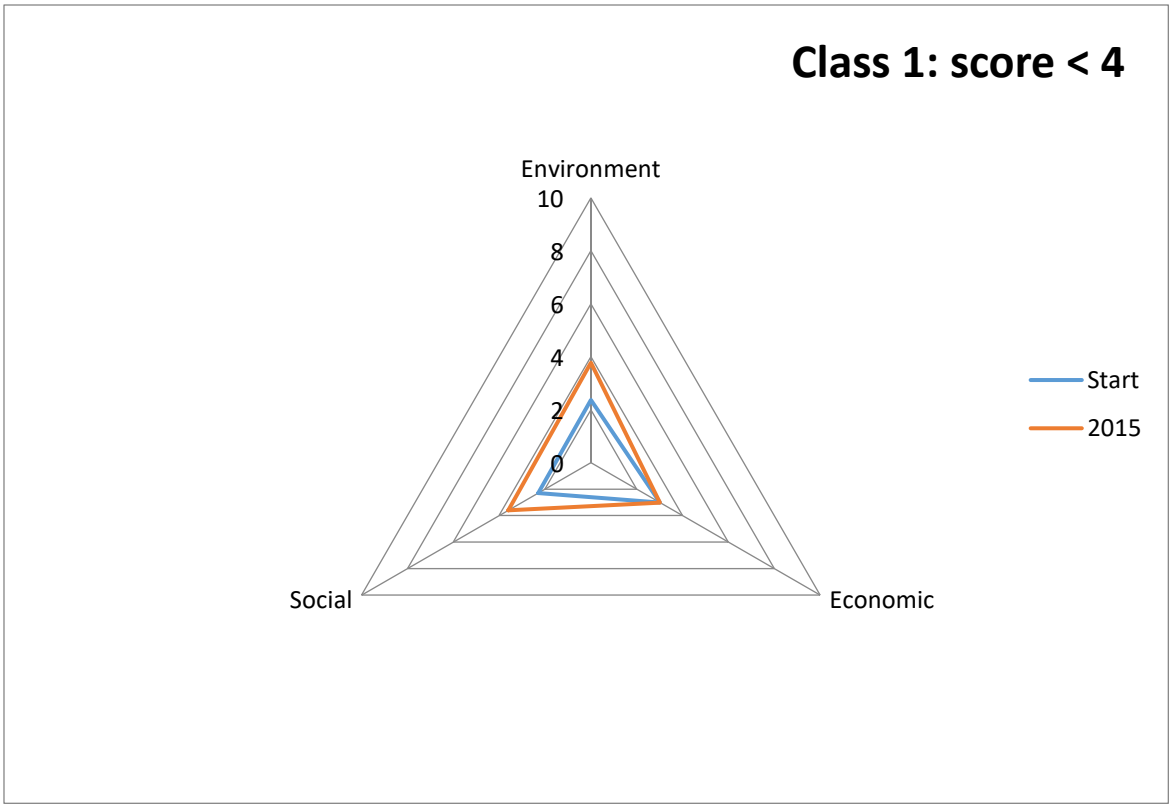

Figure 34: Evolution of sustainability indicators per principle for Class 1: score <4

Class 2 is constituted by the 14 farms with a score between 4.0 and 5.5 in 2015 (average of 4.7; Figure 35). These farms have experienced a greater evolution than the previous group (average increase of 1.5 points). Evolution affects all areas, including the economy. The scores of "environmental" and "social" principles are those that have most progressed (2.5 to 4 for the "environment" and 3.6 to 5.9 for the "social"). These farms have, in 2015, substantial production factors that they have often increased compared to the moment of their installation. By increasing the land, they have been able to diversify the types of land, improve the irrigation ratio. They have developed and diversified the types of crops and livestock, improved manure production, etc. Some have non-farm incomes that give them some financial security, in a risky environment for agricultural production. These farms are distinguished from those of the first group, especially regarding the membership of farmers' organizations, the educational level of children and adults and the lack of remoteness. If compared with the previous group, the level of sustainability appears higher, scores remain very average with a low level of equipment, little livestock capital, poorly developed variety of crops and animals. Thus, even if capabilities exist, the process of agroecological intensification remains limited.

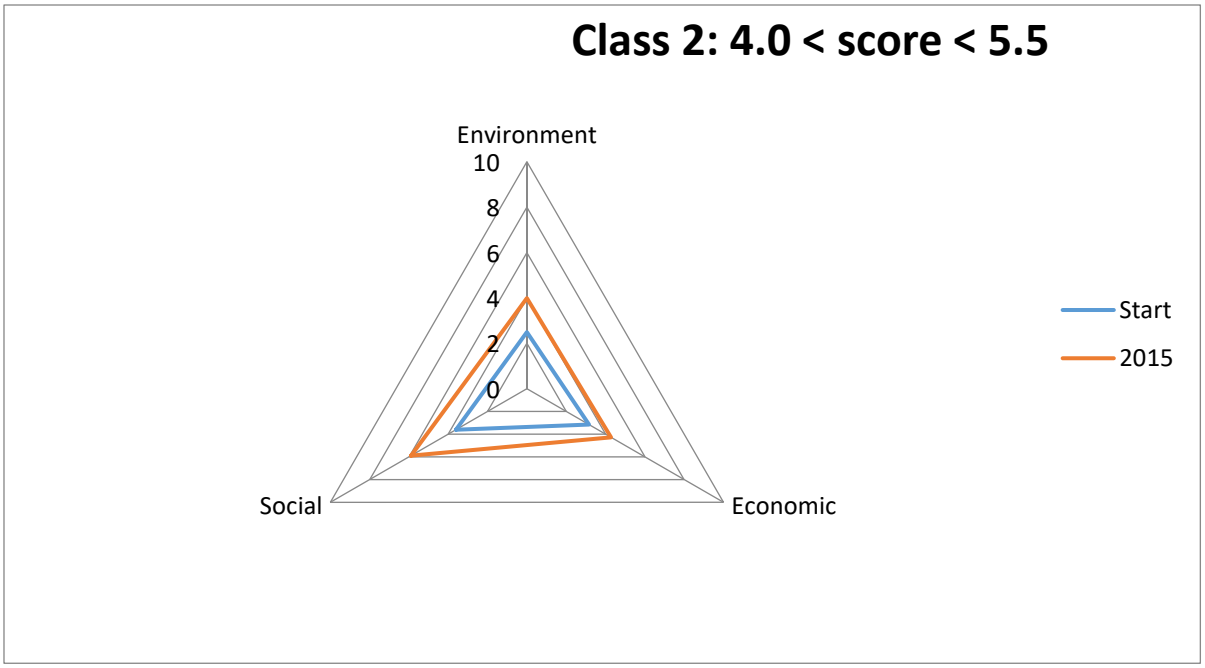

Figure 35: Evolution of sustainability indicators per principle for class 2: 4.0 < score < 5.5

The last class includes five farms with the best sustainability scores in 2015 (over 5.5; average 6.2; Figure 36). This group has the highest increase (+2.6 points from the installation until 2015), even if these farms already had better scores at installation (3.6 points on average, i.e., one point more than the first group). The average score has increased by 2.6 points; all the principles have evolved by at least 2 points. This is the "socio-territorial" principle, which is the highest with a score of 7.7 in 2015. This principle includes market access indicators, membership of professional networks and the level of education. Farms in this group that were well equipped, have made progress in this area.

The farms in this group are the biggest farms in our sample (n°1, 5, 9, 11 and 18). That is to say, those that have the most production factors in 2015, much of which was acquired since their installation by investing the profit obtained from agricultural production, but also from financial resources derived from non-agricultural activities, and in a few cases from financial institutions (banks or micro-credit). The availability of production factors allowed them to diversify their activities, both in agriculture (food, forage and perennial crop, etc.) or livestock (dairy cattle, pigs, etc.), generally with high UAA, many livestock animals and improved breeds, as well as equipment and buildings. These farms are close to cities and markets which facilitates their access to training, integration in projects or programs, but especially facilitates the commercialization of their products. In some cases, they may carry out material services to use their good quality equipment and process products to improve the added value of products. These are farms that follow an intensification pathway that combines the different forms: conventional through some components of the Green Revolution, systemic by developing complementarity between activities, and agroecological by diversifying.

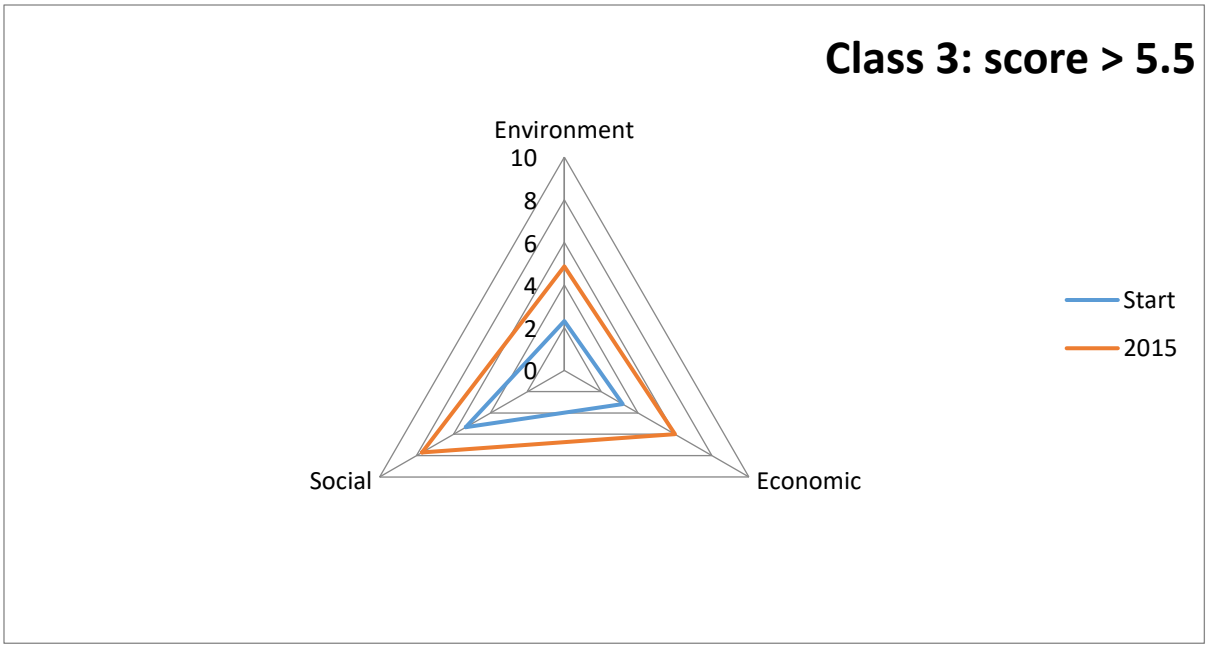

Figure 36: Evolution of sustainability indicators per principle for class 3: score > 5.5

The average overall score of the 24 farms is around 5/10, with a slight variation. As for intensification indicators, it is generally the oldest farms that have the best levels of sustainability.

2.2.3.4. Types of pathway

The number of surveyed farms is low (24) and there is a great diversity of situations and evolutions difficult to analyse. By making a pivot table with the average scores of indicators (intensification and sustainability) of each farm, and taking into account economic indicators, four farm types were identified (Figure 37). We note that farm n°21 was not taken into account because sustainability and intensification scores are both very low making it, in fact, a case apart and, difficult to integrate into one of the groups.

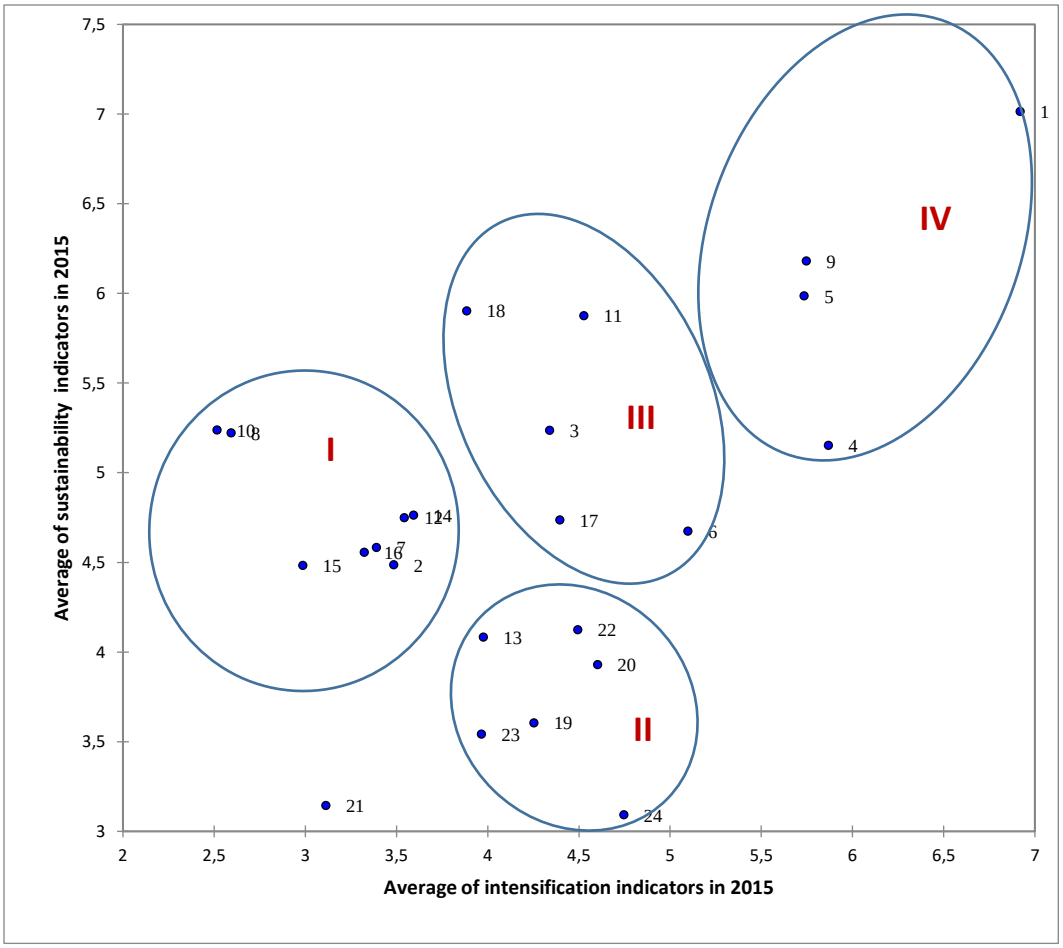

Figure 37: Typology according to intensification and sustainability scores

2.2.3.4.1. Type 1

The first type involves extremely weak farms in terms of the intensification process when sustainability appears with a significant score. The intensification score is smaller than 4 and sustainability is between 4.5 and 5.5. These farms are fairly well-endowed with land compared to the rest of the region (UAA is on average 279 acres) but with few livestock animals. These are farms which are orientated towards agricultural production, but with relatively low physical productivity due to limited agricultural intensification. These are rather traditional farms. The number of mouths to feed is higher than on other farms, as well as active family workers. They own land with a very important share from inheritance. They have traditional systems with a good level of diversification but have not adopted improved techniques or breeds. They have invested very little. They have a fairly easy market access. Economically, the average indicator is 3.7/10. The score is low and that is reflected in a per capita income just slightly above the poverty line in Madagascar, but there is a high variability within this group.
This type of farm is quite traditional, with a low level of intensification and low productivity, responsible for weak economic performance.

2.2.3.4.2. Type 2

This type, unlike the first one, has a high score of intensification compared to the sustainability score, which is low. It includes six farms. It is characterized by very low production factors, especially land (on average 135 acres, and only 44 acres per family worker), very little equipment, but an animal capital higher than type 1. These farms face various problems and in

particular the remoteness of the territory for some, which limits access to markets, the share of commercialized products, but also limits the access to various agricultural support projects or programs. Land availability is also one of the problems of this group, illustrated by farm n°24. In fact, this farm is one of the 24 that have the least in terms of UAA, but has a high productivity/ha. Therefore, for this farm the lack of land is one of the factors that limits its ability to produce and which makes it sensitive in terms of sustainability.
As for the first type, the average score of the economic indicators of this type is 3/10. In terms of poverty, the score ranges from 0 to 8, with an average of 4, a value from Ar 525,000 to 625,000. The overall income per worker and farm capital/active worker does not differ from type 1 farms. Therefore, along with the first type, these farms are among those who are struggling. Nevertheless, there are farms with average economic levels, like farms n°20 or n°22, with poverty indicators of 8 and 5, respectively. These are farms that, despite the weakness of their production factors, engaged in a rather conventional or systemic intensification process.

2.2.3.4.3. Type 3

The type 3farms have relatively high scores and are fairly balanced between intensification and sustainability. They have a high endowment of production factors which enabled them to intensify and diversify activities whether in agriculture or livestock. Two of them practice dairy farming in addition to other animal production, three produce improved breed animals. Furthermore, all of them use improved seeds and have irrigated rice yields higher than 4t/ha. A conventional type intensification, but also by diversifying and adopting practices of agroecological intensification as intercropping and lying fallow.
These farms are not isolated; they are well established in the market and in farmers' organizations networks or in agricultural development projects/programs. They are moderately equipped (draft animals). The educational level of the manager and of his children also positively affects the score of sustainability. Economically speaking, these farms lie high above the average of the region: the average of economic indicators is 6 points with a high income per person since the poverty index is higher than 9/10 (which means an annual income per person three times higher than the poverty line). The overall income/active worker of these farms varies from 6 to 9, or a value between Ar 1.6 and 3.2 million per active worker. Similarly, for the agricultural capital/active worker, the average score is 5 for a value between Ar 9 and 11 million.

2.2.3.4.4. Type 4

Type 4 includes the farms that have succeeded both in terms of intensification and sustainability. Four farms belong to this type with very high performances for most indicators. In agriculture, these farms are highly diversified, especially with food, forage and perennial crops. Besides being diversified, they are very efficient through the use of improved seeds and innovative techniques, but also a high level of equipment (motorized) and a very high UAA/family AAWU (130-600 acres). These production factors, that they have mostly acquired gradually, and the intensification process that followed enabled them to achieve good productivity, with for example a good rice yield higher than 5t/ha on average.
Livestock performance on these four farms are as high as for agriculture. They produce different species of animals, but dairy cattle farming and pig farming, which are largely composed of improved breeds, differentiate them from the other farms. In fact, these are the farms with the largest areas, the biggest herds and the most equipment and buildings.
From a perspective of sustainability, farms have the same level as those of type 3, with the exception of farm n°1. This farm stands out clearly and appears exceptional in many ways. The four farms in this group are all farms that have been settled for over 20 years, with a fairly large

initial capital or external resources that enabled them to invest very early, and to capitalize and diversify. They are easy to access and each one has known to benefit from this advantage whether in terms of commercialization, education or membership of projects, programs or farmers' organizations.
From an economic perspective, these four farms have a very high performance. Agricultural and total income with a score of around 10/10 and an agricultural capital/average active worker with a score of around 8, from Ar 30 to 50 million. This, compared to the previous type, the agricultural capital/active worker and the total income per worker are higher.

2.3. Main lessons

As a result of the work carried out, we can identify some first general lessons on the situation of farms and their intensification pathways in the Vakinankaratra region.

2.3.1. A great diversity of pathways but always with a diversification of activities

Even if the number of farms surveyed is low (24), we can note that there is a great diversity of situations and evolutions. The intensification pathways adopted by the farm managers are different, as well as evolution, that even if the initial conditions were pretty close, they are rarely similar.
Thus, in the Vakinankaratra region, several **agricultural intensification "strategies" can be adopted (and are adopted) by farmers**. They may be based on: lowlands rice, crops on *tanety*, fruit and market garden production, dairy farming, small livestock farms, combination of agricultural and non-agricultural activities, etc. As shown in the case studies, all types of production can be the basis of the agricultural intensification process; rice cultivation often plays an important role in these processes, because it ensures the food base of the family and is also widely commercialized, but it is generally only one of the productions involved in the intensification process. There is no real specialization, neither in rice cultivation nor in dairy farming, which are the two main productions of the cases studied.
Thus, in the pathways, an element that returns almost every time the intensification process is advanced, is the diversification of activities. **The intensification process is accompanied by a diversification of agricultural activities**. This process is the opposite of the specialization of agricultural activities that often characterizes a conventional type of intensification. It is based on an increasing mobilization of various resources and their integration. Diversification is simultaneously a component of anti-risk strategies adopted by farmers to cope with frequent and very different impacts (see below), and also a structural element of the intensification strategy itself that aims for a better use of all the resources that the farm has access to, by utilizing the integration of activities and their complementarity in terms of biomass, labour, land, family needs, market, etc. Characteristics that we can attribute to systemic and agroecological intensification. By combining these different types of intensification, the pathways seem to lead farms to a relatively balanced situation between productivity and sustainability.
Thus, in the region intensification rhymes with diversification, which has many implications in terms of support to rural areas. The intensification processes are more complex than sectoral or thematic approaches developed mostly by research and agricultural development. Therefore, in these diversified systems, highly targeted innovations only have relatively reduced impacts on the entire production system or farm activities. Only systemic approaches can provide the key to understanding the situations and the ongoing processes on the farms. This demands the

diffusion of technical packages (some technical innovations) and advice in order to improve farm resources.

2.3.2. Availability of production factors, a key element of intensification process

2.3.2.1. Intensification according to available production factors

An approach to an intensification process cannot succeed without production factors. Through the different pathways illustrated by the farms, it was clearly established that those that achieve a high level of intensification have a minimum of production factors, both in quantity and quality.
By using the same intensification classes, the average capital of farms was determined and shown in Figure 38.

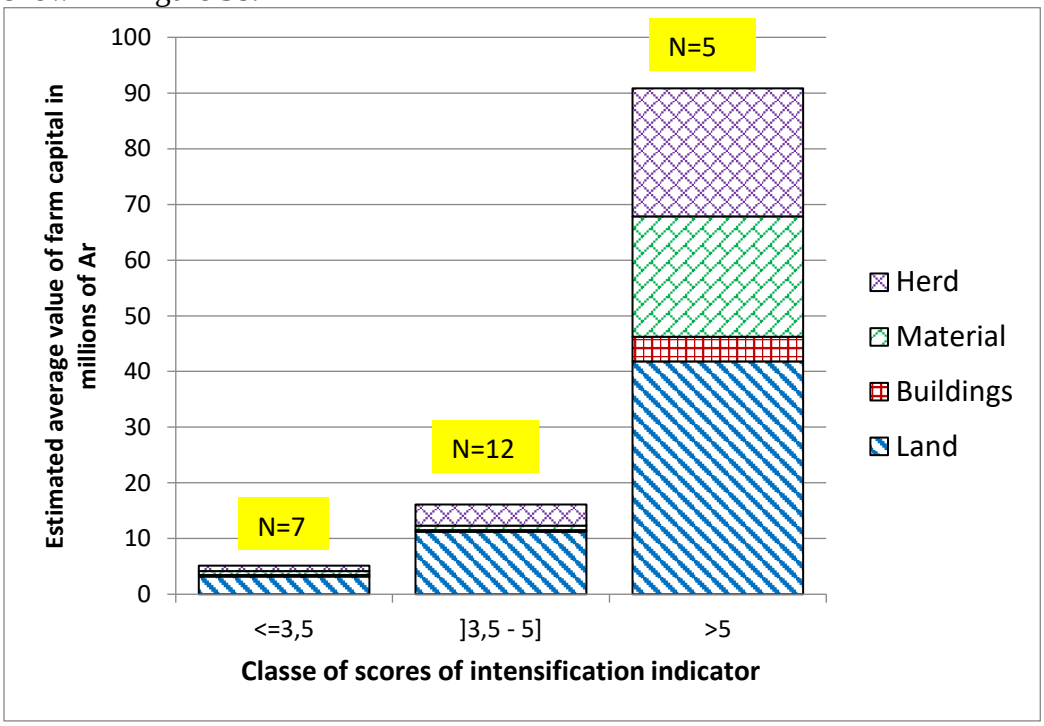

Figure 38: Average value of farm capital according to the level of intensification

The five most intensified farms have an average farm capital that was assessed in 2015 at Ar 90 million. This capital is quite well distributed among the main subdivisions that are land, equipment and livestock.
The average capital decreases with the intensification score: farms with a score between 3.5 and 5 have an average capital of Ar 16 million representing 7% of the group 3, and the least intensified farms are those that have a farm capital which is extremely low: Ar 5 million accounting for 6% of the capital of "large" farms that have intensified.
In addition, the composition of this capital differs for the least intensified groups, from 63 to 70% of the capital is represented by land, while for the big intensified farms, the land represents only 46%, leaving great importance to livestock and equipment.

2.3.2.2. Processes sensitive to the balance between production factors

The successful process not only demands high availability of production factors, but also a good balance between them. Imbalances between production factors may hinder the changes that are

necessary and which the farmer himself aspires to for a better productivity of his farm. These imbalances may take different forms, which are often demonstrated by a lack of complementarity and even a certain incapacity of one or other available production factors.
The imbalances between production factors sometimes lie between land and equipment, or between land and livestock. The most common imbalances are between land and workforce. A farm that sees its family workforce increasing gradually while the available land is very limited, risks seeing production falling out of step with the family workforce. If nothing is done to develop productive activities on the farm, the family workforce finds itself in under-employment, and some of the active workers must sell its labour outside, but often at a low income that does not allow maintaining the overall productivity of the farm or saving to invest in production factors. The example of farm n°7 illustrates the phenomenon with land which has stagnated at a very low level compared to the number of mouths to feed and the number of active workers (Figure 39).

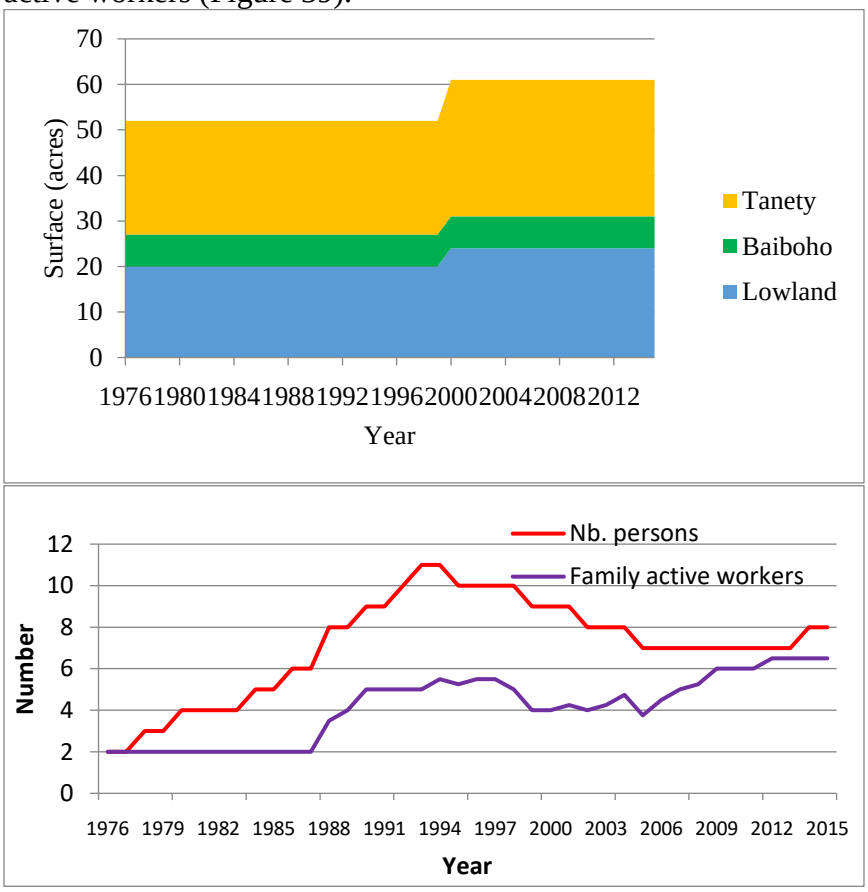

Figure 39: Evolution of land and workforce in farm n°7

Here we find a scenario in which family workers are obliged to use off-farm work, often as farm labourers on other farms, but sometimes also performing non-agricultural activities (manufacture of bricks, etc.), and this in an effort to survive because the income from these activities is very low. Thus, it is hardly possible for this farm to increase the available land by purchase, and thus it must content itself with what it has in its possession (85% of the land acquired by inheritance). Consequently, the level of intensification achieved by this farm after 41 years is at a very low level (2.4 out of 10).
At the level of the observed farms, there is rarely a real balance between the different factors of production. Although part of the land has been acquired by inheritance, it generally represents the largest part of farm capital. Among other investments it is the capital stock that appears to

be preferred by farms to initiate the intensification process, but unfortunately livestock activity often appears very risky.
This notion of imbalance between production factors appears as a real constraint, at the level of the observed farms, to intensify and fully express productivity potential.

2.3.2.3. Highly autonomous process with a low use of external inputs

The use of purchased farm inputs, and especially mineral fertilizers, remains low even in farms where the intensification process appears relatively successful. In fact, all farms opt for organic manure to fertilize their crops by using livestock effluents. For this purpose, farms tend to follow agro-ecological intensification process through nutrient recycling within their own farms and with little recourse to external inputs such as mineral fertilizers.
However, using only organic manure is due mainly to the few available resources, and sometimes because of the lack of mastery in the use of mineral fertilizers (dosage/crop). Moreover, some farmers believe in the bad effects of mineral fertilization, in the long term, on soil fertility and soil quality.
For farms that use mineral fertilizers, the dosage (average dosage of 21 kg/ha) often remains very low compared to that of organic fertilizer (average dosage 5.7 tonnes/ha). As for mineral fertilizers, the use of phytosanitary products is not developed. In agriculture, these products are used only occasionally and usually in a very localized way. For livestock farming, it is especially the bovine herd that receives veterinary care. Poultry almost never receive veterinary care and it is not uncommon that diseases kill all the poultry on the farm.

2.3.2.4. Fragile processes susceptible to external shocks

In our sample, many farms have suffered one or more shocks that have often contributed to deteriorating the living standards of families and to compromise the intensification pathway. These shocks can be of different nature. The most common concern climatic conditions (hail, cold, flood, and drought). This type of shock affects a large part of the farms located in the district of Mandoto, where most farm managers reported a continual delay of the rains in the last few years, causing a decrease in crop production.
Shocks associated to the problem of insecurity are not uncommon, it is a real constraint for some farmers who tend to limit investment in livestock and sometimes even to abandon certain activities. In this case, we find farm n°7, which, during the first thirty-four years of its existence, had patiently increased its herd by breeding, increasing from a stock of two to eleven heads. In one night, the farmer was robbed of all the animal livestock and most of his savings (Figure 40).

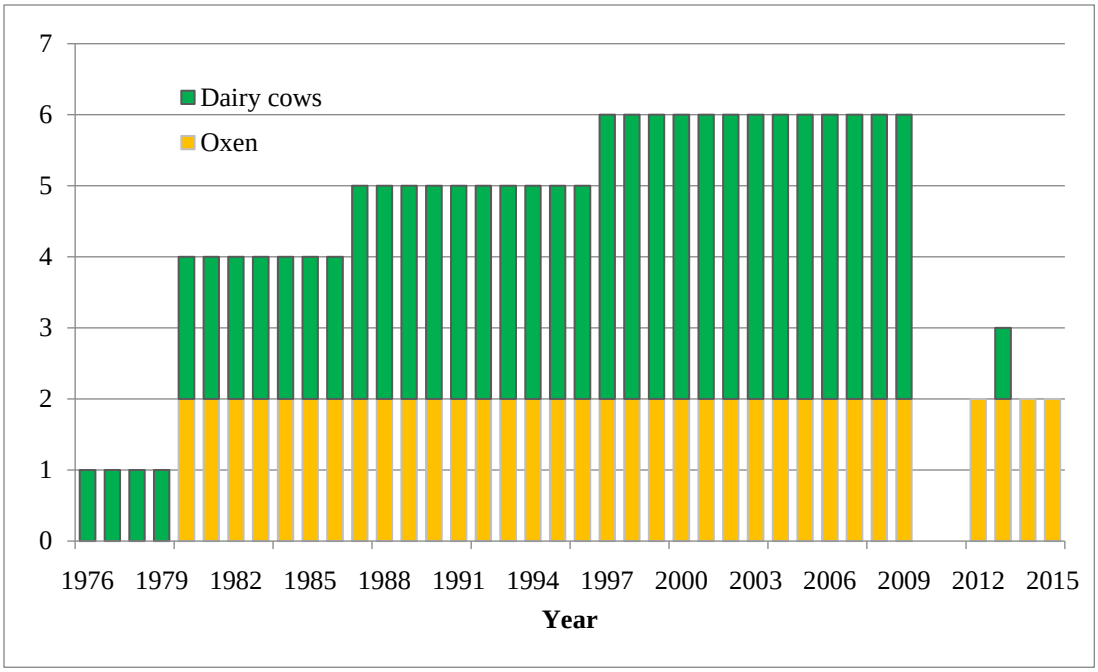

Figure 40: Evolution of bovine herd in farm n°7

On the other hand, shocks can also be linked to the damage of pests or diseases (animal and/or human). A certain number of farms have seen their entire herds decimated by disease in certain periods of their pathway. Such cases have already been mentioned in the "characterization of pathways" with farms n°15 and 16, that have lost their pig herd as a result of the outbreak of African swine fever in Mandoto region.

The case of farm n°17 clearly illustrates the fragility and sensitivity of a process undertaken against shocks that may occur at a given time on the farm. The situation described by this family farm demonstrates on the one hand the close link between the family and the farm, and on the other hand the fungibility of capital between these two units, that are the unit of consumption and the unit of production.

In this example, we find a farm which has significant production factors (compared to all farms) but which has suffered a series of external shocks that compromised its intensification pathway by affecting the availability of the family workforce on the farm. This is an opposite situation to the one previously described in section 2.2.3.1 with farm n°7, describing the importance of a balance between production factors, particularly between the workforce and other factors of production.

Farm n°17 has a very limited number of family workers (only two active workers in 2015), but many factors of production: 5.9 ha of UAA, four pairs of zebu and the equipment level is more or less suitable (Figure 41). With such available factors, the farm should not find it very hard to engage in a process of intensification. Unfortunately, the two younger sons and the mother died respectively in 2006, 2013 and 2014. These events caused a considerable decrease in the number of family workers. The manager finds himself forced to employ a permanent workforce and hire a lot of daily employees paid by task. Expenses allocated to the remuneration of these employees are high: 88% of costs in crop activities for daily paid employees, and almost whole charges of structures allocated for livestock production.

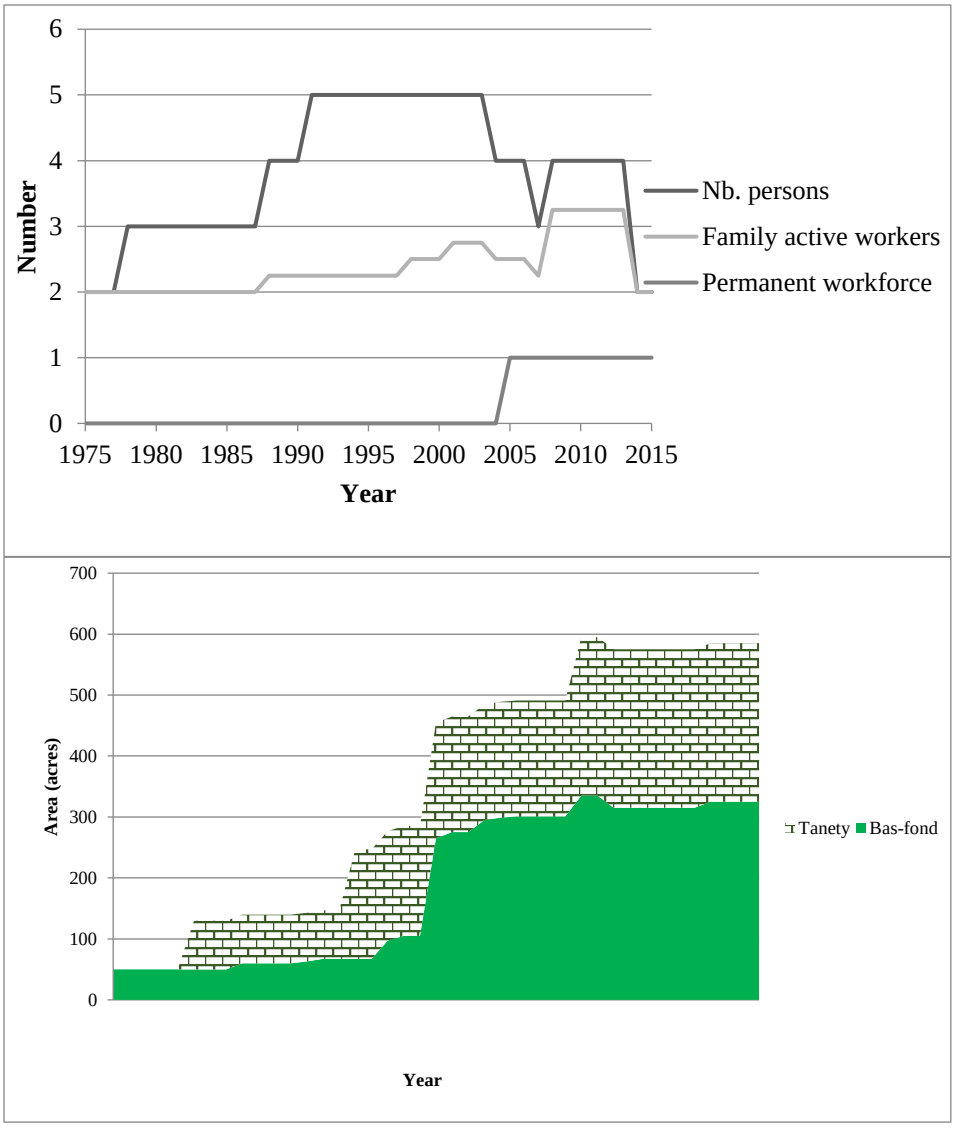

Figure 41: Evolutions of workforce and agricultural surface in farm n°17

Finally, if economic performance is good (income per active worker is higher than Ar 2.4 million, entirely from agricultural activities), the overall level of intensification is very low (with a total score of 4 on 10).

2.3.2.5. Processes related to family evolution

In the sample, farms started their activities with relatively low production factors and fairly similar techniques, often of traditional type. The number of mouths to feed and family workers were also low at the start, usually there are two family workers, the parents, for two or three mouths to feed.

On certain farms, the number of mouths to feed, and technically the number of family assets increases rapidly compared to the production factors available. This evolution of the number of family members (mouths to feed) might be a constraint to the capacity of investment of the farm and limit the intensification process.

Such a situation was observed with farm n°14, where the number of mouths to feed and the FAAWU were considerably increased, evolving from two persons at the start (1991) to 10 persons, with a 7.5 FAAWU (Family Annual Agricultural Work Unit) in 2015. The level of

intensification of this farm is low, with a score of 3 in 10. In addition, the annual income obtained by the active family workers is one of the lowest, with only around Ar 300,000.

2.3.2.6. An intensification that reasons at farm scale

The diversity of activities is the rule for all the farms of the region and our sample confirms this situation. And for the farm manager, even if he doesn't think this way, it is the productivity related to all the activities that is important. Thus, the intensification process must complement innovation, at a given moment, and be analysed at global farm level, especially to appreciate the effects on productive activities, labour and family.

2.3.2.7. Levels of intensification very variable according to activities

Related to the previous point, a farm that has several activities can carry out very different intensification processes, depending on the activities. For example, a farm that intensifies in a conventional way (Green Revolution: improved varieties, inputs, improved technics, etc.), its rice production can remain very "traditional" in its livestock activities. These ways of functioning should be studied to guide the development actions better.

3. PERCEPTIONS OF THE PARTICIPANTS IN RURAL DEVELOPMENT

Marie Ligy Arison, Paulo Salgado and Jean-François Bélières

3.1. Methodology and progress of work

3.1.1. Choice of stakeholders

3.1.1.1. The major types of participants

The participants involved in meetings of the **ProIA** initiative were grouped into ten major groups: *(i)* administration, *(ii)* agribusiness, *(iii)* local communities, *(iv)* security forces, *(v)* equipment suppliers, *(vi)* suppliers of inputs, *(vii)* training and research institutions, *(viii)* farmers' organizations, *(ix)* farm support organizations, (*x)* farmers.
The decision was made to have at least two representatives of all types of participants and to ask the most active institutions in the agricultural development of Vakinankaratra region to participate.

3.1.1.2. Limits of representation (caution should be taken in the reading and interpretation of the results presented in this section)

For some participants, the ideas and proposals presented during the meetings are those of individuals present at the meeting but they do not really represent the point of view of the institution to which they belong or that they represent. Thus, an institution can have activities that the representative at the meeting does not know about, but its representative cannot state them during his speaking engagements. Each participant responded according to his/her skills and knowledge, according to the service to which he/she belongs. The inventory of the actions in progress and the solutions proposed cannot be regarded as exhaustive. Nevertheless, people attending the workshops are known and recognized for their knowledge and skills in their areas of expertise; and with the wide range of institutions represented in the workshops, we have an inventory that can be considered complete.

3.1.2. The approach taken

The approach taken to stakeholders' meetings can be broken down into three main stages: *(i)* during the first meeting, we presented the objectives of the **ProIA** initiative and the results of the bibliographic study on agricultural intensification, in connection with the public policies implemented in Madagascar and in the Vakinankaratra region, *(ii)* then we presented and discussed real cases of pathways of intensification in farms during the three workshops, and *(iii)* finally, during the last two meetings, we presented a summary of the work carried out on specific cases with a more general analysis of the context of agricultural intensification in Madagascar in order to formulate proposals for concrete actions to remove the blocking factors and to translate development actions into research questions, with the active participation of the stakeholders.

3.1.2.1. Presentation of the subject and first discussions on intensification

The first workshop with the stakeholders started with the presentation of the **ProIA** initiative: the objectives, the actions carried out and expected results. How do the participants in rural development intend to support agricultural intensification in Madagascar? What are their

priority procedures and actions? What are their perceptions on the sustainability of agricultural intensification in the region?
Subsequently, the presentation of the first results of the bibliographic study helped to initiate the debate on the various forms of intensification and the point of view of stakeholders. The presentation consisted of an analysis on the long-term evolution of agricultural intensification in Madagascar and in the Vakinankaratra region, within the political, economic and social areas. Emphasis has been placed on the different concepts of agricultural intensification, on the impact of agricultural policies on intensification, and on agricultural performance with some examples of intensification in the Vakinankaratra region. The discussion session that followed showed the interest of stakeholders in this subject, the variety of perceptions about what is or should be agricultural intensification, but also almost unanimously on the difficulties encountered to boost sustainable agricultural intensification, particularly because of the limited resources available but also because of the instability of guidelines and public policies.

3.1.2.2. Presentation and discussion of case studies

The illustrations of the pathways of agricultural intensification in the Vakinankaratra region were presented, case by case, each one followed by a discussion session. During the three workshops dedicated to examples, fifteen cases among the 24 pathways were presented to stakeholders by agricultural engineers who carried out the surveys. All presentations were published in print format and distributed to participants at the beginning of the meeting. After each presentation and in order to initiate the discussion, some questions were posed to stakeholders. Are we speaking about agricultural intensification in the specific case of the example shown? What are the types of intensification observed? Is this intensification dependent on non-agricultural activities? Is intensification sustainable? What are the margins of intensification for this farm? In relation to the situation on this farm and from the farmer's perspective, do you think that this strategy is the best one?
The ability to discuss a specific, well documented case, and follow the pathway of a farm's development has allowed us to focus the debates in reality and develop systematic approaches. Initially those cases that appeared to be a specific or secondary case have later assumed importance because of the frequency of recurrence. Conversely, those that were seen as the "norm" at the beginning of the discussions were seen afterwards as exceptions. We can mention as an example diversification versus specialization. For many, agricultural "intensification" was a synonym for "specialization" in agricultural production, however, real cases have shown that often in the pathways of farms, intensification was associated with the diversification of activities. Similarly, real case studies have helped to bring alive the systems that make up the farm and family, the cropping and livestock systems, etc. While often stakeholders, because of their "specialization subject", tend to focus and concentrate on one sector.

3.1.2.3. Summary and report of previous meetings

At the beginning of each workshop, a summary was presented to revisit the subjects discussed during the previous meeting. At the beginning of the 5th meeting, a summary of the results of the 24 intensification pathways studied was presented with the objective of facilitating the change of scale in discussions, passing from real cases into a more global vison of the problems of agricultural intensification in the region.

3.1.2.4. Identification of constraints and solutions proposed

The stage of identification of constraints began with the presentation of a first list of constraints established from the constraints identified during the discussions on the results of the bibliographic study and field surveys. The discussions with stakeholders have enabled the validation of this list by specifying, eliminating and adding constraints. Finally, by using a participatory approach, stakeholders wrote on coloured cards, distributed at the beginning of the meeting, the actions that their institutions have in progress to address each constraint identified. This first set of cards was glued on wooden tables, to get a first sight of what has been already done. Then, a second set of cards allowed the writing of action proposals to remove barriers to intensification (to be carried out in the future).

3.1.2.5. Prioritization of constraints and research questions

A few days before the last meeting, the validated list of constraints was distributed to all stakeholders in order to prepare the stage for the prioritization of constraints. They were asked to write on a form provided for this purpose, the two constraints that they considered as priority for each type of constraints: *(i)* technical, *(ii)* economic, *(iii)* social, *(iv)* political, and to give it back in the beginning of the meeting. The results of this prioritization were presented and then the workshop organisers focused on translating the actions given as priority into research questions.

3.1.3. Work progress

The meetings with stakeholders were organized at intervals of three weeks between April and June 2016. A total of five meetings, one-day each, were held in Antsirabe. The participants were: *(i)* 25 representatives of the institutions involved in the agricultural development of Vakinankaratra region, *(ii)* 8 engineers responsible for the field surveys, and *(iii)* coordination team of the **ProIA** initiative in Madagascar (5-7 researchers).

Stakeholders felt involved in discussions in order to defend their point of view on agricultural intensification. For the last two meetings, a participatory approach was adopted, using coloured cards where each representative inscribed his/her ideas, which helped to ensure the participation/contribution of all.

3.2. Results

3.2.1. The main points discussed and position of stakeholders

3.2.1.1. The context of agricultural intensification in Madagascar and in the Vakinankaratra region

The first debates, after the presentation of the results of the bibliographic study, consisted on the involvement of farmers of the Vakinankaratra region in agricultural intensification efforts. Stakeholders considered that this involvement is widespread, and that farmers solve problems that prevent them from intensifying. The main obstacles concern especially:
The difficult access to inputs, for example improved seeds, agricultural equipment and material. There are three main reasons to explain this difficulty: *(i)* the high cost of inputs and equipment, *(ii)* the remoteness of farms relative to the point of sale (for example, improved seeds); hence

the need for the establishment of decentralized seed producers or multipliers, *(iii)* the lack of information, to which the solution could be to educate and inform farmers.
The decrease in available arable land in irrigated areas due to the absence of an entity for the management of infrastructure which was represented by state welfare bodies before the structural re-organization and disengagement of the state.
The price structure of agricultural products in Madagascar, with the industry dominated by collectors and intermediaries who impose their prices. Technical problems are those that concern farmers the most, but even with adequate technical support, without a market, farmers cannot sell their products. The solution would be firstly to solve the economic problems in order to ensure a market with attractive prices for both parties (producers, processors/consumers), and subsequently to promote technical support.
Funding and limited availability of credit. Farmers are afraid to invest because of the many risks that they have to face in agricultural production (climate risks, theft, diseases, etc.). The solution of reducing risks and persuading farmers of the need to intensify would be to increase the level of skills of farmers via, for example, training and information, establishment of an insurance for agricultural activities and increase of demonstrations in the field (field-courses).
The prevailing insecurity in Madagascar; in fact, in remote areas, thefts are frequent in agriculture (theft of crops) and also in livestock production (theft of cattle). To address these security problems, the solution proposed by one of the stakeholders would be to create a safe area (provided by the army, for example) and in which the farmers could intensify their production without the problems of theft; this initiative would also be an excellent showcase to observe the real capacity of intensification of the region.
A development policy based on development projects limited in time and that finish before finishing its actions. The proposal that emerged from discussions was that we must involve farmers in the entire project process, from its conception phase (the co-design approach, already adopted for the **ProIA** initiative). In this way, farmers will feel that they are part of the projects and will be more motivated to continue the activities initiated by the project.
The relationship between the level of education and the innovation adoption rate has been raised; many studies have shown that those who adopt agricultural innovation are often those who have a high level of education. But in general, it is difficult to really know what role the level of education plays in the adoption of agricultural innovation.
During the first debates, the knowledge base of the farmers' organizations has been called into question. In fact, it is always easier for the lenders or researchers to address a group of people rather than a single individual. Farmers' representatives testify being more comfortable within an innovation platform. Instead of creating new organizations, the existing farmers' organizations should be restructured to promote information exchange.

3.2.1.2. About the case studies

The participants have criticised the methodology and more precisely, the small number of case studies investigated with cases which do not represent the reality of all the farms of the Vakinankaratra region. For example, really enclosed farms were not represented in the study. The objectives of the study are to be reminded of notably those who cannot question the representative with a sample so small. The aim is to understand some of the diverse situations and illustrate in a detailed and comprehensive way interesting pathways (positive as well as negative). There are few isolated farms in the sample, but there some, even so. Furthermore, it is true that one of the difficulties in Madagascar is the lack of information to assess the real scenery of farmers' situation (the last agricultural census was carried out in 2004 and the last population census in 1993).

One of the participants, made the observation that it would be interesting to see how the fact that farmers have been surveyed might cause a modification in their strategy, linked to a new vision of their own situation and evolution.

The main ideas discussed on intensification pathways were the following:

- ✓ **Strategies of farm diversification**

Most of the pathways presented illustrate farms that have intensified by diversifying their agricultural production. However, in a conventional intensification framework it is often specialization that is considered to be an intensification method. For some participants, this diversification is an anti-risk strategy, and a way to better enhance the resources available on the farm. Farmers may also diversify their activities perhaps because they cannot sell off all their products and at sufficiently remunerative prices to ensure the needs of the family. For other participants, on the contrary, the more diversified the activities the greater the risk. This statement is especially true if we limit the analysis to a single activity, but when we bring the analysis to the whole production system, diversification allows the farmers to obtain better results. Diversification actually increases the revenue by reducing the risk, but is it really an intensification strategy? In fact, if we really move towards agricultural intensification, we must have the means to avoid risk. In addition, even with a diversification strategy to reduce the risk, the intensification process remains sensitive to "surprises".

- ✓ **Importance of the availability of factors of production and the balance between them**

The lack of and imbalance between production factors have been mentioned in many cases. Manpower and equipment are important for a farm, but are undervalued on the farm due to the lack of land. Furthermore, all the examples of successful intensification relate to farmers who were able to recover enough production factors that helped them to intensify with a certain degree of stability. This situation has brought to the attention of the participants, the priority of support to agricultural development (priority on the access to production factors). Without a minimum of production factors (land, manpower, materials, etc.), there is little chances that the farmer gets to initiate an intensification process allowing him to develop.

- ✓ **Variability of the level of intensification between activities**

Participants highlighted that for most illustrations, there is a gap between the level of intensification of agriculture and livestock, even if the two activities are complementary. On the one hand, some farmers intensify agriculture to become self-sufficient and neglects livestock activities, maybe because of the constraints of insecurity and disease related to livestock production. On the other hand, some farmers use agriculture to support livestock activities (dairy production) on their farm, maybe because they do not have secure tenure of their land.

- ✓ **The importance of nonfarm income and off-farm activities**

For some illustrations, participants highlighted the importance of nonfarm income on the financial stability of the farm. This financial stability has enabled the farmer to invest in production factors (land, equipment, etc.), to overcome the problems of food security and to intensify agricultural production (agriculture and livestock). Some farmers have chosen to develop off-farm activities (provision of commercial and animal haulage services), maybe due to the lack of capital or production factors. According to the participants, it would be more interesting for these farmers to migrate to areas where agricultural salary is more appealing.

- ✓ **Close relationship between agricultural production and family**

Discussions also focused on the particularity nature of family farming, with a strong link between the production activities and the family. The different aspects of production (technical, economic) and consumption (family) are combined to influence the pathway. The strategies of farm intensification are strongly influenced by the family (family stresses). The relationship between agricultural intensification and the number of children in the family seems important. In the illustrations presented, the families that have a high number of children struggle to grow

their business. Maybe, family size represents the greatest opportunity, or on the contrary, a greater constraint to intensification.
Among the observed findings, an important but often forgotten aspect, is the farmers' welfare, which can create a decisive force to implement some strategies. However, because of a too sector-based approach, this aspect was not taken into account sufficiently.

3.2.2. Constraints to intensification

The debates on the illustration of intensification pathways helped to highlight the constraints on intensification observed from real case studies. Several constraints, already discussed during the presentation of the bibliographical study, were confirmed by the pathways: *(i)* insecurity confirmed by several cases of farms that had problems to intensify after the theft of their livestock; *(ii)* animal diseases above all for breeding, linked to a lack of health coverage (only 13 veterinarians in 90 communes in Vakinankaratra region), *(iii)* the fear of farmers related to the risk of farming, *(iv)* their reluctance to demand help from microfinance institutions; in some cases, farmers do not know how to use the funds they have requested, and instead of investing the borrowed money in agriculture (seeds, inputs, equipment, etc.), they buy other goods (clothes, food etc.), *(v)* the lack of materials, when neither development projects, nor the state, seem to prioritize support for the acquisition of farm equipment.

Other constraints to intensification have been revealed by the case studies: *(i)* the lack of technical ability because some farmers do not follow the technical route correctly and do not always get good results, *(ii)* land tenure insecurity; farms that have chosen to intensify in terms of land have better economic results; land insecurity pushed some farmers to develop other activities, *(iii)* the expansion of counterfeit products on the market, especially food, demotivates farmers to intensify livestock farming, *(iv)* climate hazards to which it would take a risk insurance system where the risk would be shared between the microfinance providers and the producer, *(v)* the low level of education, as the best trained young people do not return to farming activities, but they prefer to become managers and work in the administrative sector, *(vi)* family problems (illness, death, etc.) that impact production factors and strategies.

The different constraints identified from bibliographic studies and cases of intensification pathways were grouped into four categories: *(i)* technical; *(ii*) social; *(iii)* economic, and *(iv)* political and governance. This list was then validated by the representatives of the stakeholders. From the validated list, participants were asked to prioritize these constraints: each participant had to identify two constraints that he/she considers priorities in each of the four groups of constraints. The ranking was made from the total marks obtained in each group of constraints. The results of prioritization are shown in Table 23.

Table 23: List of prioritized constraints

Group		Constraints	Marks obtained/ total distributed
Technical constraints	1	Decrease in available arable land	10 / 30
	2	Difficulty of access to agricultural inputs	10 / 30
Social constraints	1	Rural insecurity	15 / 27
	2	Land tenure insecurity	13 / 27
Economic constraints	1	Structuring of unfavourable prices to producers	12 / 27
	2	Lack of market organization and price fluctuation	10 / 27
	3	High interest rates	10 / 27
Political constraints	1	Remoteness and poor condition of roads	16 / 30
	2	Incapacity of government to ensure security and justice	16 / 30

3.2.3. Current actions and proposed solutions to meet constraints

The actions in progress to respond to each type of constraint have been noted by each representative of the stakeholders. The results highlighted which actions had already been carried out by each stakeholder. They also highlighted the constraints for which little or no actions were carried out. Regarding future actions, proposals from stakeholders were divided into three categories: *(i)* actions concerning the stakeholder that formulated it, *(ii)* actions made by one stakeholder, but to be carried out by other stakeholders, and *(iii)* actions regarding both the stakeholder who formulates them and other stakeholders.

When analysing the various tables on the proposed solutions, participants noted that the state is requested to solve almost all the constraints on intensification. The players expect much of the state, while at present the state intervenes less and less in development actions; this is why the ASC and RFAD were created. But they are still affiliated with the state and when the state is weakened, all structures related to it are also weakened. According to the stakeholders, a greater coordination between the decentralized levels and the central government would be necessary, and especially a greater action capacity at the decentralized level (regional and communes).

According to the participants, the constraints are very numerous, which suggests that the policies implemented so far are disjoined, do not last and that the means engaged are weak compared to the challenges. Nevertheless, responsibility should be shared. Some participants consider that the solution would be to favour a little more the farmers' organizations in order to continue development actions. According to the testimony of a participant, at SPAD platform level, it is envisaged to build multi-stakeholder innovation platforms. All the projects that are currently being put together integrate this platform to structure, formalize and organize permanent links between research and farmers' organizations.

3.2.4. Translation of actions into research questions

The joint design of research questions was one of the aims of the meetings with stakeholders. For each priority constraint, the first step was to take into account the action proposals identified by the stakeholders as solutions to problems. Then, in a second phase, research question proposals were issued and discussed among participants.

About the priority technical constraint "difficulty of access to agricultural inputs", three solutions have been proposed: *(i)* analysis of sectors, the impact of prices and profit on farms, the competitiveness of imported inputs compared to local inputs, the organization of marketing channels, *(ii)* analysis of price structure, distribution of value added in the marketing channels, and identification of factors that cause price increase, and *(iii)* analysis of the relevance of input use. Thus, we should raise questions on what do farmers really want. Do they really mean the access to inputs, or do they mean the access to inputs adapted to farmers' needs and their context? Whatever the type of intensification, there is always a need for inputs (mineral or organic), the question is also if they can choose (especially the quality of products).

In social terms, rural insecurity is the first priority. This is a delicate subject. Is research able to do something regarding this constraint? Isn't it a regulatory role of the state? Nevertheless, studies could be carried out: *(i)* to evaluate the impact on agricultural production and regional development of Vakinankaratra region of insecurity, this could clarify the ideas of the state about the real impact caused by this insecurity, *(ii)* about the illegal sectors. But who will carry out this study? *(iii)* on the social organization for defending land tenure (traditional), *(iv)* about the origins of this insecurity, trying to understand why some people drift into a movement of "*dahalo*" (theft): what were they before? Were they farmers? According to the testimony of a participant, before 1970, there were very few robberies compared to today. It is because of these social movements in Madagascar that robberies have increased. Initially, few people got rich by stealing and reselling zebus. Today, one has to make large networks, which are very well organized and managed by people "well-placed" in Malagasy society. Some stakeholders believe that zebu robbery will last longer; if it stops, the price of meat in urban areas will double or even triple.

3.3. Conclusion of the participants

The meetings carried out with the stakeholders enabled the identification of some important point of views on agricultural intensification in the Vakinankaratra region. These illustrations have shown the diversity of farms studied and the particularity of each intensification case. Stakeholders were able to observe by means of real case studies the different types of intensification, farmers' strategies of intensification, and the main obstacles to intensification. The discussions highlighted the opinion of several participants in rural development, the actions that could or should be undertaken to remove the constraints to intensification and to boost agricultural development in the Vakinankaratra region.

4. CONCLUSION

This case study involved three complementary actions that helped to highlight, firstly, different situations of intensification undertaken by farms at a regional level in the last decade, after a bibliographical study; and secondly, through real case studies of farms in the Vakinankaratra region thanks to surveys conducted in the field. In addition, a third action carried out with the participation of various regional development participants; this action allowed the combination of informal knowledge available at the stakeholders' level with that of the scientific knowledge to achieve results that really matter for the intended final users. After carrying out the various steps for this study, this document was written to present the different results obtained. This document allows the identification of some first general teachings on the situation of farms and their intensification pathways in the Vakinankaratra region. Taking out all statistical representation, and even all the diversities practiced in the region, this study allowed the understanding of different examples of possible developments of farms over a long period and especially the probable intensification situations in this type of family farm. The procedure undertaken for the realization of this study can therefore serve as a basic tool for any research work oriented towards the same theme since it is the first of its kind.

With the field work carried out within the context of this study, we were able to track the pathways of intensification since farm implementation up to 2015, as well as the evolution of their sustainability. An appreciation of the economic results of farms' agricultural intensification in 2015 has also been established. Thus, we have documented the progress of each farm in terms of available production factors, practices and techniques used and the results obtained. Despite the small size of the sample, a wide variety of situations and pathways was observed. Most of the cases documented in this study can be classified as original, with adopted intensification pathways different from each other, and evolutions that even with fairly similar initial conditions, are diversified. The starting situations are often similar: a farm with inherited land using the total dewatered land (*tanety*). Rarely, some farms are bought, usually by immigrants.

In a general context, it was highlighted that the age of farms is a determining factor in the completion of an intensification process. The oldest farms are those that manage to obtain good results, both in terms of intensification and sustainability. They are also those that produce a good economic performance, especially in terms of work productivity and profitability of activities. The productivity of capital is a slightly relevant indicator in the poorest farms, it makes sense for farms that have invested and which must achieve a high economic performance, for capital to be profitable. But, capital (production factors, such as land, animals, equipment, etc.) is lacking most in the smaller farms which engage in an intensification process. This constraint of too limited production factors has been identified in each of the case studies: bibliographical study of farm pathways, discussions with stakeholders.

The study has also revealed that agricultural intensification is a process that is part of an operational pathway, a life cycle, coming from the installation to the transmission of heritage to new generations. This point is sometimes hidden in the support of agricultural development initiatives with short or medium-term programs, and that maybe do not fit well enough in an accompanying farm approach in their development strategy with differentiated support that is adapted to different phases: the installation and acquisition of factors, the intensification with improvement of techniques and performance, and a slight capitalization, the preparation of the establishment of young people and the transmission of heritage/production factors.

Among the cases studied, we note that the oldest farms were able to adapt to their environment over time and significantly improve their production factors along with the practices and techniques of crop and livestock farming. Farm managers have adopted a better strategy to improve their agricultural potential and, hence, have progressed in terms of productive capacity.

Moreover, it was probably easier for them to increase their production factors in periods when the cost of land, which is the basis of agricultural production, was still accessible to most people. Somehow, the oldest farms have benefited from a better starting base compared with younger farms, who started at less favourable periods, when the land begins to weigh on the economy, particularly lowland plots, given the pressure on land. The practice of cultivation on *tanety* is privileged, including an expansion of upland rice, and the adaptation of a large crop diversity.

In almost all of the observed farms, there is a strong crop-livestock integration. Through these activities, it has been shown that farmers opt for diversification which, for most, is seen as a survival strategy. On one hand, diversification effectively minimizes risk-taking linked to specialization, and on the other hand, it meets subsistence needs.

In general, the sample exhibits a low evolution of intensification. The majority of farms start with very limited resources and show modest growth. In this context, the type of activities carried out presumably affects the level of intensification achieved by farms. It was observed that despite a general diversification of activities on the farms observed, those who opt for some form of specialization have better results, like farms oriented towards dairy farming. Generally, a farm that has a good level of intensification also has a good level of sustainability and economic performance. Beyond the effects related to the choice of indicators, the results show that in this studied area of Madagascar, there is a pronounced tendency of farmers to develop a combination of different forms of intensification: conventional but especially systemic and agroecological. Research and development should engage in a better knowledge of practices, objectives and strategies developed by farmers to guide their actions and build on these achievements without seeking to impose or adapt models developed in other contexts.

Some small farms, despite the fact of being limited by their low production factors, achieve a medium level of intensification. And sometimes a very good level per surface unit, since the highest productivity per hectare of UAA is obtained in one of the smallest farms which nonetheless is under the poverty line. But the level of sustainability of these small farms is low. These farms, due to the lack of production factors, generally have poor economic performance, which keeps the family in a situation of poverty and food insecurity. This is the situation that is widespread in the region, which means that our sample does not represent the general situation. Because our sample has a greater number of farms well-furnished in terms of production factors and that achieve relatively good levels in terms of intensification, sustainability, and economic performance that enables them to have a relatively good standard of living.

In terms of agricultural productivity, although considered as complementary activities, agricultural activities are often more productive compared to livestock ones. The study sample is composed of fairly diversified farms, and productivity differences are quite significant between the most and the least productive. Production factors are a key element of intensification. Farms with the most successful process of intensification have considerable production factors that allow them to increase their production substantially. However, an imbalance between these factors can be detrimental to the productivity of the operation, even if one of the factors is available in large quantities. The imbalances encountered in our sample involve land and manpower; these imbalances limit the economic performance of the farm because the family members are sometimes forced to go and sell their workforce to other farms, with lower wages than the average productivity of family labour on the farm. Some difficulties may also arise and interfere with the intensification processes already in progress, which sometimes forces the farm to abandon some activities and start on a new basis. These difficulties demonstrate the fragility of the established processes and their sensitivity to external shocks. Depending on the circumstances, the shock can have different origins, such as climatic hazards, insecurity or damage related to pests or diseases.

Putting into perspective the pathways followed with the major types of intensification shows that it is a combination of forms of conventional approach, systematic and agroecological, which is often implemented on farms that engaged in an intensification process. For others, survival strategies are often a strain on their intensification attempts. In our sample, some farms, especially the more intensified ones, are similar to the conventional form by reference to their production factors, particularly their agricultural equipment and materials, which are quite effective. A minority of farms also seem to get closer to the ecological form with their conservation farming practices and using only organic manure to fertilize their crops. However, their knowledge in terms of scientific agroecology is often very limited and the lack of techniques inhibit the development of this approach. In addition, the majority of the observed farms uses a form of intensification that follows the systematic approach in a broad sense. The majority of the surveyed farms act primarily for reasons of survival. They tend to combine all the factors at their disposal, such as labour and capital, as well as traditional knowledge. Globally, there is not a singular form of intensification because a part of each defined intensification approach is always found within the various agricultural practices in the various strategies adopted by farmers.
It has been clearly established that the intensification process is accompanied by a diversification of agricultural activities. However, besides agricultural diversification, non-agricultural diversification also complements the productivity of some farms. In rare cases, non-farm activities play a major role with their financial aspects related to agricultural activities. Despite an intensification process already under way at several farms, most do not succeed for various reasons. Failures usually occur because of external factors, thus independent of the farmers, but can also come from within the farm, related to the decisions taken. Farmers are not all risk-averse, several cases studied have shown it. They can take some risks that may be beneficial (e.g. sale of oxen to have the capital needed to purchase land).

Based on the bibliographical study, discussions enabled the conclusion that many of the farms in the Vakinankaratra region have already started an agricultural intensification process. However, a fair number of obstacles impeding the conclusion of this process has been listed. They involve several areas that depend, for the most part, of elements external to the farm, including funding, insecurity and even development policy problems, etc. For the case study, opinions differ regarding the diversification strategy applied by the surveyed farms; if for some diversification is an anti-risk strategy, others claim that it can increase the risks faced by farmers. The importance of the availability and the balance between production factors was unanimously explained as a key aspect that has provoked inherence to agricultural development support. Then, development participants have highlighted the need for some farms to practice non-agricultural activities to obtain greater financial stability. Then the particularity of family farming has been put forward by highlighting the close relationship between agricultural production and family. Most of the constraints mentioned in the bibliographical study emerged in the case studies. The illustrations have nonetheless revealed other aspects that tend to impede the proper conduct of the process undertaken by farmers, especially the lack of technical expertise, land insecurity, climate hazards and family problems.

The solutions proposed to reduce barriers caused by the different constraints to intensification highlighted the importance of the intervention of the state in development actions. Development participants support the need of good coordination between the central State and the decentralized levels. Given the plurality of observed constraints, it was concluded that the policies implemented are questioned because they can easily be altered due to a lack of resources involved. Given the current state of the situation, the best alternative would be to promote farmers' organizations for sustainability of development actions.

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6. GLOSSARY

ADV : Agricultural Development Volunteers
AECA : Association of Savings and Self-Management Credit
AFFWU : Annual Family Farm Work Unit
AGEPMF : Microfinance Project Implementation Agency
AIZ : Agricultural Investment Zones
APB : Association of Bank Professionals
APDRA : Association of fish production and rural development in Africa
Ar : Ariary
AROPA : *Andrin'ny Rafitra Ombom-Pamokatra ny Ambanivohitra*
ASF : African Swine Fever
AUE : Association of Water Users
AVSF : Agronomists and Veterinarians Without Borders
AWU : Annual work unit
BRL : Bas-Rhône Languedoc
BVPI : National Irrigation Watershed Program
BVPI SE/HP : Project Watershed and Irrigation in the South East and the Highlands
CA : Conservation Agriculture
CAADP : Comprehensive Africa Agriculture Development Programme
CARD : Coalition for African Rice Development
CE : Farm manager
CEA : Country Environment Analysis
CECAM : Savings Bank and mutual agricultural credit
CIDR : International Centre for Development and Research
CIRAD : Centre for International Cooperation in Agronomic Research for Development
CNCD : National Centre for Development Cooperation
CNEARC : National Centre for studies in agronomy for hot climates
CREAM : Centres of Research, Studies, and Support to Economic Analysis
CSA : Agricultural Services Centre
CTD : Decentralized territorial communities
CV : Coefficient of variation
DCPE : Economic Policy Framework Document
DIAL : Development, Institutions and Globalization
DMC : Direct seeding mulch-based cropping systems
DRDA : Regional Directorate for Agricultural Development
DRDR : Regional Directorate of Rural Development
DSRP : Strategic document for the reduction of Poverty
EA : Farm
ENSOMD : Madagascar Millennium Development Goals National. Monitoring
EPM : Periodic Household Survey
EPP PADR : Permanent Pilot Team for the Rural Development Action Plan
ESW : Madagascar Economic and Sector Studies
EU : European Union
FAFIALA : Experimentation and dissemination centre for management of *tanety* by farmers
FAO : Food and Agriculture Organization of the United Nations
FAOSTAT : FAO extensive library of agricultural statistics
FDA : French Development Agency
FIFAMANOR : *Fiompiana Fambolena Malagasy Norveziana*
FMI : International Monetary Fund
FOFIFA : *FOibem-pirenena momba ny FIkarohana ampiharina amin'ny Fampandrosoana ny eny Ambanivohitra* (National Applied Research Centre for Rural Development)
FORMAPROD : Training and Improving Agricultural Productivity Programme
FRDA : Regional Agricultural Development Fund
GDP : Gross Domestic Product
GSDM : Madagascar Direct Seeding Group
GTDR : Rural Development Working Group
Ha : Hectar
IDEA : Sustainability Indicators of Agricultural Farms
IISS : International Institute of Social Sciences

ILO	: West Coast Irrigation Project
IMF	: Institute for Micro Finance
INRA	: The National Institute of Agronomic Research
INSTAT	: National Institute of Statistics
IRC	: Improved Rice Cultivation
IRD	: Institute of Research for Development
ISDA	: International Swaps and Derivatives Association
ISTOM	: Higher Education School of International Agro-Development
K	: Capital
Kcal	: Kilocalorie
Kg	: Kilogram
MAEP	: Ministry of Agriculture, Livestock and Fisheries
MAP	: Madagascar Action Plan
MB	: Gross margin
MCA	: Millenium Challenge Account
MEF	: Ministry of Environment and Forest
MinAGRI	: Ministry of Agriculture
MinAgri	: Ministry of Agriculture
MinEl	: Ministry of Livestock
mm	: Millimetre
MO	: Workforce
MRHP	: Ministry of Marine Resources and Fisheries
n°	: Number
nbr/Nb	: Number
NEPAD	: New Partnership for Africa's Development
NGO	: Non-Governmental Organization
ODR	: Rural Development Operation
OP	: Farmers' Organizations
ORSTOM	: Office for Scientific and Technical Research Overseas
PADANE	: North-east Agricultural Improvement and Development Project
PADR	: Action Plan for Rural Development
PAS	: Structural Adjustment Program
pers	: Person
PGE	: General Policy of the State
PGIA	: Poverty, Gender and Inequality Assessment
PIC	: Integrated Growth Poles Project
PNDR	: National Rural Development Programme
PNIAEP	: National Investment Plan for Agriculture, Livestock and Fisheries
PNVA	: National Agricultural Extension Programme
PPP	: Purchasing power parity
PPRR	: Rural Income Promotion Programme
PRDR	: Regional Programme for Rural Development
PRIASO	: South-West Region Agricultural Infrastructure Rehabilitation Project
ProIA	: IntensAfrica project
PSA	: Agricultural Sectoral Programme
PSAEP	: Agriculture Livestock and Fisheries Sector Programme
RA	: Agricultural Census
RDPU	: Rural Development Policy Unit
RG	: Global Income
RNA	: National Agricultural Census
RNM	: Malagasy National Radio
ROR	: Network of Rural Observatories
Rv	: Income
SACSA	: Service Strategy for Farmers
SFD	: Decentralized Financial Systems
SNMF	: National Microfinance Strategy
SPAD	: Highland production systems and sustainability
SRI	: System of Rice Intensification
STD	: Territorial Services and Decentralized Services
T	: Tonne

TRS	: Traditional Rice System
UAA	: Used Agricultural Area
UNDP	: United Nations Development Programme
WFP	: World Food Programme