Household choices in rice cultivation in a social-ecological system and impacts on productivity: Lessons from Anororo, Lac Alaotra, Madagascar

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List of Acronyms

AFD: French Development Agency
BVLac: Bassins Versants du Lac Alaotra
CIRAD: International Centre for Agronomic Research for Development
FOFIFA: National agronomy research centre
SOMALAC: Société malgache d'aménagement du lac Alaotra (Malagasy company for the development of Lac Alaotra)
SRA: System of Rice Amelioration
SRI: System of Rice Intensification
Abstract

Understanding the linkages between natural resources and resource users, as well as the context in which they develop, is central to current research on natural resource management and biodiversity conservation. Agriculture plays an important part in these discussions as it is both a driver of environmental degradation and an agent of poverty, but simultaneously improvements in agriculture can contribute to poverty alleviation and provide incentives for conservation. It is therefore of great importance to understand the constraints limiting attempts at improving productivity and how farmers’ choices are affected by endogenous (such as assets and skill) and exogenous (such as environmental variation and shocks) factors.

This study concentrated on rice cultivation in a village forming part of an important social-ecological system in Madagascar, the Lac Alaotra wetland, which is the main rice-growing region of the country and a Ramsar site of international importance. We investigated what decisions farmers make regarding inputs (fertiliser use, labour, area under cultivation) and how these choices affect rice yield, how households react to stochastic variation in the form of rainfall and how their livelihood and cultivation decisions might change under scenarios of great stochasticity, as forecast by current climate change predictions for Madagascar. I discuss limitations to improving rice productivity in Madagascar, in particular with regards to new technologies, and how risk-averseness may be a driving force behind cultivation and productivity choices. This may lead to an increase in poverty and reliance on the marsh in terms of marsh products, fishing and winter rice expansion, which in turn would cause an increase in the pressure on the natural environment.

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1. INTRODUCTION

1.1. The critical triangle of poverty – environment – agriculture

The linkages between natural resources and their users are increasingly studied as part of social-ecological systems (SES), that is to say systems in which interactions between humans and natural resources are highly interdependent (Janssen et al., 2010, Schluter et al., 2009, Anderies et al., 2004). Fisheries and harvesting are two examples of such systems, where the livelihoods of humans living in these systems are intrinsically linked to the resources they use and the ecosystem services provided by the natural environment. Social-ecological systems tend to be robust to existing variations but extreme changes, for example through uninformed policies or climatic shocks, may challenge their resilience and lead to a collapse of the system (Janssen et al., 2007).

Understanding the linkages within SES, including local needs and uses of natural resources, is paramount to effective conservation action and the effective management of natural resources and the failure to take them needs into account has been lacking from many conservation projects (Nicholson et al., 2009, Garnett et al., 2007, Mehta and Kellert, 1998).

Agriculture is the principal livelihood of the rural poor and accounts for most land use in developing countries, and thus it exerts a powerful influence on environmental considerations and is central to poverty-environment links (Scherr, 2000, Zeller et al., 2000). Population growth and agricultural expansion threaten both the rural poor and environmental quality through slash-and-burn agriculture, pollution and salinisation (Scherr 2000). Poor performance in agriculture is related to poverty as the poor often lack the means to invest in more productive technologies, which maintains them in a state of poverty (Barrett et al., 2001). This has led to the idea of a “critical triangle” between agriculture, poverty and the natural environment (Vosti and Reardon, 1997). Investigating the links between the three components of this triangle is therefore at the forefront of both conservation and poverty alleviation concerns. The more we know about how farmers make resource allocation decisions, the more likely we are to identify the right
technologies and policies to improve livelihoods as well as the environment (Deolalikar and Vosti, 1993).

Madagascar is an example of such an interface between poverty, environment and agriculture as it is one of the poorest countries in the world (Stifel et al., 2010), relies on a largely rural economy (Minten and Barrett, 2008) and is a hotspot of biological diversity (Myers et al., 2000). Lac Alaotra is the largest lake in Madagascar and is of great economic importance to the island as the country’s main rice-growing region (Randrianarisoa and Minten, 2001). Rice is the staple crop in the country and represents the major livelihood of a large part of the population. The lake and associated wetland have high conservation importance and the area was recognised in 2003 as a Ramsar site of international importance (Andrianandrasana et al., 2005). However, the lake is also under great threat. Population has exploded in the region following high immigration in the last 50 years and slash-and-burn cultivation, burning of the marsh and introduced species have caused the disappearance of many endemic species and a degradation of the resource base (Copsey et al., 2009a, Andrianandrasana et al., 2005).

Madagascar is a highly stochastic environment: both intra- and inter-annual rainfall are unusually unpredictable compared to mainland Africa (Dewar and Richard, 2007). ENSO (El Nino Southern Oscillation) events (Ingram and Dawson, 2005) and the regular passage of cyclones contribute to this high variability/poor predictability. In addition, the incidence of cyclones has increased with climate change (Barrett et al., 2007) and predictions forecast an increase in the frequency and intensity of storms and cyclones in the region (Webster et al., 2005), placing farmers in a context of high yield risk and livelihood insecurity.

1.2. Aims and objectives

This study focused on one village, Anororo, and aimed at improving the understanding of how farmers make decisions regarding cultivation, what constraints they may face and providing information to help inform management
decisions in the social-ecological system of Lac Alaotra. There were four key objectives:

Objective 1: To establish a clear picture of rice cultivation practices carried out in the village and the factors that affect or limit them, including:

1. the extent of the use of pesticides and fertilizers;
2. the impact of wealth on practices; and
3. aspects of land tenure.

Objective 2: To examine the impact of environmental stochasticity, in particular variable rainfall, on rice yield and decisions.

Objective 3: To study how future changes may affect rice cultivation, focusing on the impact of climate change on rice yields and household decisions.

Objective 4: To gain a clearer understanding of the roles of risk and uncertainty in rice cultivation and livelihoods.

1.3. Thesis structure

Chapter 2 gives a background to the linkages between poverty and agriculture, and how these relate to the management of natural resources. It also describes the current state of knowledge of determinants of crop productivity, in particular in the context of Madagascar, and presents the different rice cultivation techniques available to farmers in developed countries, discussing their relative merits and limitations. Finally, it introduces the study area, in particular with respect to rice cultivation.

Chapter 3 describes the methods used in the study, starting with the protocol used for collecting information about rice cultivation decisions, then describing the statistics and models used to analyse the data.
The results of the study are presented in Chapter 4, starting with the cultivation calendar and economic characteristics of informants, then investigating practices and determinants of productivity in Anororo. It finishes with an analysis of environmental stochasticity and responses to scenarios under climate change.

Finally, Chapter 5 discusses these findings and places them in the broader context of farmers' choices and practices in Madagascar and in the rest of the world. In particular, I discuss how uncertainty may influence farmer decision-making and propose avenues for policies and interventions.
2. BACKGROUND

2.1. Social-ecological systems and natural resources
Social-ecological systems (SES) are defined as systems in which multiple interdependent dynamics between humans are mediated by their interaction with the biophysical system (Janssen et al., 2007, Anderies et al., 2006, Anderies et al., 2004, Walker et al., 2002). Therefore many conservation issues revolve around social-ecological systems, including those associated with harvesting and fisheries (Holdo et al., 2010, Schluter et al., 2009). Understanding these systems requires an understanding of the linkages between the different components of the system (Figure 3.1.); in particular, it requires an understanding of how humans interact between themselves and with the resources they rely on for their livelihoods, within the context of physical and human capital (Anderies et al., 2004).

![Conceptual diagram of a social-ecological system](image)

**Figure 2.1.** Conceptual diagram of a social-ecological system (reproduced from Anderies et al. 2004)

The link between rural poverty and resource degradation is often seen as a “downward spiral” where poverty drives people into resource exploitation but poor people do not have the capacity to mobilize the resources to invest in the
improvement of the resource base (Scherr, 2000). Poor people also rely heavily on the natural environment from which they derive a number of ecosystem services, including the collection of water, food, fuel, medicinal plants and raw material for housing and artisanal crafts (Millenium Ecosystem Assessment, 2005). Poverty reduction depends on the conservation of natural resources (Adams et al., 2004) and the consequences of environmental degradation are greater for the poor who may not have the assets to cushion the effects. However the downward spiral is both avoidable and reversible (Scherr, 2000). Engaging local people, in particular the marginal poor, is increasingly considered as an integral part of conservation projects (Chan et al., 2007, Garnett et al., 2007, Millenium Ecosystem Assessment, 2005, Wells et al., 1992).

Integrated Conservation and Development Projects (ICDPs) aim to match resource management by communities with development initiatives, thereby removing the pressure on the poor to degrade the resource base to meet their immediate needs (Chan et al., 2007, Garnett et al., 2007). Although ICDPs seek to reconcile development and conservation, there are in reality few win-win situations (Adams et al., 2004, Robinson et al., 2004, Wells et al., 1992) and development and conservation often have conflicting objectives and impacts (Chan et al., 2007, Adams et al., 2004). Benefits from ICDPs may not trickle down to the poorer strata of the society to whom poverty alleviation programs should be directed (Garnett et al., 2007). Development can exacerbate existing problems rather than solve them (e.g. increased wealth in Equatorial Guinea means an increased demand for bushmeat (East et al., 2005)) or create new ones (e.g. building a road to give access to remote villages also improves access and trade for poachers and illegal loggers (Garnett et al., 2007)). Therefore there will be trade-offs between conservation and development objectives where they are not convergent and both goals need to be explicitly defined (Chhatre and Agrawal, 2009, Robinson et al., 2004). In addition, threats to the environment do not necessarily come from small communities but from mining, irrigation schemes, resettlement programs and commercial logging, often backed by rich and powerful interests (Wells and McShane, 2004).
Natural resource management requires an understanding of the context in which it is set, in particular in terms of social, physical and natural assets present. In other words, ICDPs and resource management take place within social-ecological systems, and so these need to be understood for conservation action to be effective. Because dynamics are inherent to these systems, change and trajectories are also determining to the success of any action (Garnett et al., 2007).

2.2. The place of agriculture in conservation

Agriculture is an important concern for conservation initiatives as there is a strong link and fierce competition for land between agriculture and the conservation of natural resources. Agriculture causes runoff of pesticide and fertiliser, increased water usage and conversion of natural systems to agricultural land (Scherr, 2000). Soil degradation is a severe problem in developing countries: Scherr (1999) reports that 16% of agricultural land area in those countries has moderately or severely degraded since mid-century. Such degradation has impacts not only on productivity but also on biodiversity and water quality (Scherr, 2000).

Agriculture holds an important place in development programs as it is tightly linked to poverty in rural areas (Scherr, 2000, Zeller et al., 2000). Environmentally destructive practices such as slash-and-burn and expansion into marginal lands tend to be associated with poorer households (Scherr, 2000). Agricultural land ownership is linked to possession of other assets (Dorosh et al., 1998). Therefore the agricultural landless also tend to be the poorest (Randrianarisoa and Minten, 2001) and caught in persistent poverty (Stifel et al., 2010). Poorer households also tend to have smaller yields than richer households, up to 35% lower (Randrianarisoa and Minten, 2005). Poor people tend to have limited capacity to mobilize critical resources such as cash or labour and this prevents them from investing in highly profitable or effective practices (Scherr, 2000, Reardon and Vosti, 1995). Conversely, improvements in productivity can also impact positively on development. In Madagascar they result in lower food prices, higher wages for unskilled workers and better welfare indicators (Minten and Barrett, 2008). This is because higher yields cause decreases in prices, but prices fall disproportionately
less. Therefore increased productivity benefits local net food buyers without disadvantaging producers. (Minten and Barrett, 2008) found that in Madagascar, a doubling of rice yields is associated with a 65% to 89% increase in wages (Minten and Barrett 2008). Increasing productivity of household activities can also increase household income and therefore relieve constraints on better resource managements.

Conservation may also depend on improving agricultural practices that also conserve resources, but adequate incentives need to be in place. In particular, new practices need to be more profitable or beneficial to the farmer than existing practices and need to be economically viable in the context of risk and constraints in which the farmer evolves (Scherr, 2000). For example, the use of vegetative barriers or contour strips to reduce soil erosion will be adopted if these barriers are made of local materials that can be used by the farmers for consumptions or cash sales (Scherr, 2000). In El Salvador, the successful adoption of soil conservation technology was achieved through integrating productivity-improving and soil conservation components and by putting in place institutional incentives to adopt both components (Sain and Barreto, 1996).

Finally, with population growth becoming an increasing threat to natural resources throughout the world (Garnett et al. 2004), meeting consumption needs will be increasingly difficult, with devastating consequences on both development and conservation (Sachs et al., 2010). Development agencies recognise food security and improvement of livelihoods as the main axes of poverty alleviation programs (Doss et al., 2008, Rao and McGowan, 2002). In this context, improving productivity of agricultural systems will be paramount to meeting the growing needs of the world’s population and may contribute to ICDPs both through poverty alleviation (as seen above) and by reducing the pressure on natural systems (Moser and Barrett, 2006).
2.3. Rice cultivation

Rice is one of the key staple foods throughout the world, in particular in Asia and Africa where it represents the majority of calorific intake (de Laulanié, 2003). It dominates the agricultural landscapes in countries like Madagascar, in particular at a subsistence level, and is central to discussions on crop improvements and poverty alleviation (Barrett et al., 2010b, Minten et al., 2006).

2.3.1 Constraints on improving rice productivity

Rice yields respond to a range of production factors, such as advances in equipment and better water management but farmers face multiple constraints (Minten and Barrett, 2008). Constraints on labour productivity (yield, or more generally output, per unit of labour invested) is perceived by farmers as a limiting and important factor, including in terms of access to inputs such as equipment and labour (Minten et al., 2007). Increasing fertiliser uptake is central to current development strategies. Minten et al. (2007) show poorer farmers have a higher marginal return than richer farmers and therefore would benefit from initiatives aimed at increasing fertiliser input. However, the excessive cost of fertilizer can make it prohibitive for the poorer farmers, as it is the case in Madagascar (Minten et al., 2007).

Another obstacle to increasing productivity is the high level of inefficiencies observed in current systems, that is to say the return of input to output is less than optimal. Only 77% efficiency of rice production was observed in Bangladesh (Rahman, 2003). Inefficiencies were explained by differences in infrastructure, soil fertility, experience, tenancy and the share of non-agricultural income (Rahman, 2003).

The size of the area cultivated can also affect productivity. The inverse farm size–productivity relationship predicts that there is a decrease in the marginal return from farming as farm size increases, so that smaller farmers are more productive per unit of area than large farmers. This relationship was first observed in Russian farmers (Chayanov, 1986) and since then has been noted in many parts of the world, including Asia (Akram-Lodhi, 2001, Benjamin and Brandt, 2002, Sen, 1966, Carter,
1984), Africa (Kimhi, 2006, Barrett, 1996, Collier, 1983) and Latin America (Berry and CLine, 1979). The reasons for the inverse productivity-size relationship are still debated. It could be due to the lower opportunity cost of labour in small farms, which leads to increased land productivity (Randrianarisoa and Minten, 2001). However, labour constraints in poor households can lead to very high opportunity costs of labour (Moser and Barrett, 2006), which would invalidate this hypothesis. Another explanation is that small farmers are more likely to be net buyers of crops because of market imperfections and thus will over-supply labour on their own farms to avoid having to buy the crop. As a result, they are more productive than larger farms; this theory is supported by the recent findings of Barrett and Bellemare (2010) in Madagascar.

2.3.2 Traditional techniques of cultivation and innovations of rice in Madagascar
Rice cultivation is central to the Malagasy rural economy. In 2008 Madagascar produced 3 million tonnes of rice (FAO, 2008) and the Malagasy consume 110kg of rice per person per year, which regularly ranks them in the biggest rice consumers in the world (UPDR, 2000). Rice land ownership, along with cattle, is a sign of social status and prestige. Demand for new agricultural land is high and comes at the expense of forests (Randrianarisoa and Minten, 2001). In order to understand the potential for productivity-boosting technologies in rice production in Madagascar, it is important to place them in the context of the standard cultivation techniques, briefly outlined below.

There are two main methods for cultivating rice used in Madagascar: direct seeding and transplanting. Direct seeding or broadcasting refers to seeds being sown directly onto the field on either dry soil (dry seeding) or puddled soil (wet seeding) (de Laulanié, 2003, Grist, 1986). The second method commonly used is transplanting, where young plants are first grown in a nursery at high density and where conditions are better controlled. At around 30 days, they are removed from the soil and transplanted into the inundated field. In general, transplanting gives higher yields than direct seeding, but it is more labour intensive (Grist, 1986). However, if
transplanting is done too late, the plant has missed its potential to tiller (grow secondary stems from the main stem) and this will result in a reduced yield. Therefore any delays to the calendar due to late onset of rain can be very detrimental to rice yields, in particular for photoperiodic varieties (Ducrot and Capillon, 2004). In Madagascar, average yields using transplanting vary from region to region but generally fall between 2 and 3 tonnes per hectare (Moser and Barrett, 2006). Both transplanting and broadcasting are commonly used; in a study in Lac Alaotra by Ducrot and Capillon (2004) they were combined on the same plot on a quarter of the fields.

In the 1960s, French missionary and agronomist Henri de Laulanié discovered by chance that yields could be doubled, if not tripled, by transplanting at a much younger age, around 7 days. This is thought to be due to the high tillering capacity of rice: by transplanting earlier, the rice has more time to tiller. He also found that this early transplanting acted in synergy with wet-and-dry techniques (fields are regularly drained, supposedly to allow aeration of the soil) and low planting density. Recommendations for this new technique, called SRI (System of Rice Intensification), are now also to plant a single seedling every 25cm squares to allow for mechanical weeding, since those improved conditions for rice also encourage weed growth (de Laulanié, 2003). Another technique is also used in Madagascar, SRA (System of Rice Amelioration), but its only recommendation is in-line transplanting to allow for weeding and its effects on yield have not been scientifically demonstrated.

SRI requires 38 to 54% more labour than traditional methods (SRT), 62% of which is for weeding and 17% for transplanting (Moser and Barrett, 2003b, Rakotomalala, 1997, Moser and Barrett, 2006). Even taking into account the extra labour, the returns still far outweigh those of traditional methods. Barrett et al. (2004) find, consistent with other studies (Rajaonarison, 1999, Rakotomalala, 1997), that in Madagascar SRI more than doubles productivity when comparing SRI and traditional plots by the same farmers, therefore accounting for any individual farmer effects. Test plots suggest that SRI is sustainable, as no reduction in yield has been observed through time (Moser and Barrett, 2006).
Because SRI produces much-improved yields, it appeared at first to be ideal for improving livelihoods of the poorer farmers who lack the capital and access to credit necessary for expensive inputs (Moser and Barrett, 2003b). However, in Madagascar adoption rates have been low and disadoption high: across five sites surveyed by Moser & Barrett (2003b), disadoption rates ranged from 19 to 100%. Moser and Barrett (2003a) show that 62% of 1300 communes they studied did not practice SRI at all, and only in 3% of the communes did more than a quarter of the farmers practice it. Only 9% of SRI adopters ever put all the land into SRI in a single year. Conformity effects and seasonal liquidity constraints due to the high labour demands of SRI have been put forward as explanations for these disappointing results (Moser and Barrett, 2006).

2.4. Risk and farming decisions – the case of Madagascar

Madagascar is a highly variable environment, which exposes farmers to considerable risk. Madagascar’s climate is characterized by unpredictable intra-annual and inter-annual precipitation (Dewar and Richard, 2007) amplified by ENSO (El Nino Southern Oscillation) events (Ingram and Dawson, 2005). This unpredictability is considered a driving force in the evolution of the Madagascar wildlife (Dewar and Richard, 2007).

The unpredictability of Madagascar’s climate, in particular rainfall, is critical to rice cultivation as climatic shocks, such as drought or flooding, have a great impact on productivity (Minten et al. 2007). Their effect is of differential intensity on poor and rich farmers: poor farmers experience losses double to triple those of rich farmers because they cannot afford the same mitigation measures (e.g. hiring extra labour to replant lost plants) (Minten et al., 2007). Plots without irrigation are more likely to be flooded (Randrianarisoa and Minten, 2005) but a large proportion of landholders in Madagascar has poor water control (Ducrot and Capillon, 2004). Farmers also face risks over and above those of water control, such as equipment availability, duration of the hungry gap and availability of cash, which determine the control of crop timing and the success of the year’s crop (Ducrot and Capillon, 2004).
The way farmers deal with risk has received some attention from the development community (Doss et al., 2008, Reardon and Vosti, 1995, Caveness and Kurtz, 1993). Unstable income can lead to more risk aversive to investments in land improvements (Reardon and Vosti, 1995). Farmers deal with risks by adopting measures which appear inefficient but allow them to deal with them ex ante (in anticipation of the shock) or ex post (to cope with the shock) (Doss et al., 2008). An example of ex ante risk mitigation is that, although it is not advised to transplant past mid-January, late rains force farmers to transplant up to mid-February once every four years (Ducrot and Capillon, 2004). They offset the poor tillering by increasing plant density, but this requires having stock of plants to transplant. Thus, in preparation for late transplanting, farmers generally prepare quantities of seeds that are much higher than recommended (80-120kg per hectare) (Ducrot and Capillon, 2004). As an example of ex post risk mitigation, when farming households cannot cope with shortfalls in production, they diversify labour and land resources as a precaution, which limits the adverse effects of production risks but decreases productivity (Larson and Plessmann, 2009).

2.5. Study site

2.5.1. Lac Alaotra

Lac Alaotra is the largest lake in Madagascar, covering an area of 456 km2 in the central highlands, 200km North East of Antananarivo. It forms part of the larger Alaotra basin, which covers 6,855 km2 (Ferry et al., 2009). It is surrounded by a series of escarpments (Battistini, 1972) and lies at an altitude of 750m. It is composed of two main zones other than the lake: the marsh area surrounding the lake (530 km2) and the rice cultivation perimeter (820 km2) (Ferry et al., 2009). The soils in Lac Alaotra, initially rich in organic matter, currently present signs of nutrient deficiency (Randrianarisoa and Minten, 2001).

The Alaotra region has a tropical highland climate with two distinct seasons: a warmer wetter “rainy season” from November to March and a colder, drier season from April to October. Temperatures vary from 17°C in July to 27°C in January. Annual rainfall ranges between 800 and 2000 mm and averages at 1200mm (Ferry
et al., 2009), but almost 90% of this rain falls during the rainy season (Ferry et al., 2009).

Fishing is the second most important livelihood around the lake after rice cultivation but the system is currently overexploited and a closed season has been put in place in an attempt to manage it sustainably (Copsey, 2007). Marsh products including medicinal plants are collected in large quantities and are used to make baskets and mats or to build houses. In Anororo alone, the village under study, the value of marsh products has been estimated at a staggering 120 million Ariary (Rakotoniaina, 2001), but little is known about the harvest rate or the sustainability of these activities. The marsh also provides many ecosystem services, including flood control and siltation prevention, both benefitting rice cultivation (Pidgeon, 1996). Conservation interests, with the designation of a Ramsar site of international important and the presence of many endemic and threatened species, therefore lie adjacent to high economic stakes (Ferry et al., 2009).

2.5.2. A brief history of rice cultivation in Lac Alaotra
Rice cultivation infrastructure was first built in the 1940s and 1950s under the French colonisation and by 1945 33,000 hectares of rice fields had replaced the marsh in the basin (Pidgeon, 1996). When Madagascar became independent in 1960, the land reverted back to State ownership (Jacoby and Minten, 2007). In 1961, a parastatal body was put in place to lead the agrarian reform in Lac Alaotra: the SOMALAC (Société malgache d'aménagement du lac Alaotra) conducted irrigation improvements, including major drainage works and siltation prevention, and restructured the organisation of rice cultivation in the area (Jacoby and Minten, 2007). Land was given in four-hectare plots to farmers and land titles formalised for a small “maintenance fee”. However the complex and lengthy procedures meant that a considerable number of plots were never titled (Jacoby and Minten, 2007).

It is during this period that Alaotra grew to be the main rice producer of the country, earning its name of “rice basket of Madagascar”, and from independence to 1968 the region received a number of grants from the WorldBank (WorldBank, 1992) and production increased by 50% (Randrianarisoa and Minten, 2001). The State
withdrew its support to modern irrigation and the SOMALAC was dissolved in 1991 (Randrianarisoa and Minten, 2001); since then maintenance and further development of the irrigation system have been sporadically funded, largely by international aid grants such as the World Bank and the French Development Agency (AFD).

2.5.3. The current situation of rice cultivation in Lac Alaotra

Because the network of canals and plots around Lac Alaotra resembles a net, the unit of division within each perimeter is called maille or “mesh” (Jacoby and Minten, 2007). Any land outside those irrigated perimeters is called hors-maille, or “outside the mesh”, but can benefit from traditional irrigation of varying quality. A total of 100,000 hectares of rice are cultivated around Lac Alaotra, a third of which are in maille and 72,000 hectares are hors maille (Jacoby and Minten, 2007).

Figure 2.2. Map of Lac Alaotra and cultivation perimeters. (Reproduced from Charmes, 1975)
Since the collapse of the SOMALAC, each PC has been managed by local farmers through the Water Users Associations, also called tambazuta (Rakotoniaina, 2010, pers. comm.). With little financial means for the tambazuta to dedicate to maintenance or reparations, rice infrastructure such as weirs and canals has fallen into disrepair. In addition, inheritance has led to division and scattering of plots owned by each household, which means few plot have direct access to irrigation and drainage canals and thus limited water control. Only 3-5% of the paddy fields in Lac Alaotra are considered to have a secure water supply; on all other lands, rainfall determines the date when the fields are flooded and the duration of flooding and drying (Ducrot and Capillon, 2004).

Malagasy society is highly organised and deeply rooted in tradition and in a devotion to ancestors. The pressure to conform to social norms is very high in Madagascar. This also affects rice cultivation, notably with fady days, where work in the rice fields is prohibited. According to (Jarosz, 1994), this system was put in place to permit farmers to carry out activities other than rice, such as fishing. However, it can have severe impacts on rice cultivation as it delays the cultivation calendar by limiting the number of days on which work can be done. In some regions of Alaotra, this amounts to over 60 days a year (Bellemare, 2009). The unique system in place in Anororo, the study village, means that over 90 days a year are fady.

2.5.4. Current projects in Lac Alaotra

Currently the main rice cultivation development programme in Lac Alaotra is BVLac (Bassins Versants du Lac Alaotra) run by CIRAD (International Centre for Development Agronomic Research) and AFD, mainly focussing on hillside cultivation and rice cultivation under vegetation cover (Granjean, 2010, pers. comm.). In Amparafaravolo, the Koloharena cooperative encourages farmers to produce SRI organic rice. Twelve farmers are currently involved in the programme and will soon receive Ecocert organic certification (Pargee & Pargee, 2010, pers. comm.). Finally, Durrell Wildlife Conservation Trust has been involved with Aloatran communities since 1996 and since 2005 has facilitated the creation of village associations to protect the marsh (Copsey, 2007).
3. METHODS

3.1. Data collection

Fieldwork was carried out in Anororo, Lac Alaotra from mid April to the end of June 2010, and comprised primarily focus groups and semi-structured interviews. The following sections describe the details of how data were collected and informants chosen, and how the data were analysed.

3.1.1. Site choice

The village of Anororo is located on the western side of the lake (17°31’S, 48°26’E) in the district of Amparafaravolo and is made of two fokontany (smallest administrative unit in Madagascar): Anororo-town and Antananatsimo. It is part of the wider commune of Anororo which comprises several villages. The village is located on the edge of the marsh and is 9km from the nearest road (Copsey, 2007).

Figure 3.1. Map of Lac Alaotra and associated marsh and indicating the location of Anororo. (Reproduced from Copsey et al., 2009b)
Anororo was chosen because previous and ongoing research has been carried out there (Guillera Arroita, 2008, Lahoz Monfort, 2008, Copsey, 2007), which not only eased the logistics but also provided a valuable context for the present study.

Residents of Anororo do not necessarily cultivate rice fields on the commune territory, nor are all rice fields within the commune cultivated by Anororo residents, thus it was decided that the study would concentrate on residents of Anororo village in both fokontany. Participants were chosen based on their residency in the village and their involvement in rice cultivation (see below for more detail on sampling).

### 3.1.2. Research Assistants

Apart from rare exceptions, people in the village only speak Malagasy and form a tightly knit community welcoming but wary of foreigners. An assistant was essential to ensure communication with the community. The assistant was a recent high school graduate. He was trained in socio-economic surveys prior to interviews, a skill which he improved during the pilot study. Three further experienced research assistants donated their time to train the main assistant, translate the questionnaires, introduce the study to authorities and lead the focus groups.

### 3.1.3. Focus groups

A first meeting was organised with 24 rice cultivators to introduce the study to them, give them a chance to ask questions and to hold a preliminary focus group with general questions such as regarding salaries and rice varieties. A further focus group was held to investigate the rice cultivation calendar and the different steps in cultivating rice. The same 24 rice cultivators were involved, but they were split into two groups of 12. One of these groups contained those who had been less outspoken in the first focus group, which gave them the opportunity to express themselves.

Participants were chosen by the assistants for being important rice cultivators in order to gain the trust of the community and to respect local custom. Because rice cultivation is an important part of their livelihood, they were more likely to be very knowledgeable about calendars, water user associations and farming techniques.
3.1.4. **Semi-structured interviews**

The questionnaires were drafted prior to reaching the field site, then revised in the light of the information gained during the focus groups and informal conversations with villagers and assistants. They were further revised after the focus group to improve the wording. In order to test the questionnaires, a short pilot study was carried out on three respondents chosen for their familiarity with the study to allow questions to be discussed more freely. It was also an occasion to train the main assistant further. The final questionnaire was translated into Malagasy by the assistants and then checked for accuracy by a Malagasy staff member of Durrell. There was unfortunately no time for back-translating, but care was taken before starting that the meaning and purpose of each question was understood by the main assistant. See appendices 1 and 2 for final questionnaires (English version).

The questionnaire started with general information about all the members of the household, about the area of land cultivated and the ownership status and about livelihood activities carried out by each member of the household. Then we enquired about the number of days worked in rice cultivation in each cultivation activity (e.g. ploughing, transplanting, etc.) by each family member in other farmers’ fields and in the family’s field and the number of hours of hired labour. The following section regarded inputs and cultivation methods. The questionnaire then asked about trends in the past 10 years and how cultivation decisions might change under a change in the proportion of adverse years. The interviews ended with questions about perceptions of the marsh and of land use in Alaotra.

Because of the complexity in land tenancy and ownership in Lac Alaotra (Bellemare, 2009), I defined a landholder as a household who was responsible for making the decisions regarding the cultivation of their land, including landowners cultivating their own lands and tenants cultivating someone else’s land. Based on local expert opinion provided by Durrell staff, the local assistants and focus group participants, households were divided into four types. Landholders were divided into large and small landholders as the size of the area under cultivation may affect their rice cultivation decisions. The cut-off point between the two groups was set at four hectares based on local expert opinion and because this is the initial SOMALAC plot size. Amongst the people who did not cultivate themselves but worked in rice
cultivation as labour (either paid or as helpers), a distinction was made between those who owned land but did not cultivate it (non-cultivators) and those who did not own land at all (landless households).

Small and large landholders were asked the questions in Questionnaire A, which took on average one hour and a half. Landless and non-cultivating households answered Questionnaire B, which took on average half an hour. A total of 94 interviews were carried out with 20 large landholders, 40 small landholders, 19 non-cultivators and 15 landless households. Respondents were paid 1000 Ariary for their time (US$0.46, the equivalent of a fifth of a day’s wage in rice fields). This was the same amount as that paid by other researchers who have conducted studies in the village and judged an appropriate compensation of people’s time, especially during the busy harvest time.

3.1.5. Sampling strategy
For all but large landowners, random cluster sampling was used, following the methods described in Bernard (2006). This technique allows random sampling when no sampling frame is available and population distribution is unknown. A map of the village was drawn using a GPS, and points were placed along the edges and numbered. A pair of numbers was randomly generated (using annex A of Bernard, 2006) and the corresponding points on the map were joined. More pairs were randomly generated until all the points were linked to another point. This resulted in a grid of uneven squares on the map. Each intersection was numbered. A number was randomly generated, then we went to the corresponding point on the map and did street intercepts. First, after briefly introducing the project, we asked the first person we met basic questions to determine their category, and if this was not the category we were sampling at the time, we would not interview them and ask a second person. If they were in the appropriate category, we then arranged an interview with a member of the household.

The sampling strategy was different for large landowners as there are far fewer in the village; instead we used disproportionate sampling. We established a sampling
frame by finding who in the village had more than four hectares. During each of the two focus groups we asked participants who they knew who had more than four hectares, including the people in the room. With an assistant and a key informant, we added names to the list until they could not think of anyone else. 20 names were randomly picked and interviews scheduled with the cultivators.

The respondent was a member of the household who they considered most likely to be able to answer the questions and was available to do so. This was often, but not exclusively, the head of the household. In many cases both husband and wife were present during the interview. Interviews were scheduled in advance at a time suitable to the respondent.

3.2. Data analysis

3.2.1. Descriptive statistics
All data were analysed and graphs produced using Microsoft Excel and R (R-Project, 2010). All contingencies between categorical variables were calculated using Fisher’s exact tests. For continuous response variables with normal distributions and categorical explanatory variables, ANOVAs were used. When distribution was not normal, data was transformed or generalized linear models (glms) were used to account for different error structures. Glms were also used when some of the explanatory variables were continuous. Proportion data was arcsine square root transformed and non-normal count data was log-transformed or included the specification of a poisson distribution. In the event of overdispersion, quasi-poisson distribution was used. Some data required more specific analyses, which are described in more detail in the following sections.

3.2.2. Assignment of wealth categories
K-means clustering was used in order to attribute a category of wealth to each household based on a the number of certain possessions they owned. K-means clustering groups observations to maximise between-group variance and minimise
within-group variance in a number of variables, in this case possessions. Therefore it places households that owned the similar possessions in the same groups.

### 3.2.3. Cobb-Douglas production function

Yield is typically modelled as a diminishing returns curve with inputs (Barrett et al., 2010a, Barrett et al., 2006, Kimhi, 2006, Bouman, 2001, Herdt and Mandac, 1981). There are a range of different functions that can be used (Minten and Barrett, 2008, Barrett et al., 2006, South et al., 2005, Randrianarisoa and Minten, 2001, Minten et al., 2007). We used the Cobb-Douglas production function to model the relationship between yield and inputs (Landge et al., 2010, Lahoz Monfort, 2008, Naeem-ur-Rehman and Anwar, 2006, Black and Lynch, 2001, Barnum and Squire, 1979), because it is readily transformed into a linear function, allowing ease of estimation:

\[
Y = a_0 \prod_{i=1}^{n} I_i^{a_i} 
\]  

where \( Y \) is yield, \( I_n \) is the nth input variable (inputs may include labour, area and fertiliser) and \( a_n \) is a real number associated with input \( I_n \). Log-transforming both sides gives the following linear equation:

\[
Y = a_0 + \sum_{i=1}^{n} a_i \ln(I_i) 
\]

A first model was built using only area and total labour as inputs. However, area and labour are but a few determinants of yield, and unobserved household differences such as skill, motivation, plot quality and level of water control may affect the model. Therefore a mixed effects model was used to account for household effects (model 1). A poisson error structure was used and both area and labour were log-transformed to fit the production function. A second model was also built to include other inputs, namely method type and amounts of pesticide, herbicide and fertiliser used (model 2).
3.2.4. Relationship between yield and rainfall

As the nature of the relationship between yield and rainfall was not known, a generalized additive model (GAM) was used to investigate this relationship. A GAM estimates unspecified non-parametric functions of the explanatory variables which are "connected" to the response variable through a link function. This means it fits different non-parametric functions to different parts of the data and adds them together (Wood, 2006). To account for unobserved household differences, a GAM with mixed effects (GAMM) was used with yield as a function of area and rainfall, and using poisson distribution (model 3).
4. RESULTS

4.1. Organisation of work during the year

It seems that there is no fixed calendar for cultivation in Anororo, but there are time constraints and a particular sequence of activities to follow. For example, in both focus groups it was mentioned that transplanting cannot be done before wetting the soil, however the exact timing for both may change from year to year and between plots, depending on rain and distance to canals. The only fixed dates are the opening and the closing of the Sahamaloto dam on which the SOMALAC land in Anororo depends: the dam opens on the 20th November and closes on the 25th April. In May, the fields are drained and the harvest can commence. After the harvest, rice is left to dry and stacked in the field, then beaten manually or with cattle or kibotas (small tractor) to detach the grains (Appendix 3). Fig. 4.1. summarises the cultivation calendar in Anororo.

<table>
<thead>
<tr>
<th>Activity</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>January</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ploughing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wetting the soil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>and Levelling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nursery work</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broadcasting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transplanting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harvest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post harvest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 4.1. Calendar showing the dates of the different rice cultivation activities in Anororo. Start and end of irrigation are indicated in dotted lines; draining is not punctual and so is indicated with criss-crossing; the rice season starts in October although preliminary activities may be from time to time carried out in previous months; June marks the last of the post-harvest activities.
4.2 Economic characteristics of the sample population

4.2.1. Education, gender and ethnicity of the respondent

Of the 94 households interviewed, 90 were of Sihanaka origin; the remaining four were Merina, the ethnic group of the Antananarivo region. 30 women and 64 men were interviewed, but there were significant disparities between respondent groups in the proportion of men and women interviewed (Fisher's exact test, p< 0.001). All the respondents in the large landholder households were men whereas 12 out of 15 landless household respondents were women. The respondents were not necessarily household heads, but women in the landless households considered they were as knowledgeable as their husbands about the number of days worked in the fields as men, whereas men in large landholder households considered themselves more knowledgeable than their wives about the decisions made regarding their fields.

Households were similar in size, with an average of around two adults and two children for all four categories of respondents, which is consistent with other studies. An ANOVA showed the differences in number of adults and total number of people in the household were not significant between categories (F= 1.3, p= 0.27 and F= 0.85, p= 0.47 respectively).

The average age of respondent also significantly varied between groups (ANOVA: F=8.9, p<0.001). The average age of respondents in large landowner households was highest, followed by small landholder households and non-cultivator households. The average age of respondents in landless household was the smallest (see Table 4.1.).

Level of education was also significantly different between groups (ANOVA: F= 18.3, p<0.001). The average number of years in formal education of respondents in large landholder households was much higher than other respondent groups, corresponding to just below Baccalaureate level (Table 4.1).
4.2. Wealth ranking

Wealth ranking using both possessions and farming equipment and using possessions only gave exactly the same grouping of households. Using possessions as well as area cultivated gave a similar grouping: the only effect it had was to downgrade four households into the poorest class, where the majority of households were.

Wealth was correlated to respondent category (Fisher’s exact test, p=<0.001), with all four rich respondents large landholders, and the vast majority of landless and non-cultivators ranked as very poor (80% and 89% respectively). The small landholders were split between the poor and the very poor categories (23% and 73% respectively), and a notable 30% of large landholders were in the very poor category.

4.3. Livelihoods choices and rice cultivation

In total, over 15 activities contributing to the household’s livelihoods were mentioned, with each household carrying out between one and seven activities. The four major activities of interest were rice cultivation (discussed in greater detail below), fishing, the collection and use of marsh products and off-season rice cultivation. More of the landless non-cultivator households carried out fishing and

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**Table 4.1. Average age and number of years of formal schooling attended (with associated standard deviation) of the respondent in all four household categories.**

<table>
<thead>
<tr>
<th></th>
<th>Age Mean</th>
<th>Age Standard dev.</th>
<th>Number of years in school Mean</th>
<th>Number of years in school Standard dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large landholders</td>
<td>42</td>
<td>7</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Small landholders</td>
<td>44</td>
<td>11</td>
<td>5.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Non-cultivators</td>
<td>51</td>
<td>11</td>
<td>4.8</td>
<td>2.3</td>
</tr>
<tr>
<td>Landless</td>
<td>33</td>
<td>9</td>
<td>4.4</td>
<td>1.6</td>
</tr>
</tbody>
</table>

---
marsh product collection than small landholders, whereas very few of the large landholders carried out these activities. The results were similar when dividing by wealth ranking: very poor households spent more time in fishing and collecting marsh products than poor households, and none of the rich households were involved in these activities (Table 4.2).

Respondent groups also differed significantly in the total number of livelihood activities carried out by the households (ANOVA: F= 3.86, p<0.05). Small landholders and non-cultivators had a high number of activities. Both the landless and the large landholders had low livelihood diversity (Table 4.2).

**Table 4.2. Involvement in fishing, marsh product collection and off-season rice cultivation of the different households for each cultivation group and wealth group and significance to the ANOVA.**

<table>
<thead>
<tr>
<th></th>
<th>Fishing</th>
<th>Marsh product use</th>
<th>Off-season cultivation</th>
<th>Number of livelihood activities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percentage of the group partaking in this activity</td>
<td>Mean</td>
<td>St. dev.</td>
<td></td>
</tr>
<tr>
<td><strong>Large landholders</strong></td>
<td>15%</td>
<td>5%</td>
<td>20%</td>
<td>3.25</td>
</tr>
<tr>
<td><strong>Small landholders</strong></td>
<td>65%</td>
<td>50%</td>
<td>40%</td>
<td>4.3</td>
</tr>
<tr>
<td><strong>Non-cultivators</strong></td>
<td>79%</td>
<td>79%</td>
<td>26%</td>
<td>3.8</td>
</tr>
<tr>
<td><strong>Landless</strong></td>
<td>80%</td>
<td>67%</td>
<td>33%</td>
<td>3.5</td>
</tr>
<tr>
<td><strong>Significance</strong></td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>-</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td><strong>Rich</strong></td>
<td>0%</td>
<td>0%</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td><strong>Poor</strong></td>
<td>50%</td>
<td>37%</td>
<td>33%</td>
<td></td>
</tr>
<tr>
<td><strong>Very Poor</strong></td>
<td>70%</td>
<td>59%</td>
<td>32%</td>
<td></td>
</tr>
</tbody>
</table>

Because time to invest in any given activity is limited, one might expect a trade-off between work in one’s own rice fields and work in other’s fields. However, it does not seem that there is a direct relationship between the number of hours small and
large landholders worked in their own field and the number of hours spent in others’ fields.

Nonetheless, there is a significant difference between all four respondent categories and the number of hours worked in others’ fields (Fig. 4.2.). A generalized linear model (with quasi-poisson distribution) shows that landless and non-cultivating households work a significantly higher number of days in others’ fields than small landholders (p>0.001 for both), and large landowners work a significantly smaller number of days (p<0.05).

![Figure 4.2. Total amount of time spent by households as hired labour in other farmers’ fields (all members included) for each household cultivation category (+/- standard error). Codes: small landholder: L4H; landless: LL; large largeholder: M4H; non-cultivators: NC](image)

4.4. Inputs and costs to rice cultivation in Anororo

4.4.1. Land rental and sharecropping

There are three types of tenancy agreements in Anororo: 1) for money; 2) set-harvest agreements, where rent is paid as a set tonnage of rice (often around 1 tonne per hectare); and 3) sharecropping. Sharecropping is not strictly tenancy, as the land is given to another household to cultivate and the harvest split in half. Respondents
seemed to view sharecropping as cultivating the land together, where one household provides the land and the other the inputs and finances. The landowner can provide additional labour or share part of the harvest costs; however they make none of the decisions regarding how the land is cultivated. For this reason, we always considered sharecropping as being cultivated by the tenant.

Land rental was quite common in Anororo: 18 of the cultivating households (small and large landholders combined) did not own any land and relied on renting land to cultivate. In total 40 of the 60 landholders rented some or all of their land, often using a combination of agreements. All three types of agreements were widespread in Anororo, set-harvest agreements being the most common (Table 4.3.).

Table 4.3. Proportion of tenant households interviews and incidence of tenancy agreements recorded.

<table>
<thead>
<tr>
<th>Type of tenancy agreement</th>
<th>Renting</th>
<th>Renting only</th>
<th>Set harvest</th>
<th>Set price</th>
<th>Half of the harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion of landholders</td>
<td>67%</td>
<td>30%</td>
<td>36%</td>
<td>22%</td>
<td>20%</td>
</tr>
<tr>
<td>Proportion of tenants</td>
<td></td>
<td>45%</td>
<td>55%</td>
<td>30%</td>
<td>32%</td>
</tr>
</tbody>
</table>

4.4.2. Methods of cultivation
In 2009 the vast majority of the 60 respondents who cultivated land themselves used transplanting. Only one person, a small landowner, used broadcasting only. Six small landholders (15%) and five large landholders (20%) employed both transplanting and broadcasting on a portion of their field, but this proportion tended to decrease as the area of cultivated area increased, though not significantly (Fisher’s exact test, p=0.81).

SRA and SRI are very rare in Anororo: only five households used SRA in 2009, four of which were large landholders. Only one used SRI, but it was not true SRI as only the young transplanting age recommendation was respected; there was no wet-and-dry
cultivation and transplanting was not done in squares to allow for weeding. This
cultivator was also one of those who used SRA and even though he dedicated 5 ha to
SRA and 8ha to SRI, these represented only 15% and 24% respectively of his
cultivated area. He was also the richest person interviewed, and likely the richest
person in the village. The other four cultivators who dabbled in SRA only dedicated
half a hectare to it, which was always less than 3 to 5% of their total land surface.
Because so few households used these techniques, statistical analyses were not
carried out.

**4.4.3 Mechanization of cultivation in Anororo**

Of the 56 respondents who were asked about equipment used, all but two used a
*kibota*. Two households used cattle, of which one used it exclusively. One household
did not use any equipment at all. Twenty-two respondents owned their own *kibota*,
and 10 borrowed one from a member of family. Eighteen respondents rented the
equipment, with total costs averaging at 180 000 Ariary (US$83) (median: 90 000
Ariary or US$42), depending on the number of activities it was used for and the size
of the plot of land. Some respondents reported the cost of hire was determined per
hectare, and costs varied between 50 000 (US$23) and 80 000 Ariary (US$37) per
hectare. For transport, the rent was exclusively paid in rice, usually at a rate of 3 *vata*
(39 kg) every 10 bags.

**4.4.4. Pesticide, herbicide and fertiliser use**

Pesticide and herbicide use were very widespread (87% of small landholders and all
large landholders). A Fisher’s exact test showed no significant difference between
large and small landholders in whether they used pesticides and herbicides or not (*p*
= 0.16 and *p*=0.28 respectively).

In terms of the quantity applied to their fields, large landholders applied more
pesticide in absolute terms but not relative to the area they cultivated. Farmers did
not always use pesticides on all their plots and no plot-by-plot information was
taken so it was impossible to further investigate potential interactions between
amount used and respondent category.
In contrast to the literature, only a relatively small number of respondents did not use fertiliser (30% of small landholders and 15% of large landholders). Organic fertiliser was used by similar proportions of small and large landholders (45% and 42% respectively) but more of large landholders used chemical fertiliser (65% versus 30% of small landholders). Only one small landowner and four large landholders used both types of fertilisers. A Fisher’s exact test showed that these differences between small and large landholders in the kind of fertiliser applied were significant (p= 0.018) but there was not significant difference between the two groups in whether they used fertiliser at all or not (p=0.34).

There is a large amount of variability in the amount of chemical fertiliser small landholders applied per hectare, indicating a wide range of decisions regarding the use of this input. However, they tended to apply more organic fertiliser per hectare than large landholders.

Figure 4.3. Average amount of chemical (a) and organic (b) fertiliser used by each landholder category (+/- standard deviation).

Codes: small landholder: L4H; large landholder: M4H
4.4.5. *Use of hired labour versus family labour*

There was a lot of variation in the amount of family and hired labour invested in the cultivation of one hectare of rice (*Table 4.4.*). This is reflected in the costs of cultivating one hectare of rice (hired labour only). The cost of hired labour was estimated during the focus groups at 3000 to 5000 Ariary per day per person for day labourers, depending on the cultivator and the employee's bargaining power. Employees can also be hired for the whole year or for a determined number of months, and are then paid either in rice or in money for the value of the rice.

Table 4.4. Average amount of time (person-hours), with standard deviation, spent in the household’s land by family members, hired labour and all types of labour combined, with average cost of hired labour (Ariary).

<table>
<thead>
<tr>
<th></th>
<th>Family labour (person-hours)</th>
<th>Hired labour (person-hours)</th>
<th>Total labour (person-hours)</th>
<th>Cost (Thousand Ariary)</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>344</td>
<td>695</td>
<td>1039</td>
<td>2780</td>
</tr>
<tr>
<td>st. dev.</td>
<td>333</td>
<td>433</td>
<td>540</td>
<td>1734</td>
</tr>
</tbody>
</table>

This variation in time investment between family and hired labour is partly explained by the size of the area cultivated. As area increases, both family labour and hired labour increase (*Fig. 4.4.*). Although both linear regressions gave significant results (p<0.001 for both), hired labour has a steeper increase with area than family labour. This means that as the area household cultivated increases, the input of hired labour increased more than family labour.
4.5. Constraints on cultivation: the case of non-cultivators
Amongst the households who rent out their land rather than cultivate it, the reasons for not cultivating were fairly unanimous: they could not afford it. Fourteen out of the 19 people (74%) explained that they did not have the necessary finances and 8 out of 19 people (42%) mentioned a lack of equipment as a reason for not cultivating (including three who mentioned this as the only reason). In fact, apart from one household who did not cultivate their field because of high risks of flooding, every single respondent who did not cultivate their field themselves mentioned finances or equipment as a reason for not cultivating.

4.6. Returns to investment in rice cultivation
The mixed effect model (model1) showed that both the size of the area cultivated and the number of person-days of labour have a significant effect on yield (Table
4.5.) The log-linear relationship between area and yield is clear (Fig. 4.5.), which supports the use of a Cobb-Douglas production function. However there was a lot of noise in the labour data and separating family labour and hired labour removed the effect of labour (p= 0.25 and p =0.076 respectively). If family labour was removed altogether, hired labour had a significant effect (p= 0.045).

The more complex model (model 2) including pesticide, herbicide and fertiliser did not show these inputs as having a significant impact on yield (Table 4.5.); the high variability in amount used per hectare and lack of plot-by-plot data might account for this lack of effect.

Figure 4.5.

a) Yield in 2009 as a function of area cultivated. One outlier was excluded for clarity but included in the analyses. The diminishing returns effect is clearly visible.

b) Yield in 2009 as a function of area cultivated, log-transformed. This shows a linear function on the log-transformed data is likely to be a good fit.
### 4.6. Stochasticity in rice cultivation and its impacts on cultivation decisions

#### 4.6.1. Relationship between rainfall and yield

Rice cultivation is heavily dependent on rain availability, and so stochasticity in rainfall may affect yield. Both area and rainfall were included in the GAMM (model 3), but although area showed a curve highly similar to one expected from the Cobb-Douglas equation (confirming the suitability of this model), yield showed no clear relationship with total rainfall (Fig. 4.6.). The only real pattern came from the disastrous yields in 2005 which create a dip at the 1800mm rainfall. Because of the limited dataset, it was not possible to link rainfall to a change in yield.

This model used rainfall data from 2000 to 2009 on the 1° grid scale, as the more accurate 0.5° grid scale data only existed until 2007. Running individual monthly rainfalls showed no coherent pattern, while the variation in the rainfall in April, May and June, months of extreme rainfall for 2005, and in particular the number of years with no rain in those months, meant that the model could not converge. However, visually there did not seem to be any relationship between total yield and rainfall or rainfall in individual months.

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th></th>
<th>Model 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intercept</td>
<td>Area</td>
<td>Labour</td>
<td>Intercept</td>
</tr>
<tr>
<td>estimate</td>
<td>6.41</td>
<td>0.79</td>
<td>0.23</td>
<td>6.25</td>
</tr>
<tr>
<td>s.d.</td>
<td>0.69</td>
<td>0.10</td>
<td>0.10</td>
<td>0.75</td>
</tr>
<tr>
<td>p-value</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.05</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
Instead of using rainfall, I then used year as a proxy. It is clear from this that 2005 was a bad year for rice cultivation. Interestingly, yields seemed to increase after 2005, and yields in 2006 and 2009 were significantly different from 2000 to 2004 (Table 4.6).

**Figure 4.6.** Graphical results from the generalized additive model with mixed effects, showing the relationship between yield and area (a) and yearly rainfall in the past 10 years using 1° scale (b). The diminishing returns are clearly visible on figure “a”. The few number of lines on the x axis in “b” indicate there are few data points on which the model was based, therefore reducing its reliability. The dip in yield is created by one year only, 2005.

Instead of using rainfall, I then used year as a proxy. It is clear from this that 2005 was a bad year for rice cultivation. Interestingly, yields seemed to increase after 2005, and yields in 2006 and 2009 were significantly different from 2000 to 2004 (Table 4.6).

**Table 4.6.** Years showing a significant difference in yield with 2000. The estimate shows the difference from the intercept in 2000; 2005 is negative so the yield was smaller. Both 2006 and 2009 gave greater yields.

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2006</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>estimate</td>
<td>-0.78</td>
<td>0.16</td>
<td>0.19</td>
</tr>
<tr>
<td>st. error</td>
<td>0.075</td>
<td>0.062</td>
<td>0.065</td>
</tr>
<tr>
<td>p-value</td>
<td>&lt;0.001</td>
<td>&lt;0.05</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>
4.6.2. A closer look at 2005 and its impacts on farmers

Clearly 2005 was a catastrophic year for rice cultivators in Anororo, with a near-half decrease in average yields (Fig. 4.7), and although total rainfall that year cannot account for the bad yield, evidently something happened to affect production to such an extent.

According to the 0.5 grid data, 2005 is actually one of the years with the least amount of rain in total. However, if we look at individual months, 2005 had very extreme rainfalls relative to other years: April was the driest in the last 10 years, but December, May and June were the wettest in the last 10 years. Considering May and June are the harvest season, unexpected high rainfall during these months may have adversely impacted on the harvest.

![Figure 4.7. Average yield (tonnes) per hectare over the past 10 years (+/- standard error).](image)

Out of the 42 respondents who were asked why their harvest was worse on some years than others, 38 mentioned flooding as a cause for a bad harvest, including 33 who mentioned flooding in 2005, against 10 in all other years combined. In fact, 2005 was only ever mentioned as a bad year because of flooding. The other reasons
for a bad year were using broadcasting rather than transplanting (3 responses); because a dyke broke (1); drought (5) and a change in land quality because of a change in landlords (2). Flooding in 2005 was therefore an overwhelming response in comparison to other causes for bad yields. This contrasts with answers from the focus groups which unanimously stated that drought was worse for rice cultivation than flooding.

Regardless of what caused 2005 to be such a disastrous year for rice cultivation, it had a severe impact on farmers. Out of the 52 respondents who cultivated that year, 31 (60%) had a decrease in yield of at least 50% of what this household had over the past 10 years. This includes 16 households whose yield was only 10% of their average yield. Eight households (15%) had absolutely no rice that year, in spite of having worked their land. Therefore a considerable number of households made a loss and many had nothing in return for their considerable investment.

One of the respondents explained that when there is a bad year such as 2005, farmers may feel the repercussions for up to five years. To verify this hypothesis, I looked at the area cultivated in 2006 in relation to yield in 2005. Although it is difficult to establish any causation from these data, those people who did decrease their land seemed to have done so having heavily suffered from 2005.

4.6.3. Response to higher shock frequency

Cultivated area: The vast majority of respondents indicated that if the number of adverse years doubled they would keep their land the same, which explains the mitigated response to the disastrous yield in 2005. No one ever said they would increase the area they cultivate if they had bad years more frequently, but large landholders said they would decrease their land significantly more often than small landholders (Fisher’s exact test, p= 0.001).

Actions: Actions varied from increasing inputs to asking the government for help or asking for training in cultivation techniques. More frequently, respondents explained they would start another livelihood activity (30% of respondents) or invest more in an existing activity (50% of respondents). There was no difference between large
and small landholders in whether they would start a new activity, but small landholders reported more often that they would invest in an existing activity. The overall difference between the two groups in what actions they would take was significant (Fisher’s exact test, \( p = 0.049 \)). However, many also explained that they did not have a choice and so they would just have to adapt and live with bad years as they came.

Activities: Large landholders and small landholders differed significantly in the activities they would transfer their efforts to (Fisher’s exact test, \( p = 0.036 \)). This is not surprising since there are existing differences between those groups in what activities they currently take part in. The principal activities mentioned were small businesses, fishing, the cultivation of vegetables and winter rice cultivation, although the latter was only mentioned by small landholders. Over half of small landholders mentioned they would shift their efforts onto fishing.
5. DISCUSSION

In this section, I discuss the case in Anororo within the wider context of Madagascar and elsewhere, in terms of input use and constraints on productivity. This leads to a wider examination of obstacles to improving productivity, in particular in the adoption of new technologies. This study demonstrated that small hard-to-predict events might make a year catastrophic for farmers, with severe consequences for their livelihood. This indicates that exogenous shocks, and therefore averseness to risk, may be a huge component of decisions regarding cultivation, one that has so far largely been overlooked in studies in the area. I discuss the impact of risk averseness on cultivation decisions and avenues for policy to intervene in order to reduce production inefficiencies and improve technology adoption. I finish with a consideration of the future of Lac Alaotra and recommendations for future work.

5.1. Inputs in rice cultivation

5.1.1. Pesticides, herbicides and fertilisers

This study showed that pesticides, herbicides and fertilisers are widely used in Anororo. Herbicides in particular are very widely used. The main herbicide used in Anororo, 2,4-D commonly known as Desormone, has demonstrated toxicity to water organisms (Kegley, 2000-2010). Because the rice fields and the marsh are not independent systems in terms of water flow, herbicides leak into the marsh. The harmful consequences of herbicide use on the marsh have not been fully investigated, but it seems dangerous to advocate increased use of this herbicide, if any, particularly given the value of the marsh for maintaining the natural resource base for the sustainability of agriculture in the region, in addition to fisheries and biodiversity.

Fertiliser use is slightly less widespread than herbicide or pesticide, but a large number of farmers do use either chemical or organic fertilisers. Such a high use of fertilisers was unexpected, as the general wisdom in Lac Alaotra is that fertiliser use
is declining (Lala Jean, 2010 pers. comm.). It is also in opposition to other studies in Madagascar that have found that fertilizer use is generally low in Madagascar in comparison to other rice-producing countries (Minten et al., 2007). According to Ducrot and Capillon (2004), farmers rarely fertilize their fields and Minten et al. (2003) report 94% of Madagascar’s households do not use chemical fertilizer and only 36% use organic fertilizer.

The high cost of fertiliser seems to be the reason for low application rates, in particular for poor farmers for whom the effective cost of fertilizer is up to 30% greater (Minten et al., 2007). Copsey et al. (2009b) finds that people in Anororo reported the current price of fertilizers is prohibitive for farmers. However Minten et al. (2007) estimate willingness to pay for fertilizer at 575 Ar. per kg, which is very close to fertiliser prices in Lac Alaotra, around 600 Ar. (Copsey et al., 2009b). In addition, Yanggen et al. (1998) have estimated the minimum ratio of the value of marginal return over fertilizer cost and show that this ratio has be over 2 and preferably 3 in order to be attractive to farmers in view of climatic risk. Randrianarisoa and Minten (2005) find that in Lac Alaotra, this ratio never reaches 2, which could explain why uptake has been so limited, as risks of drought and flooding are too high to be worth the input. These studies make it even more surprising that in the present study mineral fertilizer use was so high in Anororo, with 60% of large landholders and 30% of small landholders using it.

Organic fertiliser use was also high, with around 45% of people using it. As with mineral fertiliser, these results were unexpected. It is unclear why there was such a high use of organic fertiliser, except that the abundance of cattle in the village make the use of manure virtually free. Access to organic fertiliser is often mentioned as one of the major constraints on productivity improvements in Sub-Saharan Africa and Madagascar (Minten and Barrett, 2008). If the reasons for high fertiliser use in Anororo become better understood, there is scope to apply these results to other villages to improve access to organic fertiliser.

Anororo also has an unusually high level of mechanization. Most other studies report a low use of cattle, and few report the use of kibota. Studies have shown that
equipment does not have a major effect on productivity (Minten et al., 2007) and, considering the high cost of equipment, bought or rented, small average rice area does not generally justify individual investments in mechanization (Randrianarisoa and Minten, 2001). Our results are even more puzzling in a context of high availability of cattle, which fertilises the soil as it is ploughed and is a much cheaper investment. However it is slightly more time consuming and time constraints might prove determinant in farmer choices (see below). Also, de Laulanié (2003) reports that to the Malagasy it may be unseemly to use cattle destined for consumption to work the fields.

There are two possible, not mutually exclusive, explanations for these discrepancies between Anororo and other villages. The first is that farmers in Anororo are wealthier than farmers in other parts of Madagascar, since it has traditionally been an important rice-producing commune. Indeed Lac Alaotra is exceptional in Madagascar for its high credit uptake (Jacoby and Minten, 2007). However, fertiliser and pesticide use is low in other parts of the basin (Minten et al., 2007), so Anororo seems unusual even in the context of Lac Alaotra. The second possible explanation is that because there is in Madagascar a very high pressure to conform (de Laulanié, 2003), because Anororo has had a high adoption of input use since they were introduced by in 1986 (Feau 1987) and because tractors have been used for a long time, it is possible that in the village this is simply the accepted way of cultivating.

5.1.2 Hired labour and family labour
The demand and offer for agricultural labour is great in Madagascar. Lapenu and Zeller (2000) find that 50% of the households they studied earned a wage from agricultural hired labour at some point in the year, and this was more prevalent in poor households than in rich ones. Our results confirm these findings, as the landless and non-cultivators spent more time in hired labour than other households.

Although total labour had an effect on yield, it is surprising that we could not detect an effect of hired labour and family labour when they were separated. This may be due to the small sample size. Perhaps it is also because family labour is more a
function of household size than choice to invest. Another explanation would be that family labour is not as efficient as hired labour and hence has less of an effect on productivity. Randrianarisoa (2001) also finds that returns from family labour are low, and that smaller farmers have lower labour productivity. Barrett et al. (2008) point out that households often over-provide labour on their own farm. By contrast, Rahman (2009) found that in Bangladesh the substitution of family farm workers with hired labour did not have any effect on efficiency. Feder (1985), on the other hand, predicts that diminishing returns from labour are caused by hired labour which is prone to shirking and requires greater supervision than family members. This is confirmed by Barrett et al. (2010a) and (Deolalikar and Vijverberg, 1987) who find family labour more productive as they have an interest in the enterprise, as opposed to hired labour, which requires higher supervision costs.

5.2. Non-cultivators and reverse share-tenancy

High costs of cultivation are a barrier to the poor who cannot afford it. If conformity is indeed at play, then the standard costs of cultivation are generally higher in Anororo than in other places and so the barrier to entry is even higher, which would account for the high number of people who rent out their land. This study also confirms previous research (Bellemare, 2009) showing that there is reverse tenancy in Lac Alaotra, where tenants are richer than the landowners. Reverse tenancy is unusual because landowners are typically considered wealthy. In Madagascar land is mostly inherited and the land market is very limited; as a result landowners can be too poor to cultivate, whereas richer households with better access to cash can afford to pay for both costs of cultivation and rent (Randrianarisoa, 2001).

5.3. Constraints and challenges in improving productivity

Considering inputs and mechanized equipment are widely used in Anororo, the question remains of how can productivity be increased to meet the needs of a growing population. A starting point is the observation that best management practices are not always followed in Madagascar and there are many misconceptions surrounding rice cultivation and inefficient practices which could be improved. Although fields are flooded to limit weeds, there is also the widely held myth that water is the rice’s food and a tendency to over-flood which leads to inefficiencies and
water usage conflicts (de Laulanié, 2003). Also, although removing soil from roots during transplanting can avoid transporting pests into the field (Grist, 1986), it also greatly affects the time it takes for the plants to recover from transplanting, and thus reduces the time available for tillering (de Laulanié, 2003). Better training for farmers is therefore likely to improve productivity, and indeed at the end of interviews many respondents expressed the wish for agronomists to visit their village. In the 2004 national survey, only 7% of households reported having had contact with an extension agent in the past (Minten et al., 2007) which shows there is a huge scope for improvement following best management practices.

There are also technologies that can improve yields over and above traditional methods. SRI is a cultivation technique that has consistently been shown to increase yields in Madagascar (Barrett et al., 2004). The use of mechanical weeding also means that a reduced use of herbicides would be possible, with positive effects on the marsh. So why has it not been met with resounding success? Many explanations have been put forward for both low adoption and high disadoption, which I will now discuss.

**Difficulty:** One of the reasons behind disadoption of SRI may be that it really is very difficult for farmers to change their technique from one planting closely spaced sturdy seedling to handling delicate seedlings planted at regular intervals (Moser and Barrett, 2003b). Indeed, mastering the technique can take several years. Moser and Barrett (2006) did not find any effect of learning-by-doing but found that unobserved farmer characteristics (such as skill, motivation, knowledge of the system) account for a large proportion of adoption success.

**Unprofitability:** SRI on a very small area might make it unprofitable and lead to disadoption. Indeed, in their first year of using the technique, those who continued with SRI cultivated an area 72% larger than those who disadopted (Moser and Barrett, 2003b). However even farmers who continue with the method and report higher yields don’t put all their land into SRI (Moser and Barrett, 2003b).
Cultural resistance: In rural villages, there can be a significant pressure to conform to social norms, which can be a considerable brake to innovations (Platteau, 2000). In Madagascar especially, the general rule is to do and say as everyone else (de Laulanié, 2003). If someone was to deviate from accepted norms, which can include cultivation practices, the individual could receive non-monetary social penalties (Moser and Barrett, 2006). The importance of community ties means they rank over productivity, and indeed de Laulanié (2003) reports that young men disadopted SRI because they did not wish to appear like over-achievers, and did not want to provoke the jealousy of the elders and the ancestors. Therefore if SRI adoption suffers from a “tall poppy syndrome”, where high achievers are brought down by the rest of the community, this could prove a real obstacle to improving productivity in Madagascar.

Labour liquidity constraints and seasonality of cash flow: Because labour is often the only resource of poor households, labour-intensive techniques like SRI are often seen as positive (Moser and Barrett, 2006). However, the seasonality of rice cultivation and its coincidence with the “hungry gap”, a time when poor households have finished their stocks of rice and face a food shortage before the next harvest (Moser and Barrett, 2006), means that labour may in fact the limiting factor in adoption of SRI (Moser and Barrett, 2006). The seasonality of rice production is central to the liquidity constraints impeding adoption of SRI. The returns to SRI take months to materialise, but agricultural day labour are often received daily. Poor households tend to rely on paid agricultural to make ends meet during the hungry gap as little informal credit is available (Moser and Barrett 2003b). Working in other farmers’ fields directly conflicts with household rice production as the labour is needed at the same time, and so it can impede adoption of SRI (Moser and Barrett, 2003b). Indeed, people who have tried SRI tend to have another income source unrelated to rice and wealth and stable income are positively correlated with adoption of SRI (Moser and Barrett, 2006), indicating that farmer liquidity is an important factor in farmer adoption. As Moser and Barrett (2003b) state: “sometimes the scarcity of cash makes labour, the only means by which the poor can earn cash, the scarcest input of all.”
**Risk avoidance:** SRI brings higher yield risk because of the transplanting and water management method. Because it requires draining, farmers risk over-drying their field if water supply is unreliable, and especially in areas where water is not well controlled and where farmers do not check their fields daily. Drying fields also makes the plants more susceptible to insect pests and rodents (Barrett et al., 2004). SRI also increases yield risk by increasing the time that plants spend in the field and not in the nursery, as they are transplanted younger. These increased risks might be a significant barrier to poor risk-averse farmers (Barrett et al., 2004). The issue of dealing with risk in a highly stochastic environment is a key issue in Anororo, which I expand upon below.

**5.4. Dealing with risk**

Our results show that a single event, in this case late rains in 2005, can have catastrophic consequences on farmer’s livelihoods, with impacts felt long afterwards. Average yield was halved in comparison to other years, and some farmers found themselves at harvest with wages and credits to pay back and no income from agriculture. In another study, it was found that the passage of a cyclone reduces the value of agricultural products by 7%, with the poor suffering more than the rich (Randrianarisoa and Minten, 2001). The costs of such an unpredictable event can push farmers to be quite risk-averse with consequences on the decisions they make regarding cultivation (Reardon and Vosti, 1995, Ducrot and Capillon, 2004, Barrett et al., 2007).

Risks related to environmental stochasticity have been largely left out of discussions about SRI and yield improvement in Madagascar, with a few exceptions (Ducrot and Capillon, 2004, Barrett et al., 2004). Barrett et al. (2004) suggest that the increased yield risk associated with SRI may not be acceptable by a large part of the population, even given large returns. Only farmers who have an above average risk tolerance or the financial means to mitigate losses should they arise can afford SRI (Barrett et al., 2004). They also attribute the greater uptake of SRI in Asian countries to the capacity of Asian farmers to bear yield risk, unlike their poorer Malagasy counterparts.
The extent to which farmers forego income for safety depends on the type and level of risks faced and on their willingness and capacity to take on those risks (Larson and Plessmann, 2009). Here we analyse in more detail how these three components of risk (cost, bearing capacity and perception) affect decision-making by farmers.

**Ex-ante risk avoidance:** In order to prepare for shocks and not bear the cost when they arise, farmers tend to go for lower yield, lower cost strategies, which are often regarded as inefficient. For a shock of particular frequency and magnitude, the farmer is not inefficient if the cost of risk avoidance is lower than the cost incurred by the shock, even if the overall productivity is not optimal. Indeed Larson and Plessman (2009) find that the costs associated with risk-coping strategies in the Philippines (diversified production, under-utilisation of fertilisers etc.) are smaller than those associated with variable weather and price conditions.

The cost of ex-ante risk avoidance may be foregone productivity by not using more expensive methods which would increase yield but also increase the cost of the risk, for example by increasing debt if the crop fails. It may also be more direct costs, for example investment in more plants in the nursery to transplant in the event of crop failure, which we found to be used in Anororo. The cost of cultivation is directly related to the cost of risk because whatever investments have been made, these will result in either debt or a reduced capacity for cultivation the following year. The actual cost of risk may vary from farmer to farmer depending on their assets: a farmer who inherited a kibota or land do not have to invest in them, which reduces their investment and hence the cost of cultivation.

**Ex post risk coping:** A household which does not solely depend on rice cultivation may be able to absorb the shock better, therefore willingness to take on the risk might increase with risk-coping ability. Hence potential productivity gains will be made by those who can already cope with risk. Risk can therefore be a source of persistent poverty because it forces the poor to choose lower-than-expected return strategies, although there can also be differences in the ability of individuals to cope ex post with shock (Santos and Barrett, 2006).
**Perception of risk:** Perception of risk may be just as important in determining whether a farmer will adopt a technology or not. Ducrot and Capillon (2004) find that there are important differences in farmers’ perceptions of risks and choices to deal with these risks, even between farms with similar management. Caveness and Kurtz (1993) found that in adoption of agroforestry practices, factors that provided a sense of security to farmers, such as land ownership and labour availability, reduced aversion to the taking up of new practices. Also, risk perceptions may change markedly over time, showing both interseasonal and interannual variation. Indeed, farmers’ perceptions of risk can respond to recent local events such as cattle raids or droughts (Doss et al., 2008). In Alaotra, disadoption of SRI in the Koloharena initiative confirms these results and show how risk perception may be central in taking up new technologies. Recommendations regarding planting density for SRI are rarely followed, and farmers often plant two or three plants per 25cm square rather than one. Even though this decreases their yield, their perception is that only planting one would be too much of a gamble (Pargee, 2010, pers. comm.). Also, many farmers left the cooperative after delays in shipping the rice as they became mistrusting of the program and became worried they would never get paid (Pargee, 2010, pers. comm.).

5.5. **Avenues for policies and interventions**

The impact of risk-avoidance in Lac Alaotra indicates there are three possible avenues for policy and interventions to improve willingness to take-on risk. The first is to reduce risk directly, or to reduce the magnitude of its impact on yield. The second is to improve households’ capacity to cope with risk *ex post* without foregoing productivity. The last is the act on their perception of risk. It is likely that a successful strategy would need to act on all three components.

Although the focus of development interventions is being removed from irrigation work (Ducrot and Capillon, 2004, Ferry et al., 2009), water control has a huge effect on productivity and may be important in regulating the magnitude of risks, by making the system less dependent on rainfall and thus less variable. The government and donors have grown weary of further investments in irrigation
schemes given the general lack of results from past interventions (Randrianarisoa and Minten, 2005). However most of these interventions focussed on construction, which is central to improving irrigation but pointless unless the local management capacities are in place to ensure ongoing maintenance (Randrianarisoa and Minten, 2005). The current water users associations cannot ensure the maintenance of the infrastructure. Payment of fees is rare and Randrianarisoa and Minten (2005) show that willingness to pay for irrigation maintenance is low and insufficient to meet the costs, even though people believe in the utility of improved infrastructure. Ducrot and Capillon (2004) propose development initiatives should aim to build organizational capacity rather than the adoption of techniques that assume the ability to anticipate. This is true for both water users associations and cooperatives for which little management capacity currently exists.

Innovations that provide greater income stability and smooth out cash flow may be “adoption ladders”, allowing cash-constrained households to overcome steep entry barriers into other technologies and to cope better with risk (Moser and Barrett, 2003b). Activities can be thought complementary to other technologies like SRI if they can sustain the household during the hungry gap and provide the cash necessary to hire workers. Off-season crops (crops that are planted after the rice harvest and harvested before rice cultivation starts again), milk production and metalworking are suitable activities (Moser and Barrett, 2003b). Indeed diffusion of off-season crops has been widespread with no disadoption (Moser and Barrett, 2003b), showing that the lack of adoption of SRI and the high disadoption rates cannot be simply put down to cultural resistance to change. The advantage of off-season cropping is that it provides an income just before the rice season starts, and requires labour at a lull in household activities. In addition, it tends to improve soil fertility by putting nutrients back into the soil (Moser and Barrett, 2006, Moser and Barrett, 2003b).

5.6. Livelihoods and the future of Lac Alaotra
Households diversify their livelihoods as a risk reduction measure, in response to decreasing returns or because of liquidity constraints. It can also be a strategic
decision because of complementarities between activities (for example crop-livestock integration practices) (Barrett et al., 2001). Non-farm activities are typically a pathway out of poverty, but the landless and capital poor cannot overcome the steep entry barriers and investments needed (Barrett et al., 2001). *Ex post* coping strategies might lead to further inefficiencies by forcing households into lower-return strategies, such as investing time in other livelihoods at the expense of rice cultivation (Doss et al., 2008, Barrett et al., 2007).

In our study, many farmers mentioned diversifying their livelihoods and investing more time and effort into another activity under scenarios of higher climatic risk. The main activities that were mentioned were businesses and fishing; winter rice cultivation was also mentioned on a number of occasions. Current climate change predictions envisage higher rainfall and climate unpredictability for Madagascar (Webster et al., 2005). Under higher climatic risk and larger number of adverse years, farmers are likely to move towards these activities and increase the pressure on the marsh. There is high interchange between fishing and rice cultivation, and fishers mention rice cultivation both as desirable (Copsey et al., 2009b) and as a fallback if returns from fishing were to be insufficient (Wallace, 2010, pers. comm.). As found elsewhere in Africa, (Bene et al 2003), we find that fishers are not necessarily the poorest, who cannot afford gear and thus are excluded from the more productive fisheries. Those who burn the marsh to fish snakehead (*Channa striata*) in Lac Alaotra are those without the equipment to fish the more prized species such as the carp (Copsey et al., 2009a).

The landless people tend to be the poorest people, as is the case in Anororo. The landless also tended to be younger. These results suggest that as population increases, a greater number of young landless people will find themselves with difficulties to make a living, and will fall back on those activities which require little input and have little or no access costs. Increasing population size and a fixed area of land for cultivation may result in an oversupply of labour which may drive down wages (Randrianarisoa et al., 2009). Some households in Anororo already reported difficulties in finding employment. If hired labour in rice fields becomes limited, then the only ways in which people, in particular women, can make a living will be the
collection of marsh products. This increase of the level of off-take in the marsh might have severe consequences for its conservation, especially since the level of sustainability is unknown. Offering new livelihood opportunities to the people of Lac Alaotra will be essential to ensure both the sustainability of the system and to avoid an increase in poverty. Such activities are already proposed in some parts of the basin; for example the Amparafaravola farmer cooperative Koloharena is training women in candle-making in cooperation with a fairtrade organisation (Pargee, 2010, pers. com.)

5.7. Study limitations and recommendations for future research

5.7.1. Study limitations

A possible source of error in the questionnaires was the necessity of using a translator. This, added to his lack of prior experience in conducting interviews or in translating, could have introduced error or biased the answers. Fortunately, many of the questions were quantitative and easy to check for translation. Great care was taken during the interviews and constant vigilance and cross-checking for consistency ensured the surveys were appropriately administered.

The other main possible source of error was respondent error. Many questions depended on recall, which can be unreliable, and it becomes more so the further back into the past respondents are asked to remember. However, using recall data to create a quasi-panel dataset has been used in other research (Besley and Case, 1993, Moser and Barrett, 2006). In Lac Alaotra no records exist of time or financial investment, of yield or of other productivity measurements. Recall is therefore the only available way to get at this type of information. Furthermore, although the cultivators do not think in terms of time and investment, they seemed confident in their estimates of yield or of the number of days they have spent working their field.

In addition, the national agricultural research institute of Madagascar, the FOFIFA, found that farmer recall in lowland rice areas to be extraordinarily accurate (Moser and Barrett, 2006).

The study would have benefitted from plot by plot data, which would have allowed more quantitative analyses of the amounts of inputs used and their effect on
productivity. However it would have been unfeasible to collect this level of detail in the given time frame. It was considered more important to use the available time to increase the number of respondents.

The GAM was limited in our ability to apply it to the data because of the small number of years of data. There was a trade-off between length of the time series and the accuracy of the data as the number of years recalled increased. A meta-analysis with data from previous studies in the same area and other regions might be able to shed more light on the effect of rainfall on yield. A better alternative would be to train farmers to keep records of yield, area and inputs, which would not only make them approach their cultivation in a rational manner and become aware of profits or losses (de Laulanié), but would also make analyses more reliable and would avoid saturating population with interviews. Furthermore, getting accurate and relevant rainfall data proved difficult. Although local meteorological stations collect rainfall data, there are many missing datapoints, rendering the data useless for analyses such as these. Freely available data (such as the GPCC etc.) are either available at too coarse a scale (1 degree or above) or contained incomplete time series of interpolated data.

5.7.2. Avenues for future research
Risk averseness and how farmers deal with risk are clearly determinant factors in decision-making, and so management of Lac Alaotra would greatly benefit from increased understanding of these issues. Information-gap (info-gap) analysis allows to model outcomes that are robust to uncertainty rather than optimal (Ben-Haim, 2006). It has been applied to a wide range of topics including conservation biology (e.g. Walshe and Massenbauer, 2008, Regan et al., 2005), economics (e.g. Beresford-Smith and Thompson, 2009) and project management (Regev et al., 2006). Its application to farming decisions in Lac Alaotra could shed light on how to identify productivity-improving technologies that are robust to climatic uncertainty, and explain the way that many farmers currently make risk-averse decisions.
Finally, winter rice cultivation and the sustainability of the collection of marsh products have so far received little attention. However both are important livelihoods and important parts of the social-ecological system of Lac Alaotra. Improved understanding of their impact on the marsh and of current and likely future practices are needed for the sustainable management of Lac Alaotra.

5.8. Conclusion
Risk and stochasticity are major driving forces in Madagascar and these results show that extreme climatic events such as floods can have devastating and lasting effects on farmers and their livelihoods. Interventions that assume the ability to cope with these risks may meet difficulties. Under current predictions of increased risks of flooding under climate change, it is important, now more than ever, to find either find productivity-boosting technologies that are robust to risk or to implement actions which allow farmers to cushion the effects of risks. However, under the current population growth rate, increasing productivity alone will not be sufficient to avoid the pressure on and eventual depletion of the marsh resources. If there is to be a future for Lac Alaotra, conservation action needs to focus on improving existing livelihoods and creating new ones.
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GUILLERA ARROITA, G. 2008. Occupancy and detectability of Hapalemur alaotrensis - Recommendations for monitoring MSc, Imperial College.
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APPENDIX 1 – Questionnaire A

SEMI-STRUCTURED INTERVIEW

Introduction (specific phrasing by assistant to cover the following points):
• I am a university student gathering information about rice farming activity around Anororo to understand how people make choices about which activity to do and how this could change in the future.
• I am asking questions about the livelihood that you make from rice farming, the reasons behind this and the costs involved in doing this. All information will be kept confidential.
• The interview is expected to take approximately half an hour.
• Please do not answer any question that you do not wish to answer.
• If you have any questions, please ask me at any time.

A. Background information & demographics:

1. DATE _______________ TIME _______________ INFORMANT CODE __

2. QUARTIER _______________ 3. ETHNIC GROUP Sihanaka / Other: _____

4. ABOUT THE HOUSEHOLD (table 1):
4.1 Who currently lives there (Only people over 12 years old and not at school)?
4.2 For each of them, can you tell me:
  • Their age and gender
  • Their level of education attended (number of years)

<table>
<thead>
<tr>
<th>Name/position in household</th>
<th>Gender</th>
<th>Age</th>
<th>Education</th>
</tr>
</thead>
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</tbody>
</table>

5. How many children (under 12 or still at school) live in the household? _______

6. OTHER PEOPLE SUPPORTED OUTSIDE OF HOUSEHOLD _________________________

***

B. Land ownership or rental
7.1 HOW MANY HECTARES DO YOU OWN?  
7.2. DID YOU BUY OR INHERIT THIS PLOT?  Bough  Inherited 
(If bought:) HOW MUCH?
7.3. DID YOU RENT OUT THIS LAND LAST YEAR?  Yes  No  Part of it 
(If they have only rented out part of it:) HOW MANY HECTARES DO YOU RENT OUT?  
(If they have rented out some or all of their land): HOW WERE YOU PAID AND HOW MUCH? 

7.4. DO YOU HAVE ANY OTHER RESPONSABILITIES OR COSTS REGARDING THE FIELD YOU RENT OUT? IF SO, WHAT ARE THEY?  

C. Livelihoods
8. FOR EACH MEMBER OF THE HOUSEHOLD MENTIONED IN 4.1, NAME ALL THE ACTIVITIES THEY CARRIED OUT LAST YEAR DURING THE WET AND THE DRY SEASON. THESE ARE THE ACTIVITIES THAT CONTRIBUTE TO THE HOUSEHOLD’S SUBSISTENCE. WHAT PROPORTION OF THEIR TIME DID THEY SPEND IN EACH ACTIVITY? (Give 20 marbles to represent time spent in each activity)

| Season | Individual 1 | | | | | | | | | | | |  |
|--------|--------------|---|---|---|---|---|---|---|---|---|---|---|---|---|
|        | CR  | CR  | CRC | CL | P | S | E | B/E | PM | Other: | Other : |
| wet    |     |     |     |    |   |   |   |     |    |          |            |
| dry    |     |     |     |    |   |   |   |     |    |          |            |

| Season | Individual 2 | | | | | | | | | | | |  |
|--------|--------------|---|---|---|---|---|---|---|---|---|---|---|---|---|
|        | CR  | CR  | CRC | CL | P | S | E | B/E | PM | Other: | Other : |
| wet    |     |     |     |    |   |   |   |     |    |          |            |
| dry    |     |     |     |    |   |   |   |     |    |          |            |

| Season | Individual 3 | | | | | | | | | | | |  |
|--------|--------------|---|---|---|---|---|---|---|---|---|---|---|---|---|
|        | CR  | CR  | CRC | CL | P | S | E | B/E | PM | Other: | Other : |
| wet    |     |     |     |    |   |   |   |     |    |          |            |
| dry    |     |     |     |    |   |   |   |     |    |          |            |

| Season | Individual 4 | | | | | | | | | | | |  |
|--------|--------------|---|---|---|---|---|---|---|---|---|---|---|---|---|
|        | CR  | CR  | CRC | CL | P | S | E | B/E | PM | Other: | Other : |
| wet    |     |     |     |    |   |   |   |     |    |          |            |
| dry    |     |     |     |    |   |   |   |     |    |          |            |

| Season | Individual 5 | | | | | | | | | | | |  |
|--------|--------------|---|---|---|---|---|---|---|---|---|---|---|---|---|
|        | CR  | CR  | CRC | CL | P | S | E | B/E | PM | Other: | Other : |
| wet    |     |     |     |    |   |   |   |     |    |          |            |
| dry    |     |     |     |    |   |   |   |     |    |          |            |

(If there are more individuals, add a page)
9. RANK THE ACTIVITIES YOU MENTIONED IN ORDER OF THEIR IMPORTANCE FOR THE HOUSEHOLD’S SUBSISTENCE.

<table>
<thead>
<tr>
<th>CRM</th>
<th>Rice cultivation in the household’s fields</th>
<th>S</th>
<th>Salary (for something other than rice)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRA</td>
<td>Rice cultivation in others’ fields</td>
<td>E</td>
<td>Animal Rearing</td>
</tr>
<tr>
<td>CRCS</td>
<td>Winter rice cultivation</td>
<td>E/B</td>
<td>Store</td>
</tr>
<tr>
<td>CL</td>
<td>Vegetable cultivation</td>
<td>PM</td>
<td>Marsh products</td>
</tr>
<tr>
<td>P</td>
<td>Fishing</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**D. Work in someone else’s field**
(Ask the questions in this section only if rice cultivation in someone else’s field was mentioned in the previous question).

9. LAST YEAR FOR EACH SEASON (in the main rice growing year):
How many days did each individual work on someone else’s field in each cultivation phase? Were they helping (no salary or share of harvest) or being paid? Was this a seasonal or a daily contract?

<table>
<thead>
<tr>
<th>Individua</th>
<th>Number of days</th>
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</thead>
<tbody>
<tr>
<td>Contract</td>
<td>Ploughing</td>
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<tr>
<td></td>
<td>Nurserying</td>
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<td></td>
<td>Levelling</td>
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<td>Maintenance</td>
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<td>Transplanting</td>
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<td></td>
<td>Harvesting</td>
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<td></td>
<td>Beating</td>
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<tr>
<td></td>
<td>Posting</td>
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<td></td>
<td>Water control</td>
</tr>
</tbody>
</table>

(Add a sheet if necessary)

11. (If applicable) WHY DO YOU HELP?__________________________________________

12. (If they are landowners) WHY DO YOU NOT CULTIVATE YOUR LAND YOURSELF?__________________________________________

***

**G. Future changes**
28. IS IT EASY TO FIND WORK IN RICE CULTIVATION?__________________________________________

29. WHAT WOULD YOU DO IF, IN THE FUTURE, IT WAS MORE DIFFICULT TO FIND WORK IN RICE CULTIVATION?__________________________________________
H. Uses of the marsh

FOR THE FOLLOWING STATEMENTS, PLEASE SAY WHETHER YOU STRONGLY DISAGREE, DISAGREE, NEITHER AGREE NOR DISAGREE, AGREE OR STRONGLY AGREE: THIS COULD GIVE SOME INTERESTING RESULTS. ADD “I DON’T KNOW”

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Neither agree nor disagree</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>It would be a better use of the marsh (than the current situation) to grow rice on it</td>
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<tr>
<td>There is no need for more rice land for people in the area</td>
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<tr>
<td>Rice farming has no impact on the animals and plants living in and around the lake</td>
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<td>I would like more rice land for myself</td>
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<td>The current uses of the marsh are more important than converting it to rice fields</td>
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I. Possessions

PROPERTY OWNED BY THE HOUSEHOLD (INDICATE QUANTITIES; IF QUANTITY UNKNOWN TICK [✓] BOX) (other than rice field if applicable)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>NUMBER</th>
<th>ITEM</th>
<th>NUMBER</th>
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<tbody>
<tr>
<td>Concrete house</td>
<td></td>
<td>Mobile phone</td>
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<tr>
<td>Traditional house</td>
<td></td>
<td>Television</td>
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<tr>
<td>Shop / store</td>
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<td>Generator</td>
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<td>Geese</td>
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<tr>
<td>Motorcycle</td>
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<td>Other:</td>
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<tr>
<td>Fishing equipment</td>
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</table>

WHAT RICE CULTIVATION EQUIPMENT DOES THE HOUSEHOLD OWN?

<table>
<thead>
<tr>
<th>ITEM</th>
<th>NUMBER</th>
<th>ITEM</th>
<th>NUMBER</th>
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</thead>
<tbody>
<tr>
<td>Cattle for ploughing</td>
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<td>Ploughing cart</td>
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<tr>
<td>Kibota</td>
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<td>Large tractor</td>
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<tr>
<td>Pesticide sprayer</td>
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<td>Other:</td>
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</tbody>
</table>

***

WERE YOU INTERVIEWED (long interviews) BY ANDREA AND/OR ONE OF HER ASSISTANTS (SOLOFO, JOACHIN, LUHANAUD)? Yes No

DO YOU HAVE ANYTHING ELSE TO ADD OR ANY QUESTIONS?
APPENDIX 2 – QUESTIONNAIRE B

SEMI-STRUCTURED INTERVIEW

Introduction (specific phrasing by assistant to cover the following points):
• I am a university student gathering information about rice farming activity around Anororo to understand how people make choices about which activity to do and how this could change in the future.
• I am asking questions about the livelihood that you make from rice farming, the reasons behind this and the costs involved in doing this. All information will be kept confidential.
• The interview is expected to take approximately half an hour.
• Please do not answer any question that you do not wish to answer.
• If you have any questions, please ask me at any time.

A. Background information & demographics:
1. DATE __________ TIME __________ INFORMANT CODE __
   _______________________

2. QUARTIER ________________ 3. ETHNIC GROUP Sihanaka / Other: __________
   _______________________

4. ABOUT THE HOUSEHOLD (table 1):
4.1 Who currently lives there (Only people over 12 years old and not at school)?
4.2 For each of them, can you tell me:
   • Their age and gender
   • Their level of education attended (number of years)

<table>
<thead>
<tr>
<th>Name/position in the household</th>
<th>Gender</th>
<th>Age</th>
<th>Education</th>
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5. How many children (under 12 or still at school) live in the household? ______

6. OTHER PEOPLE SUPPORTED OUTSIDE OF HOUSEHOLD ________________________________

***

B. Land ownership or rental
7.1 DO YOU OWN OR RENT RICE LAND? Rent Own No
   (If they own a rice plot, ask all the question up to 7.4; if they only rent a field, only ask questions 7.2 and 7.5; if they both own and rent land, ask all the questions)
7.2. HOW MANY HECTARES? Rent: _________ Own: __________
7.3. DID YOU BUY OR INHERIT THIS PLOT? Bough □ Inherited □

(If bought:) HOW MUCH?

7.4. DID YOU RENT OUT THIS LAND LAST YEAR? Yes □ No □ Part of it □

(If they have only rented out part of it:) HOW MANY HECTARES DO YOU RENT OUT? ______

(If they have rented out some or all of their land): HOW WERE YOU PAID AND HOW MUCH?

7.5. (Tenants) HOW MANY HECTARES DID YOU RENT? ______

HOW DID YOU PAY AND HOW MUCH? ______

C. Livelihoods

8. FOR EACH MEMBER OF THE HOUSEHOLD MENTIONED IN 4.1, NAME ALL THE ACTIVITIES THEY CARRIED OUT LAST YEAR DURING THE WET AND THE DRY SEASON. THESE ARE THE ACTIVITIES THAT CONTRIBUTE TO THE HOUSEHOLD’S SUBSISTENCE. WHAT PROPORTION OF THEIR TIME DID THEY SPEND IN EACH ACTIVITY? (Give 20 marbles to represent time spent in each activity)

<table>
<thead>
<tr>
<th>Season</th>
<th>Individual 1</th>
<th>CR</th>
<th>P</th>
<th>CR</th>
<th>A</th>
<th>CRC</th>
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<th>S</th>
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<th>B/E</th>
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<tr>
<th>Season</th>
<th>Individual 2</th>
<th>CR</th>
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<th>A</th>
<th>CRC</th>
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<tr>
<th>Season</th>
<th>Individual 3</th>
<th>CR</th>
<th>P</th>
<th>CR</th>
<th>A</th>
<th>CRC</th>
<th>S</th>
<th>CL</th>
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<thead>
<tr>
<th>Season</th>
<th>Individual 4</th>
<th>CR</th>
<th>P</th>
<th>CR</th>
<th>A</th>
<th>CRC</th>
<th>S</th>
<th>CL</th>
<th>P</th>
<th>S</th>
<th>E</th>
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<table>
<thead>
<tr>
<th>Season</th>
<th>Individual 5</th>
<th>CR</th>
<th>P</th>
<th>CR</th>
<th>A</th>
<th>CRC</th>
<th>S</th>
<th>CL</th>
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<th>B/E</th>
<th>PM</th>
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</tbody>
</table>

(If there are more individuals, add a page)
9. RANK THE ACTIVITIES YOU MENTIONED IN ORDER OF THEIR IMPORTANCE FOR THE HOUSEHOLD’S SUBSISTENCE.

<table>
<thead>
<tr>
<th>CR</th>
<th>CR</th>
<th>CRC</th>
<th>CL</th>
<th>P</th>
<th>S</th>
<th>E</th>
<th>B/E</th>
<th>PM</th>
<th>Autre:</th>
<th>Autre:</th>
</tr>
</thead>
</table>

D. Work in someone else’s field
(Ask the questions in this section only if rice cultivation in someone else’s field was mentioned in the previous question).

9. LAST YEAR FOR EACH SEASON (in the main rice growing year):
How many days did each individual work on someone else’s field in each cultivation phase? Were they helping (no salary or share of harvest) or being paid? Was this a seasonal or a daily contract?

<table>
<thead>
<tr>
<th>Individual</th>
<th>Number of days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plough</td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
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</tbody>
</table>

(Add a sheet if necessary)

11. WHY DO YOU WORK IN SOMEONE ELSE’S FIELD?

***

E. Rice cultivation in the household’s fields
12. LAST YEAR, HOW MANY DAYS DID EACH MEMBER OF THE HOUSEHOLD WORK ON YOUR RICE FIELDS EACH PHASE OF CULTIVATION?

<table>
<thead>
<tr>
<th>Individual</th>
<th>Plough</th>
<th>Nursery</th>
<th>Levelling</th>
<th>Maintenance</th>
<th>Transplanting</th>
<th>Harvest</th>
<th>Beating</th>
<th>Post</th>
<th>Water control</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
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</tbody>
</table>
13. LAST YEAR, HOW MANY PEOPLE WORKED ON YOUR LAND AND HOW MANY DAYS FOR EACH PHASE OF CULTIVATION? Separate help, exchange and paid work. Where possible, precise whether hired labour is paid daily or monthly/yearly.

<table>
<thead>
<tr>
<th>Contract</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plough</td>
</tr>
<tr>
<td></td>
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</tbody>
</table>

HOW LONG DOES IT TAKE YOU TO GO TO EACH OF THE PLOTS YOU CULTIVATED LAST YEAR?
HOW LONG DO YOU SPEND IN THE FIELD (HOURS) ____________________

14. LAST YEAR, WERE YOUR PLOTS IN “MAILLE” OR “HORS-MAILLE”? (If both, how many hectares)
Maille: ________________  Hors-maille: ________________

15. WHAT RICE FARMING SYSTEM DID YOU USE?  Direct seeding: ______
    Transplanting: ______  SRA: ______  SRI: ______

16. LAST YEAR, DID YOU CULTIVATE ANYTHING ELSE ON YOUR LAND? (If so, what, and how many hectares)
__________________________________________

17. LAST YEAR, WHAT RICE VARIETIES DID YOU USE? (If more than one, how many hectares of each)
__________________________________________

18.1 LAST YEAR, DID YOU USE PESTICIDES? HOW MUCH? ____________________
18.1. LAST YEAR DID YOU USE HERBICIDES? HOW MUCH? ____________________
19. LAST YEAR DID YOU USE FERTILISERS? WHAT KIND? HOW MUCH? ____________________

20. WHAT YIELD ARE YOU EXPECTING THIS YEAR AND WHAT SURFACE DID YOU CULTIVATE?
__________________________________________

21. WHAT YIELD DID YOU GET LAST YEAR (REMIND THE AREA CULTIVATED)
How much did you keep for planting? ____________________
WHAT DID YOU DO WITH THE REST?
Sold: 
Kept for food: 
Given: 
Other: 

<table>
<thead>
<tr>
<th>When?</th>
<th>Amount sold</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>


<table>
<thead>
<tr>
<th>Year</th>
<th>Harvest</th>
<th>Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td></td>
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<tr>
<td>2005</td>
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<tr>
<td>2004</td>
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<td>2003</td>
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<td>2002</td>
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<tr>
<td>2001</td>
<td></td>
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<tr>
<td>2000</td>
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</tbody>
</table>

If there was a change in the surface cultivated: why?
If there were very good or very bad years: why?

***

F. Past changes

23. WHAT IS YOUR YIELD ON A GOOD, A BAD AND A NORMAL YEAR? HOW MANY GOOD, NORMAL AND BAD YEARS DID YOU HAVE IN THE PAST 10 YEARS?

23. WHAT IS THE PRICE OF A KG OF RICE ON A GOOD, A BAD AND A NORMAL YEAR? HOW MANY GOOD, NORMAL AND BAD YEARS DID YOU HAVE IN THE PAST 10 YEARS?

<table>
<thead>
<tr>
<th>Year</th>
<th>Yield</th>
<th>Proportion of good, normal and bad years</th>
<th>Years</th>
<th>Price (range)</th>
<th>Proportion of good, normal and bad years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td></td>
<td>Good</td>
<td>Good</td>
<td></td>
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<tr>
<td>Normal</td>
<td></td>
<td>Normal</td>
<td>Normal</td>
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<tr>
<td>Bad</td>
<td></td>
<td>Bad</td>
<td>Bad</td>
<td></td>
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</tbody>
</table>

25. **(only if they have not answered fully to question 22:)**
OVER THE PAST TEN YEARS, HAS YOUR HARVEST:

<table>
<thead>
<tr>
<th>Increased</th>
<th>Decreased</th>
<th>It varies</th>
<th>It’s always the same</th>
<th>Cannot remember</th>
</tr>
</thead>
<tbody>
<tr>
<td>If there was a change, why?</td>
<td></td>
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</tbody>
</table>
26. (only if they have not answered fully to question 22:)
OVER THE PAST TEN YEARS, HAS THE SURFACE YOU CULTIVATED:
Increased  Decreased  It varies  It’s always the same  Cannot remember
If there was a change, why ?  

27. OVER THE PAST TEN YEARS, HAS THE NUMBER OF PEOPLE WHO WORKED ON YOUR LAND:
Increased  Decreased  It varies  It’s always the same  Cannot remember
If there was a change, why ?  

G. Future changes
28. WHAT WOULD YOU DO IF, IN THE FUTURE, YOU HAD TWICE AS MANY BAD YEARS FOR YOUR HARVEST ?

29. WHAT WOULD YOU DO IF, IN THE FUTURE, YOU HAD TWICE AS MANY BAD YEARS FOR THE PRICE OF RICE?

H. Uses of the marsh
FOR THE FOLLOWING STATEMENTS, PLEASE SAY WHETHER YOU STRONGLY DISAGREE, DISAGREE, NEITHER AGREE NOR DISAGREE, AGREE OR STRONGLY AGREE: THIS COULD GIVE SOME INTERESTING RESULTS. ADD “I DON’T KNOW”

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Neither agree nor disagree</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>It would be a better use of the marsh (than the current situation) to grow rice on it</td>
<td></td>
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<tr>
<td>There is no need for more rice land for people in the area</td>
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<tr>
<td>Rice farming has no impact on the animals and plants living in and around the lake</td>
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<td>I would like more rice land for myself</td>
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<tr>
<td>The current uses of the marsh are more important than converting it to rice fields</td>
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I. Possessions
PROPERTY OWNED BY THE HOUSEHOLD (INDICATE QUANTITIES; IF QUANTITY UNKNOWN TICK [✓] BOX) (other than rice field if applicable)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>NUMBER</th>
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<th>NUMBER</th>
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<tbody>
<tr>
<td>Concrete house</td>
<td></td>
<td>Mobile phone</td>
<td></td>
</tr>
<tr>
<td>Traditional house</td>
<td></td>
<td>Television</td>
<td></td>
</tr>
<tr>
<td>Shop / store</td>
<td></td>
<td>Zebu</td>
<td></td>
</tr>
<tr>
<td>Generator</td>
<td></td>
<td>Geese</td>
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</tr>
<tr>
<td>Motorcycle</td>
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<td>Other:</td>
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<tr>
<td>Fishing equipment</td>
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WHAT RICE CULTIVATION EQUIPMENT DOES THE HOUSEHOLD OWN?

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<tr>
<th>ITEM</th>
<th>NUMBER</th>
<th>ITEM</th>
<th>NUMBER</th>
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</thead>
<tbody>
<tr>
<td>Cattle for ploughing</td>
<td></td>
<td>Ploughing cart</td>
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<tr>
<td>Kibota</td>
<td></td>
<td>Large tractor</td>
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<td>Pesticide sprayer</td>
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<td>Other:</td>
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WERE YOU INTERVIEWED (long interviews) BY ANDREA AND/OR ONE OF HER ASSISTANTS (SOLOFO, JOACHIN, LUHANAUD)?

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<th>Yes</th>
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DO YOU HAVE ANYTHING ELSE TO ADD OR ANY QUESTIONS?
APPENDIX 3 – RICE CULTIVATION TECHNIQUES

Tonta in Anororo –
Harvested rice left to dry in piles while the field is drained and the soil dries

Beating of the rice using cattle near Andreba. The animals trample the stems to detach the grains.

Manual beating of the rice in Anororo
**Kibota** – small tractors used in Anororo for work in the field and transport

Rice left to dry after the harvest

Crude irrigation structure used to replace the failing infrastructure