Livelihoods on the edge: farming household income, food security and resilience in southwestern Madagascar

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SUMMARY

Southwestern Madagascar is not only one of the "hottest biodiversity hotspots" globally, but also a food insecurity hotspot with severe levels of poverty and undernourishment. Large parts of the regional forest have been lost in past decades, and many of the endemic species are at the verge of extinction. At the same time, the research region is among the most underdeveloped parts of Madagascar, which is itself one of the poorest countries globally. Thus, there is the dual challenge of safeguarding the livelihoods of one of the poorest rural communities while preserving the unique biodiversity. Acknowledgment of this dual challenge gave rise to the SuLaMa project (Sustainable Land Management in southwestern Madagascar) the present dissertation is a part of. Within southwestern Madagascar, the SuLaMa project region is confined to the Mahafaly Plateau, consisting of the coastal littoral in the west and a limestone upland in the east.

Three chapters comprise the core of this dissertation. The first chapter investigates the insurance function of livestock to cover food expenses during a drought year with failing annual crops. In rural Madagascar, zebu cattle are the most prominent herded animal, livestock numbers are high, and the heads of cattle a household owns is a strong indicator of both prestige and social status. Given the high sociocultural value of zebu cattle in Malagasy culture, many authors and development actors question the economic rationale of zebu herding. Empirical micro-level data on the actual role of livestock herding in terms of household economics is missing, though. We intend to narrow this knowledge gap by analysing the economic importance of zebu herding in the Mahafaly region. The analysis takes into account (i) the general role of animal husbandry and (ii) non-cattle related livelihood strategies that can buffer smallholder households against the effects of severe droughts and associated crop failures. To do this, we conducted a longitudinal survey as well as a recall survey covering the "lean" or "hunger" season (12/2013-05/2014). The results show that households generated less then 5% of total cash income from food crop sales, and spent on average >50% of their total cash income on food purchases. Proceeds from the sale of livestock accounted for >45% of cash food expenditures on average. In sum, we documented a substantial insurance function for zebu herding, but – even more importantly for the poorest households – also for small ruminants, i.e. goats.

The second chapter investigates causal links between regional hunger, poverty and environmental degradation, including feedback loops, among these factors. Despite a large number of regional rural development programmes in the research region, little effective progress in terms of agricultural income or well-being among farming households was observed. Anecdotally, the

research region is being called a “project cemetery”. At the same time, environmental degradation and the loss of biodiversity are frequently cited as problems of the region. Why is southwestern Madagascar apparently locked in such a catastrophic socioeconomic and ecological state?
The second chapter presents a causal analysis of the above-mentioned situation from a *social-ecological systems* perspective, including an analysis of potential *social-ecological traps.*
Specifically, we have analysed interactions between seasonal rainfall, agricultural production, household income, and strategies to cope with widespread hunger. The study is based on high-resolution survey data and longitudinal interview data covering all of 2014. In addition to our primary data sources, we incorporated results from previously published studies on the Mahafaly area focussing on current data from the SuLaMa project. The causal analysis makes use of the tools of *systems analysis,* particularly using causal loop diagrams to assess crucial social-ecological interactions. We found a complex interplay of pronounced seasonality in income generation, recurrent droughts and crop failures, high agricultural investment risks, and governance failures on several levels. This interplay results in a gradual depletion of environmental assets, livelihood impoverishment, and hinders capital accumulation, as well as sustainable agricultural intensification. Several social-ecological traps and their interactions entrench the Mahafalian smallholder population in deep poverty while the productivity of the environment gradually declines. The study provides new insights into the causes of persistent poverty and continuing loss of environmental assets on the landscape level. Finally, we propose key leverage points to unlock current traps and facilitate more sustainable development in southwestern Madagascar. Among these leverage points are, in particular, income sources that are not based on arable agriculture.

The first and the second chapters suggest that alternative income sources beyond arable agriculture are crucial for a regional sustainable development. The third chapter builds on this conclusion and analyses the potential of plant oil produced from the seeds of the cactus pear (*Opuntia spp*.) as an alternative income source. Cacti of the genus *Opuntia* are highly abundant in the region, particularly as living fences on private farmland in the littoral of the Mahafaly area. Highly priced seed oil can be extracted from the seeds of its fruit. To investigate the economic potential of seed oil production – and/or the local commercialisation of *Opuntia* seeds for seed oil production, we inventoried *Opuntiae* in field hedges through GIS analyses, and estimated the amount of seed oil that can be produced per household based on *in situ* sampling and laboratory analysis. To assess the socioeconomic impact of a potential large-scale project of regional *Opuntia* seed oil production, we conducted interviews with 51 farming households as to preferences for the utilisation of *Opuntiae* and *Opuntiae* products, including human consumption and utilization as animal fodder.

We found five different *Opuntia* varieties belonging to at least three different species. Two of the *Opuntiae* are highly important today socioeconomically, as they contribute >50% to total food intake during annual periods of food shortage. Conversely, three *Opuntia* varieties are not eaten by local residents. These varieties are more spiny, and respondents mentioned higher seed content in the fruit that would lead to digestive problems and constipation. However, the *Opuntia* varieties with inedible fruit were more abundant in the field hedges. The combination of low local nutritional use but high abundance and high seed content offers promising potential for regional *Opuntia* seed oil production. As *Opuntia* seed oil demands a high price on international markets, we conclude that the production of *Opuntia* seed oil from the project area and the sale of *Opuntia* seeds may bring livelihood improvements to some of the poorest rural communities in Madagascar.

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ACF	Action contre la faim *(Action Against Hunger)*
BMBF	Bundesministerium für Bildung und Forschung (*German Federal Ministry for Education and Research*)
CDD	Conseil diocésain de développement *(Diocese Development Council)*
CGIAR	Consultative Group on International Agriculture Research
CLP	Causal loop diagram
CNA	Centre National Antiacridien (*National Anti-Acridine Centre*)
CPFW	Challenge Program on Water and Food
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
FAO-ICARDA	International Center for Agricultural Research in Dry Areas / Cactus network
FOFIFA	Centre National de Recherche Appliquée au Développement Rural (*National Centre of Applied Research for Rural Development)*
GIZ	Gesellschaft für internationale Zusammenarbeit *(Association for International Cooperation)*
IFPRI	International Food Policy Research Institute
INSTAT	Institut National de la statistique de Madagascar *(National Statistical Institute in Madagascar)*
LCD	Least developed country
M4P	Markets for the poor
MNP	Madagascar National Park Management
NGO	Non-Governmental Organization
SES	Social-ecological systems
SET	Social-ecological trap
SuLaMa	Sustainable land management in southwestern Madagascar
TNP	Tsimanampetsotse National Park
UNICEF	United Nations International Children's Emergency Fund
USDARS	United States Department of Agricultural Research Service
WFP	World Food Program of the United Nations
WWF	World Wide Fund for Nature

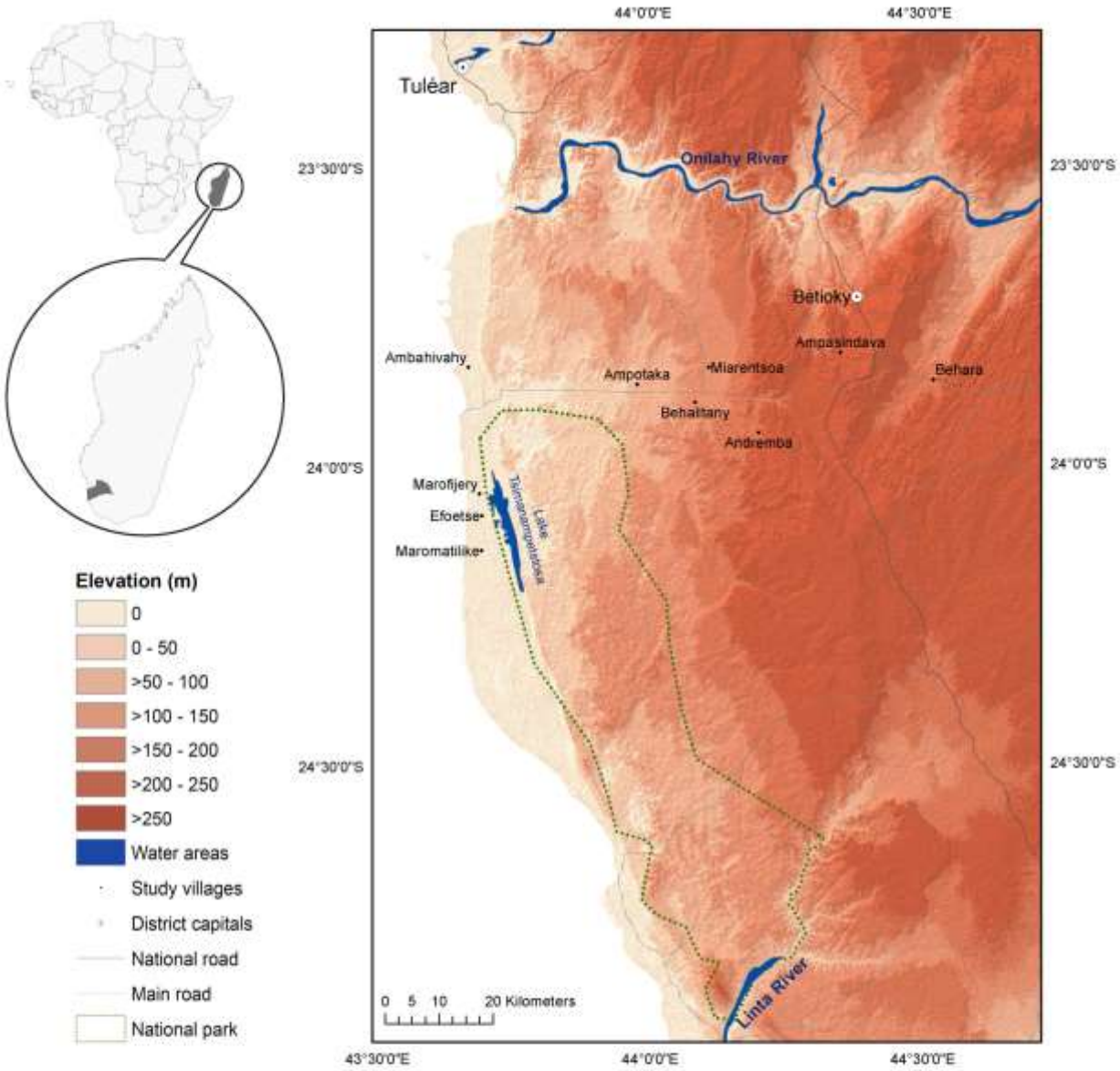

Figure 1: Map of the study area

INTRODUCTION

Southwestern Madagascar is not only one of the "hottest biodiversity hotspots" globally (Myers et al. 2000, Ganzhorn et al. 2001), but also a global food insecurity and poverty hotspot (WFP 2015). The region harbours unique, highly endemic biological diversity: Its natural vegetation consists of highly specialised dry spiny forest with a plant and animal endemism rate of 75- 90%. The level of endemism is among the highest in Madagascar (Fenn 2003, Gautier & Goodman 2003), which has, as such, one of the highest rates in the world (Myers et al. 2000). However, the regional biodiversity is under threat: 45% of the regional forest cover has been lost in the past four decades (Brinkmann et al. 2014), and many species are at the verge of extinction (Waeber et al. 2015).
At the same time, Madagascar has become one of the poorest countries in the world (World Bank 2015) and has exceptionally high levels of undernourishment, particularly in the semi-arid southern provinces (WFP 2015). In spite of an absence of (civil) war, Madagascar is one of the few countries on this planet which has lower per capita income today than in the 1960s following its independence (World Bank 2015). If this were not bad enough, the situation in southwestern (SW) Madagascar is worse than the average situation in Madagascar: The region is quite disadvantaged in terms of education, general infrastructure, market access, health and governmental extension services (Minten and Barrett 2008, EPM 2011), but also in terms of precipitation (CNA 2015). In recent years, crop failures and severe food insecurity in the region have been reported incessantly (WFP and UNICEF 2011, WFP 2013, WFP and FAO 2014, WFP 2015).

There is thus a twofold challenge in safeguarding one of the poorest communities in sub-Saharan Africa (SSA) while preserving its globally unique biodiversity. Acknowledging this twofold challenge gave rise to the SuLaMa project (Sustainable Land Management in southwestern Madagascar, http://www.sulama.de) the present dissertation is a part of. The overarching project goal is to develop sustainable land use practices in SW Madagascar. SuLaMa includes researchers from a broad range of disciplines such as ecology, zoology, agronomic sciences, animal husbandry, economics, cultural geography and forestry. In fact, prior to the SuLaMa research project, the region received little research attention, and few scientific studies had been conducted and/or were not well documented (Hoerner 1991, Waeber et al. 2015).

The SuLaMa project was organized in 7 work packages (WPs) including WP7 (agroeconomics) headed by Prof. J. Barkmann. This dissertation summarises some of the central work conducted in WP7. WP7 was added to SuLaMa to respond to reviewer calls that demanded a more thorough and detailed treatment of agricultural production than was previously projected by the SuLaMa project

proposal. Initially, the regional diffusion of agricultural innovations (cf. Rogers 1995) was one of the priority activities of WP7. The goal was to identify factors and/or processes leading to the (non-) adoption of agricultural innovations in the Mahafalian area. With that knowledge in hand, we had hoped to substantially facilitate the design of promising innovations. For the respective studies, we partnered with WP2 (agronomy/agro-ecosystem science, Prof. A. Bürkert, Dr. S. Hanisch) to initiate on-farm innovation and demonstration trials. In addition to joint implementation on the ground, WP2 provided an analysis of the influence of agro-ecological factors such as the addition of manure, rainfall and soil parameters on crop yields (cf. Hanisch 2015).
Among other components, the WP7 innovation studies included (i) an inventory of already existing, past agricultural innovations in the region (see questionnaire in Annex 1). They also explored future innovations including (ii) on-farm trials together with WP2 on the adoption of improved cropping inputs/techniques (i.e. drought-resistant seed varieties, use of organic fertilizer; see questionnaire in Annex 2), and (iii) an adoption experiment on vegetable gardening in the littoral (also together with WP2; see questionnaire in Annex 3).

Ad (i): Apart from two introduced beans and very simple, locally produced tools, hardly any agricultural innovations were identified in an extensive survey including >350 households (HHs) in 14 villages. The results of the SuLaMa baseline survey confirmed this result (Neudert, unpublished). Unfortunately, it was also impossible to gain access to documents on the success (or rather failure) of past innovations, e.g., as the regionally responsible GIZ office in Tuléar had still suspended regular operations because of the European Union boycott of the self-declared Malagasy "transition government", which governed Madagascar after the *coupe d´état* from 2009 until early 2014.

Ad (ii): In collaboration with WP2, we ran manure demonstration trials during the 2012-13 annual cropping season in two experimental villages (two control villages, pre-test - post-test design). In the experimental villages, on-farm demonstration plots with a high dose of added manure were established. To diminish the impact of drought on results, a "fast" maize variety was used, as well as sorghum and millet. Unfortunately, the added manure did not result in an agronomically significant improvement of yields (Hanisch et al. 2013). Furthermore, the local affiliate (CDD) of the World Food Program (WFP) initiated a *food-for-work* project in one of our control villages, including adding manure during the trials. Thus, the experimental setup to measure the impact of demonstration trials on innovation related attitudes could not be realized, and a statistical analysis of the attitudinal data did not reveal a consistent respondent reaction to the trials. Expanding the

geographical coverage and in collaboration with CDD/ WFP, we repeated the crop demonstration trials in the succeeding year.
In the annual cropping season 2013/2014, we thus enlarged our demonstration trials to 8 villages and 4 control villages (also pre-test - post-test design). However, in that year, rain-fed agriculture either failed completely due to insufficient or poorly distributed rainfall, or annual crops were completely destroyed by locusts, confirming reports from broader SW Madagascar (FAO & WFP 2014). Consequently, as in the year before, an analysis of the attitudinal data did not reveal a consistent reaction of farmers to the trials, and the adoption of these agricultural innovations did not show a positive trend in the villages surveyed.
In fact, overall attempts to improve cropping systems have shown only very limited success in the region (Hanisch 2015).

Ad (iii): In 2012, vegetable seeds were handed out for free to ~85 HHs by WP2 in Efoetse. However, even for rather "successful" vegetables (e.g. Chinese cabbage, carrots), several months later, less than 20% of those obtaining seeds had actually had any harvests and no commercialisation had taken place at all. Our survey results showed that participants most frequently cited that they were handed out for free as the reason for accepting the vegetable seeds.
Therefore, we switched to a vegetable adoption experiment involving realistic seed market prices in 2013. We contracted local shop owners or market vendors from 10 littoral villages (2 per village) to sell vegetable seeds at a realistic price, accounting for transportation costs from Tuléar. The sellers were also provided with information on vegetable growing, a poster explaining vegetable gardening technically (see Annex 4) and advertisement for vegetable seeds (see Annex 5) both drawn by a local artist. In these villages a representative random survey of innovation knowledge and attitudes was conducted prior to the intervention (t0, n=413). However, vendors barely sold vegetable seeds and adoption of vegetable gardening was almost zero in the villages surveyed.

In sum, highly adverse institutional as well as climatic conditions prevented WP7 from the generation of observational and experimental data sets on regional innovations regarding activities (i) and (ii) of the innovation focus. In contrast, the experimental component (iii) was terminated before it was scheduled because a core result had become more dramatically evident than expected: Under the highly variable precipitation regime in the region and given the overall vulnerable livelihood situation of the local farming population, vegetable gardening is not regarded as an immediately promising activity. Although we provided information and access to seeds at realistic market prices, adoption was close to zero. This result does not rule out that more comprehensive

initiatives may induce a stronger adoption of vegetable gardening. However, it clearly shows that there are limitations, such as the regional availability of seeds, unfamiliarity with vegetables and a lack of vegetable gardening know-how.

It was the second research objective of WP7 to carry out a longitudinal survey (LS) on arable agriculture in the project region. In an LS, respondent HHs were repeatedly administered the same questions, i.e. on farming inputs, cash incomes and expenditures (see I.-III.). In our case, the completed surveys were administered, collected and computed *bi-weekly.* Since 73% of the population >18 years old is illiterate in the region (Neudert et al. 2015), we prepared and tested diaries based on pictograms to overcome difficulties of illiteracy (Wiseman et al. 2005, see Annex 6). Households were contracted to keep these pictorial diaries, and to enter data daily (see below).
The LS had the overall objective of generating detailed, high-resolution data complementing the baseline survey conducted by WP6 (economics). A recall survey alone, such as the SuLaMa baseline survey, appeared inappropriate to the socioeconomic reality on the ground, as local, illiterate households do not keep any written records on their household budgets, prices, yields, etc. The LS had multiple foci:

(I.) An agronomic perspective on arable agriculture focusing on:

1. farming inputs (tools, fertilizer, pesticides, family labour, waged farm labour)
2. farming outputs (assessment of yields),

(II.) an agroeconomic perspective:

3. Cobb-Douglas production functions (Cobb and Douglas 1928) are being estimated for use in SuLaMa's integrated modelling of land use decisions using the longitudinal dataset as described in (I.),

(III.) and a household economics perspective focusing on incomes and expenditures with a special emphasis on seasonality. The surveyed parameters included:

4. crops bought and sold
5. income and expenditures for on-farm labour
6. livestock bought and sold
7. cultural expenditures and income (e.g. funerals, marriages, sacrifices, presents, etc.)
8. non-farm income (industry, mining, tourism, handicrafts)
9. cash expenditures and income for medicine and education
10. cash expenditures for and income from consumption goods (e.g. alcohol, batteries, lamp oil etc.)
11. money sent to and received by family members from outside.

Households participating in the LS were chosen as a stratified random sample based on household clusters generated from the SuLaMa baseline data (Neudert 2013) and the WP7 innovation surveys. Sampling weights were applied so that the dataset was representative for the study area (see Annex 7 for details). After a training and piloting period of four weeks, including feedback workshops to fine tune survey administration, data collection for the longitudinal survey started in December 2013. To complement the longitudinal study, two recall surveys with all households participating in the LS were conducted. The first recall survey covered the lean season 12/2013-05/2014 (see questionnaire in Annex 8), and the second one the entire year of 2014 (see questionnaire in Annex 9). These complementary recall surveys focused on strategies to cope with food shortages that were not covered in the LS, including migration of HH members, changes in livestock holdings, borrowing money, collecting wild food, food intake patterns as well as food aid received.

In addition to the original work presented here, WP7 included two M.Sc. projects. Both had the goal of complementing the research conducted by WP7. The first was performed by Claudia Coral and took place in 2013/2014. Her study followed a "markets for the poor (M4P)" approach (van den Berg et al. 2006) focusing on (i) the role of markets in poverty alleviation, (ii) constraints restricting farmer participation in agricultural value chains (ii) strategies used to hinder/enhance market access, and (iii) a survey on agricultural inputs (i.e. fertilizers, pesticides, tools, seeds). She also collected data on market participation and seasonality of agricultural production, which contributed to chapter 2 of the present dissertation where she is a co-author. Her study is cited as Coral (2014). My input for her thesis provided support for her study and questionnaire design, identifying key marketplaces, and organizational issues regarding fieldwork in Madagascar.

The second M.Sc. project was done by Lucile Manon during the dry period in 2014 (May-September), and focused on cassava stock management by farming households in the study region. In fact, a preliminary finding from our surveys was that local farmers sell their cassava stocks soon after harvest even though they buy cassava back later in the year at a time when prices increase. Her thesis was built on that, and her study consequently addressed reasons for the immediate sale of cassava stocks and cassava post-harvest strategies in the region, i.e. its storage, preparation, post-harvest deterioration, pests, use of pesticides, etc. Her study is cited as Manon (2014).
My input for her thesis provided support for a representative stratified random sampling, whereas she used my sampling weights (see Annex 4) and harvest data from HHs participating in the LS. Moreover, she received organizational support and I partly organized her fieldwork.

Three empirical studies make up the core of this dissertation. In **chapter 1**, longitudinal data sampled from 12/2013 to 05/2014, and the first recall survey are analysed. Here, we investigated the insurance function of livestock in covering food expenses during the hunger season of a drought year accompanied by a widespread failure of annual crops.

The 2013/2014 annual crop season experienced severely low precipitation, poorly distributed rains, and a locust invasion leading to widespread crop failure (WFP and FAO 2014), making our study a "natural experiment". In rural Madagascar, zebu cattle are the most prominently herded animal, and the number of heads a household owns is a strong indicator of both prestige and social status (Fauroux et al. 1987). Because of the high sociocultural value of zebu cattle in the Malagasy culture (von Heland and Folke 2014), there is substantial disagreement on the actual role zebu cattle herding plays in terms of livelihood security. Wüstefeld (2004) claimed that zebu might have an insurance function in semi-arid Madagascar, that is, livestock could be sold in order to buy food staples when arable crops fail. However, many authors and development organisations tend to deny the importance of an insurance function, and regard zebu animal husbandry as an "economically irrational" activity (Rauh 1992, Klein et al. 2008, Jamison-Cash 2015). Consequently, regional biodiversity conservation and development projects have largely ignored animal husbandry, as the potential for sustainable intensification appears low (cf. Wüstefeld 2004, Klein et al. 2008). Empirical micro-level data on the actual role of livestock herding in terms of HH economics is missing, however. With this study, we intend to narrow this knowledge gap by analysing the economic insurance role of zebus by surveying (i) cash income from all major agricultural activities, (ii) cash income from zebu as well as other livestock, (iii) off-farm and non-farm income sources, and (iv) cash expenditures on food and other consumption goods. This dataset sheds empirical light on the actual role of zebu, as well as a non-cattle related livelihood and coping strategies to buffer smallholders against the effects of severe droughts and associated crop failures in southwestern Madagascar.

The results show that HHs generated less then 5% of total cash income from food crop sales, and spent, on average, >50% of their total cash income on food purchases. Households employed diverse strategies to cope with the crop failure, such as reducing food intake, collection of wild foods, reliance on food aid, and emigration of HH members to urban areas. Poor HHs also engaged in low-return activities such as waged farm labour on neighbours´ fields. Proceeds from the sale of livestock accounted for >45% of cash food expenditures, on average. In sum, we documented a

substantial insurance function from zebu herding, but – in part more importantly for the poorest households – also for small ruminants, i.e. goats.

There is a persistent view of a "cattle complex" in Madagascar. Proponents of the cattle complex hypothesis assume that local land managers accumulate livestock in order to gain social status but are not willing to sell their cattle (Réau 2002, Wüstefeld 2004, Klein et al. 2008, Jamison-Cash 2015). The results of this study severely challenge this view, as an important actual insurance function is documented. The "cattle complex" narrative led to low support for pastoral development projects by donor agencies in the past, which tended to exclusively promote arable farming and biodiversity conservation projects in southern Madagascar (Wüstefeld 2004, Kull 2014). The virtual exclusion of livestock from development activities in southwestern Madagascar should be reconsidered based on the results of the study presented.

Chapter 2 investigates causal links between hunger, poverty and environmental degradation, including feedback loops, among these factors in the region. The analysis is based on longitudinal data for the entire year of 2014. In addition, a recall survey covering exactly the same period was conducted (see Annex 7) and the results of a complementing market participation survey are included (Coral 2014). Further complementing the longitudinal study as well as the SuLaMa baseline survey, we also measured agricultural yields from households participating in the longitudinal survey *in situ*.

Despite a large number of regional rural development programmes, no effective progress in terms of agricultural income or well-being among farming households was observed in SW Madagascar: The region has been called a "project cemetery" (UNICEF 2011). At the same time, environmental degradation and the loss of biodiversity are prevailing problems.
Why is SW Madagascar apparently locked in its dismal socioeconomic and ecological state? What is the relationship between the productivity of smallholder farming and the status of surrounding forest and rangeland ecosystems? Chapter 2 presents a causal analysis from a *social-ecological systems* perspective to address these questions (Folke et al. 2010). Specifically, we analyse interactions between seasonal rainfall, agricultural production, household income, and strategies to cope with hunger. In addition to our primary data sources, we incorporated results from previously published studies on the Mahafaly area, mainly stemming from the SuLaMa project.

To guide our analysis, we use the concept of *social-ecological traps* (SETs) frequently used to

conceptualize the causal interplay of environmental degradation and livelihood impoverishment (Enfors 2013, Boonstra and De Boer 2014). SET analyses are inspired by resilience theory. An SET is said to exist if feedback loops between social and ecological systems mutually reinforce each other in a way that leads towards unfavourable system states (Cinner 2011). To assess crucial social–ecological interaction loops in the Mahafaly area, we used tools from systems analysis (Sterman 2000), particularly causal loop diagrams (CLD) (cf. Sendzimir et al. 2011).

The analysis reveals a complex interplay of pronounced seasonality in income generation, recurrent droughts and crop failures, high agricultural investment risks, and governance failures at several scales. These interplays result in a gradual depletion of environmental assets and hinder capital accumulation and sustainable agricultural intensification for the large majority of local farming households. Based on a CLD analysis, we identified a set of interacting, partly self-reinforcing SETs, which have entrenched the Mahafalian smallholder population in deep poverty while the productivity of the environment declines.

The study provides new insights into the causality of poverty and loss of environmental assets in SW Madagascar. We conclude that current development and conservation agendas suffer from too limited a view of how contemporary social-ecological systems on the Mahafaly Plateau operate. Our results suggest not only that environmental degradation, poverty and hunger are closely linked, but also that they self-reinforce each other. Therefore, these challenges should be addressed simultaneously. A major development challenge in the Mahafaly region is to move beyond the prevailing focus on “coping”, and instead to build a resilience of trajectories for the long term. Therefore, the following key issues should be considered: (i) a sound social-ecological systems understanding is required prior to interventions, (ii) highly risky agriculture and highly variable environmental conditions should be accounted for, where also the (iii) likelihood of failure of “improved cropping systems” should be anticipated, and (iv) insurance to protect against frequently occurring crop failure should be established so that HHs can re-establish themselves after droughts and escape the traps identified. In particular, a focus on non-farm income sources might help to establish trajectories where both livelihoods and biodiversity can thrive in the long term.

Chapter 1 and **chapter 2** identify a stronger focus on income sources beyond arable farming – partly beyond agriculture including animal husbandry – as a crucial step for the sustainable development of the region. **Chapter 3** builds on that and analyses the potential of cactus pear (*Opuntia spp*.) seed oil as an income source for farming HHs in the littoral of the Mahafaly Plateau.

Cacti of the genus *Opuntia* are highly abundant in the region, particularly as living fences on private farmland. Traditionally, *Opuntiae* are an important plant for the livestock-based economy of the region: Their cladodes provide dry season food and water for livestock, and humans consume its fruit particularly during food shortages (Kaufmann 2004, Larsson 2004). Little is known, however, about (i) the quantitative abundance of *Opuntiae* in SW Madagascar, and (ii) about the importance and exact uses of *Opuntia* species and/ or varieties in the region (Kaufmann 2004).

High priced seed oil can be extracted or pressed from the seeds of *Opuntia* fruit. To investigate its economic potential, we inventoried *Opuntiae* in field hedges through GIS analyses, vegetation inventories, and estimated the amount of seed oil that can be produced based on field sampling and laboratory analysis. To assess the socioeconomic impact of a potential large-scale project of regional *Opuntia* seed oil production, we conducted interviews with 51 farming HHS on preferences for the utilisation of *Opuntiae* and *Opuntiae* products, including human consumption and utilization as animal fodder (see questionnaire in Annex 10).

The research objectives of this study were:

a) To identify the different *Opuntia spp*. and/or varieties and assess their quantitative abundance in field hedges.

b) To assess the potential competition between traditional uses of *Opuntia spp.* fruit, particularly during the lean season (human consumption, contribution to food security, economic activities, utilization as fodder) and seed oil production.

c) To assess potential seed oil production per average farming household. This includes an *Opuntia* inventory, an estimate of fruit quantity/HH, the determination of the seed content of the fruit, as well as of the oil content in seeds.

d) To determine the overall potential of commercialised *Opuntia* seeds as an alternative income source requiring (i) a comparison of the seed oil content in a global context and (ii) consideration of accessible value chains/commercialisation options, including actual and potential uses of by-products (e.g. fruit pulp, presscake) of *Opuntia* seed oil.

We found five different *Opuntia* varieties belonging to at least three species. Two of the varieties contribute >50% to total food intake during the lean season. Conversely, three *Opuntia* varieties are not eaten by local residents (*O. ficus-idica*, *O. stricta*, and a species/variety locally called

"rengevoke"). These varieties are more spiny, and respondents mentioned a higher seed content in the fruits leading to digestive problems and constipation. The vegetation inventories showed that the *Opuntia* varieties with inedible fruits are more abundant in the surveyed field hedges. The combination of low local nutritional use, high seed content, and high abundance offers promising potential for regional *Opuntia* seed oil production from two varieties. However, to avoid competition risks between human nutrition and a commercialisation of local *Opuntia* seeds, regional sourcing strategies should exclusively target *Opuntiae* with inedible fruit. In sum, the rising international demand for *Opuntia* seed oil may bring livelihood improvements to some of the poorest rural communities in Madagascar.

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Chapter 1: The insurance function of livestock: farmers' coping capacity with regional droughts in southwestern Madagascar

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[1] I did the fieldwork, data collection and data analysis. Jan Barkmann contributed to the initial idea, the study design, as well as the writing of the manuscript.

ABSTRACT

In semi-arid areas, rangeland herding is generally attributed to an insurance function for smallholder households relying otherwise on rain-fed agriculture. In southwestern Madagascar, zebu cattle are the most prominent herded animal, and the heads a household owns is a strong indicator of both prestige and social status. Given the extreme socio-cultural value of zebu cattle in Malagasy culture, however, many authors question the actual economic rationale of zebu accumulation. Consequently, improved cattle herding has been widely ignored as a suitable target for development interventions. Empirical micro-level data on the actual role of zebu herding in terms of household economics is missing, though.

With this contribution, we intend to close this knowledge gap by analysing the economic importance of zebu herding against (i) the general role of animal husbandry and against (ii) non-cattle related livelihood and coping strategies to buffer smallholders against the effects of severe droughts and associated crop failures in SW Madagascar.

We conducted a longitudinal household and farming survey (n=150 households, stratified random sampling, *bi-weekly* data acquisition) in southwestern Madagascar (Mahafaly Plateau and the adjacent littoral) covering the lean season of a drought year aggravated by a severe locust invasion. From 12/2013 to 05/2014, households generated less then 5% of total cash income from food crop sales, and spent on average >50% of their total cash income on food purchases. Proceeds from the sale of livestock accounted for >45% of cash food expenditures. Remittances from outmigrated household members were the 2nd most important income source. Similarly, the collection of wild food, e.g. wild yams and cactus fruits, and the reduction of food consumption were widespread coping strategies. Many households also relied on food aid from NGOs. The sale of zebu contributed a highly variable share to total lean season income, whereas the poorest households relied least on zebu sales.

In sum, we can document a substantial insurance function from zebu herding, but – for poorer HHs even more importantly – also for small ruminants, i.e. goats and sheep.

Keywords: Africa; Madagascar; semi-arid regions, insurance function; food security; rural development

1. INTRODUCTION

In semi-arid southwestern Madagascar, rural smallholders experience an annual "lean season" (Malagasy: *kere*). Combined with low absolute agricultural yields, the lean season is a result of a pronounced seasonality of food production, which is, in turn, induced by a strong dichotomy between a short rainy season and a long dry season. Rainfall variability within and between rainy seasons increases the level of uncertainty for agricultural production (Cooper et al. 2008, Ratovonamana et al. 2013). At dry, agriculturally marginal sites such as southwestern (SW) Madagascar, agricultural systems that also rely on cattle herding offer major advantages over systems relying exclusively on arable agriculture (Wüstefeld 2004).

In semi-arid areas of Madagascar, farming households regularly keep animals such as goats and zebu cattle (Wüstefeld 2004, Neudert et al. 2015), and livestock can be sold in order to buy food staples when arable crops fail (Swift 1986). Hence, animal husbandry can be considered as an *ex-ante* risk-management strategy. Because of the extremely high social value of zebu cattle in the Malagasy culture (Fauroux et al. 1987, Wüstefeld 2004), however, there is substantial disagreement on the actual role that zebu cattle play in terms of livelihood security. Some authors tend to deny the importance of an insurance function, and regard zebu animal husbandry as an "economically irrational" activity (Rauh 1992, Jamison-Cash 2015). This assessment is based on several observations.

- Substantial resources in terms of labour, water and rangeland biomass are needed for zebu production. Still, farmers are reluctant to sell or consume zebu cattle except for culturally mandated practices such as funerals, circumcisions, and marriages (Wüstefeld 2004).
- The size of a zebu herd is widely regarded as an indicator of social status. For example, traditional graves are adorned with skulls from the zebu herd for the deceased (male) household head (SuLaMa Marp 2011).
- Despite high livestock numbers, there is no systematic dairy production (SuLaMa Marp 2011).
- Zebus are believed to have a strongly negative impact on biodiversity, for example on the endemic biota in and around the Tsimanampetsotse National Park (TNP) in SW Madagascar's Mahafaly region (Réau 2002, Kaufmann and Tsirahamba 2006, Ratovonamana et al. 2013), which is one of the "hottest biodiversity hotspots" globally (Ganzhorn et al. 2001). These forests harbour unique, largely endemic flora and fauna, and contribute considerably to livelihood security (Andriamparany et al. 2014).

Consequently, some regional conservation and development projects have ignored animal husbandry, as the potential for sustainable intensification appeared low (cf. Zaal 1999, Wüstefeld 2004). Systematically sampled data on the economic role of zebu cattle is scarce at best, however (Wüstefeld 2004).

Three current developments are pressuring traditional zebu husbandry in the Mahafaly region. First, the substantial expansion of cropland has reduced the total amount of forest and rangeland accessible to herders (cf. Brinkmann et al. 2014). Second, the only slowly abating political crises in Madagascar since 2009 have precipitated a demise of law and order, and resulted in an increase in cattle theft. The *Malaso* (Malagasy: cattle thieves) have evolved into organised, criminal gangs who use modern weapons and attack entire villages (Feldt 2015, Götter 2015). Particularly the extension of the TNP from 43,200 to 207,000 ha in 2010 (Kiefer 2011) is restricting traditional migration routes of zebu transhumance and access to water sources within the TNP. Locals report that stiff fines are imposed if cattle are kept in the TNP.

If zebu herding does have an important insurance function, these pressures may destabilise the already vulnerable livelihoods in the region. Against this background we conducted a detailed socio-economic longitudinal survey using a representative stratified sample of farming households (n=150). The households (HHs) span a transect from the Mahafaly coast (littoral) west of TNP to the upper parts of the Mahafaly Plateau east of TNP (see Figure 1). The study covers the 2013/2014 cropping season, a year known to yield an insufficient harvest of annual crops for many households in the region (WFP and FAO 2014, Hanisch 2015).
To comprehensively assess the insurance role of zebu husbandry, we surveyed (i) cash income from all major agricultural activities, (ii) income from zebu as well as other livestock, (iii) off-farm and non-farm income sources, (iv) cash expenditures on food and other consumption goods. This database sheds empirical light on the actual role of zebu, as well as other livestock and non-farm income sources, and may provide hints to potential interventions and self-organising developments that can effectively increase livelihood resilience (cf. Ellis 2000).

1.1 Risk-management, coping strategies and livelihood diversification

Even if there is a lasting view of African farmers as “subsistence farmers” (Barrett et al. 2001) including farmers in SW Madagascar (SuLaMa Marp 2011, Neudert et al. 2015), there is in fact little evidence to support this view. Particularly African farmer households whose livelihoods are

vulnerable to climatic risks are often forced to adopt livelihood strategies beyond subsistence agriculture (Barrett et al. 2001). In Sub-Saharan Africa (SSA), around 34% of HH income is, in fact, estimated to come from non-farm sources (Haggblade et al. 2010). The importance of non-farm income is underscored by a positive relationship between non-farm income and HH welfare indicators across most of rural Africa (Ellis 2000, Barrett et al. 2001). More diversified livelihood systems have the additional advantage of being more easily adapted to changing ecological, agronomic or institutional environments (Ellis 2000). Thus, non-farm income has a clear potential to increase socioeconomic resilience at the household level (Ellis 2000). Livelihood diversification by rural households is, thus, regarded as an *ex-ante* risk management strategy.

Ellis (2000) coined the term risk *mitigation*, distinguishing between *ex-ante* and *ex-post* risk mitigation strategies. Similarly, Alderman & Paxson (1992) differentiate between risk *coping* and risk *management* strategies. While risk *management* has the goal of reducing the riskiness of income generation *ex-ante (*e.g. though livelihood diversification*),* risk *coping* strategies relate to both self-insurance (e.g. *ex-ante* precautionary savings) and *ex-post* short-term strategies in response to a shock (Davies 1996). The accumulation of a large herd of zebus, for instance, can be viewed as precautionary savings, as it represents an asset that can be liquidated in times of need (Dercon 2002). Risk *coping/ex-post* risk mitigation strategies habitually aim at maintaining minimum food consumption levels, health expenditures, or social status (Adams et al. 1998). *Ex-post* coping strategies include the liquidation of assets (e.g. sell and/or consume), reallocation of labour, temporary reduction of food consumption, temporary outmigration of household members, and reliance on loans or gifts from family members or social networks (Adams et al.1998, Cekan 1992).

1.2 Insurance function of livestock in Sub-Saharan Africa (SSA)

Households in semi-arid Africa may keep livestock as a buffer stock to insulate their consumption from fluctuations in income and crop performance. Particularly in SSA, livestock has been discussed as a crucial asset for vulnerable households to safeguard livelihoods and food consumption against income and agricultural production shocks (Fafchamps et al. 1998, Kinsey et al. 1998, McPeak 2004). Livestock is purchased to accumulate capital in higher income years, and sold to satisfy consumption requirements in lower income years. Empirical studies, however, do not provide unanimous support for such a buffer or insurance hypothesis (Rosenzweig and Wolpin 1993, Fafchamps et al. 1998, McPeak 2004). Specifically for semi-arid Africa, there is evidence that cattle is used less to smooth out consumption in times of crop shortfalls than has been expected

(Fafchamps et al. 1998).

Structurally, the insurance function of cattle is limited by the correlation of *income shocks* and *asset shocks* (McPeak 2004). For example, exogenous shocks such as extended droughts, floods or fires, can result in low harvests from arable agriculture, and a loss of cattle at the same time. Furthermore, robbery or civil unrest can largely undermine the capacity to store wealth securely in the form of livestock. The buffering capacity of zebus is further reduced by a decline in zebu prices, which is induced by higher market supply when many zebu holding HHs liquidate their cattle assets simultaneously, as households are affected by the same shocks.

1.3 The special role of zebus in Malagasy culture

The socio-cultural role of zebus in Malagasy societies is well researched, mainly from an anthropological perspective (Fauroux et al. 1987, Fauroux 1989, 1994, Anfani 2005, Jamison-Cash 2015). In line with these results, zebus are of high socio-cultural importance, also in the Mahafaly region (SuLaMa Marp 2011, Feldt 2015). Households hold 16.9 $\pm$ 3.5 head of zebu (mean $\pm$ 1 SE) (Neudert et al. 2015). Both in the local *Mahafaly* and *Tanalana* cultures, the exchange of livestock serves as an expression of family obligations and social networks. Most significantly, zebus represent a religious connection between the living and the ancestors (Fauroux 1989, von Heland and Folke 2014) and are consequently regarded as sacred animals.

In the literature dealing with zebus, their socio-cultural importance has dominated scientific narratives for a long time, while the economic importance of zebus has been recognized rather recently in Madagascar (Wüstefeld 2004). Indeed, zebu keepers are often regarded as economically irrational, as zebus are said to contribute little to local livelihoods (Rauh 1992, Ferguson 1990, Jamison-Cash 2015). In fact, cattle holders rarely consume zebu meat themselves (*ibid*); and despite high livestock numbers, animal protein consumption is very insufficient in southwestern Madagascar (UNICEF 2013, ACF 2014). Correspondingly, many of the authors cited in the book by Wüstefeld (2004) claim that the main motivation for accumulating zebus is to establish social status and to use zebus in cultural rituals.

Little is known, however, about the economic importance of zebu husbandry (Wüstefeld 2004), and many assume that the zebus´ economic insurance function is inferior to their socio-cultural role (see References in Wüstefeld 2004).

1.4 Background and research questions

During the cropping season for annual crops from November 2013 to May 2014, southwestern Madagascar experienced a partly very low rainy season and partly poorly distributed rains (WFP and FAO 2014). In addition, the cyclone *Haruna* hit the area in February 2013. It brought patchy rainfall to parts of SW Madagascar, and wind and inundation damage to crops and other parts (WFP and FAO 2014). However, there are no reports of widespread cattle die-offs caused by the drought or the cyclone. Early signs of a severe locust plague in the region prompted the Food and Agriculture Organization of the United Nations (FAO) to start an anti-locust campaign in November 2013. The campaign reduced damages compared to previous locust outbreaks, but some villages were hit hard, though (FAO 2014, WFP and FAO 2014, *own survey data*). In sum, crop failures in annual crops were regionally widespread, while emergency food aid was channelled into the region spearheaded by the World Food Program (WFP), and ACF (French: *Action contre la faim*), among others (ACF 2014, WFP 2015).

Our longitudinal dataset starts in December 2013, covering the typical lean season from the start. Due to the failure of annual crops in particular, famers experienced an extended lean season in 2013/4. Consequently, it appeared likely that a substantial share of households had to invoke the insurance function of livestock (cf. Wüstefeld 2004). Thus, we were in a prime position to investigate how "subsistence" farming households cope with multiple shocks, and which role their livestock assets play in coping with these shocks. Specifically, we analysed the correlation of cash income from zebus with off-farm and non-farm income, as well as with the sale of arable crops for the lean and cash crop harvest season (12/2013-05/2014). Through this, we provide a view into households' livelihood and coping strategies among which they can choose in order to survive in such harsh circumstances.

2. STUDY SITE

The Mahafaly Plateau is a semi-arid area in southwestern Madagascar. The local population belongs to the *Mahafaly* and *Tanalana* ethnic groups. Directly at the coast, there are fishing villages of the *Vezo* people. Local land users are small-scale farmers: the average farm size is 1.1 ± 0.1 ha and every HH owns an average of 2.4 ± 0.1 fields (*own data*; mean ± 1 STE). The area belongs to the poorest and most disadvantaged areas in Madagascar (SuLaMa Marp 2011), which is itself among the 10 poorest countries in the world (IMF 2015). It is estimated that 90% of inhabitants live below the poverty line (INSTAT et al. 2003, EPM 2011). The few freshwater resources are heavily contaminated with pathogenic bacteria (Rasoloariniaina et al. 2014), soils are poor and the built infrastructure is weak (INSTAT et al. 2003). Rainfall is low with a west to east gradient (mean: 200 mm-600 mm annually; CNA 2015), rendering arable agriculture highly risky (Hanisch et al. 2013, Hanisch 2015).

Local farmers grow cassava *(Manihot esculenta)* and sweet potatoes (*Ipomoea batatas)* as staple crops. Among the annual crops are: maize *(Zea mays*), millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor),* and different leguminoses such as the *Antsamby (Vigna radiata)* and *Lojy (Vigna unguiculata)* beans *(own survey data),* and several other *Vigna* species (Hanisch 2015). Rarely, vegetables such as tomatoes, onions and garlic are planted in home gardens *(own survey data).* In general, malnutrition is widespread in the area (UNICEF 2010, 2013), and famines have worsened in recent years (WFP and FAO 2014).

The Mahafaly region is one of the global "hottest biodiversity hotspots" (Ganzhorn et al. 2001). Closer to the littoral, the natural vegetation consists of highly specialised dry spiny forest, which has a plant and animal endemism of around 75%-90%, the highest in all of Madagascar (Fenn 2003, Gautier and Goodman 2003). Close by is the national park *Tsimanampetsotse* (TNP), that was extended in 2010 (Kiefer 2011). All study villages are relatively close to the TNP (see Figure 1). Local park authorities prohibit the access of livestock into the park.

3. METHODS

3.1 Sample design and administration of the survey

The local growing and harvest season took place from December 2013 to the end of May 2014. Covering that period, we conducted a longitudinal survey involving 150 households. Based on an interdisciplinary baseline survey in 2012 (including 934 HHs with >20 villages lying on a transect), HH clusters were developed (Neudert 2013). A two-step cluster analysis was run based on categories of HH economic activities (agriculture, animal husbandry, use of natural resources and non-agricultural activities). The HHs were finally subdivided into 6 clusters (Neudert 2013), (see Table 1, classes 1-6).

Table 1: Household cluster description, frequencies and sampling weights for regional extrapolation**;** Source: Neudert 2013, *Cluster based on own data from innovation surveys in 2012 & 2013

Cluster	Cluster description	Absolute frequency in population	Relative frequency in population %	Absolute frequency in stratified sample	Relative frequency in stratified sample%	Sampling weight for extrapolation
1	Traders	91	17.95	18	12	1.50
2	Livestock-rich	31	6.11	18	12	0.51
3	Fishermen	54	10.65	0	0	0.00
4	Wage workers	25	4.93	18	12	0.41
5	Normal farmers	131	25.84	18	12	2.15
6	Forest-resource dependent	88	17.36	18	12	1.47
7	Innovative HHs*	87	17.16	60	40	0.42
All		**507**	**100**	**150**	**100**	

Since the focus of this study is farming households, we omitted fishing households (CL 3) and added a new class of "innovative" households (CL 7), based on innovation surveys in 2012 and 2013. We conducted stratified random sampling, as we wanted to sample the HH clusters from Neudert (2013) to the same extent (18 HHs from Cluster 1-6, excluding 3). However, we sampled 60 HHs from Cluster 7, since we also wanted to put a special emphasis on innovative farming HHs, i.e. farmers that grow different crops and/or use agricultural inputs and/or tools. Each HH was given a random number (N=507) and we chose the HHs by the highest numbers for each cluster. This resulted in a sample of 150 HHs distributed over a total of 11 villages (see Figure 1).

Sampling weights of the cluster (strata) were calculated through:

$W_i = [(n_i / N) / (s_i / S)]$ (see Table 1), where:

n_i= is the number of HHs in strata i (absolute frequency in population)

N= is the total number of HHs in the sampling frame (N=507)

s_i= is the size of the sample having elements belonging to strata i, (absolute frequency in stratified sample);

S= is the size of the sample (N= 150)

These weights were used to adjust for the uneven sampling in the strata and were needed for the extrapolation to the total population in the study area.

In a longitudinal survey, respondent households are repeatedly administered the same questions. In our case, the completed surveys were collected and computed *bi-weekly.*

In the project region, 73% of the population >18 years old is illiterate (Neudert et al. 2015). Therefore, we used pictograms to ease the cognitive burden of the survey for illiterate respondents (Wiseman et al. 2005). The pictograms were essentially pictures in table forms (see Annex 6). Households were contracted to keep these pictorial diaries and entered cash incomes and expenditures daily.

The surveyed parameters included:

1. farm input (tools, fertilizer, pesticides, etc.)
3. crops being bought and sold
4. livestock being bought and sold
5. income and expenditures for on-farm labour
6. cultural expenditures + income (e.g. zebus for funerals, sacrifices, presents, etc.)
7. non-farm income (industry, mining, tourism, handicrafts)
8. cash expenditures and income for medicine and education
9. cash expenditures for and income from consumption goods (e.g. alcohol, cigarettes, coffee, batteries, etc.)
10. money sent to and received by family members from outside

A pre-study of 4 weeks took place, and we collected feedback in several workshops to improve the final survey instrument. The HHs entered the sums of expenditures and income for the parameters to be recorded in pictograms. Although the pictograms were collected and computed only every 2nd week, each household was visited weekly for supervision. Our trained research assistants supported them in entering the data, and made sure that the HH understood the pictograms correctly. Finally, our research assistants entered the data into a Microsoft ACCESS database.

In addition to the longitudinal study, we conducted a recall household survey covering the same period (12/2013-05/2014) involving socio-economic HH characteristics, HH migration, crop pests, livestock holding variance over time, different coping strategies such as the numbers of meals eaten in different periods, the collection of wild food, the borrowing of money, as well as food aid received by NGOs.

3.1.1 Statistical analysis

a) Total cash income and cash expenditure data

Shapiro-Wilk tests were run on total income and expenditure data in order to test if the data was normally distributed. Additionally, Grub´s tests for outliers were conducted. In fact, none of the surveyed variables followed a normal distribution (p=0.01, Shapiro-Wilk test), and all surveyed parameters contained outliers. Most income and expenditure sources had a strong left-sided frequency distribution, that is most HHs were in the lower income/expenditure frequency and very few occurred in high income/expenditure frequency. Furthermore, the dataset also contained many zeros. Thus, we opted to use non-parametric tests.

b) Differences between HH clusters in cash income and cash expenditures from distinct economic activities

In order to test whether there were statistical differences between the HH clusters´ distinct activities (e.g. sales of livestock, income from farm labour etc.), non-parametric Kruskal-Wallis tests were conducted (Sheskin 2004). Next, multiple comparisons through the Dunn´s procedure including Bonferroni corrections were applied. These *post-hoc* tests were applied if the Kruskal-Wallis test indicated an overall existence of differences (see section 4.1 and 4.2).

c) Correlation between livestock numbers per HH and cash income per HH

In order to investigate whether only livestock-rich people sold livestock on balance, we analysed the correlation between the numbers of livestock that households possess and the cash income generated from the sale of livestock. Because the data was not normally distributed (p=0.01, Shapiro-Wilk test) and many zeros occurred in the dataset, we performed non-parametric Spearman-Correlation tests (see section 4.3).

d) Share of HHs engaged in different livelihoods and coping strategies

In addition to the analysis of HH expenditures and HH income, it is also necessary to look at the ratio of HHs who are engaged in different livelihood and coping strategies (Ellis 2000). Likewise, we wanted to estimate the relative profitability of the different economic activities.

So as to see if there were significant differences in applying different livelihood and coping strategies between the HH clusters, we conducted chi-x^2 and Fisher's exact tests for each of the possible pairwise comparisons (see section 4.4).

e) Coping strategies vs. food compensation

In section 4.5, the reduction of meals was calculated as the price difference between the number of meals eaten per day during the lean season and the harvest season per HH, multiplied by the number of persons per HH. Prices per dish were average values for meals in the region (adults: 650 ariary/dish; children: 400 ariary/dish (own survey data; 3100 Ariary=~1€).

4. RESULTS

4.1 Cash Income from food crops and expenditures for food crops

Concerning both total income and expenditures for food crops, we found no significant differences between the HHCL. Since neither the analysis for expenditures was significant ($K_{(5,)}$=10.1, p=0.7; with a mean rank score of CL6=53.0, CL2=66.9, CL3=68.2, CL5=74.8, CL1=84.7, CL7=85.7) nor the analysis for income (K =8.5(5) p=0.13 , with a mean rank score CL6= 51.4, CL3=67.9, CL1= 74.3, CL5=80.1, CL7=82.4, CL2=84.3), we pooled the data for the subsequent analysis.

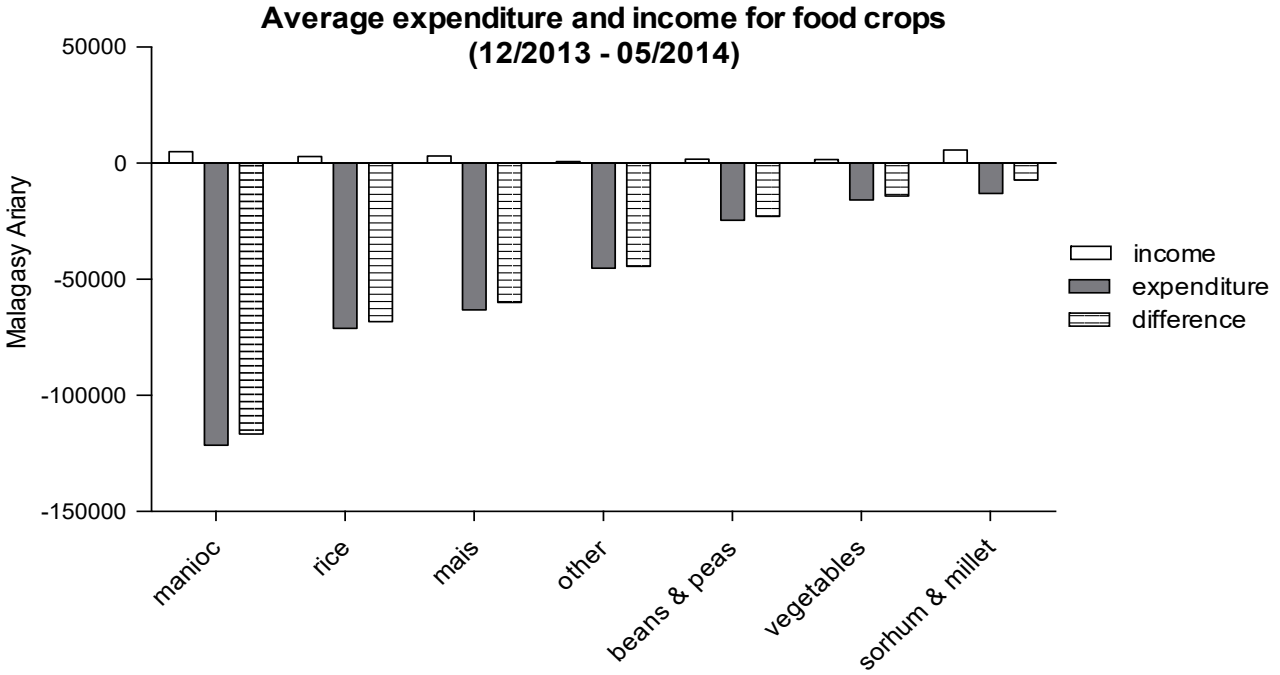

Figure 2: Average cash expenditures and cash income for food crops per HH betweeen 12/2013 – 05/2014, n=150, sampling weights applied. "Other" refers to peanuts, sweet potatoes, etc.

As we see in Figure 2, HHs generated very little cash income from food crops during the 2014 growing and harvest season, and HHs did, on average, spend much more cash on buying food then on selling food.

Concerning cash food expenditures, manioc was the most often purchased crop followed by rice and maize. Low-quality rice, which comes mainly from Pakistan, is traded in the villages, but is not grown in the region. Besides, different varieties of beans were traded, most of them belonging to *Vigna spp*. All vegetables (garlic, melons, onions, tomatoes) together made up only roughly 2% of all food cash expenditures. On average, a farmer earned only 21,000 Ariary (~7€) during the 6 months from selling food crops, but spent almost 17 times as much: ~350,000 Ariary (~115€) for buying food crops.

4.2 Cash income from and expenditures for animal husbandry, off-farm and non-farm income

The sums of total animal husbandry, off-farm and non-farm income, neither differed between HH clusters´ total cash income (Kruskal-Wallis tests: total income: $K_{(5)}$=3,9, p=0.6; with a mean rank score of CL5=63.5, CL6=64.1, CL1=77.5, CL7=78.7, CL2=80.3, CL3=85.06;) nor total expenditure ($K_{(5)}$ =8.1 p=0.13, with a mean rank score CL6= 58.0, CL3=61.2, CL7= 76.4, CL5=81.5, CL2=84.6, CL1=92.5). Concerning specific activities, however, such as income from paid labour or cash income from livestock, we found numerous differences between the household clusters (see below).

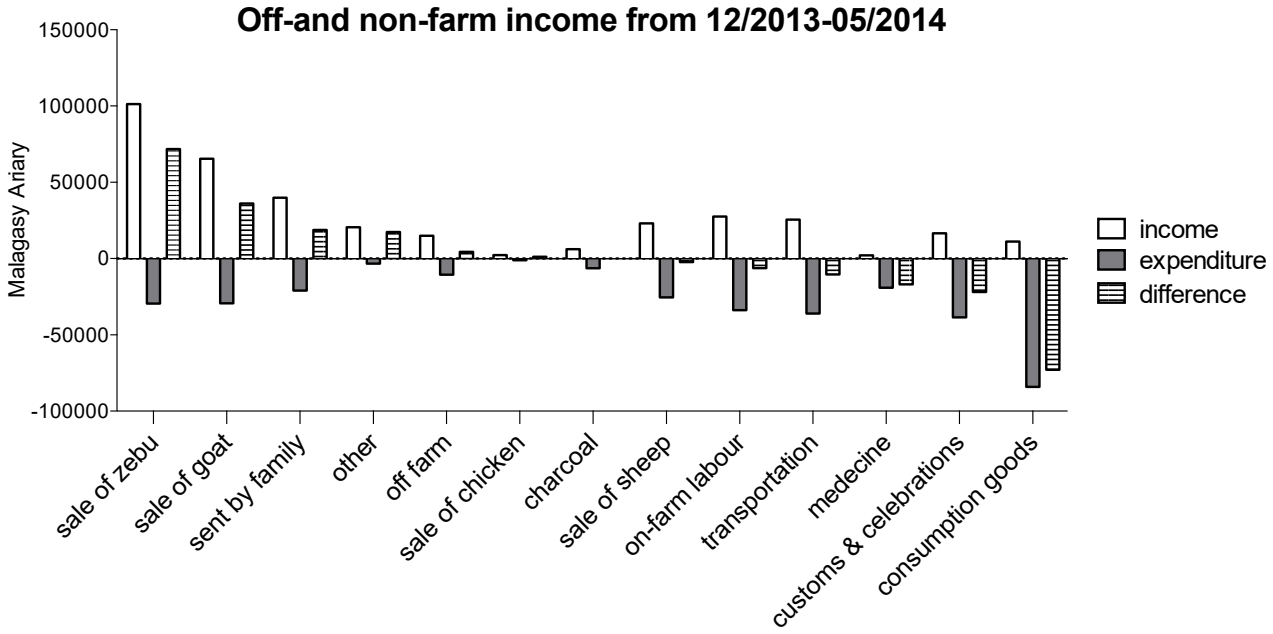

Figure 3: Cash income and expenditure from animal husbandry and trade, and from off-farm and non-farm income sources, sampling weights applied (summed food balance= ~350 000 Ar, see Fig.2)

When we compare Figure 2 and Figure 3, it is obvious that cash crops contributed only 5% of total average cash income, though food was by far the main cash expenditure item (43-56% of total cash expenditures, around 350,000 on balance).

HH spent around 12% of total cash expenses for the consumption goods other than food, such as alcohol, cigarettes, batteries, lamp oil, etc. Expenses for customs and celebrations (e.g. funerals, marriages and religious events) constitute the 3rd most important expenditure class, followed by medicine and education.

Livestock-rich and big field owners (Cluster 2) spend 8.5% of their total cash expenses on farm labour. The wage worker HH (CL4) and forest resource dependent HH (CL6) gained significantly more cash through labour on others' fields then the other HHCL (p=0.03, Dunn´s test). Around 12% of all HHs stated that they had at least one family member who had emigrated – either temporarily or permanently – due to HH income constraints in the period covered. Money being sent by family members from outside was the 3nd most important cash income source on average

after the sale of zebus and goats (see Figure 3). Big field owner and livestock-rich HHs (CL2) received significantly more often money from family members from outside than forest resource dependent HHs (CL6) and the "innovative" HHs (CL7) (p=<0.05).

Livestock-rich HHs (Cluster 2) and wage workers (CL4) spent a relatively large proportion of total cash on zebus but did earn more than they spent on zebus. The poor forest-resource dependent HHs (CL 6) and the "innovative" HHs (CL7) invested little in zebus; instead they sold zebus on balance. "Normal" farmers with little livestock and small fields (Cluster 5) earned significantly less from zebus than all other HHs (p=<0.05 compared to CL1 and CL7, p=<0.1 compared to CL3, CL4 and CL6 in Dunn´s tests), but did sell goats and sheep instead. They are also the HHs that possessed fewer zebus then the other HH cluster members on average (only significantly less then CL2, see Figure 5).

Zebus were in general the most important cash income source followed by goats and money that was sent by family members from outside (see Figure 3). During the lean period of 2013/2014, HHs derived around 51% of their total net cash income from selling livestock (~200,000 Ariary).

4.3 Correlation between livestock assets and income

The analysis showed that there is a weak correlation between the number of heads of zebu or goats per HH and the amount of money earned from the sale of zebus or goats (r=0.31, p=0.001 and r=0.22, p=0.001, respectively). This result indicates that livestock revenue is correlated with the size of the herd, but that the correlation is not very strong, though. For example, livestock-rich HHs (CL2) posses significantly more zebus and goats then the other HHCL (p=0.001); however, they did not sell significantly more (cf. Figure 4 and Figure 5).

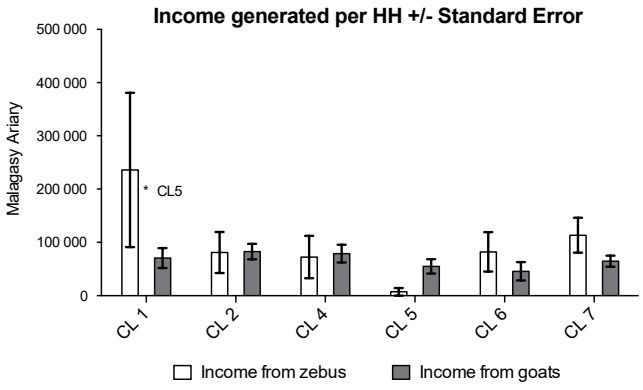

Figure 4: Average cash income generated from livestock by HHCL between 12/2013-05/2014, Error bars indicate +/- 1 S.E

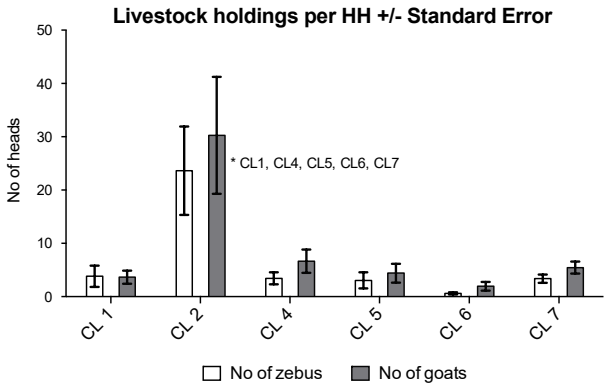

Figure 5: Average livestock holdings by HHCL, Error bars indicate +/- 1 S.E.

Interestingly, only the trader households (CL1) earned significantly more cash income through zebus on average then households from other HHCL (p=0.001). Normal agriculturalists of CL5 sold very few zebus. Comparing cash income from zebus to cash income from goats, we found that

income from goats was more evenly spread among the different HHCL, and that there was less variance within the HHCL (see Standard Error bars in Figure 4).

4.4 Coping strategies

After conducting chi-x^2 and Fisher´s exact tests on each of the possible pairwise comparisons, we found significant differences between the HHCL concerning their implemented coping strategies. Almost all HHs – from all clusters – did collect wild foods (see Figure 6), mainly in the forests, while only wage workers (CL4) collected wild food significantly more often then the innovative HHs (CL7). Most often cited were yam roots (*Dioscorea spp.)* and the cactus pear *(Opuntia spp.).*

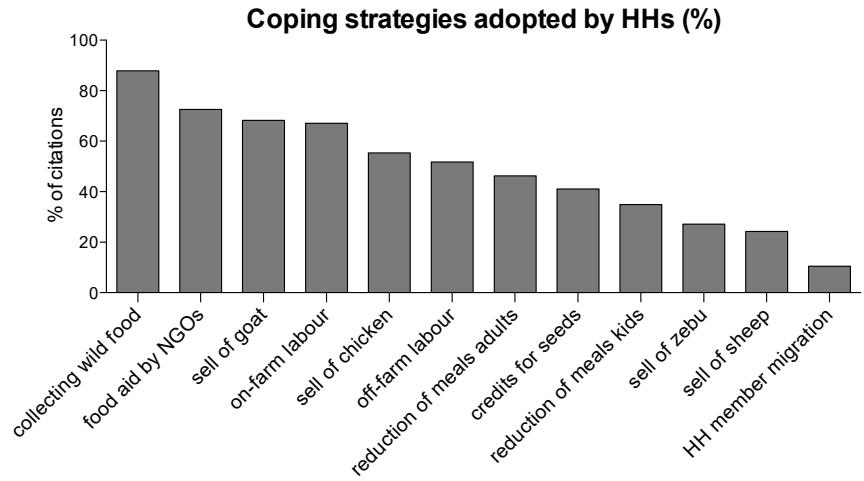

Figure 6: % of HHs that adopted coping strategies, sampling weights applied (see Methods)

Secondly, a big share of all HHs (72%) received food aid mainly through food-for-work programs from NGOs and predominantly in the form of beans (~10kg on average) and maize (~50kg on average) (*own data*). Normal agricultural HHs (CL5) received food aid significantly more often than traders (CL1) (p=<0.05). Great shares of all HHs (67%) also practiced waged on-farm labour, although there were differences between the HHCL: wage workers (CL4) and forest resource dependent HH (CL6) engaged significantly more often in on-farm labour than the traders (CL1) and large field owners (CL2) (p= <0.05).

The selling of goats was practiced much more by HHs (68%) than the selling of zebus (27%).

Another coping strategy was the reduction in the number of meals/consumption, whereas the reduction of meals for children was less common (34%) than the reduction for adults (46%). The forest resource dependent HHs of CL6 reduced their consumption for adults significantly more often than traders (CL1) (p=<0.05).

As mentioned before, 12% of all HHs had at least one family member who emigrated temporarily; innovative HHs of CL7 migrated significantly more often then the livestock-rich HH from CL2 (p=<0.05). Furthermore, asking credits particularly for seeds was widespread: around 40% of all

HHs borrowed money, whereas there were no significant differences between the HHCL. From these credits, ~90% were informal and came directly from family members, neighbours or shop owners, and the average credit taken was only 3940 ± 630 Ar (1.27€ ± 0.20€) without any interest (*own survey data*).

4.5 Insurance function of livestock in relation to food expenditure

In this section, we will look at the insurance function of livestock, that is, how much food expenditure costs could be compensated through the sale of livestock in the covered lean period by the different HHCL. As we saw, the kind of, as well as the amount of livestock that was sold differed between the HHCL.

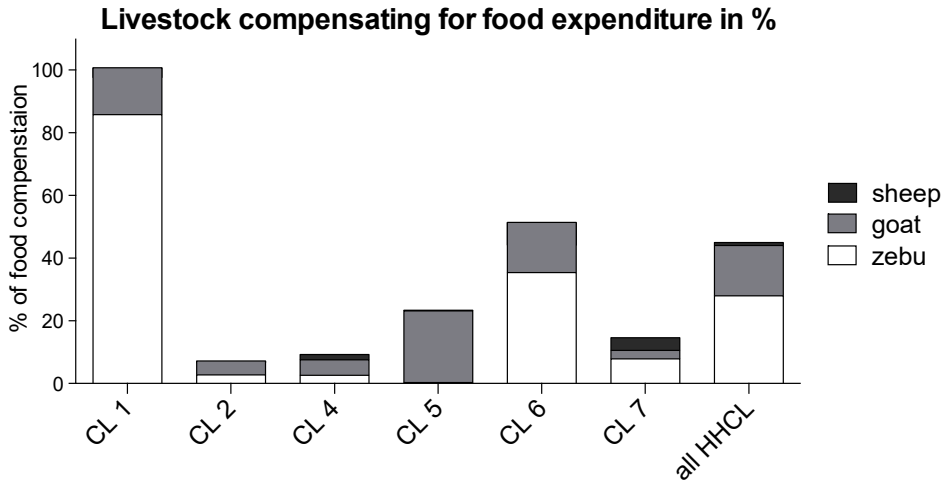

Figure 7: % of livestock net cash income that could compensate for food net cash food expenditures between 12/2013-05/2015, sampling weights applied for "all HHCL" (see Methods)

All HHs excluding normal farmers (CL5) could compensate between 5-36% of their net cash food expenditure through the sale of zebus (see Figure 7). The traders, however, sold much more, and the normal agricultural HHs (CL5) sold goats instead of zebus.

Concerning income from the sale of goats, there were no significant differences between the HHCL (see Figure 4). The net sale of goats compensated for between 5-16% of all net food expenses. Selling sheep still compensated for between 0-4% of food cash expenditures.

Summing up all livestock sales and applying sampling weights to the total population, livestock compensated for > 45% of all food cash expenses.

4.6 Synthesis/ Coping strategies as monetary food compensation in %

Figure 8 synthesizes the impact of coping strategies with respect to the food shortage experienced.

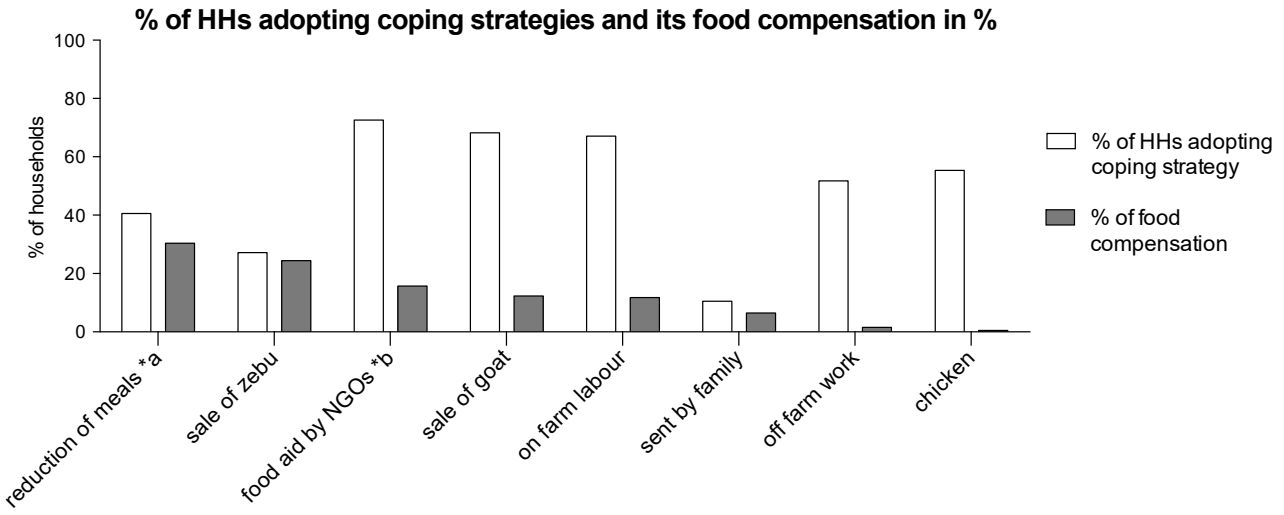

Figure 8: comparism between the % of HH that adopted different coping strategies and the % of food costs that these could compensate (sampling weights applied), *a reduction in meals is calculated, as described in 3.2.e, *b food aid compensation was calculated through crop mass that HHs received, multiplied by average market prices in the region (own survey data)

The reduction in meals accounted for 30% of food shortage. The sale of zebu made the 2nd biggest contribution, followed by food aid from NGOs. Considering around 72% of all HHs received food aid, its average contribution to compensation is relatively low, however (16%).

Waged on farm labour, which a great share of all HHs practiced (67%, see Section 4.4) contributed only 11% to food compensation on average. We found the same pattern for off-farm labour, which consists mainly of construction work, charcoal production, sisal rope manufacturing and handicraft. These activities were in sum conducted by many HHs, but contributed only little to compensation for the food gap.

Money being sent by family members from outside was only practiced by 12% of all HHs, but contributed to around 6% of food compensation on average, however.

5. DISCUSSION

In the rainy season of 2013/4, there was insufficient rainfall, locust plagues occurred, and hardly any household produced a surplus of food crops from arable agriculture. In fact, virtually no households produced even enough for auto-consumption. Our dataset clearly confirms the reports of crop failure in the region (ACF 2014, WFP and FAO 2014). These events made our survey period a "natural experiment" to observe details of household coping with a drought year exacerbated by additional shocks.

Using a highly-detailed longitudinal data set, we could document:

1) How the different HHCL safeguarded their consumption and survival during the crisis
2) Which role livestock played in compensating for food deficits, and
3) What kinds of coping strategies were implemented by the different HHCL

In the following, we will discuss the role of the different livelihood and coping strategies with regard to their contribution to total net income and their insurance function for crop failure.

5.1 Insurance function of livestock

Approximately 51% of total cash income came from livestock sales during the 2013/2014 lean season, and could compensate for around 45% of cash food expenditures in the study region. Most explicitly, these findings indicate the substantial role that livestock plays in the region during a drought year and, thus, clearly confirms the insurance function of livestock at times of arable crop failure.

We found that more then 67% of all HHs sold goats and 27% sold zebus in the period covered. Both species were sold by HHs from all livelihood clusters, including livestock-poor households (see Figure 4 and Figure 5). Goats are more important than zebus for poorer HHs, e.g. from CL4 (wage workers) and CL5 ("normal" agriculturalists), who are the poorest HHs according to our dataset.

Although livestock-rich and large field owners from CL2 tend to possess significantly more zebus and goats than all of the other HHs, they sold very few livestock. Most likely, they hold larger capital then the other HHCL and they don't have to sell, especially considering that livestock prices usually drop during extended "lean periods" (*own survey data*). These findings show that relatively better-off households were not, yet, hit very hard by the 2013/2014 drought, and/or have more

adaptive capacity. While some households sold zebus, others also purchased zebus, taking advantage of the lower zebu prices during the lean season.

Concerning livestock, the cash balance of both zebu and goat is positive if added up across all HHCL, i.e. far more animals were sold than bought. Given the representative nature of the survey, we expect that substantial amounts of animals were sold from the project region´s HHs to outside traders or butchers, most likely from the nearby towns of Tuléar and Betioky. There are also reports of "mobile slaughters" in the region that sell meat on local as well as urban markets.

5.2 On-farm labour

Even though many HHs engaged in waged on-farm labour (67%), this played only an inferior role in total cash income. This is due to the low wages paid of 500-1,000 Malagasy Ariary/day (0.15-0.30 € per day) (*own survey data*). There are diverse sets of salary arrangements, however, that may also include in kind payments. Thus, the contribution of on-farm labour may be underestimated (*own survey data*).

We found that livestock-rich and large field owners HHs (CL2) could afford to spend 9% of their total cash expenses for on-farm labour. They do have a negative cash balance for on-farm labour, while wage workers (CL4) and forest resource dependent HHs (CL6) have a positive balance. Hence, HHs from CL4 and CL6 most likely work on fields of HHs of CL2. Households of CL2 have significantly larger cultivated areas than CL3, CL6 and CL7 ($p=<0.05$, *own data*), and almost certainly need a larger workforce.

Farmers working for cash on others' fields are usually the poorest HHs in such rural settings, as they have the fewest skills, education and capital, and are the least specialised HHs (Barrett et al. 2001). In line with these findings, the wage workers (CL4) were also the ones with the lowest total income in our dataset. Due to crop failure and food deficits, poor HHs (e.g. CL4 and CL6) engaged in low profitable activities such as waged farm labour, charcoal production or other off-farm activities in order to survive.

5.3 Off-farm sources

Many HHs engaged in different activities to earn off-farm income (50%), but off-farm contributed only up to around 2% of total net HH income. The most common ones are charcoal and sisal production (ropes) and construction activities. These work niches, however, are also extremely poorly paid at less then 0.5 € /day (*own survey data*).

5.4 Consumption reduction and nutrition

Households from all clusters did reduce their food consumption during the 6-month period covered compared to the prior 6 months. The poor HHs from CL6 reduced their consumption significantly more often then the other HHs. According to our dataset, children were less affected by the reduction in consumption (34%) than adults (46%). Still, 36% of children are chronically undernourished in the area (ACF 2014), and the reduction in consumption leads to severe malnutrition and undernourishment in the region (WFP and UNICEF 2011, ACF 2014, WFP and FAO 2014).

5.5 Social networks

Even though only 12% of HHs have HH members who work outside the villages, money sent from outside was the 3rd most important income source on average. This is most likely because there are more attractive working options in other areas, and wages in industrial businesses and urban areas are higher than in the villages. Indeed, a lot of HHs have family members working outside either in (semi-) urban areas or in industrial businesses (e.g. mining) who send money to their families in our study area.

5.6 Food expenses

For all HHCL, we recorded a strongly negative cash balance for food from arable agriculture. In physical terms, this gap in food supply was made up by food imports facilitated by traders mainly supplying regional markets such as in Itomboina (plateau) and Efoetse (littoral, see Figure 1), where most people go to buy food (Coral 2014). Another factor that poses a large constraint for HHs is the regional rise in food prices, which commonly occurs during lean seasons (Coral 2014).
Still, most HHs earned more cash in total then they spent for food when taking all income sources into account. In fact, only Cluster 2 (large field owner and livestock rich) and Cluster 5 (normal farmers) spent more cash on food then they earned in total. Households from CL5, however, have the highest HH frequency in the area (see Table 1). Consequently, many HHs could still spend a minimum of resources on social obligations and other consumption goods.

6. CONCLUSION

Livestock plays an integral part in the social, cultural and economic life of southwestern Malagasy communities. Our findings show that livestock was indeed able to compensate for a substantial share of crop failure and thus increased livelihood resilience, that is the ability to cope with change and crisis (Folke et al. 2002).

Agriculture is risky in the region, rainfall is uncertain and often distributed only in small patches (Hanisch 2015), whereas the mobility of livestock has clear advantages. Climate change projections for southern Madagascar show an increase in extreme weather events such as cyclones and prolonged droughts (Tadross et al. 2008, Fitchett and Grab 2014), suggesting that rain-fed farming will become even more difficult in the future.

Alternative income sources are scarce to non-existent in the region, and as the empirical evidence about livelihood research in SSA shows, there are ample barriers to rural farmers looking for high-return non-farm activities (Barrett et al. 2001). Among these barriers are a lack of skills and education, lack of access to capital, as well as market imperfections and weak infrastructure ((Mitchel and Coles 2011).

In line with the literature on livelihood and coping strategies, we have identified animal husbandry as an *ex-ante* risk management strategy, but also as a form of self-insurance coping strategy. Temporary outmigration, on the other hand, was an important *ex-post* risk-mitigation. Unfortunately, the vast majority of households also had to rely on a substantial reduction in food consumption in spite of food aid provisions.

The economic importance of livestock for smallholders in SSA is increasingly being recognized, but the “cattle complex” remains the mainstream view (Wüstefeld 2004, Klein et al. 2008). That is, it is assumed that local land managers are not willing to sell their cattle. Instead, more and more livestock is accumulated in order to gain social status. This view, however, has led to inferior support for pastoral development projects in the past by donor agencies and bilateral supporters, which above all promoted farming and conservation projects (Zaal 1999, Wüstefeld 2004, Scales 2014).

The exclusion of livestock from development activities in southwestern Madagascar, however, is not an option given its high social-cultural importance, and as we saw, its crucial insurance function for crop failure in this harsh environment.

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Chapter 2: Social-ecological traps prevent rural development in southwestern Madagascar

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[2] I did the study design, fieldwork, data analysis, and wrote most of the manuscript. Jan Barkmann contributed to the study design, the initial idea of the study and the writing of the manuscript. The market participation data comes from Claudia Coral, based on her fieldwork, and she wrote small parts of the manuscript. Elin Enfors Kautsky wrote parts of the manuscript and particularly contributed theoretical support on social-ecological traps and systems analysis. Rainer Marggraf discussed and supervised the manuscript.

ABSTRACT

The semi-arid Mahafaly region in southwestern Madagascar is not only a unique biodiversity hotspot globally, but also one of the poorest regions in the world. Crop failures occur frequently, and despite a great number of rural development programmes, no effective progress in terms of improved yields, agricultural income, or well-being among farming households has been observed. Alongside limited success in improving local livelihoods, environmental degradation and the loss of biodiversity are prevailing problems.

Why is SW Madagascar apparently locked in to its socioeconomic and ecological state? What is the relationship between the productivity of smallholder farming and that of surrounding forest and rangeland ecosystems? What would it take to turn current trends around, improving local agriculture and rural livelihoods, while at the same time maintaining the region's unique biodiversity? This paper presents a causal analysis from a *social-ecological systems* perspective to address these questions. Specifically, we analyse interactions between seasonal rainfall, agricultural production, household income, and strategies to cope with widespread hunger. The study is based on high-resolution survey data and longitudinal interview data covering 150 farming households, collected over the full year of 2014.

The analysis reveals a complex interplay of pronounced seasonality in income generation, recurrent droughts and crop failures, high agricultural investment risks, and governance failures at several scales. The interplay results in a gradual depletion of environmental assets and hinders capital accumulation and sustainable agricultural intensification. Households are insufficiently buffered and insured against the resulting repetitive income and food security shocks. This can be understood as a set of interacting social-ecological traps, which entrench the Mahafalian smallholder population in deep poverty while the productivity of the environment declines.

The paper provides new insights about the causality of hunger, poverty and loss of environmental assets in a global biodiversity hotspot. Finally, we propose a set of key issues that needs to be considered to unlock this severe lock-in and enable transformation towards a more sustainable development in SW Madagascar.

Keywords: Madagascar, social-ecological traps, poverty traps, food security, livelihoods

1. INTRODUCTION

The semi-arid Mahafaly region in southwestern Madagascar (SW Madagascar) is a global biodiversity hotspot (Ganzhorn et al. 2001) and one of the poorest regions in Sub-Saharan Africa (World Bank 2015a, WFP 2015a). The region is characterised by a unique spiny forest, and although biodiversity loss is proceeding at an alarming rate, the level of endemic species of plants and animals is still extremely high (Jasper and Gardner 2015). Smallholder agriculture and animal husbandry are the main sources for the local population's livelihood. As in other semi-arid areas, a pronounced seasonality of precipitation poses a constraint to production in addition to the low precipitation itself (Barron et al. 2003, Minten et al. 2009). Droughts as well as extended dry spells during the rainy season occur frequently (Hanisch 2015), and have increased in past decades (Tadross et al. 2008, WFP 2015a). Regional agricultural yields are low, averaging 1-5 ton/ha for cassava, and 0.5-2 ton/ha for maize (Bayala et al. 1998, Hanisch 2015).

Two seasonal peaks characterize food availability. The first peak coincides with the harvest of annual crops (mainly cereals and legumes) around April/May, the second with the harvest of cassava, the main staple crop, in July/August. Often already beginning in November – and steadily increasing until the harvest of cereals and legumes much later – a large number of households (HHs) have been suffering from severe food shortages (Wüstefeld 2004). Locally, this recurrent "lean season" or "hunger season" is called *kere*.

The development challenges in SW Madagascar have not gone unnoticed. In the absence of effective national government interventions, emergency food distribution has been regularly organised in recent years, by the World Food Programme (WFP 2015b), for example. A number of private charities as well as international development cooperation agencies have attempted to improve existing farming systems, reduce malnutrition, improve education, and initiate livelihood diversification. Informally, however, SW Madagascar is known as a "project cemetery", with very little or no effective progress in terms of improved yields, agricultural income and/or general livelihood improvements for the local population (UNICEF 2011, Hanisch 2015).

Similarly, the biodiversity conservation sector in Madagascar has been given a great deal of support by international organisations (Kull 2014). However, the conservation policies implemented have had limited success so far (Kaufmann 2008, Scales 2014). For example, 45% of the spiny forest has been lost in the past 40 years (Brinkmann et al. 2014), and many endemic species are at the verge of extinction (Ganzhorn et al. 2001, IUCN 2015).

Why is SW Madagascar apparently locked in such a socio-economic and ecological state? What is the relationship between the productivity of smallholder farming and that of surrounding forest- and rangeland ecosystems? What would it take to turn current trends around, improving local agriculture and rural livelihoods while at the same time maintaining the region's unique biodiversity? Increasingly, it is being realised that officials, researchers and development practitioners have often relied on oversimplified models of regional social-ecological dynamics (Moreau 2008, Kaufmann 2008, Scales 2014) and unfounded myths about Madagascar's environmental history (Kull 2000, Scales 2014). Instead of a dynamic and detailed appraisal of the trade-offs as well as the synergies of protection and utilisation of the regional landscapes, Malagasy conservation policies tended to downplay the problematic socio-economic impact of ambitious pro-biodiversity projects (Ghimire 1994, Ferraro 2002, Kaufmann 2008).

In order to avoid such an oversimplification, we take a resilience-inspired *social-ecological systems* approach (Folke et al. 2010). This approach focuses specifically on potential social-ecological traps and their dynamics in order to comprehensively analyse the development trajectories in the agroecosystems of SW Madagascar. The paper builds on a rich empirical dataset, including a high frequency longitudinal agro-economic survey to study HH cash income and expenditures chronologically, a recall survey to study HH coping strategies for food and cash deficits, a market participation survey that provides a value chain perspective on smallholder farming, and an assessment of harvest data from the participating households. Our own data are complemented with findings generated through the *SuLaMa* project (http://www.sulama.de). These include research on drivers of environmental change (Brinkmann et al. 2014, Goetter & Antsonantenainarivony 2015, Waeber et al. 2015), biodiversity decline (Ganzhorn et al. 2001, Fricke 2015), challenges to improve agricultural systems (Hanisch et al. 2013, Hanisch 2015), natural resource management (Ratovonamana et al. 2013, Andriamparany et al. 2014, Manon 2014, Andriamparany 2015, Ranaivoson et al. 2015), livestock herding including its economic importance (Feldt 2015, Götter 2015, Hänke & Barkmann *submitted*), socioeconomic HH characteristics and livelihood diversification (Neudert 2013, Hänke et al. 2014, Neudert et al. 2015), value chains (Coral 2014) and institutional changes in the region (Götter and Neudert 2015). Furthermore, a number of reports from international organisations working in the area such as ACF, FAO, UNICEF and WFP were available.

2. SITE DESCRIPTION

The Mahafaly Plateau is a semi-arid area in southwestern Madagascar. It stretches from the littoral in the west to the higher parts of the plateau in the east. The area belongs to the poorest and most disadvantaged areas in Madagascar (EPM 2011), which is itself one of the poorest countries in the world (IMF 2015, World Bank 2015b). The large majority of inhabitants are smallholder farmers (>97%) and/or livestock herders (>60%) (Neudert et al. 2015). Local livelihoods fundamentally depend on locally available natural resources (SuLaMa Marp 2011). In general, malnutrition and hunger are widespread in the area, and have worsened in recent years (own data, WFP & FAO 2014). Rainfall is low, displaying a gradient from roughly 200 mm/yr. in the west to 600mm/yr. in the east (CNA 2015, see Annex 11 for rainfall in 2014). Agronomic droughts have become a chronic problem in recent years, and the frequency of dry spells in southern Madagascar has increased (Tadross et al. 2008, WFP 2015b). The littoral is characterized by sandy soils, and the plateau by calcareous soils (Hanisch 2015). Soil quality is poor, and constrains agricultural productivity through low water holding capacity, low levels of nutrients, and low organic carbon (Andriamparany 2015, Hanisch 2015). On the plateau, groundwater is hardly accessible, with the main groundwater level at 70 m below the surface (de Haut de Sigy 1965). In the littoral, groundwater is easily accessible, but its salt content is too high for irrigation (Guyot 2002, Hanisch 2015).

In this paper, we will analyse the Mahafalian social-ecological system, consisting of rural farm households and their local natural resource base. The system we describe, however, is not an isolated entity. Markets, social networks, family and clan lineages interact with other social-ecological systems at other scales, i.e. outside the study region.

3. ANALYTICAL FRAMEWORK AND METHODS

3.1 Social-ecological traps as a lens for analysis

To guide our analysis, we will use the concept of *social-ecological traps* (SET) (Enfors 2013, Boonstra and De Boer 2014). The impeding development of "traps" has been studied and identified in the rural development literature (e.g. Barrett & Carter 2008), in the ecological literature (e.g. Carpenter et al. 1999) as well as in resilience literature (Carpenter & Brock 2008, Cinner 2011, Steneck et al. 2011, Enfors 2013). The concept of SET is used to conceptualize the causal interplay of environmental degradation and livelihood impoverishment (Boonstra and De Boer 2014). It refers to situations where feedbacks between social and ecological systems mutually reinforce each other and lead towards unfavourable system states (Cinner 2011).

Poverty traps tend to describe the lock-in of people in poverty in a way that is *a posteriori* disconnected from ecosystems, and often describe traps as an exclusively socioeconomic problem (Barrett et al. 2008, Maru et al. 2012). As a result, studies on poverty traps have been criticized in disregarding important ecological parameters (Dasgupta 2007, Maru et al. 2012), as there is evidence for causal relations between both domains, i.e. rural poverty and environmental degradation (Barrett et al. 2011, Sendzimir et al. 2011).

In contrast, SET analysis highlights the ongoing interconnections between people and their natural environment (*social-ecological systems*; SES). Employing systems analysis (Sterman 2000), special emphasis is placed on key system variables, causal feedback loops, and external drivers (Cinner 2011, Sendzimir et al. 2011, Enfors 2013).

The CGIAR's (Consultative Group on International Agriculture Research) Challenge Program on Water and Food (CPWF) applied SET analysis to synthesize what they referred to as six problematic "resilience traps" (RT) from more than 120 research projects globally (CPWF 2014, Vidal 2014). These relate to 1) high risk situations, 2) high ratio between consumption and production, 3) variability that is difficult to deal with, 4) poor access to resources, 5) disenabling policy, and 6) cultural issues that may prevent change (cf. Table 2). In a previous contribution, Barkmann et al. (2015) suggested using these six traps to explain the recalcitrance of poverty in the Mahafaly area. Here, we expand on this suggestion by regarding the "resilience traps" as mechanisms that create and reinforce SET, and evaluate from that perspective in detail if – and how – the resilience traps contribute to the lock-in dynamics observed in SW Madagascar.

Table 2: Resilience traps (Vidal 2014, CPFW 2014) applied to SW Madagascar's Mahafaly region (Barkmann et al. 2015)

Resilience trap	Characterisation
a. Consumption/production traps	The rate of consumption/outtake of bio-resources is too close to or exceeds the production rates – leading to a vicious cycle of resource mining.
b. Variability traps	Small investments in agricultural farming systems do take place (resource limitations make these very small). However, as risks manifest themselves (recurrent droughts, insect invasions, cattle theft), investment failures prevent the medium-term accumulation of capital as well as livelihood improvements.
c. Risk traps	Because of multiple farming risks, incentives to invest in agricultural farming systems are objectively low for smallholder farming HH who lack virtually any capacity to buffer income shocks. Local households "learn" that investments are risky, further increasing their risk aversion.
d. Policy traps	Disenabling policies and lack of transparency prevents markets and resources from being used effectively.
e. Resource access traps	Most farming HHs have only very small plots of arable land – and lack access to irrigation water. Both limitations place a cap on agricultural per HH income.
f. Cultural traps	Mindsets can prevent change. Although local people tend to respect supernatural taboos, and social rural life is strongly influenced by adherence to traditional cultural and clan values, farming decisions tend to be fairly pragmatic given risks and resource constraints.

3.2 System analysis

To assess patterns of casual relationships, we use systems analysis (Sterman 2000), particularly using causal loop diagrams (CLD) to assess crucial social–ecological interactions in the Mahafaly area (see Figure 11). These CLDs illustrate hypotheses about the structure of the relationships behind persistent poverty and environmental degradation in SW Madagascar (cf. Sendzimir et al. 2011), pointing to the potential traps and mechanisms that create them.

In the feedback loop, plus and minus polarity characterize relations between the different variables. Inside the loop, a variable's value may change due to an impact from outside (e.g. an external driver) or due to changes in another variable's value. If the loop exclusively includes relations of the same polarity, it is labelled R (reinforcing). If the loop inverts the path of change, then it is labelled B (balancing) (Sendzimir et al. 2011).

We define a *key system variable* as a biophysical, political, social or economic variable that *prima facie* plays an essential role in shaping the development trajectory of the SES. We regard the capacity to sustain HH food security, HH income, HH buffer/insurance (i.e. against drought and famine) and selected Ecosystem Services as key system variables. Important *external drivers* are defined as variables operating at different scales beyond the Mahafaly area which can influence key system variables considerably (cf. Enfors 2013).

3.3 Field data collection

The input data for the systems analysis comes from four primary sources[3]:

(a) high frequency longitudinal agro-economic survey to study HH cash income and expenditure chronologically,

(b) recall survey to study HH coping strategies for food and cash deficits,

(c) market participation survey to facilitate a value chain perspective on smallholder farming, and

(d) an assessment of agricultural harvests from the households participating in (a) and (b).

a. Longitudinal study of household incomes and expenditures

To assess household incomes and expenditures, we conducted a longitudinal survey from the beginning of January 2014 to the end of December 2014 involving 150 systematically selected households. Of the selected HHs, 90 HHs constitute a subsample of a baseline survey conducted in 2012, including 934 HHs in 24 villages (Neudert 2013). Households participating in this study were assigned to 6 clusters based on main livelihood strategies (agriculture, animal husbandry, use of natural resources, and non-agricultural income). Households from the fishing cluster were omitted, since the focus of this study was on farm households. In addition to the subsample of the baseline survey and in order to diversify the set of agriculturally focused households, we added a cluster of "innovative" households, which use more and/or other agricultural inputs than most households. The HHs of this cluster were drawn from a dedicated innovation survey conducted in 2012 and 2013 (Hänke & Barkmann *unpublished*). Using stratified random sampling, 18 HHs were selected from Clusters 1-6 (excluding the fishing Cluster 3), and 60 "innovative" HHs from Cluster 7. The resulting set of sampled HHs is distributed over 11 villages (see Figure 1). Ten of the 150 selected HHs were found to have migrated out of the study area, resulting in a total of 140 participating HHs. We applied sampling weights to adjust for the uneven sampling in the strata, and in order to be able to extrapolate our results to the total population in the study area (for details, see Annex 12). The parameters of the longitudinal survey included:

a. bought farm input (tools, fertilizer, pesticides etc.)

[3] In addition to these primary data sources, we incorporate results from previously published studies on the Mahafaly area including several studies stemming from the SuLaMa project (see Introduction) (Ganzhorn et al. 2001, Hanisch et al. 2013, Neudert 2013, Ratovonamana et al. 2013, Andriamparany et al. 2014, Brinkmann et al. 2014, Coral 2014, Hänke et al. 2014, Manon 2014, Andriamparany 2015, Götter 2015, Götter & Antsonantenainarivony 2015, Götter and Neudert 2015, Feldt 2015, Fricke 2015, Hanisch 2015, Neudert et al. 2015, Ranaivoson et al. 2015, Waeber et al. 2015, Hänke & Barkmann *submitted*) into which the four primary sources were also involved

b. crops being bought and sold
c. livestock being bought and sold
d. cash income and expenditure for on-farm labour
e. cultural expenditures + income (e.g., zebus for funerals, sacrifices, presents etc.)
f. non-farm income in cash (industry, mining, tourism, handicrafts)
g. cash expenditures and income for medicine and education
h. cash expenditures for and income from alcohol, cigarettes, coffee, batteries, etc.
i. money sent to and received by (external) family members

We asked respondents to keep daily diaries of the above activities, purchases and spendings. In the project region, 73% of the population >18 years old is illiterate (Neudert et al. 2015). Therefore, we used pictograms (Wiseman et al. 2005; see Annex 6) to support the written explanations in the daily record sheets that we provided. Every week, a team of two trained research assistants visited each respondent HH to support record keeping, and to collect report sheets.

After a training and piloting period of four weeks, including feedback workshops to fine tune survey administration, data collection for the longitudinal survey started. Participating HHs were formally contracted, and received a remuneration of 5,000 ariary per month (~1.6€, for comparison = ~ 7 kg of cassava or a small chicken). Thus, participating households were slightly better off than non-participating households, as the remuneration included an incentive component in addition to offsetting the labour needed to keep the record sheets. After quality control, data were entered into a Microsoft ACCESS database.

b. Recall survey of coping strategies

To complement the longitudinal study, we conducted a recall survey with all 140 respondent households covering the 12-month period of the longitudinal survey. The recall survey focused on strategies to cope with food shortages, including migration of HH members, changes in livestock holdings, collection of wild food, borrowing of money, as well as food aid received.

c. Market participation survey

To complement the farm-centred perspective of the longitudinal and the recall survey, an additional survey on market participation was conducted. The market participation survey provides a value chain perspective on smallholder farming (van den Berg et al. 2006, Mitchel & Coles 2011). As we were interested in general trends and mechanisms of market participation, a mix of quota sampling and spatial sampling was conducted targeting commercially active farmers (n=64) as well as local traders (n=56) (for details, see Coral 2014). Following the guidelines from Van den Berg et al. (2006), we sought to analyse how seasonal cash constraints relate to farming activities and food availability.

d. Assessment of agricultural harvests and food self-sufficiency

To get an understanding of the extent to which farm households were self-sufficient or not, we assessed the agricultural yields from all households participating in the longitudinal survey. All yields are reported in dry-matter kilograms (kg_{DM}) per crop, and summed up over all arable plots per HH. Our assistants accompanied HHs to their fields during the harvest season. Field outlines were done directly in the field using GPS tracking. In this way, field sizes (in ha) were determined (n=358). Raw yields were determined *in situ* directly after harvest by our assistants using field scales in ~70% of all yield data points. Dry matter was determined through oven drying at 65°C, proportion factors were calculated (Hanisch 2015, see Annex 13) and fresh harvests were converted into kg_{DM} using these proportion factors. In addition, shell-seed proportion factors by Hanisch (2015) were applied to beans, millet and sorghum.

We also recorded yield estimates of farmers in local units (oxcarts, sacks of rice, baskets, and of tin cans originally containing 100 ml of condensed milk: *"kapoky*"). These yield estimates in local units were compared to our own measured harvests, and averaged to calculate conversion factors from local units to kg_{DM} (see Annex 13). The conversion factors were used for the ~30% of cases where we could not determine the harvest ourselves *in situ*.

We then converted all harvest data into kilocalories (kcal) to estimate food self-sufficiency based on arable crop harvests. Food exchanged for labour or obtained from self-raised animal sources is not included, however. We calculated Minimum Dietary Energy Requirements (MDER) per HH to estimate undernourishment (FAO 2004). Human dietary energy requirements differ by gender, age, body mass index and levels of physical activity (FAO 2008). Accordingly, MDERs vary by country, in time, and also depend on the gender as well as the age structure of the population. Taking national population statistics into account, the FAO (2004) published weighted MDER averages for Madagascar, expressed as kilocalories (kcal) per person per day. Accordingly, the Malagasy MDER is 1,700 kcal/person/day (FAO 2004). To estimate the MDER/HH/2014 for our sampled households, 1,700 kcal was multiplied with the number of people per HH times 365 days. Subsequently, we converted all food harvests by our sampled HH from kg into kcal based on conversion factors (USDARS 2015). To finally calculate the percentage of food self-sufficiency per HH, the MDER/HH/2014 was compared to the total produced kcal/HH in 2014.

4. RESULTS

4.1 Agricultural production (arable crops) and household self-sufficiency in 2014

Households have average land holdings of 2.6 ± 0.2 ha (mean ± SE) distributed over 2.4 ± 0.1 plots (own field measurements). Close to 75% of the total cultivated area is used for four main agricultural products: cassava *(Manihot esculenta)*, maize (*Zea mays*), cowpeas *(Vigna radiata)*, and mung beans *(Vigna unguiculata)*. Farmers generally grow cassava and sweet potato (*Ipomoea batatas)* as continuous crops, often intercropped with beans or peas on old fields with low soil fertility. Fields that have been recently cleared with slash-and-burn are commonly used for annual crops such as maize, millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor),* and different pulses.

Table 3: Harvest overview from the 2013/14 cropping season. N=140. Source: harvest survey and longitudinal survey. [1]Kcal for individual crops were converted through datasets from USDARS (2015)

Crop	N	% of HH	Crop yield (kg/HH)				Kcal[1]			
			Mean	Standard Error	Min	Max	Mean	Standard Error	Min	Max
Cassava	139	99.3	375.3	102.6	0	11,230.4	600,411	164,137	0	17,968,656
Cowpea	134	95.7	35.9	8.1	0	719.5	29,050	6,584	0	582,799
Maize	112	80.0	18.7	4.8	0	558.8	68,183	17,673	0	2,039, 748
Millet	43	30.7	14.6	5.1	0	476.6	55,189	19,357	0	1,801,603
Mung beans	119	85.0	22.8	3.7	0	287.6	78,245	12,815	0	986,510
Sorghum	31	22.1	9.1	6.0	0	844.6	30,050	19,866	0	2,778,755

The year 2014 was poor in terms of rainfall. Total annual precipitation for the Mahafaly region varied between 175 mm (littoral, west) and 500 mm (plateau, east; see Annex 11). Consequently, agricultural harvests were low and consisted largely of cassava. The on-farm yield assessment showed that the cassava harvest averaged at 375 kg per HH (see Table 3). Due to locust invasions that destroyed most maize plots, maize yield was exceptionally low (mean: < 20 kg/HH). Harvests of legumes averaged between 23 and 36 kg per HH (if grown), but the variance was large. Households in the littoral, which also grew millet and sorghum, harvested 10-15 kg of these crops on average.

Table 4: Produced kcal by HH in relation to HH size and Minimum Dietary Energy Requirements (MDER). N =140. Total produced kcal/HH is the sum of all kcal produced in 2014/HH. MDER is 1,700 kcal/day/person (FAO 2004), and was multiplied with the HH size and 365 days. The deficits (kcal) are the total kcal produced/HH/2014 minus the total MDER in kcal/HH/2014.

	Mean	Standard Error	Min	Max
Household size	7.5	0.3	1.0	30.0
Total Kcal produced/HH/2014	1,015,091	225,538	0.0	24,410,908
Total MDER (in kcal)/HH/2014	4,618,292	170,313	620,500	11,789,500
Self-sufficiency (kcal in %) in 2014	21.4	3.8	0.0	393.4
Deficits (kcal) in 2014	-3,570,447	260,372	-11,715,308	18,205,908

Households produced, on average, only 21% of their minimum dietary energy requirements (MDER; Table 4). Eighty per cent of all HHs produced <25% of their MDER, ~11% produced 25-50%, ~6% produced 50-100%, and only ~4% more then 100%.

In the next section we investigate how these annual production averages manifested themselves in terms of food availability and cash flows at different periods of the year.

4.2 Seasonality of food availability and cash flows

Annual crops were harvested from March to May, and cassava in July and August (see Annex 14). The market participation survey showed that the majority of farmers perceived that they had enough food from April to October, whereas they perceived a general food shortage from mid-October to end of March (see Figure 9a; *market participation survey*). Following the harvest periods closely, food expenditures decreased from March to May and from August to September (see Figure 9b). One to two months after the cassava harvest, food expenditures increased steadily and reached their maximum in November-March.

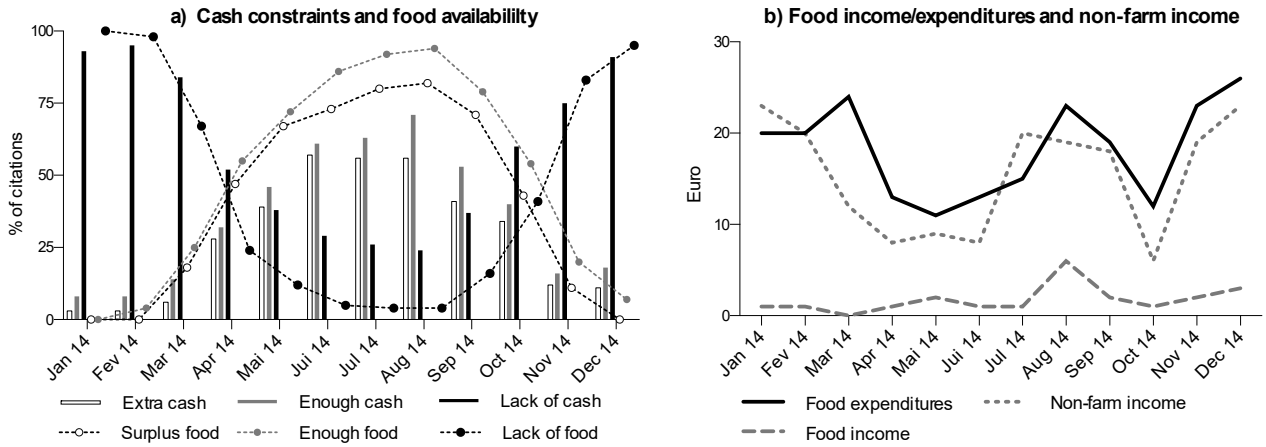

Figure 9a: Cash constraints and food availability based on market participation survey; **9b:** Average food income, expenditure and non-farm income in 2014, sampling weights applied, 1€ =3337 ariary on average for 2014 (oanda.com). N=140

Most respondents stated that they were cash constrained throughout roughly half the year, mirroring precisely the seasonal patterns of food self-sufficiency (Figure 9a, Spearman: r=0.98, p=<0.01). However, 30% of respondents stated that they were cash constrained throughout the whole year.

The longitudinal survey revealed that HHs on average earned ~23€ from crop sales in 2014, but spent more than ten times that for food purchases (~250€ on average). Given that most HHs lack cash savings, farm households had to use a range of non-farm income sources to cope with this situation. Chronologically, the correlation between food expenditures and non-farm income is significant and strong (Spearman, r=0.63, p=<0.01, see Figure 9b).

In the next section, we will examine these non-farm income sources, as well as other coping strategies employed by local farmers, in more detail.

4.3 Strategies to deal with food and cash shortages

Farmers used a range of non-farm income sources, such as construction work, wage labour on neighbouring farms, charcoal production, trade, and handicrafts to cope with food and cash shortages.

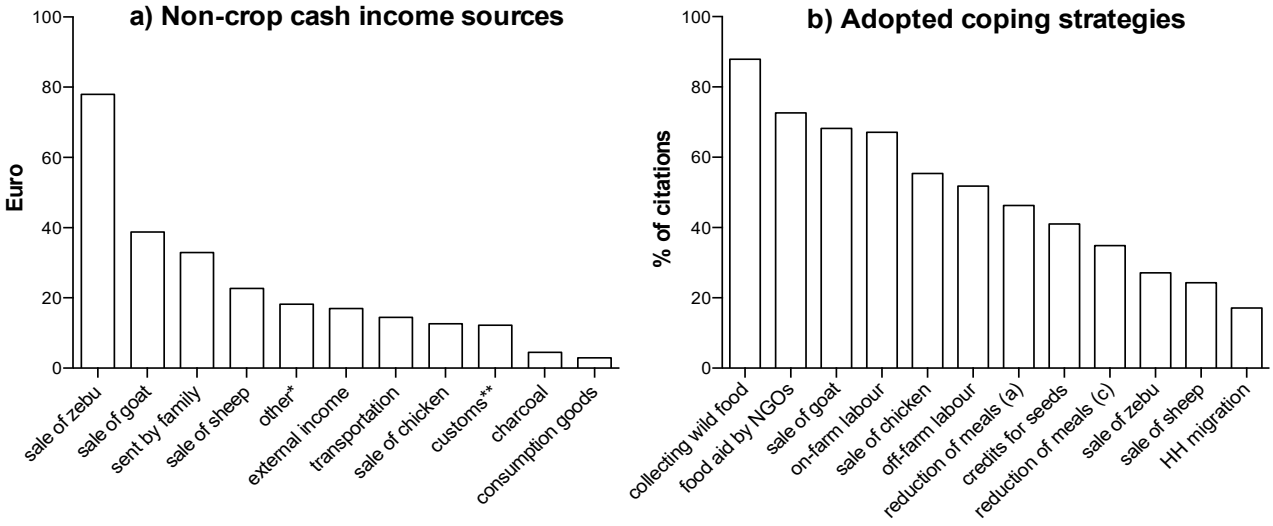

Figure 10a: Average non-crop cash income sources per HH in 2014, sampling weights applied (see Methods), N=140, Source: longitudinal survey. 1€ =3337 ariary on average for 2014 (oanda.com) *other is mainly the sale of wild plants, mangos and straw for construction material **_customs_ is mainly presents cash received through traditional sociocultural events (ceremonies, sacrifices, marriages, births, etc., Malagasy: _lilin-draza_ or _fombaamam-panao_). **10b:** % of HH that adopted coping strategies, sampling weights applied (see Methods), N=140, Source: recall survey (a) refers to adults, (c) refers to children

The far most important strategy was to sell livestock, primarily zebus and goats, accounting for 56% of all HH cash income in 2014. After livestock sales, remittances from emigrated HH members – mostly residing in urban areas – were the second most important cash income source (see Figure 10a). Around 12% of all HHs had at least one family member who emigrated (temporarily) in the lean period, however, ~7% of HH emigrated completely in 2014.

Still, more than 80% of HHs were reported to collect wild food to cope with the cash/food shortage (see Figure 10b) In terms of collected wild food, the fruit of the prickly pear cactus *(Opuntia spp.)*

and yam roots (*Dioscorea spp.*) were most often cited. A large proportion of all HHs (>70%) also received food aid by NGOs, predominantly through food-for-work programs.
Almost half of the HHs reported that they reduced the number of meals eaten per day or total food intake, respectively during the lean period. Thirty-six per cent of HHs stated that food intake had to be reduced not only for adults, but also for children. Forty per cent of all HHs borrowed money from informal credit networks consisting mainly of family members or neighbours. Most widespread was credit for seeds. If prompted to comment on formal credit institutions found in the nearby towns of Betioky and Tuléar, farmers mentioned a lack of effective access to and lack of trust in these institutions.

5. Current social-ecological system interactions in the Mahafaly region

Summarizing the results, 2014 was a difficult year for the farmers in SW Madagascar, as the majority of HHs suffered from extended periods of cash shortages that coincided with food shortages. Agricultural yields only provided some 20% of household nutritional needs, and non-farm income sources did not suffice to cover the food gap for most HHs. As a consequence, farmers had to employ a range of coping strategies. For more than a third of the HHs, this included reducing nutrition for children.

In the following, we will give a short background on external pressures for our SES based on secondary data sources.

a. Environmental degradation in southwestern Madagascar

Southwestern Madagascar is one of the "hottest biodiversity hotpots" globally (Myers et al. 2000, Ganzhorn et al. 2001). Towards the littoral, the natural vegetation consists of a dry spiny forest with plant and animal endemism rates of up to 90% (Fenn 2003, Jasper & Gardner 2015). However, 45% of forest has been lost in the past four decades (Brinkmann et al. 2014) mainly due to farmland expansion (Waeber et al. 2015). Farming practices are extremely extensive, and without the use of any advanced agricultural inputs (Coral 2014, Hanisch 2015).
The study area includes the *Tsimanampetsotse National Park* (TNP) (see Figure 1). The management of the national park, and particularly its extension in 2010 (Kiefer 2011), is controversial among local communities. Conflicts are frequent, with livestock banned from the park *(recall survey*) and herders partly ignoring grazing rules (Ratovonamana et al. 2013, Feldt 2015). Livestock numbers are high, with HHs owning 16.9 $\pm$ 3.5 zebu and 25.1 $\pm$ 3.6 small ruminants on

average (Neudert et al. 2015). The animals graze on agricultural residues, on rangelands at the periphery of the villages, and in the remaining forests pressuring regional biodiversity (Ratovonamana et al. 2013, Feldt 2015). Fire clearing natural vegetation for grazing land is a common strategy to resprout grasses (Feldt 2015) that hinders forest regrowth (Kull 2004).

b. Agricultural risks in SW Madagascar

Although about 30 droughts and famines have been documented in southern Madagascar over the past 200 years (Wüstefeld 2004), poorly distributed precipitation and subsequent crop failures have been the norm within the past five years (WFP & UNICEF 2011, WFP 2013, WFP and FAO 2014, WFP 2015). The intensity and frequency of extreme weather events – in addition to droughts and dry spells, including cyclones during the rainy season – have increased in southern Madagascar (Usman and Reason 2004, Tadross et al. 2008, Virah-Sawmy 2009, WFP and FAO 2014, WFP 2015). The region was hit hard by cyclones *Haruna* in 2013 and *Fundi* in 2015; cyclones were previously uncommon in SW Madagascar (Tadross et al. 2008). Extreme weather events are predicted to increase further (Tadross et al. 2008, IPCC 2014).

c. The political crisis in Madagascar

Madagascar experienced a *coupe d'état* in 2009. As a result, the country became progressively isolated: It was banned from the African Union and reprimanded by the European Union. Most international donors stopped support to the illegitimate Malagasy government. With foreign support making up ~40% of all governmental spending, the public sector was hit hard (Ploch and Cook 2012). The country's economy stalled, poverty increased, the infrastructure weakened, and many governmental services collapsed (World Bank 2013). Particularly in southern Madagascar, social insecurity increased due to organized cattle raider groups (*Malaso*; Feldt 2015, Götter 2015). Also, undernourishment increased significantly: Today Madagascar has one of the highest levels of child malnutrition worldwide (WFP 2015a).

Regular constitutional order of sorts was restored only in 2014.

d. Population pressure

Madagascar´s population has quadrupled during the past 50 years (World Bank 2015b). Particularly in rural SW Madagascar, population growth is high (EPM 2011). In our study of villages, the mean household size is 7.5 people (see Table 4).

As a result, land scarcity has become a severe agricultural constraint in the region (Coral 2014), with much of the previously forested area having been converted to agricultural land (Brinkmann et

al. 2014). Due to the scarcity of agriculturally suitable land, slash-and-burn systems with long fallow periods are increasingly giving way (i) to short-cycle rotations with short fallowing periods and (ii) to continuous agriculture close to the villages (Coral 2014, Hanisch 2015).

In Figure 11 we have synthesized our results, highlighting some important social-ecological interactions, which currently characterize the Mahafalian SES. Key system variables include (i) the pronounced seasonality of precipitation (and consequently harvests), (ii) the challenge of dealing with drought and dry-spells, (iii) the political crisis in Madagascar and (iv) population growth. These variables are structuring regional SESs, as they form a set of system interactions that keep farmers in persistent poverty while the surrounding landscape is being degraded.

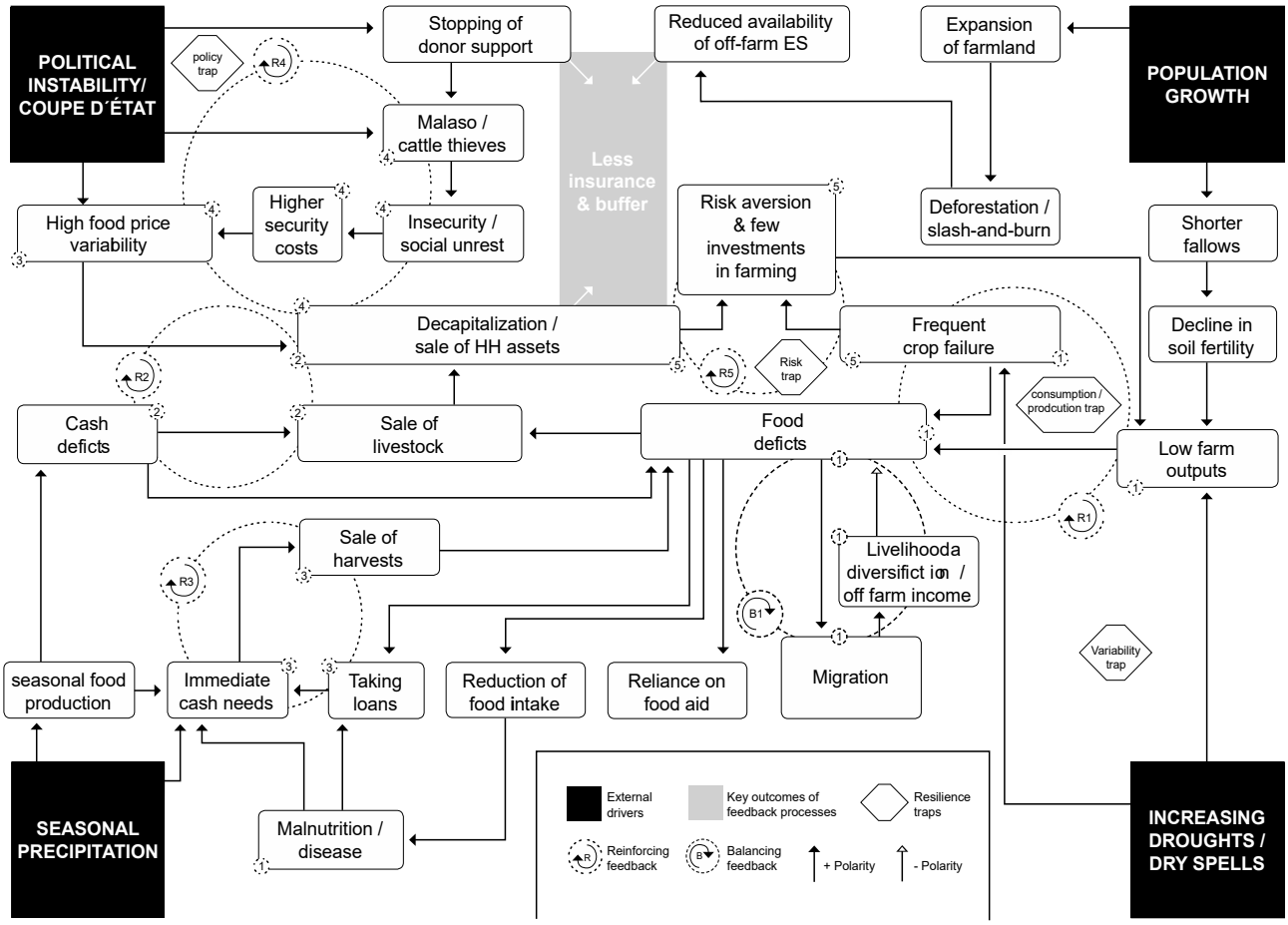

Figure 11: A social–ecological feedback diagram exemplifying how 4 external drivers interact with key system variables through feedback processes that reduce the (i) HH buffer/insurance, (ii) reduce the productive potential of the agro-ecological system, (iii) create increasing food insecurity and which lead to (iv) livelihood impoverishment. Plus and minus polarity arrows characterize relations between the different variables. + polarity signifies that both variables' values change in the same direction. – polarity indicates if one variable's value changes, the other one moves in the opposite direction. Inside a feedback loop, a variable may change due to an impact from outside (e.g. external driver) or due to changes of another variable inside the loop. If the loop sustains the direction of change (i.e. lower/higher) then it is labelled R (reinforcing). If the loop inverts the path of change, then it is labelled B (balancing) (Sendzimir et al. 2011). System analysis was done in Vensim software (Ventanna Software Inc.); graphical illustration was kindly performed by Hugo Bertram Rohrbeck.

6. DISCUSSION

In the following section, we assess to what degree the six resilience traps as described in Table 2 can be seen as causal mechanisms for persistent poverty, hunger, and environmental degradation in the Mahafaly region. The assessment is based both on our results presented above and other findings presented in Section 5.

6.1 Resource consumption/production traps

The consumption/production trap occurs when the rate of consumption/outtake of natural resources is too close to the rate of production (CPWF 2014). There are numerous indications that the overall land use system in the Mahafaly region is not sustainable from a natural resources point of view. Forty-five per cent of the regional forest has been lost over the past 40 years (Brinkmann et al. 2014) (Figure 11, top-right). Soils of arable land have significantly lower soil fertility compared to soils of rangelands and forests in the Mahafalian area (Fricke 2015), indicating nutrient mining. After converting regional forest to maize fields through slash-and-burn, Milleville et al. (2001) found a decrease of 60% in available phosphorus, 55% in nitrogen, 44% in carbon, and 27% in potassium after 5 years. Moreover, an increase in soil density was observed which reduced soil permeability significantly (ibid). Simultaneously, maize yields declined form 2 t ha^{-1} in the first year to less than 0.5 t ha^{-1} after five years (Milleville and Blanc-Pamard 2001). Slash-and-burn farming (Malagasy: *hatsaky*) thus contributes substantially to soil impoverishment and declines in soil fertility in SW Madagascar (Figure 11, middle-right).
Fallow periods have also been substantially shortened over time, giving way to continuous cropping. In fact, from 358 arable plots belonging to the surveyed 140 HHs, fallowing was only practiced in 5.8% of all fields during the past 20 years (*recall survey;* Figure 11, middle-right).

To cope with cash and food deficits, farmers heavily rely on revenues from selling livestock (Figure 11, middle-left). But livestock herding tends to degrade the remaining forests (Ratovonamana et al. 2013). High livestock densities are problematic for the regional vegetation, particularly in the littoral of the Mahafaly area (Feldt 2015, Götter et al. 2015). While woody biomass collected in the forest is the only local fuel source, many urban areas in western Madagascar are also supplied by wood and charcoal from the dry spiny forests of the region (Dirac et al. 2006). Indeed, we found charcoal making to be a widespread strategy employed by farmers to cope with cash deficits (*longitudinal survey*). Thus, the extent of forest cover as well as forest ecosystem quality from a

biodiversity conservation point of view continues to be under pressure. The loss of forest has, in turn, negative consequences on food security, as the habitat for wild plants – particularly wild yams – is lost, which are frequently collected when farmers face periods of food shortage (Andriamparany 2015; Figure 11, top-middle).

In sum, certain key resources are extracted at a higher rate than they are replenished. That is, key aspects of the system are in a "resource mining cycle" (CPWF 2014), which both threatens the current production capacity of the Mahafalian agro-ecosystem (Figure 11, middle-right), as well as the unique forest biodiversity of the region (Ganzhorn et al. 2001, Waeber et al. 2015).

We conclude that there are multiple lines of evidence for the existence of a production/consumption trap.

6.2 Variability trap

In a variability trap, small investments do take place, but the large variability (e.g. of rainfall) leads to frequent investment failures, which prevent any substantial development from emerging from this investment.

The high variability of environmental conditions, particularly rainfall, results in frequent crop failures, particularly of the cash crops maize and beans in the project region (Figure 11, middle-right). This hinders capital accumulation, and in turn, places a cap on HH capacity to invest further in agriculture (Figure 11, R5, top-middle). Furthermore, capital accumulation is hindered by the seasonally recurring need for external food and cash. As soon as harvests are in, educational fees for children are due, and important socio-cultural events (festivals for harvest, rain, and the ancestors) result in costs that even poor households need to bear if they wish to maintain good social standing (*longitudinal & recall survey*). Besides, loans have to be repaid, either in cash or in food (*longitudinal & recall survey*; see Figure 11, down-left).

From February to April, the hottest and wettest months, various tropical diseases occur regularly in the region (e.g. hepatitis, typhus, diarrheal diseases, and occasionally malaria; UNICEF 2013), resulting in considerable health expenditures (*longitudinal data;* Figure 11, down-left). The reduction in food intake (Figure 6b) further increases vulnerability to such diseases, particularly for children (UNICEF 2010, 2013). In turn, disease and undernourishment constrain agricultural productivity, and hence reinforce low farm outputs (Figure 11, R1, down-left).

Even if there is no particular pressing need in some households for spendings in the above categories, post-harvest is the only time when resources are available at all to fulfil postponed

desires for household- and consumption goods. As a consequence, many households sell their crops immediately after harvest (*longitudinal data,* Manon 2014). At that time, however, food prices are low with many sellers in the market. In contrast, prices increase dramatically during the lean period (*market participation survey*) – particularly after droughts and crop failures in southern Madagascar (WFP 2015a). Similarly, when HHs sell livestock to purchase food staples, animal prices tend to be lower, as many HHs sell livestock at the same time (*recall survey data*; Figure 11, top-left).

Due to the need to use income from livestock sales to offset food shortages during several months of the year, HH assets are regularly depleted, and accumulation of capital is hindered. This is *self-reinforcing feedback* (Figure 11, middle-left, R2) often characterized in the literature as a typical *poverty trap* (e.g. Carter et al. 2007, Barrett 2008, Carter & Lybbert 2012). Overall, the variability-induced shocks in food production make it very difficult for households to save enough capital to invest in more profitable agricultural activities. Thus, the direct effect of the *variability trap* results in both low yields (Figure 11, middle-right) and low adaptive capacity to overcome low yields (Figure 11, top-middle). This represents a further self-reinforcing feedback, which essentially perpetuates the trap dynamics (Figure 11, middle-left, R3).

6.3 Risk traps

A risk trap can occur when high-risk situations reduce internal incentives to invest in agricultural systems (CPWF 2014).

Agricultural risks are manifold in the Mahafaly region. Even in good years, rainfall is low, with precipitation in the littoral close to the threshold for any agricultural production (Kaufmann 2004). In addition, poorly distributed rains (dry spells) during the rainy season, locust invasions and cyclones, all of which manifested themselves in the regional cropping season 2013/14 (WFP & FAO 2014, Hanisch 2015), pose substantial additional risks.

Historically, there are reports of good harvests in the 1980s and 1990s when large volumes of maize were exported from SW Madagascar to the neighbouring French island of La Réunion (Klein et al. 2008, Minten et al. 2010). Thus, rather than being a region completely unsuitable for agriculture, the Mahafaly Region is an area where existing patterns of environmental variability make agriculture a high-risk business facing multiple uncertainties. Obviously, this high-risk environment further reduces the incentives of risk-averse smallholders to invest in agriculture – even if the expected value of certain investments was positive in the long run.

Under these conditions, households may profit from a diversification strategy with respect to household income – particularly from a food security perspective – compared to a focus on investments in arable agriculture only. The households investigated relied largely on a mixed land use system in which animal husbandry plays an important insurance function (for a more detailed analysis, see Hänke and Barkmann *submitted*). As the fundamentally risky farming environment suggests, direct investment in agriculture is limited, as input levels of fertilizer, plant protection agents, machinery, tools, and herding equipment is extremely low (*longitudinal survey*; see also Coral 2014, Feldt 2015, Hanisch 2015). Local, non-certified seeds for annual cash crops (maize, legumes) are the only major agricultural input that is being purchased, and which is only used on the most fertile fields (*recall data*).
Households are reluctant to invest more as investments may fail. The observed lack of investments can, thus, be characterized as a risk trap, and this kind of risk aversion (Wolgin 1975, Eakin 2000) notoriously affects farm yields negatively, and also contributes to the resource trap identified above (Figure 11, middle-middle).

In sum, the extremely low agricultural investments seen in the Mahafaly region appear as a result of the interaction between the *risk trap* and the *variability trap* (Figure 11, down to middle-right). Further traps contribute to the apparent lock-in, however (see following subsections).

6.4 Policy trap

Policy traps occur when disenabling policies and lack of transparency hinder investment, as markets and resources are prevented from being used effectively (CPWF 2014).
As a direct consequence of the *coupe d'état* in 2009, most international donors stopped their support to the Malagasy government. Consequently, regional governmental services collapsed, including the public education and health systems, maintenance of infrastructure, public safety, and agricultural extension (World Bank 2013).
The case of the public security sector illustrates the cascading effect of the crisis, as zebu keeping has become a highly risky activity in southern Madagascar due to cattle raiders (*malaso*; Feldt 2015, Götter 2015). While small-scale cattle theft has certain roots in traditional southern Malagasy customs (Hoerner 1982, Fauroux 1989), more aggressive *malaso* groups used the collapse of the public safety system in southern Madagascar to arm themselves and turn to organised crime. The *malaso* do not only attack herding households, however. These days, traders regularly have to pay

"security fees" in order to travel safely to the marketplaces in the region (Coral 2014), which in turn results in higher food prices for the local population (Figure 11, upper-left, R4).
Another example is the anti-locust campaign (2013-2016) developed by the FAO that did not receive full funding. As a consequence, uncontrolled locust populations developed and spread in 2013 (FAO 2013). Locusts destroyed ~80% of the maize yield of the farmers sampled, illustrating the country's low capacity to deal with such crises.

Clearly, the policy trap has made the country less resistant to shocks, such as droughts, cyclones and insect infestations (World Bank 2013), reinforcing feedback cycles R2 and R4.
Furthermore, reduced and/or more expensive market access (*malaso*) aggravates the seasonal price peaks in the area, and makes external inputs more expensive – effectively reinforcing the *risk* and the *variability trap*. Although these constraints occur at multiple levels (i.e. national, regional and local), they are interdependent, exemplifying what Barrett and Swallow (2006) have referred to as a *fractal poverty trap* (Figure 11, top-left).

6.5 Resource access traps & cultural traps

Resource traps refer to situations where access to resources, such as land, put a cap on revenues despite high productivity (CPWF 2014). In that exact sense, resource traps are not a major issue in the Mahafaly region: Productivity is so low that the conditions for the resource trap are not met. However, it is the lack of access to fertile land and particularly the lack of rainfall and/or easily accessible irrigation water that fundamentally prevent higher productivity. Water is probably the most limiting factor for agricultural upgrading in SW Madagascar (Hanisch 2015). Once more water would become available, prospects for regional agriculture would brighten substantially. Unfortunately, current climate change predictions do not point to an imminent improvement of the situation; instead, the high current frequency of droughts seems to indicate a worsening trend (Tadross et al. 2008, IPCC 2014).

Many farming HHs report that labour availability is a major constraint to enlarging their plots (Coral 2014), particularly since weeding is labour intensive (*longitudinal data*). Given the lack of high quality land and effective access to irrigation water as well as the high investment risks in agriculture, lack of labour appears to be a result of low productivity rather than as its cause.

Cultural traps refer to situations in which mindsets prevent beneficial change (CPWF 2014). Although the overall socio-economic situation appears bleak, it was clear from the recall survey as well as from a number of personal communications that many smallholder farmers and small traders in the Mahafaly region are willing to take advantage of attractive production and business opportunities. In comparison to the traps discussed above, the impact of the specific *cultural traps* therefore appears low. A potential exemption may be cultural traditions that command even poor households to spend substantial resources on a number of customs.[4]

[4]Also, there are cultural restrictions on charging interest on informal credit. In fact, however, households pay a fee, e.g., as prices for the goods purchased or sold are adjusted to their disadvantage if informal credit is involved. Due to the cultural sensitivities involved, we do not have sufficient survey data to quantify whether this type of informal credit *per se* is hurting or helping households.

7. CONCLUSION

In sum, a set of different interacting mechanisms related to the ratio between resource consumption and production, to risk and variability, and to disenabling policy, create a set of partly self-reinforcing, social-ecological traps in the region, which tend to perpetuate low agricultural yields, grossly insufficient livelihoods, and ongoing environmental degradation of this unique environment.

While interventions are certainly needed to counter and compensate for the lack of food and cash that a large share of the households experience during many months every year, investments in the agricultural sector do not appear to be an ideal solution. And indeed, the only "balancing" feedback we found in our systems analysis was associated with off-farm employment (Figure 11, middle-right, B1). Agricultural activities are only seasonally feasible and highly risky. Climate change projections for the broader region show an increase in extreme weather events such as cyclones, prolonged droughts and dry spells (Tadross et al. 2008, IPCC 2014), suggesting that rain-fed farming has become, and will become even more difficult in the future. Despite this fact, a large number of donors and NGOs are present in the region, almost exclusively running agricultural *food-for-work* programs. In these programs, maize was by far the most often promoted crop in 2014 (*recall survey data*). However, we found that ~80% of the maize harvest was destroyed by locusts in 2014. In addition, maize is one of the major drivers of deforestation in southern Madagascar (Réau 2002, Minten et al. 2010). This clearly shows that current development agendas suffer from a too limited view of how contemporary social-ecological systems on the Mahafaly Plateau operate.

We identify three basic requirements that need to be addressed to escape the current situation:

1. Generating support for income sources outside the current farm/livestock sector in order to (i) reduce the pressure on the unique Mahafalian biodiversity and (ii) to better hedge the risks of local rain-fed agriculture. These income sources should particularly generate benefits during the lean season, and also have a low environmental impact. Examples include small-scale poultry farming in cooperatives, yam root domestication (Hänke et al. 2014) and the processing of *Opuntia spp.* fruit from farmers' hedges (Hänke et al. *forthcoming*).
2. Coordinating simultaneous investments across multiple scales (cf. Enfors 2013, Mikulcak et al. 2015), in e.g. agricultural improvements, markets, infrastructure, health and extension services. As we saw, hunger, poverty and environmental degradation are closely linked.
3. Promoting opportunities for access to credit, capital, and insurance (cf. Carter and Barrett 2006, Hanjra et al. 2009) to effectively deal with the *risk* and *variability traps*.

The social-ecological system analysis we conducted provides new insights about causality for poverty and environmental degradation in the Mahafaly region. As Scales (2014:10) concluded in a recent article: “conservation and development needs a new paradigm in Madagascar”. Our study clearly shows that environmental degradation, poverty and hunger are closely linked, and that these challenges should therefore be addressed simultaneously.

A major development challenge in the Mahafaly region is to move beyond the prevailing focus on “coping”, and instead to build a resilience of trajectories where both local livelihoods and the region’s unique biodiversity can thrive in the long-term.

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Chapter 3: Potential of *Opuntia spp.* seed oil for livelihood improvement in semi-arid Madagascar

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[5] I did the study design, coordinated the fieldwork, the data analysis, and wrote most of the manuscript. Jan Barkmann contributed to the study design and to the writing of the manuscript. Corina Müller organised the seed oil and presscake laboratory analysis, and contacted relevant stakeholders and oil producers. Rainer Marggraf discussed and supervised the manuscript.

ABSTRACT

The littoral of the Mahafaly Plateau in southwestern Madagascar is a global biodiversity hotspot. The area is semi-arid and prone to droughts, as well as to other environmental risks, resulting in frequent crop failures, famines, and extreme poverty. Thus, the identification of suitable non-agricultural income sources has been identified as a crucial step for the sustainable development of the region.

In this contribution, we assess the potential of *Opuntia* seed oil production as an income alternative. Cacti of the *Opuntia* genus are highly abundant in the region, particularly as living fences on private farmland. From the seeds of its fruit, high-priced seed oil can be extracted. To investigate its economic potential, we inventoried *Opuntia* in field hedges through vegetation inventories, and estimated the amount of seed oil that can be produced per household based on field sampling and laboratory analysis. To assess the socioeconomic impact of a potential large-scale project of regional *Opuntia* seed oil production, we conducted interviews with 51 farming households on human *Opuntia* consumption, the utilization of its cladodes as fodder, and other livelihood functions.

We found five different *Opuntia* varieties in the research region. Two varieties are highly important socioeconomically, and contribute >50% to total food intake during periods of food shortage (annual lean or hunger seasons). Also, these varieties are eaten as a key water source. In contrast, the other three *Opuntia* varieties are not eaten by local residents. These varieties are more spiny, and their fruits are virtually inedible due to a much higher seed content. The combination of low nutritional value and high seed content suggests promising seed oil production potential for these varieties for *Opuntia*. To avoid remaining competition risks between human nutrition and the commercialisation of local Opuntia seeds, sourcing strategies should exclusively target the fruit of the two high seed varieties.

Keywords: Opuntia; seed oil; livelihood improvement; Madagascar; rural development

1. INTRODUCTION

The inhabitants of southwestern (SW) Madagascar are exceptionally poor. Every year, local communities face a "lean" or "hunger" period (*kere*) from the beginning of the rainy season to the annual crop harvest (~November-April). During that period, a substantial share of the smallholder farming population runs low on subsistence food resources as well as cash, as many households have to reduce food intake to unhealthily low levels (ACF 2014, Hänke et al. *submitted*). With the next harvest not until weeks or even months ahead, non-farm income sources, livestock sales and the collection of wild plants are crucial to physically survive the lean season (ACF 2014; Hänke & Barkmann *submitted*).

Our study region is the littoral, the coastal area of the Mahafaly Plateau (see Figure 12). The area is a biodiversity hotspot (Myers et al. 2000; Ganzhorn et al. 2001), as well as a food insecurity hotspot (WFP 2015) with widespread rural poverty and undernourishment (Hänke et al. *submitted*). At an extremely low level of farming inputs other than human labour, the agricultural development potential is limited due to low average rainfall, low soil fertility, and the absence of irrigation options (Coral 2014; Hanisch 2015). Moreover, droughts, dry spells during the rainy season and subsequent crop failures have become common in recent years (WFP 2015). With severely limited agricultural potential, off-farm income sources are crucial for sustainable regional development. Promising alternative income options are scarce, however, in this remote and infrastructurally underdeveloped area of Madagascar (Hänke et al. *submitted*).

One of the wild plants used intensively in Madagascar's southwest during the lean period is the cactus pear (*Opuntia spp.,* Malagasy*: raketa*). Multiple *Opuntia* species and/or varieties grow wild in semi-arid Madagascar[6]. Likewise, *Opuntiae* are planted as living fences around arable fields and used for livestock corrals. Traditionally, *Opuntiae* are an important plant for the livestock-based economy of the region: Their cladodes provide dry season food and water for livestock after their thorns are burned, and humans can consume the cactus pear fruit (Kaufmann 2004).

There is an increasing global interest in *Opuntiae*, particularly for the management of dry areas (Gebretsadik et al. 2013). *Opuntiae* are highly drought resistance due to their CAM physiology *(Crassulacean Acid Metabolism;* Middleton 2002). Furthermore, they tolerate soil salinity well

[6]For taxonomic details and the history of *Opuntia* species and/or varieties in Madagascar, see Section 1.1.

(Berbera & Inglese 1995; Ben Salem et al. 1996). *Opuntiae* are used to combat soil erosion (Nefzaoui and El Mourid 2007), and thrive in harsh environmental conditions in which other fruits and vegetables fail without irrigation (Han and Felker 1997). *Opuntiae* have been shown to provide yields of 13t/ha in Ethiopia (Gebretsadik et al. 2013), 30 t/ha in Italy (GAFÉIAS 2011) and up to 40t/ha in Argentina (Garcia de Cortázar and Nobel 1991). Thus, *Opuntiae* are considered particularly suitable for semi-arid, often food-insecure areas (FAO 2013), contributing substantially to rural livelihoods (Larsson 2004; Shackleton et al. 2011).

Opuntiae could be a promising cash income source for SW Malagasy residents, as high-value oil can be produced from their seeds. Opuntia seed oil is among the most valuable plant oils, with world market prices up to 500-800 US$/L (Nazareno 2015; personal communication with FAO-ICARDA). It has been shown to provide diverse health benefits (El-Mostafa et al. 2014) and it contains exceptionally high levels of non-saturated fatty acids, e.g. linoleic acid (56%-77%; Ramadan & Mörsel 2003; Ennouri et al. 2005). *Opuntia* seed oil is also rich in natural antioxidants (Osuna-Martínez et al. 2014) and has also been attributed an anti-aging effect for human skin (Feugang et al. 2006), benefits for cancer prevention (Zou et al. 2005) and the treatment of diabetes (Osuna-Martínez et al. 2014).
Consequently, *Opuntia* seed oil has become a highly attractive resource for the food, cosmetic, nutraceutical and pharmaceutical industry (Moßhammer et al. 2006; Liu et al. 2009; Jana 2012; FAO 2013; El-Mostafa et al. 2014; Guillaume et al. 2015).

1.1 *Opuntia spp.* in Madagascar

Originating from Mexico, cactus pears were introduced to Madagascar during the 17th century, and spread rapidly in the semi-arid south of the island (Kaufmann 2001; Middleton 2002). Many *Opuntia spp.* have existed in southern Madagascar for around 100 years and have natutralized (Kaufmann 2004). There may be up to 27 different *Opuntia* species and/or varieties in Madagascar (Larsson 2004; Kaufmann 2004**)**. However, there is no systematic description of Malagasy *Opuntia spp.* Based on historical records and plant material stored in the Paris Museum of Natural History, Allorge and Matile-Ferrero (2011) have shown that the following *Opuntiae* were introduced during the colonial period to Madagascar: *O. cochenillifera*, *O. dillenii*, *O. ficus-indica* and *O. monacantha*. After the eradication of *O. monacantha* due to an insect pest in the 1920s, around ten American *Opuntia spp.* were introduced in Madagascar in 1925 (Decary 1947). Many Malagasy

Opuntia spp. are often wrongly classified (Binggeli 2003) as crossbreedings, landraces and hybrids occur in Madagascar (Middleton 2015).

In southern Madagascar, landholders traditionally plant *Opuntiae* around villages, homesteads, cropping fields, and livestock corrals (Kaufmann 2001). The importance of *Opuntiae* for Malagasy pastoralists is well-documented. The plants increase the carrying capacity of the regional landscape by storing large amounts of water in their cladodes (up to 92% moisture content; Brulfert et al. 1984) and by generating substantial amounts of fodder biomass, complementing more strongly rain-dependent grassland biomass (Kaufmann and Tsirahamba 2006). Thus, *Opuntiae* are a key fodder and water resource for animal husbandry in southern Madagascar (Middleton 2002; Kaufmann 2004; Larsson 2004). Some authors claim that the rise of pastoralism as a dominating regional livelihood strategy had not been possible without the introduction of *Opuntiae* used as cattle fodder (Middleton 1999, Kaufmann 2001). With its independence from timely rains and with its high local abundance, *Opuntiae* also contributed to an increasing sedentarization of agro-pastoral societies in southern Madagascar (Kaufmann 2004).

Likewise, there is evidence that *Opuntiae* fruit provide an important food resource during the lean period for many farming households (HHs) in semi-arid Madagascar. This role becomes particularly pronounced during droughts and ensuing food shortages (Middleton 2002; Larsson 2004; Hänke & Barkmann *submitted*).

As *Opuntiae* are often described as invasive plants, they could potentially menace biodiversity hotspots such as Madagascar (Middleton 2002; Kull et al. 2014). Recent attempts to eradicate *Opuntia* plants in Madagascar have been unsuccessful (personal communication with Madagascar National Park Management). Likewise, research in South Africa has shown that although *Opuntiae* are fought by governmental programs and conservationists for biodiversity conservation goals, they contribute particularly to poor rural livelihoods, which has lead to conflicts (Shackleton et al. 2011). Thus, the attitudes toward *Opuntiae* in Madagascar may reflect stakeholder values more strongly than intrinsic plant features (Zimmermann and Olckers 2011). Although *Opuntia spp.* are non-native plants within a fragile and highly endemic ecosystem, a long time ago already, Decary (1925) claimed that semi-arid Madagascar would be uninhabitable without *Opuntia spp.* If lost, a crucial food and water resource would be absent, resulting in large-scale starvation (ibid).

1.2 Knowledge gaps and research objectives

Opuntiae have received little research attention until the past decade (Feugang et al. 2006; Nazareno and Nefzaoui 2007). *Opuntiae* from several countries have been assessed with regard to fodder quality (e.g. Nefzaoui & Ben Salem 2001; Gebretsadik et al. 2013), the chemical composition of their fruit (e.g. Tesoriere et al. 2004; Stintzing & Carle 2005; Finti et al. 2013; Yeddes et al. 2014), and seed oil characteristics (e.g. Sawaya & Khan 1982; Ramadan & Mörsel 2003; Ennouri et al. 2005; Liu et al. 2009). To our knowledge, such analyses are not available for Malagasy *Opuntiae* to date, however. Likewise, little is known about (i) the quantitative abundance of *Opuntiae* in SW Madagascar, and (ii) about the importance and exact uses of its different forms.

With the limited success of rural development efforts in southwestern Madagascar (Unicef 2011; Hanisch 2015), and few income options besides the farming/livestock sector (Hänke et al. *submitted*), *Opuntia* products such as seed oil may be an income alternative of substantial potential (Guillaume et al. 2015). However, little attention has been paid to the economic potential of *Opuntia*-derived products in Madagascar including the extraction of *Opuntia* seed oil.
In the littoral of the Mahafaly Plateau, *Opuntiae* are commonly planted as living fences to protect arable fields from livestock and intruders (SuLaMa 2011; see Figure 16). These hedges are planted around the vast majority of privately owned fields. Thus, they are very abundant and their property rights are sufficiently well-defined. Our research objectives are the following:

a) To identify the different *Opuntia spp*. and/or other varieties and assess their quantitative abundance in the field hedges.
b) To assess the potential competition between traditional uses of *Opuntia* fruit, particularly during the lean season (human consumption, contribution to food security, economic activities, utilization as fodder) and seed oil production.
c) To assess potential seed oil production per average farming household. This includes an *Opuntia* inventory, an estimate of fruit quantity/HH, the determination of the seed content of the fruit, as well as of the oil content in seeds.
d) To determine the overall potential of commercialised *Opuntia* seeds as an alternative income source, requiring (i) a comparison of the seed oil content in a global context and (ii) consideration of accessible value chains/commercialisation options, including actual and potential uses of the byproducts (e.g. fruit pulp, presscake) of *Opuntia* seed oil.

See methods section for details.

1.3 Study site

Our study region covered the littoral of the Mahafaly Plateau in southwestern Madagascar (see Figure 12). The local population belongs to the *Tanalana* ethnic group; located directly on the coast, the *Vezo* people inhabit several fishing villages. The area is semi-arid with 200-300 mm rainfall/yr. (CNA 2015; Hanisch 2015), which is close to the limit of rain-fed arable agriculture (Kaufmann 2004).

The region belongs to the poorest and most disadvantaged areas in Madagascar (EPM 2011), which is itself among the ten poorest countries in the world (IMF 2015; World Bank 2015). The few available freshwater resources are heavily contaminated with pathogenic bacteria (Rasoloariniaina *et al.* 2014) and the general infrastructure is weak (SuLaMa Marp 2011).

Because of its high salinity, the groundwater is unsuitable for irrigation (Guyot 2002; Hanisch 2015). The regional soils are sandy and of poor quality (low soil nutrients, low organic soil carbon; Andriamparany 2015; Hanisch 2015). Farmers grow cassava, sweet potatoes, maize, millet, sorghum and different leguminosis. Malnutrition is common in the area, with famines having ocurred frequently in recent years (WFP & FAO 2014; WFP 2015).

The region harbours unique, highly endemic biological diversity. The natural vegetation consists of highly specialised dry spiny forest with a plant and animal endemism rate of around 75%-90% (Fenn 2003, Jasper & Gardner 2015). The level of endemism is among the highest in Madagascar (Fenn 2003, Gautier & Goodman 2003) which has, as such, one of the highest rates in the world (Myers et al. 2000). The research area is located directly west of the *Tsimanampetsotse National Park* (TNP).

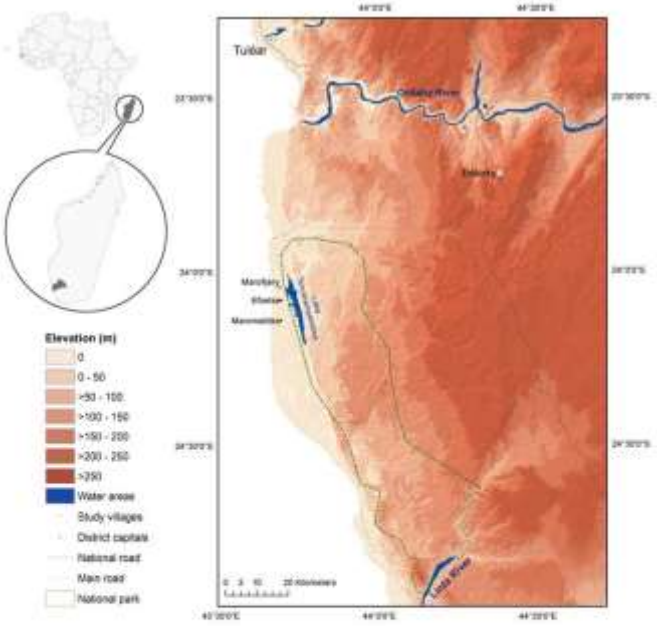

Figure 12: Map of the littoral study area; TNP after extension in 2010

2. METHODS

2.1 *Opuntia* inventory, sampling and oil estimation

The 51 HHs were selected as a subset of HHs included in a random sample of a longitudinal, agroeconomic study conducted in 2014 (Hänke & Barkmann *submitted*). During the longitudinal study, we collected household characteristics including agroeconomic, farm yield as well as field plot data. Households were selected from three littoral villages in the sample: Efoetse, Maromatilike, and Marofijery (see Figure 12). The 51 HHs have a total of 87 fields, and we identified all of the hedges using aerial photographs. The *Opuntia* inventory, as well as complementing household surveys, were supported by three well-trained field assistants, and took place from February to May 2015. The *Opuntia* inventory consisted of several steps:

a. Assessment of Opuntia cover in field hedges

In a related study (Hänke et al. *submitted*), we had determined field sizes using GPS tracking. That is, field assistants ran out the field borders *in situ*. For this study, the total coverage of field hedges was traced based on publically accessible remote sensing images (Image source: Cnes/Spot Image© taken in 2011 via Google Earth Pro©). To determine the *Opuntia spp.* cover (in m²) within hedges, the length and width of the Opuntia *spp.* hedges were measured directly in the field and the *Opuntia* species/variety was noted. To do this, we randomly selected one third of the 51 HHs, which resulted in a subsample of 17 HHs, including 29 single fields. To estimate the share of the different *Opuntiae* in the hedges in percent, the spatial cover (m^2 per species/ variety) was divided by the total hedge size (m^2) and multiplied by 100.

In addition, the total number of *Opuntia spp.* plant stems was counted in the field hedges, so that we could compare our vegetation inventories with estimates done by interview respondents that were based on the number of stems (see Figure 18).

b. Number of fruit per HH

A preliminary analysis of occurring *Opuntiae* had indicated the presence of five species/varieties (see Table 5). One of them (locally called “rengevoke”), hardly occurred and was therefore omitted. Another variety (locally called “Vilovilo”) was stated to be highly important as a food resource. Therefore, this variety was also neglected from the suceeding analyses.

In the study area, *Opuntia stricta* is a low growing plant, usually 50-100 cm tall. *Opuntia ficus-indica* is slightly taller: Around 100-150 cm. *O. monacantha*, however, grows far higher (up to >3

m). Due to the different growth forms, we applied two different methods for the fruit sampling (see below).

After mapping the occurrence of the different *Opuntiae,* 30 distinct points were randomly placed in the 29 field hedges for each of the three most often occurring *Opuntia spp*. The random location of the sampling points was supported by QGIS 2.12.2. At the sampling points, 1 m^2 squares were delineated, and the total number of *Opuntia ficus-indica* and *Opuntia stricta* fruit were counted (see Table 8). Finally, to estimate the number of fruit from these two *Opuntiae* per household, the average number of *O. ficus-indica* and *O. stricta* fruit / m^2 derived were multiplied by the spatial cover (m^2) of *O. ficus-indica* and *O. stricta* per household.

Conversely, for *Opuntia monacantha,* which grows higher and wider then the other *O. spp.* in the study area (height up to >3 m), fruit sampling was done for individual plant stems instead of m^2 (see a. and Table 9). To do so*,* the total number of fruit in 30 randomly chosen *O. monacantha* plant stems was counted. Finally, the total number of *O. monacantha* fruit per household was estimated through the number of *O. monacantha* plant stems in field hedges per household, multiplied by the number of fruit per plant stem.

Since our *in situ* analyses covered fruit production during the lean season only, we asked locals how often the different *Opuntiae* produced fruit during the year (see 2.2).

c. Seed content and seed mass determination

In order to determine the seed content per *Opuntia spp.* fruit (in mass %) and seed dry-mass (in g_{DM}) per *Opuntia spp.* fruit, 30 pieces of fruit from *O. ficus-indica, O. monacantha* and *O. stricta* were randomly sampled, freshly weighed, their seeds were extracted, hand washed, and the seeds were freshly weighed. Seed mass was divided by the total weight of the fruit and multiplied by 100 in order to determine the seed content (in mass %). Subsequently, the seeds were oven dried at 65° C for 24 hours and weighed again in order to determine the dry seed mass (g_{DM}) per piece of fruit. Seed weight (g_{dm}) and seed content (%) of the three *Opuntia spp.* were compared with t-tests.

d. Oil content determination in Opuntia spp. seeds

Preliminary analysis had already indicated an inverse relationship in the relative seed content of *Opuntiae* fruit and local human nutritional use. Consequently, it was clear early on that only the two rather inedible, high seed content species would qualify as targets for the commercialisation of *Opuntiae* fruit and seeds. Thus, we chose to conduct a seed oil analysis for only these two species. Another reason was cost constraints for the laboratory analysis. Consequently, we ran a laboratory

analysis in order to determine the oil content (in mass %) in *O. ficus-indica and O. stricta* seeds. A petroleum ether analysis was conducted with an ANKOM XT 15 Extraction System (Ankom Technology Inc.). To make sure that the seeds were fresh and undamaged, they were sourced directly in the study villages.

Through a fatty acid spectrum analysis, the level of linoleic acid was determined and a press-cake analysis for fibre, protein and fat content was conducted (analysis performed by SGS GmbH, Hamburg, Germany).

e. Extrapolation of the average Opuntia spp. seed oil production per household

To estimate the potential *Opuntia spp.* seed oil production per average HH, first (i.) the total amount of fruit/HH was calculated (as described in b.):

i. $$\frac{\text{total amount of fruit}}{\text{household}} = \frac{\text{Opuntia spp. cover (m}^2\text{)}}{\text{household}} * \frac{\text{amount of fruit}}{\text{m}^2}$$

(ii.) Then, the total seed oil (kg)/HH was calculated by multiplying the total amount of fruit/HH by the seed mass (DM) per fruit, as well as the seed oil content in mass %.

ii. $$\frac{\text{total seed oil (kg)}}{\text{household}} = \frac{\text{total amount of fruit}}{\text{household}} * \left(\frac{\text{seed weight(g}_{\text{DM}}\text{)}}{\text{fruit}} * 100\right) * \frac{\text{seed oil (mass \%)}}{100}$$

2.2 Survey

In addition to field inventories and laboratory analyses, we conducted interviews with the 51 farming HHs (see questionnaire in Annex 10). Questions addressed included:

1. Occurrence of *Opuntiae*, fruiting periods and fruiting frequency per year, total number of *Opuntiae* plant stems in their hedges (see Section 3.1, and *Partie I* in Annex 10).
2. *Opuntia* utilisation: Which varieties are used for human consumption and which as livestock fodder? When are the different varieties eaten by humans? How many? How much do they contribute to overall food intake? What are the reasons for the (non-) consumption of the different *Opuntiae*? Are there negative health impacts for both humans and livestock? (see Section 3.2, and *Partie II* in Annex 10).
3. Economic activities involving *Opuntiae:* Sale of fruit, sale of cladodes as fodder, renting out access to *Opuntia* stands for fodder (see Section 3.3 and Questions *23-27* in Annex 10).

3.1 Experience with the sale of *Opuntia* seeds*:* How much labour is needed for the collection and separation of *Opuntia* seeds*?* What would be a fair price (see Section 3.3.1 *and Partie III* in Annex 10).

4. Potential conflicts/competition arising from the commercialisation of *Opuntia* seeds (see *Partie IV* in Annex 10).

2.3 Identification of *Opuntia* species/varieties

Globally, *Opuntia* research faces the challenge of accurately identifying the different *Opuntia* species and/or varieties: There are around 190 *Opuntia* species alone – of which many have not been sufficiently described (Rebman & Pinkava 2001). To make things even more complicated, several landraces, their crossbreeds, as well as species hybrids have been reported from Madagascar (Middleton 2015). Malagasy botanists from the University of Antananarivo, members of the FAO Cactus network as well as experts on Malagasy *Opuntiae* were asked to support *Opuntia spp.* identification. However, it was not possible to identify two species/varieties based on local vernacular names and/or the images we provided (cf. Allorge and Matile-Ferrero 2011).

3. RESULTS

3.1 Occurrence of *Opuntia spp.*

Table 5: Occurring *Opuntia spp.*, their fruiting rates/year, fruit colour, and their fruiting periods; Source: *own survey data*

Botanical name	Local name	height (cm)	Degree of spininess	Fruiting rate/year	Fruit color	Fruiting period (1 2 3 4 5 6 7 8 9 10 11 12)
Opuntia monacantha	Notsoke	>300	medium	1	reddish green	
Opuntia ficus-indica	Boritotse	100-150	medium	>1	red	
Opuntia stricta	Mavozoloke	50-100	very	>1	red	
Unidentified	Vilovilo	100-150	hardly	1	yellow	
Unidentified	Rengevoke	50-100	very	1	green	

Figure 13: left to right (a) *O. monacantha*, (b) *O. ficus-indica*, (c) *O. stricta*, (d) *O. spp.* (Vilovilo), (e) *O. spp.* (Rengevoke)

A total of five different *Opuntiae* can be regularly found in the field hedges investigated. The species, local names, fruit colours and fruiting periods are listed in Table 5 and pictures in Figure 13. However, two species could not be identified (Malagasy names: *Vilovilo* and *Rengevoke)*.

O. ficus-indica was said to produce fruit several times a year and all year long. However, it was not possible for local respondents to state exactly how often. Indeed, we encountered *O. ficus-indica* plants with no flowers, with flowers, mature, as well as with young fruit at the same time during our fieldwork.

3.2. Importance of *Opuntia spp.* for human nutrition and livestock fodder

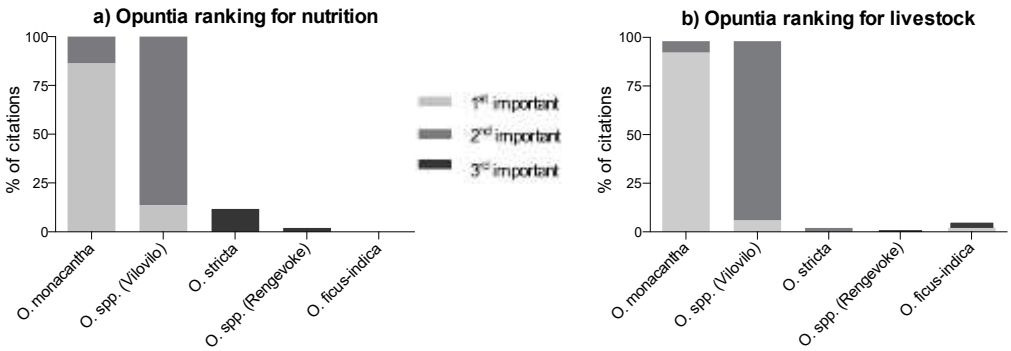

Figure 14a: Ranking of *Opuntia spp.* from human nutrition and **14b:** Ranking of *Opuntia spp*. for livestock fodder

Concerning nutrition, the respondents listed *O. monacantha and O. spp.* (unidentified, *Vilovilo)* as most important for human consumption. According to respondents surveyed, this is due to the low seed content of its fruit. In contrast, *O. ficus-indica* and *O. stricta* have a high seed content. Our

respondents reported that the fruit of these species tastes bad and that consumption results in digestive problems. Also, "*Vilovilo*" is less spiny, and thus its fruit is easier to harvest and consume.

Households collect *O. monacantha and Vilovilo* mainly between October and April, that is, during the lean season. Around 78% of HHs collect mostly in March, and 12% mostly in April. During the lean season, local farmers consume *O. monacantha* and *Vilovilo* fruit roughly 2-3 times per day (2.7 ± 0.2; mean ± 1 SE). Between 17 and 27 pieces of fruit are eaten per dish. Seventy-seven percent of the informants said that they eat dishes where *O. monacantha* and *Vilovilo* are eaten exclusively >10 times per month, and that they contribute to 56.9% ± 2.4% of their total nutrition during the lean period. Moreover, respondents specified that these fruits are also eaten as a water source, as water can become extremely scarce.

More then 50 percent of the respondents stated that *Opuntia* fruit consumption would lead to health problems, with constipation cited most frequently. Likewise, infections caused by the spines during harvesting were mentioned.

As well as for nutrition, *O. monacantha* and *Vilovilo* were ranked as the most important fodder resources of all *Opuntiae.* To be used as fodder for cattle and goats, the cladodes are separated from the plants, and the thorns are burned off (see Figure 15). According to survey respondents, the main constraints to their use as livestock fodder include diarrhoea in the animals, and physical wounds, which can lead to subsequent infections if the thorns are not sufficiently burned off.

3.3 Economic activities /Sale of *Opuntia* products

Forty-one percent of respondents confirmed that they regularly sell *Opuntia* products. However on average, they consume far more themselves than they sell. The average proportion of own consumption to sale is 88.2% ± 2.3% and 11.9% ± 2.3%, respectively. Exclusively fruits from *O. monacantha* and *Vilovilo* are sold.

Table 6: Price variation of *Opuntia* products

Parts	Unit	Price Max	Month	Price Min	Month
Cladodes	Hectare	187.500	10	135.000	3
Fruits	Ox-cart	30.000	4	20.000	3
Fruits	Basket (~15 l)	3.000	5	1.000	3
Fruits	Bucket (~10 l)	2.000	4	1.200	3
Fruits	Piece	38	5-9	13	2-3

During the dry season when grasses and herbs are scarce, herders from the Mahafaly Plateau practice transhumance and migrate to the littoral (Feldt 2015). Here, they feed their livestock with the succulent twigs of the dry forest tree *Euphorbia stenoclada* and with *Opuntia* cladodes (Feldt

2015; Götter 2015). Herders buy access rights to planted cacti areas, and some farmers in the littoral have even started to establish "fodder plantations" (Götter 2015). Four percent of the HHs in our survey sell access rights to *Opuntia* areas to transhumant herders. The price varies between 135,000 and 187,500 ariary per hectare (~42-58€, see Table 6). Also, small zebus and/or goats are occasionally exchanged for access to *Opuntia* cladodes (*own interview data*).

Fruit, however, was exclusively sold for human consumption for 13 to 38 ariary a piece (~0.004 - ~0.01€, see Table 6).

Figure 15: Burning of spines of *Opuntia spp.* cladodes on plantations in the littoral, Source: Tobias Feldt

3.3.1 Experience with the sale of Opuntia seeds

Usually, *Opuntia* seeds are considered waste by locals and discarded. From key informant interviews, we know that a local middleman bought small quantities of *O. ficus-indica* and *O. stricta* seeds between 2010-2013 for a French buyer. The seeds were shipped unprocessed, first to Antananarivo, and then to France. The sourcing stopped when the French buyer became sick.

Twenty-six per cent of the villagers surveyed had sold *Opuntia* seeds to middlemen in quantities of around 5 kg on average per year. In addition to the three villages covered in this study, several additional villages in the southern littoral delivered seeds. Villagers received a fixed price of 3,000 ariary/kg for sun-dried seeds (~0.8€). According to the villagers, a "fair" price would be 3,837 ± 269 ariary (~1.16€ ± 0.08€; Mean ± STE) per kg of sun-dried *Opuntiae* seeds (*own data*).

The villagers harvested the seeds in the following way: (i) the fruit were typically picked with spears, (ii) the fruit was separated from the thorns, (iii) the seeds were separated from the fruit, pulp and juiced by hand, (iv) the seeds were hand-washed and (v) sun-dried. After being separated from the fruit, the pulp and juice were still consumable according to our respondents. Total labour for the collection and separation of *Opuntiae* seeds was 3.3 ± 1.4 hours per kg of sun-dried seeds (*own survey data*).

3.4 *Opuntia spp.* in field hedges

Table 7: Size of field hedges in m^2 (N=87) and *Opuntia* hedges in m^2 (n=29)

Surface per field (m2)	Average	Median	Min	Max	St Error
Hedge total	6,014.6	5,188.7	318.0	25,604.0	450.6
Opuntiae in hedge	1,011.6	1,045.7	0.0	2,341.6	126.4

Each farmer has 1.6 ± 0.1 farm plots with an average plot size of 1.7 ± 0.1 ha (*own data*). The farm hedges have an average size of 6,015m^2 (>0.6 ha) per field, from which 1,012 m^2 (16.8%) consist of *Opuntia spp.* on average.

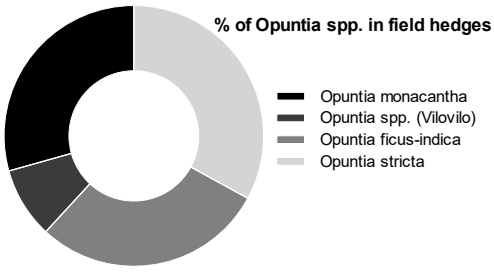

Figure 16: % of Opuntia spp. int the field hedges

Figure 17: Typical farmland in the littoral showing the living fences consisting mainly of *Opuntia spp*., *Agave sisalana* and *Euphorbia stenoclada*, Source: Google Earth Pro

Opuntia hedges consist, in sum, of 38.1% Opuntiae with edible fruit (mainly *O. monacantha,* some *Vilovilo*) and of 61.8% *Opuntiae* with inedible fruit (*O. ficus-indica* and *O. stricta,* see Figure 16). Apart from *Opuntia spp.*, farm hedges consist predominantly of *Euphorbia stenoclada* and *Agave sisalana* (*own data*).

Figure 18 shows the number of plant stems per *Opuntia spp.* per household, the sum of all *Opuntiae* stems based on vegetation inventories, and the sums of *Opuntiae* stems based on self estimates from interview respondents.

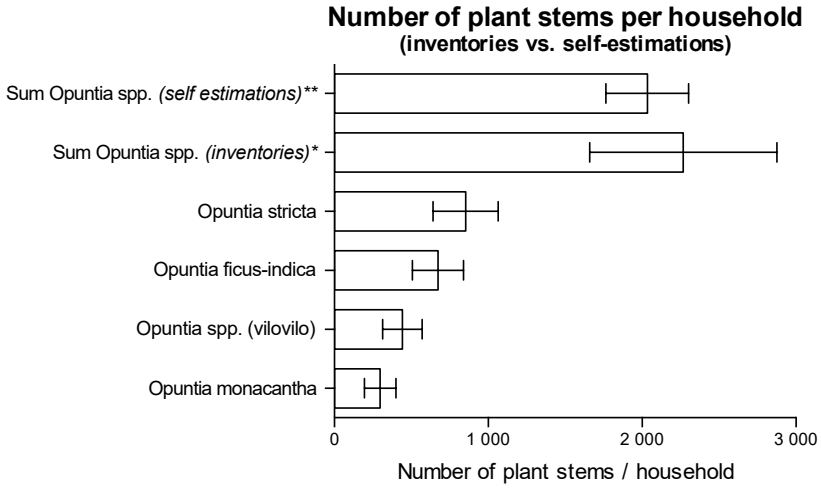

Figure 18: Number of plant stems from vegetation inventories compared to self-estimates from respondents, **Is the sum of all Opuntia spp. below, ** is based on interviews, self-estimates are sums of all Opuntia spp. in field hedges*, Error bars indicate standard error

3.5 Seed mass and seed content in *Opuntia fruits*

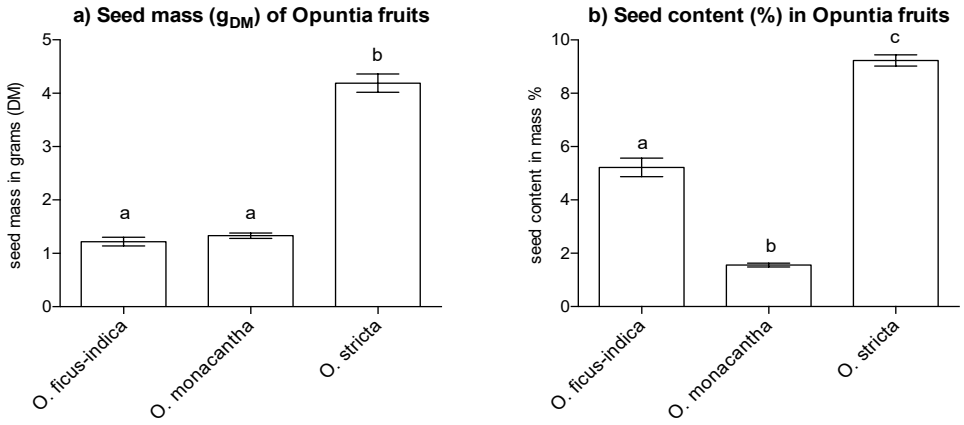

Figure 19a: Seed mass (in g_{dm}) per *Opuntia spp.* fruit and **19b:** Seed content (in mass %) per *Opuntia spp.* fruit. Error bars indicate 1 standard error; different letters indicate significant differences at p=0.001 in t-tests (a.) and paired t-tests in (b.) respectively.

Dry seed mass per piece of fruit was significantly higher in *O. stricta* than in *O. monacantha* and *O. ficus-indica* (t-tests, p=<0.001, see Figure 19a). However, as the total mass per piece of fruit also differed for the different *Opuntiae*, we also analysed the seed content (in mass %) in fruit.

Figure 19b shows that *O. stricta* had a significantly higher seed content than both *O. monacantha* and *O. ficus indica*, and that *O. ficus-indica* had a higher seed content then *O. monacantha* (paired t-tests, p=<0.001).

The two unidentified species (*O. spp.*; Malagasy: *Vilovilo* and *Rengevoke*) were omitted from the analysis (see Section 4.1 for a discussion on why).

Figure 20: from left to right: fruit of *O. spp. (vilovilo), O. stricta* and *O. ficus-indica*

3.6 Fruit estimation and potential seed oil production

The analysed *O. ficus-indica* seeds contained 7.04 mass % of seed oil, and *O. stricta,* 8.80 mass %. Table 8 presents (a.) *Opuntia spp.* surface (m^2) per HH (n=29) (b.), an estimate of the number of fruit /m^2/species in the lean season (n=30 per species), (c.) no of fruit per HH per species = combing (a.) and (b.), (d.) mass (g) per piece of fruit (fresh, n=30 per species), (e.) seed $mass_{(DM)}$/fruit , (f.) total seed $mass_{(DM)}$ / HH= based on (c.) and (e.), (g.) mass % of oil in seeds, and (h.) a final estimate of potential oil production per HH based on (f.) and (g.)

Table 8: Average yieldable oil potential of *Opuntia ficus-indica* and *Opuntia stricta* per household; mean values and standard error

Species	a. Surface (m^2)/HH	b. No fruit/ m^2	c. No fruit /HH	d.Mass per piece (g)	e. Seed mass/ piece (g_{DM})	f. Total seed mass (kg_{DM})/HH	g. seed oil mass %	h. Seed oil (kg)/HH
Opuntia ficus-indica	326.62	70.20	22,929	23.64	1.22	27.97	7.04	1.97
Standard Error	*74.66*	*3.16*	*235.56*	*0.58*	*0.08*	*0.02*	-	
Opuntia stricta	443.81	73.47	32,607	45.83	4.19	136.62	8.80	12.03
Standard Error	*96.30*	*3.15*	*303.39*	*1.91*	*0.17*	*0.05*	-	

As we see in Table 8, HHs could potentially produce 1.97 kg of *O. ficus-indica* seed oil, and 12.03 kg/HH of *O. stricta,* on average, based on the two *Opuntiae* in their field hedges.

Table 9: Average number of plant stems/HH, number of fruit/HH, and total seed weight/HH of *Opuntia monacantha*

Species	Surface (m^2)/HH	No plant stems/HH	No fruit/ plant	No fruit /HH	Mass per piece (g)	Seed mass/ fruit (g_{DM})	Total seed mass (kg_{DM})/HH
Opuntia monacantha	414.05	297.80	131.00	39,012	87.33	1.33	51.89
Sterror	*74.64*	*102.09*	*25.40*	*1,896*	*3.03*	*0.05*	*87.73*

As described in Section 2.1.b, for *O. monacantha,* the total number of pieces of fruit/HH was estimated based on the total number of plant stems/HH. However, its seed oil content was not analysed (see 4.1 for a discussion on why). Table 9 presents the results for the total number of fruit/HH and total seed mass/HH for *O. monacantha.*

4. DISCUSSION

Opuntiae are a vital part of southwestern Madagascar´s economic, social and cultural life (Kaufmann 2004). However, while Malagasy *Opuntiae* are commonly treated as an undifferentiated group of species/varieties commonly referred to by their Malagasy name *raketa* (Allorge and Matile-Ferrero 2011), we find that the different *Opuntia spp.* fulfil distinct functions for southwestern Malagasy land users.

O. monacantha and *O. spp (vilovilo)* constitute a crucial natural resource for local livelihoods. Particularly during the lean season, these plants contribute a substantial share of total food intake, provide water, and – to a smaller degree – also function as an income source. In contrast, *O. ficus-indica* and *O. stricta* are rarely eaten by humans due to their high seed content and an associated bad taste. Studies from Tunisia also report that *O. stricta* fruit is not suitable for human consumption (Yeddes et al. 2014).

Likewise, the cladodes, particularly of *O. monacantha* and *Vilovilo,* represent a key source of fodder for livestock. Without *Opuntiae*, pastoralism could probably not endure in this dry environment (Middleton 1999, Kaufmann 2001).

Our estimates on plant and fruit numbers are roughly in line with the estimates of the respondents. On average, they estimated that a total of 2,033 $\pm$ 269 *Opuntia spp.* plant stems can be found in the hedges of a household; according to our inventories it is 2,268 $\pm$ 608 per household (see Figure 18). Likewise, respondents estimated that fruit production, e.g. of *O. moncantha,* is 103 $\pm$ 10 pieces of fruit per plant stem on average (survey data); according to our inventorying it is 131 $\pm$ 25 pieces of fruit per plant stem (see Table 9).

If we sum up and transform our calculations of *Opuntia spp.* fruit production per m^2 to hectares (ha), they show average yields of around 25 tons/ha, which is in the middle range of global reported *Opuntia* fruit yields (Garcia de Cortázar & Nobel 1991, GAFÉIAS 2011, FAO 2013, Gebretsadik et al. 2013).

4.1 Which *Opuntiae* are appropriate for oil production?

Even though the spatial cover of *O. monacantha* is lower than that of *O. ficus-indica* and *O. stricta* (see Figure 16), its total fruit production is comparable (compare Table 8 and Table 9). This is due to its size of up to 4 m compared to the more stunted growth form of *O. ficus-indica* and *O. stricta* in southern Madagascar (Kaufmann 2004; *own data*). Considering that *O. monacantha* has a significantly lower seed content (see Figure 19b) at a higher total fruit weight (compare Table 8 and

Table 9), it is more suitable for human consumption. This was also clearly confirmed by interview respondents (see Section 3.2).

Potentially, there could be conflicts with a commercialisation of the seeds of *O. monacantha* and *O. spp. (vilovilo),* given their high importance for livelihoods during times of food scarcity. Their contribution to total food intake can reach >50% during the lean period (see Section 3.2). Studies from the *Androy* region report similar patterns, where locals stated that they eat up to 50-70 pieces of fruit/day during the lean period (Larsson 2004).

Fundamentally, however, it is the contrary demand on seed content exerted either by human consumption or by the needs of seed oil production that alleviate potential competition between food security and the "cash crop" production of *Opuntia* seed oil. As a case in point, the high seed content species *O. ficus-indica* and *O. stricta* were the least appreciated and least used for both human food and livestock fodder, while they were most abundant in field hedges. In fact, > 60% of all *Opuntiae* consisted of these two species (see Figure 16). While it is conceivable that waste seeds from the consumption of *O. monacantha* and *O. spp* (*vilovilo*) could be used in seed oil production, a regional oil processing company decided to source only "red" *Opuntia* fruit (*O. stricta and O. ficus-indica*), and not "green" fruit (*species/varieties not specified*), given their high nutritional importance in the *Androy* region (Phileol 2013).

The chemical components addressed in *Opuntia* seed oil marketing are not exclusive to the most-often studied *O. ficus-indica*, but are also attributed to other *Opuntia spp.* (Stintzing & Carle 2005). In this study, for example, we found a higher seed oil content in *O. stricta* than in *O. ficus-indica* (see Table 8). In *O. stricta* seed oil from our study area, a linoelic acid share of 66.6% was found, which is in the middle range of reported *O. ficus-indica* fatty acid spectrums (Ramadan & Mörsel 2003; Ennouri et al. 2005; analysis conducted by SGS Gmbh, Hamburg, Germany). Likewise, comparing Tunisian *O. stricta* and *O. ficus-indica,* Yeddes et al. (2014) found significantly higher antioxidant activities in *O. stricta* fruit.

With total seed oil contents of 7.0 (*O. ficus-indica*) and 8.8 *(O. stricta*; solvent extraction) mass %, respectively, the values of Mahafaly *Opuntia* seeds fall well within the reported ranges of oil yields. In global reports, *Opuntia* seed oil content data show large variations ranging from <4% to > 17% (Sawaya & Khan 1982; Coskuner & Tekin 2003; Ramadan & Mörsel 2003; Ennouri et al. 2006; Mannoubi et al. 2009; FAO 2013; Guillaume et al. 2015). Some of this variability may be due to

differing maturation times of the fruit (Coskuner and Tekin 2003). Some of the published studies are based on fruits that are bought on European markets (e.g. Ramadan & Mörsel 2003); others are taken directly in the field, e.g. in North Africa (Ennouri et al. 2005; Yeddes et al. 2014).
Most studies measured *Opuntia* seed oil content using solvent extractions, e.g. with hexane (e.g. Sawaya & Khan 1982; Ennouri et al. 2005; Mannoubi et al. 2009; Ghazi et al. 2013). However, if the seed oil were generated through a cold press, seed oil yields would be lower due to higher losses using mechanical oil mills. Oil producers we contacted reported oil yields of around 4-5% from Malagasy *Opuntia stricta* seeds in test pressings using mechanical mills.

4.2 A value chain approach for *Opuntia* seed oil in southwestern Madagascar

From a rural development perspective on value addition, one would strive to process *Opuntia* seeds to the maximum degree possible in the research region itself. Much of the potential income would be lost to Madagascar and to the Mahafaly area if only raw, unprocessed seeds were exported. Sometimes, however, it is an economically superior option to export raw materials from countries such as Madagascar, as there are higher import duties associated with processed goods than for raw materials. Fortunately, this consideration does not apply to Madagascar as a *least developed country* (LCD). Due to the "Everything but Arms agreement" between the European Union and several LCDs, import duties are charged neither on *Opuntia* seeds nor on seed oil (European Comission 2015).

According to market experts from the Cactus Network of the FAO (ICARDA-FAO, personal communication), most commercialised *Opuntia* seed oil stems from Moroccan production, and a small amount from Tunisia. Although Morocco and Tunisia are spatially much closer to the important European market and have a more advanced general infrastructure compared to Madagascar, the favourable labour cost differential and the low marginal cost of the exploitation of a currently underutilised resource may further argue for the competitiveness of *Opuntia* oil from Madagascar.

Among other reasons, the cosmetics industry demands *Opuntia spp.* oil because of its high concentration of linoleic acid, which has a wrinkle-reducing effect (Moßhammer et al. 2006). Furthermore, *Opuntia* oil is becoming increasingly interesting for the pharmaceutical industry due to an increasing number of *Opuntia* studies reporting positive effects on human health (Zou et al. 2005; Feugang et al. 2006; El-Mostafa et al. 2014; Osuna-Martínez et al. 2014). As of 2016, it is

uncertain, though, whether the market for *Opuntia* seed oil could actually absorb huge additional quantities without a substantial reduction in prices. *Opuntia* seed oil is currently still a niche-product (personal communication with Phileol).

Most likely, quality considerations place the most challenging constraints on research area-based processing. To maintain the high concentration of antioxidants and unsaturated fatty acids, the oil mill needs to operate in a way that minimises contamination of the seed oil and its exposure to ambient air/oxygen. In turn, this requires an advanced level of technical equipment on the part of the oil mill, skilled staff, and adequate logistics. Given the Moroccan historical experience with this resource, these requirements are easier to fulfil elsewhere than in our research region. At the country level, however, a small number of enterprises are known to be capable of extracting quality *Opuntia* seed oil as they extract other fatty and/or essential oils from local plant resources, and commercialise them successfully on a global scale (e.g. Homeopharma, Phileol).

A further consideration applies to the type of oil production. Because of the hard seeds and their relatively low oil content, an extraction with solvents has considerable cost advantages. A solvent based extraction with, e.g., hexane has the disadvantage, however, that the "chemical" solvent has to be removed from the seed oil after extraction – which becomes excessively expensive for higher grades of purification. Therefore, the quality of chemically extracted, commercial grade *Opuntia* seed oil is regarded as inferior (Naturinstitut 2015). Even if extremely low solvent contents are technically feasible, the market favours seed oils extracted by "traditional", purely physical/mechanical means. The mechanisms that result in a price premium for purely mechanically produced "virgin" olive and argan oil are in operation for *Opuntia* seed oil as well. Furthermore, the purity and natural qualities that consumers associate with Madagascar is at odds with chemical extraction from a marketing perspective, targeting the high value use of the seed oil e.g. in "natural" cosmetics.

4.2.1 By-products and other purposes

With a seed oil content of 7.0% - 8.8%, *Opuntia* seed processing with mechanical mills generates a substantial amount of presscake. The presscake of *Opuntia stricta* has a low protein (7.2%) and crude fat content (2.4%), but a high fibre content (50.5%) (analysis conducted by SGS Germany GmbH, Hamburg). Due to a fodder shortage in the project region, especially during the lean period,

Opuntiae presscake could be used to feed ruminants (e.g. zebus), as they can utilise high fibre fodder (Russell and Felker 1987; Gebretsadik et al. 2013).

Another by-product if *Opuntia* seeds are commercialised is the pulp and juice from the *Opuntia* fruit. Juice and pulp could be consumed in the household, sold, or processed to yield jam (own interview data; FAO 2013). This also includes the less appreciated *O. ficus-indica* and *O. stricta,* since the seeds, reported to cause digestive problems, would be removed. For example, *O. ficus-indica* jams are successfully marketed globally, and can be easily produced through "low-tech" techniques (FAO 2013). The pulp of *O. ficus-indica* fruit contains glucose (35%) and fructose (29%), both in dry mass (El Kossori 1998). Through the fermentation of its sugars, alcoholic beverages can also be produced (Sáenz 2013), such as beer (see. Spottzl Brewery Co. and Borderland Brewing Co. for *Opuntia spp.* beers)

4.3 Gender and institutional issues

According to local gender norms, the lower part of *Opuntia spp.* plants is considered to be a "male part", and the upper part a "female part" (Kaufmann 2004). Thus, the preparation of fodder from *Opuntiae* cladodes is an activity conducted by males, while the collection and selling of fruit is a female activity (ibid). If this cultural division of labour were to continue, a commercialisation of *Opuntia* seeds may strengthen the economic position of women in local households. However, there are recent examples from other fodder plants in the research region that the rules for resource access change, i.e. from open access towards increasing privatisation (Götter 2015). Three of the surveyed HHs sold access to *Opuntia* plantations as fodder (see Section 3.3). With previously invariant cultural constants becoming more dynamic, the future distribution of benefits from the commercialisation of *Opuntia* fruit and seeds should be monitored carefully, as there is evidence that men and/or local elites tend to benefit predominantly from market integration in marginal rural communities (Genicot 2002; Basu 2007).

Because of the strongly differing seed content of the fruit, it appears unlikely that a problematically high share of edible *Opuntia* fruit will be removed from human subsistence consumption in favour of the commercialisation of *Opuntia* seeds. Although unlikely, it cannot be ruled out completely that local elite households would try to gain preferential access to (privately owned) field hedges, and enforce a shift to planting more *Opuntiae* with inedible seeds. However, with sufficiently high seed prices, field owners may find it in their own economic interests to switch to high seed content *Opuntiae*. These "landed" households are likely to improve their food security during the lean

season. In the worst case, households not owning *Opuntia* hedges but previously having been granted some access to edible fruit may lose out. At this point, it is impossible to foresee whether the stronger overall economic base in the communities due to the commercialisation of *Opuntia* seeds can make up for this potential disadvantage.

5. CONCLUSION

The food security of rural households inhabiting the littoral of the Mahafaly Plateau has been chronically low (WFP & FAO 2014, Hänke et al. *submitted*). Two *Opuntiae* with low seed content in their fruit (*O. monacantha* and a variety locally called *Vilovilo*) are crucial for human nutrition – and even water uptake – during the annual "lean" or "hunger" season. On the contrary, the widespread *O. ficus-indica* and *O. stricta* have a high seed content, making them unsuitable for human nutrition. In fact, we find that their fruits do not contribute to the food security of local HHs. As the fruit of these two *Opuntiae* grow abundantly in the living fences of local fields, these two species suggest themselves as a seed source for seed oil production. Our estimates of the average *Opuntia* seed oil yield per household shows the potential of the collection and pre-processing (cleaning, drying) of *Opuntia* seeds as an additional income source.

O. ficus-indica fruit is available throughout the year while *O. stricta* fruit can be harvested from March to August, coinciding with the period where HHs harvest annual crops as well as cassava (Coral 2014). Complementing current – often drought-sensitive – income sources (Hanisch 2015; WFP 2015; Hänke & Barkmann *submitted*), the sale of *Opuntia* seeds appears to be a potential additional, low-risk component of total HH income. Local farming HHs only earned around 15€ per month in 2014 on average, as cash income was largely earned through livestock sales (Hänke et al. *sumbitted*). The potential sale of more than 160 kg of seeds (*O. stricta* & *O. ficus-indica* only) per average HH would generate more than 540,000 ariary a year (~155€)[7] at local prices. As the fruit needs to be harvested, the seeds extracted, cleaned and dried, there is an opportunity cost in terms of labour spent on these activities. According to respondent experiences, the complete *Opuntia* seed preparation for 1 kg took 3.3 ± 1.4 hours on average. Given the low regional wages (e.g. <0.5 € for fieldwork or construction work per day) and the absence of lucrative income activities (Hänke et al. *submitted*), opportunity costs appear low, however.

Local processing of the seed oil itself would further upgrade the local value chain, reduce transportation costs, and allow for local use of the press cake. Even without mastering the associated technological and quality challenges of upgrading, the increasing international demand for *Opuntia* seed oil may bring livelihood improvements to some of the poorest rural communities in Madagascar.

[7]Calculation is based on a single fruiting period. However, both *O. ficus-indica* and *O. stricta* give fruit several times a year. So, total seed production is higher (see Section 3.1).

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GENERAL DISCUSSION AND CONCLUSION

While the main findings have already been discussed thoroughly in their respective chapters, this concluding chapter will provide a short general discussion and conclusion, and implications for policymakers and development organisations will be deliberated.

In sum, the results of this dissertation show that crop failure and food insecurity has been "the norm" for the large majority of HHs during the period covered. Households have not produced nearly enough food for HH self-sufficiency and generated very little cash income. As a consequence, households have had to employ a range of coping strategies, which have been analysed extensively in the first 2 chapters of this dissertation.

As demonstrated in chapters 1 and 2, HH cash income was predominantly generated through the sale of livestock. In chapter 1, we also saw that selling livestock played a key role in covering food expenses during the failure of annual crops; in chapter 2 we likewise saw that HH food expenses and cash income generated from livestock were chronically correlated throughout the entire year. Thus, the view of a "cattle complex" in Madagascar is severely challenged by the results of chapters 1 and 2, as an important actual insurance function is being documented. While the "cattle complex" narrative led to low support for pastoral development projects by donor agencies in the past, the virtual exclusion of livestock from development activities in southwestern Madagascar should be reconsidered based on the results presented.
However, the gradual depletion of HH assets, i.e. livestock, leads to a diminishing HH buffer in the long term, and thereby hinders other investments.

Nevertheless, non-farm income sources were not sufficient to cover the food gaps for many HHs. Despite food aid from NGOs, many households had to reduce their food intake to unhealthy low levels. For poor households, this also included reducing nutrition for children. As we saw in Chapter 3, *Opuntia* fruit can make up >50% of total food intake for many HHs during periods of food shortages, but causes negative health impacts.

The regional farming system is extremely undeveloped, no agricultural inputs are used, seeds of unknown quality are sown and only the simplest tools are used (Coral 2014, Hanisch 2015). Despite high livestock numbers, there is virtually no integration of livestock in arable agriculture (Hanisch

2015). However, on-farm trials with manure as well as a charcoal additive did not improve agricultural yields significantly in the study region (Hanisch 2015). Similarly, many HHs participating in our longitudinal study were participating in *food-for-work* programs, whereas NGO-promoted farming practices (use of compost, manure, drought resistant seeds) could also not secure HH food security. The fundamental lack of water and/or locust outbreaks also made these "improved practices" a failure. Despite these recurring failures in the period covered by this study, most development organisations still have a strong focus on arable agriculture in the region, often following a conservation agriculture approach.

While the improvement of cropping systems is often regarded as an easy and effective way out of poverty in SSA (e.g. Diao et al. 2010) and could also safeguard food security in Madagascar (e.g. Minten and Barrett 2008), there is increasing evidence that the options for agricultural upgrading are severely limited in southwestern Madagascar (Rollin 1997, Bayala et al. 1998, UNICEF 2011, Hanisch 2015). Although the period covered in this study is a relatively short period, and is hence a "snapshot", >50% of regional HHs described their food production as "never sufficient" (Neudert et al. 2015). In fact, agriculture is highly risky in the region. Climate related risks and large variability in environmental conditions are a key constraint for upgrading regional cropping systems (see chapter 2), whereas water is probably the most limiting factor (Hanisch 2015). Irrigated arable agriculture is not feasible due to deep groundwater levels (de Haut de Sigy 1965, Hanisch 2015) or due to unacceptably high levels of water salinity in the littoral (Guyot 2002). Regional arable agriculture is thus completely rainfall dependent, and rainfall patterns are unpredictable. Climate change predictions show that rain-fed farming in SW Madagascar has become and will become even more difficult in the future (Tadross et al. 2008, Vololona et al. 2013, Harvey et al. 2014), and droughts and extreme weather events such as cyclones have increased in recent years (Usman and Reason 2004, Fitchett and Grab 2014, WFP and FAO 2014, WFP 2015).

The detailed social-ecological systems analysis performed in chapter 2 has certain limitations, as these resilience-related frameworks are not dedicated to concrete intervention options and/or poverty reduction *per se* (Maru et al. 2012, Béné et al. 2014). However, such a holistic approach provides a comprehensive analysis of the present system dynamics and can help to identify causal relationships between different domains (i.e. social and ecological systems, cf. Sendzimir et al. 2011). What these dynamics in chapter 2 suggest is not only that environmental degradation, poverty and hunger are closely linked, but that they also self-reinforce each other. The self-

reinforcing feedback identified in chapter 2 keeps agricultural yields notoriously low, and leads to livelihood impoverishment and a loss of environmental assets.

A key regional development challenge is to move beyond the prevailing focus on "coping", and instead to build resilient pathways for the long term, that is, making livelihoods more resistant to shocks (i.e. droughts, locust outbreaks and cyclones). Therefore, the following key issues should be considered:

(i) A sound systems understanding is required prior to interventions. In fact, current development and conservation agendas suffer from too limited a view of how contemporary social-ecological systems on the Mahafaly Plateau operate. In Madagascar more generally, assumptions about human-environment interactions are often based on oversimplified narratives (Kaufmann and Tsirahamba 2006, Moreau 2008, Scales 2014).

(ii) Highly risky agriculture and highly variable environmental conditions should be accounted for, where also the (iii) likelihood of failure of "improved farming practices" should be anticipated. If so, alternatives to safeguard food security are required.

Finally, (iv) insurance to protect against frequently occurring crop failure should be established so that HHs can effectively deal with such risks and re-establish themselves after crises.

The findings in chapters 1 and 2 indicate that although livestock serves as self-insurance for many HHs, lucrative non-farm income sources are scarce in the region. Moreover, highly risky arable agriculture suggests itself that a focus – in addition to and/or beyond arable agriculture – is crucial. Also, so as to reduce the pressure on the unique regional biodiversity, support for income sources outside the farm/livestock sector are needed.

Livelihoods in SW Madagascar are completely natural resource dependent (SuLaMa Marp 2011), making them particularly vulnerable to climatic risks (Boko et al. 2007, Harvey et al. 2014) and to the consequences of environmental degradation (Millenium Ecosystem Assessment 2005). More diversified livelihoods, however, are less affected by climatic risks (Thomas and Twyman 2005, Morton 2007), and there is an overall positive relationship between non-farm income and HH welfare indicators across rural Africa (Barrett et al. 2001), also in southwestern Madagascar (Neudert et al. 2015).

Finally, chapter 3 suggests that regional *Opuntia* seed oil production might be a promising non-farm income source for communities in the littoral, the most drought affected part of the study region. *Opuntia* is one of the few plants that is barely affected by droughts. *Opuntia ficus-indica* and

Opuntia stricta have a high seed content, a high local abundance but a low importance for regional food security, and could be harvested throughout the year. An evenly-distributed and secure income source throughout the year might help HHs in the littoral to overcome chronic poverty, the pronounced seasonality of agricultural income and buffer agricultural income shocks.

If the increasing demand for *Opuntia* seed oil were to continue, it could be a low-risk income source for regional livelihoods. Even without mastering the technological and quality challenges of upgrading steps on side (i.e. seed oil pressing), the sale of *Opuntia* seeds could bring livelihood improvements to one of the poorest rural communities in SW Madagascar.

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ANNEX

Annex 1: Innovation survey

Enquête « crop-plateau» 2012/2013

Village (fokontany):_____ Date (daty):_____

Nom d´enquêteur (anaran'ny mpanontany): _____

I Partie personnelle

1. Nom (anaran'ny anontania):_____ ID Répondant :____ Sexe: ☐masculin (lahy) ☐féminin (vavy)

2. Age (Tao): ☐<20 ☐20-30 ☐ 30-40 ☐ 40-50 ☐ 50-60 ☐>60

3. Combien de personnes êtes-vous dans votre ménage (firy isa'areo an-trano atoy)?_____

4. Combien de personnes de ce ménage travaillent dans les champs ?_____personnes

5. Éducation (fianara) : ☐ rien (tsy nianatra) ☐ EPP ☐ CEG ☐ université

6. Combien d´années de formation en totale ?_____

7. Etes-vous nés dans votre village (niteraka tatoa va iha)? ☐oui (eka) ☐non (aha)

7.1 Si non, quand êtes vous arrivés ici (raha tsia, ombia anareo niavy tatoy) ?_____

8. Est-ce qu´il y avait déjà des ONG/projets/institutions gouvernementales qui ont travaillé avec vous (Efa nisy projet vaha tatoy ami'areo tatoy) ? ☐Oui (eka) ☐Non (aha)

- Si oui (raha eka), lesquelles (iha avy)?_____

- Période (fotoa niasany tatoy):_____

- Activités principales (asa nataony tatoy):_____

9. Combien de fois voyez-vous des gens qui travaillent là-bas par an?_____

10. Est-ce que vous faites partie d´une association (iha va anaty fikambana)?

☐ non (aha) ☐association (fikambana) ☐coopérative (fiaraha-miasa) ☐groupement religieux (resaka finoana)

Activités principales (ino ty asa atao'areo)?_____

II Partie agricole

11. Depuis combien d´ans pratiquez-vous l´agriculture ?_____ans

12. Combien de champs avez-vous (firy baiboa areo)? _____

13. Taille en totale ?_____ha

14. Qui-possède la terre ou vous cultivez? ☐ moi même ☐loué

15. Quelle est la distance entre vos champs et celle de votre proche (misy lera firy ty mampisaraka ty baiboanao sy ny raiky anilanao eo)?_____heures (lera) ?

16. Où est le marché le plus proche de votre village (ahia bazary marigny anareo atoy)?_____

- Combien d'heure dépensez-vous pour aller là-bas (firy lera iha mande agny) ?_____

-Avec quelle moyen de transport ?_____

17. Où est le marché le plus important pour vous? ☐le même ☐autre :_____

- Combien d'heure dépensez-vous pour aller là-bas (firy lera iha mande agny) ?_____

-Avec quelle moyen de transport ?_____

18. Quel-est le matériel que vous utilisez dans vos champs ?

1.	2.	3.	4.
5.	6.	7.	8.

19. Est-ce que vous avez des zébus (manana aomby va areo)? ☐ oui (eka) ☐ non (aha) .

- Si oui, combien (raha eka, firy ty isa) ?_____ _____

20. Est-ce que vous possédez une charrette (iha va mana-sarety) ? ☐oui (eka) ☐non (tsia)

21. Est-ce que vous achetez des fertiliser pour vos champs ? ☐oui (eka) ☐non (tsia)

Si ou, lesquelles ?_____

Pour combien (Ariary)?_____ _____

22. D´après-vous, peut-le fumier améliorer les récoltes (Iha va mieritreritra fa mety ahasoa ty volinao ny fampiasa zezika)? ☐ oui (eka) ☐ non (aha) ☐je ne sais pas (tsy aiko)

23. Est-ce que vous utilisez le fumier dans vos champs ? (Mampiasa zezika amy vala traka na amy baiboa va areo)?

☐ oui (eka) ☐ non (aha)

24. Si non, pourquoi n´utilisez-vous pas le fumier?

☐ avantage d´usage de fumier n´est pas clair pour moi ☐ trop de travail ☐ aucun moyen de transport

☐ je ne sais pas où trouver le fumier ☐ usage de fumier est « fadi » ☐ je ne possède pas assez (quantité)

☐ autre:_____ _____

25. Est-ce que vous connaissez quelqu´un qui utilise le fumier dans ses champs (iha va mahafantatry olo mampiasa zezika amy ty baibony na ty vala trakany)? ☐oui, village (fokontany) ☐oui, région (faritra) ☐non (aha)

26. Qu´est-ce que vous faites pour améliorer la fertilité du sol ?

Practice	Oui	Non	Sur quelle culture
1 Brûlant de végétation	☐	☐	
2 Application de fertiliser	☐	☐	
3 Application de fumier	☐	☐	
4 Rotation des cultures	☐	☐	
5 Mise en jachère	☐	☐	
6 Utilisation des résidus de récolte	☐	☐	
7 Plantation des arbres	☐	☐	
8 Plantation de clôtures vivantes (p.ex. cactus)	☐	☐	
9 labourage du sol (pour l´ouvrir)	☐	☐	
10 Autre :			

27. Quel sont les mauvaises herbes dans vos champs, et qu´est-ce que vous faites contre eux ?

Plante	Culture	Action pour combattre
1.		
2.		
3.		
4.		
5.		

28. Si vous avez besoin de conseil agricole, qui demandez-vous (iha ty olo antoninao raha mila fanampia hevitra iha amy ty fambolea atao)? ☐ chef du village (sefo fokontany) ☐ famille (fianakavia) ☐amis (nama) ☐ chef spirituel (tangalamegna/ pasitera) ☐ autre (hafa):_____

29. Si vous avez besoin de conseil concernant des grandes décisions dans la vie, qui demandez-vous (iha ty olo antoninao raha mila fanampia hevitra iha amy raha ataonao)?

☐ chef du village (sefo fokontany) ☐ famille (fianakavia) ☐amis (nama) ☐ chef spirituel (tangalamegna/ pasitera)

☐ autre (hafa) :_____

30. Concernant l´agriculture, est-ce que vous produisez assez? Où est-ce que vous avez besoin d´une production supérieure ?

☐assez ☐faudrait produire plus

III Partie Innovation

31. Qu´est-ce qu´il y a de nouveau dans vos pratiques agricoles par rapport à il y a 5/10/ 20 ans (nisy raha vaovao va tamy ty fiaina ao raha oharina tamy 5/ 10/20 tao lasa)?

☐ rien (tsy nisy)

☐ Matériel agricole, lequel (fitaova fambolea, ino avy)?_____ Par qui (iha)?_____

Quel-est l´avantage (Ino tombontsoa areo)?_____

☐ Semences/Variétés, lesquelles (tabiry, ino avy)?_____ Par qui?_____

Quel-est l´avantage ?_____

☐ Cultures (plantes introduites), lesquelles (voly hafa azo'areo, ino avy)? _____

Par qui ?_____Quel-est l´avantage ?_____

☐ Pesticides, lesquelles (fanafody ampiasa amy vokatra, ino avy)?_____

Par qui (iha)?_____ Quel-est l´avantage ?_____

☐ Amélioration de la terre, lesquelles (fanatsara ty tany, ino avy) ?_____

Par qui?_____ Quel-est l´avantage ?_____

☐ Autres (hafa, ino avy)?_____ Par qui ?_____

Quel-est l´avantage ?_____

29. Si vous achèteriez des semences pour vos cultures (p.ex. maize, sorgho), ca serait où? ?

☐ Acheter moi-même sur le marché à Tuléar

☐ Acheter sur un marché qui est proche de chez moi

☐ Acheter vers une association villageoise (association de femmes, église etc.)

☐ Acheter chez mes amis, voisins

☐ Je n´achèterais jamais

33. Il est difficile de comprendre la quantité de fumier qu´il faut appliquer à mes cultures.

☐d´accord ☐pas d´accord ☐ je ne sais pas

34. Le fumier pu et ca me dérange.

☐d´accord ☐pas d´accord ☐ je ne sais pas

35. Le fumier pu et ca dérange mes voisins

☐d´accord ☐pas d´accord ☐ je ne sais pas

36. Si j´essais des nouvelles variétés de cultures, il y a plus de risque que ca ne donne pas du tout.

☐d´accord ☐pas d´accord ☐ je ne sais pas

37. Je n´ai pas besoin d´autres variétés car ceux que j´utilise sont les meilleurs.

☐d´accord ☐pas d´accord ☐ je ne sais pas

Annex 2: Innovation/ On-farm trial survey

Enquête sur les innovations agricoles / «crop-plateau» 2013/2014

Village (fokontany):_____ Date (daty):_____
Nom d´enquêteur (anaran'ny mpanontany): _____

I Partie personnelle

1. Nom (anaran'ny anontania):_____ ID Répondant :____ Sexe: ☐masculin (lahy) ☐féminin (vavy)
2. Age (Tao): ☐<20 ☐20-30 ☐ 30-40 ☐ 40-50 ☐ 50-60 ☐>60
3. Combien de personnes êtes-vous dans votre ménage (firy isa'areo an-trano atoa)?_____
4. Combien de personnes de ce ménage travaillent dans les champs (firy ty isan-daty miasa an-tonda amy areo atoa) ?_____personnes
5. Éducation (fianara) : ☐ rien (tsy nianatra) ☐ EPP ☐ CEG ☐ université
6. Combien d´années de formation en totale (mety firy tao ty fahareta ty fianaranao ?_____
7. Etes-vous nés dans votre village (niteraka tetoa va iha)? ☐oui (eka) ☐non (aha)
   7.1 Si non, quand êtes vous arrivés ici (raha tsia, nombia ty niavia areo tatoy) ?_____
8. Est-ce qu´il y avait déjà des ONG/projets/institutions gouvernementales qui ont travaillé avec vous (Efa nisy projet niara-niasa tama areo va ty tatoy) ? ☐Oui (eka) ☐Non (aha)

- Si oui (raha eka), lesquelles (ino iaby)?_____
- Période (fotoa niasany tatoy):_____
- Activités principales (asa nataony tatoy):_____

9. Combien de fois voyez-vous des gens qui travaillent là-bas par an?_____
10. Est-ce que vous faites partie d´une association (iha va anaty fikambana)?

☐ non (aha) ☐association (fikambana) ☐coopérative (fiaraha-miasa) ☐groupement religieux (resaka finoana)

Activités principales (ino ty asa atao'areo)?_____

II Partie agricole

11. Depuis combien d´ans pratiquez-vous l´agriculture (tokony fa firy tao zay ty nambolia areo) ?_____ans
12. Combien de champs avez-vous (firy ty baiboa areo)? _____
13. Taille en totale (tokony firy hekitara ty habe baibo nareo io) ?_____ha
14. A qui appartient le terrain ou vous cultivez ? (Ia ty tompony tany ambolea areo io ?)? ☐ moi même ☐loué
15. Quelle est la distance entre vos champs et celui de votre proche (misy lera firy ty mampisaraka ty baiboanao sy ny raiky anilanao eo)?_____heures (lera) ?
16. Où est le marché le plus proche de votre village (aia tsena marigny anareo atoy)?_____
- Combien d'heure dépensez-vous pour aller là-bas (firy lera iha mande agny) ?_____

-Avec quelle moyen de transport (mandeha amin`ino nareo lafa mamonjy tsena any?_____

17. Où est le marché le plus important pour vous(aia ty tsena tena vonje areo matetiky)? ☐le même ☐autre :_____

- Combien d'heure dépensez-vous pour aller là-bas (firy lera vao avy any) ?_____

-Avec quelle moyen de transport (mandeha amin`ino nareo lafa mamonjy tsena any)?_____

18. Quel-est le matériel que vous utilisez dans vos champs (ino iaby fitaova ampiasa areo amy baibo areo io ?)?

1.	2.	3.	4.
5.	6.	7.	8.

19. Est-ce que vous avez des zébus (manana aomby va nareo)? ☐ oui (eka) ☐ non (aha) .

Qulqu´un dans votre famille ?
- Si oui, combien (raha eka, firy ty isa) ?_____ _____
20. Est-ce que vous possédez une charrette (iha va mana-sarety) ? ☐oui (eka) ☐non (tsia)
Qulqu´un dans votre famille ?
21. Est-ce que vous achetez des engrais pour vos champs (mivily zeziky va nareo)? ☐oui (eka) ☐non (tsia)
Si ou (laha eka, ino iaby),lesquelles ?_____ _____
Pour combien (otrino ty viliny)(Ariary)?_____ _____
22. D´après-vous, peut-le fumier améliorer les récoltes (Iha va mieritreritra fa mety ahasoa ty volinao ty fampiasa zeziky)? ☐ oui (eka) ☐ non (aha) ☐je ne sais pas (tsy aiko)
23. Est-ce que vous utilisez le fumier dans vos champs ? (Mampiasa zezika amy vala traka na amy baiboa va nareo)?
☐ oui (eka) ☐ non (aha)
24. Si non (laha aha), pourquoi n´utilisez-vous pas le fumier (ino ty antony mahavy anareo tsy mampisa zeziky)?
☐ avantage d´usage de fumier n´est pas clair pour moi (tsy haiko ty tombotsoa ty fampiasa azy) ☐ trop de travail (magnabe asa)
☐ aucun moyen de transport (tsy misy fitaova handesa azy) ☐ je ne sais pas où trouver le fumier (tsy haiko hoe aia ty misy zezky io) ☐ usage de fumier est « fadi » (faly anay ty mampiasa io) ☐ je ne possède pas assez (quantité) (Tsy ampy ty zeziky nay)
☐ autre (hafa):_____ _____
25. Est-ce que vous connaissez quelqu´un qui utilise le fumier dans ses champs (iha va mahay olo mampiasa zeziky amy ty baibony na ty vala trakany)? ☐oui, village (fokontany) ☐oui, région (faritra) ☐non (aha)
Si oui, qui (la) ?_____

26. Qu´est-ce que vous faites pour améliorer la fertilité du sol (ino zany ty ataonareo mba hampamkatsy tany areo io)?

Practice	Oui	Non	Sur quelle culture
1 Brûlant de végétation (oroa)	☐	☐	
2 Application déngrais (fampiasa zezi-bazaha)	☐	☐	
3 Application de fumier (fampiasa zeziky)	☐	☐	
4 Rotation des cultures (ovaova ty voly atao aminy)	☐	☐	
5 Mise en jachère (tsy ambolea fa ajano)	☐	☐	
6 Utilisation des résidus de récolte (fampiasa taim-bokatsy)	☐	☐	
7 Plantation des arbres (ambolea zana-kazo)	☐	☐	
8 Plantation de clôtures vivantes (p.ex. cactus)(asia vala hazo mitiry)	☐	☐	
9 labourages du sol (pour l´ouvrir) (atao laboro)	☐	☐	
10 Autre (ino koa ty hafa):			

27. Quel sont les mauvaises herbes dans vos champs, et qu´est-ce que vous faites contre eux ? (ino iaby ty ahi-draty misy amy baibo areo, le ino ty atao areo hiarova ty voly areo ?)

Plante (agnarany ahi-draty	Culture (ka	Action pour combattre
1.		
2.		
3.		
4.		
5.		

28. Si vous avez besoin de conseil agricole, a qui demandez-vous (ia ty olo antoninao raha mila toro hevitra iha amy ty fambolea atao)? ☐ chef du village (sefo fokontany) ☐ famille (fianakavia) ☐amis (nama) ☐ chef spirituel (tangalamegna/

pasitera) ☐ autre (hafa):_____

29. Si vous avez besoin de conseil concernant des grandes décisions dans la vie, qui demandez-vous (iha ty olo antoninao raha mila ftoro-hevitse iha amy raha ataonao)?

☐ chef du village (sefo fokontany) ☐ famille (fianakavia) ☐amis (nama) ☐ chef spirituel (tangalamegna/ pasitera)
☐ autre (hafa) :_____

30. Concernant votre récolte dans les deux années dernières, est-ce que vous avez produit assez? Où est-ce que vous avez besoin d´une production supérieure ? (Manao akory ty fahitanao ty vokatsy areo, ampy sa mbo tokony ampitombo)

a. dernière année (tao lasa) ☐assez(ampy) ☐faudrait produire plus(mbo tokony hiohatse an´izay ?)
b. il y a deux ans (roa tao lasa) ☐assez ☐faudrait produire plus

III Partie Innovation

31. Qu´est-ce qu´il y a de nouveau dans vos pratiques agricoles par rapport à il y a 5/10/ 20 ans (nisy raha vaovao va tamy ty fambolea areo raha oharina tamy 5/ 10/20 tao lasa)?

☐ rien (tsy nisy)
☐ Matériel agricole, lequel (fitaova fambolea, ino iaby)?_____ Par qui (baka amin´ía)?_____
Quel-est l´avantage (Ino tombontsoa areo)?_____
☐ Semences/Variétés, lesquelles (tabiry, ino iaby)?_____ Par qui?_____
Quel-est l´avantage ?_____
☐ Cultures (plantes introduites), lesquelles (voly hafa azo'areo, ino iaby)? _____
Par qui ?_____Quel-est l´avantage ?_____
☐ Pesticides, lesquelles (fanafoly ampiasa amy voly, ino iaby)?_____
Par qui ?_____ Quel-est l´avantage ?_____
☐ Amélioration de la terre, lesquelles (fanatsara ty tany, ino iaby) ?_____
Par qui?_____ Quel-est l´avantage ?_____
☐ Autres (hafa, ino iaby)?_____ Par qui ?_____
Quel-est l´avantage ?_____

32. Si vous achèteriez des semences pour vos cultures (p.ex. maize, sorgho), ca serait où ? (Aia ty fivilia areo tabiry)

☐ Acheter moi-même sur le marché à Tuléar (vilia baka toliara)
☐ Acheter sur un marché qui est proche de chez moi (vilie amy ty tsena mariny anareo)
☐ Acheter vers une association villageoise (association de femmes, église etc.) (vili e amy ty fikambana)
☐ Acheter chez mes amis, voisins (any amy nama na ty mpiaramonina)
☐ Je n´achèterais jamais (tsy mivily tabiry)

IV Partie perception/Avantages

33. D´après vous, quels sont les problèmes qui limitent le développement agricole dans votre vie (laha aminareo, mety ino ty ola tsy mampandroso ty fambolea areo) ?

a. La pluie (ora)	☐ très important	☐ important	☐ moyen	☐ faible	☐ très faible
b. Insuffisance de l´eau du puits (tsy ampy ty ranom-bovo atsaká	☐ très important	☐ important	☐ moyen	☐ faible	☐ très faible
c. Infertilité du sol (tsy mamokatse ty tany)	☐ très important	☐ important	☐ moyen	☐ faible	☐ très faible
d. Pas assez de terre (tsy ampy ty tany fambolea)	☐ très important	☐ important	☐ moyen	☐ faible	☐ très faible
e. Manque de temps (tsy ampy ty fotoa)	☐ très important	☐ important	☐ moyen	☐ faible	☐ très faible
f. Main d´œuvre (tsy ampy ty mpikarama)	☐ très important	☐ important	☐ moyen	☐ faible	☐ très faible
g. Les semences/cultures (tabiry/vole)	☐ très important	☐ important	☐ moyen	☐ faible	☐ très faible
h. Manque d´éducation (tsy ampy fianara)	☐ très important	☐ important	☐ moyen	☐ faible	☐ très faible
i. Problèmes de santé (tsy salama soá)	☐ très important	☐ important	☐ moyen	☐ faible	☐ très faible
j. Crise politique à Madagascar (kirizy politika)	☐ très important	☐ important	☐ moyen	☐ faible	☐ très faible
k. Manque de sources de revenue (tsy ampy fidiran-drala)	☐ très important	☐ important	☐ moyen	☐ faible	☐ très faible
l. Accès aux micro-crédits (tsy fisia ty findrama drala)	☐ très important	☐ important	☐ moyen	☐ faible	☐ très faible

34. Que pourriez-vous convaincre pour planter des nouvelles variétés de sorgho, mil ou maize? (ino ty mety handresy lahatse anareo mba hamboly karaza sorgho na tsako hafa ?)

☐ Si je vois chez les autres que la récolte est mieux (laha ohatse ka fa misy manao, ka mahavokatse soa)
☐ Meilleur récolte dans mes champs (izay tena mamokatse)
☐ Si les cultures poussent plus vite (Voly malaky mitiry)
☐ Des cultures qui demandent moins de travail (tsy mila asa be ty fambolea azy)
☐ Pas besoin d´autres variété (tsy mila karazany hafa zahay)
☐ Autre :

35. Pensez-vous que le mil et sorgho sont des cultures bien adaptés à vos besoins?

☐ Oui, pourquoi :
☐ Non, pourquoi pas ?

36. Quelles sont des obstacles pour vous de planter le mil?

☐ difficultés de trouver des semences
☐ prix bas sur le marché
☐ je n´aime pas le gout
☐ il y a trop de problèmes avec les oiseaux
☐ demandent trop de travail
☐ Autre :

37. Quelles sont des obstacles pour vous de planter le sorgho?

☐ difficultés de trouver des semences
☐ prix bas sur le marché
☐ je n´aime pas le gout
☐ il y a trop de problèmes avec les oiseaux
☐ demandent trop de travail
☐ Autre :

38. Que pourriez-vous convaincre pour appliquer le fumier sur vos champs ?

☐ Si je vois chez les autres que la récolte est mieux (laha ohatse ka fa misy manao, ka hita fa tena mahavokatse soa)
☐ Faire un essai sur une parcelle dans mes champs pour être certain que le fumier peut vraiment améliorer les récoltes (laha ohatse ka agnohara ambolea ty ampahany amy baiboko)
☐ Faire un essai sur tous mes champs pour être certain que le fumier peut améliorer les récoltes (laha ohatse ka agnohara ambolea ty baiboko iaby iaby)
☐ S'il y avait une possibilité plus facile de transporter le fumier jusqu`à mes champs (laha ohatse ka mba nimoramora ty fitantera azy ziska amy baiboko any)
☐ Je ne pense pas que l´application du fumier peut me convaincre (tena tsy haiko na mety handresy lahatse ahy ty fampiasa zezik´areo toy)
☐ Autre (ka ino koa ty hafa mety handresy lahatse anareo ?):

39. Selon votre perception, est-ce que c´est vrai que l´application de fumier….(manao ty fahita areo ty fampiasa zeziky)?

a. Ca donne une meilleure récolte (magnasoa ty vokatse)	☐ tout à fait d´accorc	☐ d´accord	☐ je ne sais pas	☐ pas d´accord	☐ pas du tout d´accord
b. Ca demande bcp.de travail (magnabe asa)	☐ tout à fait d´accorc	☐ d´accord	☐ je ne sais pas	☐ pas d´accord	☐ pas du tout d´accord
c. Ca coute chère (lafo be)	☐ tout à fait d´accorc	☐ d´accord	☐ je ne sais pas	☐ pas d´accord	☐ pas du tout d´accord
d. Il n´y a plus de risque pour la culture (tsy atahora sasy ty vol	☐ tout à fait d´accorc	☐ d´accord	☐ je ne sais pas	☐ pas d´accord	☐ pas du tout d´accord
e. Il n´y a plus de problèmes avec des mauvaises herbes (Tsy ahi-draty)	☐ tout à fait d´accorc	☐ d´accord	☐ je ne sais pas	☐ pas d´accord	☐ pas du tout d´accord
f. Apres avoir utilisé le fumier, je n´ai plus de produits à venc (tena tsy nisy vokatse lafa nampiasa zezike raho)	☐ tout à fait d´accorc	☐ d´accord	☐ je ne sais pas	☐ pas d´accord	☐ pas du tout d´accord

40. Avez-vous déjà entendu de la technique de « zai » ? ☐oui ☐non

41. Connaissez-vous quelqu'un qui le pratique ? ☐oui, village ☐oui, région ☐non

Seulement si oui dans 40 ou 41 ->42

42. Selon votre perception, est-ce que c´est vrai que l´application de zai…

a. Ca donne une meilleure récolte (magnasoa ty vokatse)	☐ tout à fait d´acco	☐ d´accord	☐ je ne sais pas	☐ pas d´accord	☐ pas du tout d´accord
b. Ca demande bcp.de travail (magnabe asa)	☐ tout à fait d´acco	☐ d´accord	☐ je ne sais pas	☐ pas d´accord	☐ pas du tout d´accord
c. Ca coute chère (lafo be)	☐ tout à fait d´acco	☐ d´accord	☐ je ne sais pas	☐ pas d´accord	☐ pas du tout d´accord
d. Il n´y a plus de risque pour la culture (tsy atahora sasy ty vol	☐ tout à fait d´acco	☐ d´accord	☐ je ne sais pas	☐ pas d´accord	☐ pas du tout d´accord
e. Il n´y a plus de problèmes avec des mauvaises herbes (Tsy ahi-draty)	☐ tout à fait d´acco	☐ d´accord	☐ je ne sais pas	☐ pas d´accord	☐ pas du tout d´accord
f. Apres avoir utilisé le zai, je n´ai plus de produits à vendre (tena tsy nisy vokatse lafa nampiasa zezike raho)	☐ tout à fait d´acco	☐ d´accord	☐ je ne sais pas	☐ pas d´accord	☐ pas du tout d´accord

43. Avez-vous déjà utilisé du composte pour vos cultures? ☐oui ☐non

Jao, explique de quoi il s´agit !

44. Connaissez-vous quelqu'un qui le pratique ? ☐oui, village ☐oui, région ☐non

Seulement si oui dans 43 ou 44 ->45

45. Selon votre perception, est-ce que c´est vrai que l´application de composte sur vos cultures…

	Tout à fait d´accord	D´accord	Je ne sais pas	Pas d´accord	Pas du tout d´accord
a. Ca donne une meilleure récolte (magnasoa ty vokatse)	☐ tout à fait d´accord	☐ d´accord	☐ je ne sais pas	☐ pas d´accord	☐ pas du tout d´accord
b. Ca demande bcp.de travail (magnabe asa)	☐ tout à fait d´accord	☐ d´accord	☐ je ne sais pas	☐ pas d´accord	☐ pas du tout d´accord
c. Ca coute chère (lafo be)	☐ tout à fait d´accord	☐ d´accord	☐ je ne sais pas	☐ pas d´accord	☐ pas du tout d´accord
d. Il n´y a plus de risque pour la culture (tsy atahora sasy ty vol	☐ tout à fait d´accord	☐ d´accord	☐ je ne sais pas	☐ pas d´accord	☐ pas du tout d´accord
e. Il n´y a plus de problèmes avec des mauvaises herbes (Tsy ahi-draty)	☐ tout à fait d´accord	☐ d´accord	☐ je ne sais pas	☐ pas d´accord	☐ pas du tout d´accord
f. Apres avoir utilisé le composte, je n´ai plus de produits à v (tena tsy nisy vokatse lafa nampiasa zezike raho)	☐ tout à fait d´accord	☐ d´accord	☐ je ne sais pas	☐ pas d´accord	☐ pas du tout d´accord

46. Que faites vous avec les restes de la cuisine/matériel organique ?

VI Pour les questions suivants, répondez s´il vous plait si vous êtes d´accord, pas d´accord ou si vous ne savez pas.

47. Je ne sais pas quel est l´effet pour les cultures quand je mélange le sol avec le fumier (tena tsy haiko ty asa ty fampifangaroa ty tany vao ty zezike amy ty voly).

☐tout à fait d´accord ☐d´accord ☐ je ne sais pas ☐pas d´accord ☐ pas du tout d´accord ☐ne sais pas

48. Il est difficile de comprendre la quantité de fumier qu´il faut appliquer à mes cultures (sarotse aminay ty hahay ty habe ty zezike hatao amy voly io).

☐tout à fait d´accord ☐d´accord ☐ je ne sais pas ☐pas d´accord ☐ pas du tout d´accord ☐ne sais pas

49. Je n´ai pas de temps pour appliquer le fumier car les champs demandent déjà trop de travail (tsy manam-potoa hampiasa an´io zezike io satria fa rerake amy asa baibo).

☐tout à fait d´accord ☐d´accord ☐ je ne sais pas ☐pas d´accord ☐ pas du tout d´accord ☐ne sais pas

50. Le fumier pu et ça me dérange (tsy mety amiko fa membo mare).

☐tout à fait d´accord ☐d´accord ☐ je ne sais pas ☐pas d´accord ☐ pas du tout d´accord ☐ne sais pas

51. Le fumier pu et ça dérange mes voisins (membo, sady manelingely ty hafa)

☐tout à fait d´accord ☐d´accord ☐ je ne sais pas ☐pas d´accord ☐ pas du tout d´accord ☐ne sais pas

52. Si j´essaie des nouvelles variétés de cultures, il y a plus de risque que ça ne donne rien du tout. (laha ohatsy ka mamboly karazam-boly hafa zaho, mety hisy probolemo sady mety tsy hamokatsy io)

☐tout à fait d´accord ☐d´accord ☐ je ne sais pas ☐pas d´accord ☐ pas du tout d´accord ☐ne sais pas

53. Je n´ai pas besoin d´autres variétés car ceux que j´utilise sont les meilleurs (tsy mila karan-jezike hafa sasy zaho, fa mety amiko aze ampiasako henany zao io).

☐tout à fait d´accord ☐d´accord ☐ je ne sais pas ☐pas d´accord ☐ pas du tout d´accord ☐ne sais pas

54. Le zai est une pratique dont je pense que ca peut avoir un impact positif pour mes cultures.

☐tout à fait d´accord ☐d´accord ☐ je ne sais pas ☐pas d´accord ☐ pas du tout d´accord ☐ne sais pas

55. Si il y avait une autre variété de sorgho qui est mangé moins par les oiseaux, je suis prêt d´acheter des semences..

☐tout à fait d´accord ☐d´accord ☐ je ne sais pas ☐pas d´accord ☐ pas du tout d´accord ☐ne sais pas

56. Si il y avait une autre variété de mil qui est mangé moins par les oiseaux, je suis prêt d´acheter des semences..

☐tout à fait d´accord ☐d´accord ☐ je ne sais pas ☐pas d´accord ☐ pas du tout d´accord ☐ne sais pas

57. Si un essaie de zai marche bien sur un petit plot, je vais en appliquer dans un aire plus grande après

☐tout à fait d´accord ☐d´accord ☐ je ne sais pas ☐pas d´accord ☐ pas du tout d´accord ☐ne sais pas

58. Si un essaie de composte marche bien sur un petit plot, je vais en appliquer dans un aire plus grande après.

☐tout à fait d´accord ☐d´accord ☐ je ne sais pas ☐pas d´accord ☐ pas du tout d´accord ☐ne sais pas

59. L´utilisation de composte est facile pour moi car j´ai bcp de restes de la cuisine que je n´utilise pas.

☐tout à fait d´accord ☐d´accord ☐ je ne sais pas ☐pas d´accord ☐ pas du tout d´accord ☐ne sais pas

Annex 3: Vegetation survey

ENQUETE VEGGY-LITTORAL

I Partie personnelle

Village (fokontany):_____ Date (daty):_____

Nom de l´enquêteur (anaran'ny mpanontany): _____ Code :_____

1. Nom (anaran'ny anontania):_____ Sex: ☐ masculin (lahy) ☐ Féminin (vavy)

2. Age (Tao): ☐<20 ☐20-30 ☐ 30-40 ☐ 40-50 ☐ 50-60 ☐>60

3.Combien de personnes y-a-t-il dans votre ménage (misy firy isa nareo an-trano atoa)? _____

4.Éducation(fianara) : ☐ non (tsy nianatra) ☐ EPP (primaire) ☐ CEG (sécondaire) ☐Université

5.Combien d´années de scolarisation en totale (niala te firy anao)?_____ans

6.Etes-vous nés dans ce village ? (niteraka tatoa va anao)? ☐ oui(eka) ☐ non (aha)

- Si non, quand êtes-vous arrivés (raha tsia, nombia ty niavy anao tetoa) ? Il y a _____ ans

7.Avez-vous déjà travaillé avec des ONG/projects/ OG dans votre village (efa niasa tamin'ny projet va anao)? ☐ Oui (eka) ☐ Non(aha)

a.Si oui, lesquelles (raha eka, ino iaby)? _____ _____

b.Période (fotoa niasany tatoy):_____

c.Activités principales (asa nataony tatoy): _____ _

II Partie Agricole

8.Depuis combien d´années pratiquez-vous l ´agriculture (efa nisy firy tao namboleanao zay)? _____ans

9.Combien de champs avez-vous (Firy ty isam-baibo anao)?_____champs

10. Quelle-est leur taille environ (Misy firy ha ty habehany)? champ1 (baibo 1):____ha, champ 2 (baibo 2) : _____ha, champ 3 (baibo 3):_____ha

11. Quelles cultures plantez-vous dans vos champs (Ino aby ty volea areo atoy) ?

☐ Bahalazo	☐ Bele	☐ tsako	☐ Ampemba
☐ Lojy	☐ Antsamby	☐ Antsambim- bazaha	☐ Antake
☐ Kapiky	☐ (Kabaro)	☐ Taboara	☐ Voantango
☐ Voatavo	☐ Mody	☐ Kiseny	☐ Voatabia(tamatesa)
☐ Traka (preciser)	☐ Raketa	☐ Samata	☐ Brachiaria
☐ Canne a sucre (fary)	☐ Poi d´angole	☐ (Ricin (Ricinus communis) (Kinagna)	☐ Hafa (precisez)

12.Où est le marché le plus proche de votre village (aia ty bazary marigny areo atoy)? _____*nom du village/ville* (anaran'ny tana)

a.Combien de fois allez-vous là-bas (impiry mande any nareo)?_____*par mois* (isam-bola)

b.Combien de temps dépensez-vous pour y aller (alanareo firy lera ty mande agny)? _____

c.Avec quel moyen de transport (mandeha ino nareo)?

☐à pieds (tomboky) ☐ en charrette (sarety) ☐ taxi brousse ☐autre (hafa) :_____

d. Pourquoi allez-vous sur ce marché (Ino ty antony andehanareo an-tsena any)?

_____

e. Où allez-vous acheter les matériels agricoles (aia ty fivilianareo fitaova fambolea)?

_____

13. Possédez-vous des zébus (mana aomby va nareo)? ☐oui(eka) ☐ non(aha)

a.Si oui, combien ?(raha eka, firy ty isany) ?_____/numéro de zébus

b.Si non, quelqu´un dans votre famille (raha tsia, fe misy longonareo mana)?☐oui(eka) ☐ non(aha)

14. Possédez-vous une charrette ? (nareo va mana-sarety) ? ☐oui(eka) ☐non (tsia)

a.Si non, quelqu'un dans votre famille en a (raha tsia, fe misy longonareo mana)? ☐oui(eka)☐ non(aha)

15. Louez-vous des charrettes parfois (manofa sarety va nareo kindraindraiky)? ☐oui(eka) ☐ non(aha)

a. Si oui, pour combien (raha eka, otrino)? _____ Ar/jour (isan'andro)_____Ar/semaine (isan-kerinandro)

16. Si vous avez besoin de conseil agricole, qui demandez-vous? (raha mila toro-hevitse amy ty fambolea nareo, ia ty olo anontaninareo)?

a.Donnez le nom d´une personne s´il vous plait (ia ty anara olo): _____

b. relation avec vous (inonao olo io): ☐chef du village (sefo-pokontany) ☐famille (fianakavia) ☐amis (nama) ☐chef spirituelle (tangalamegna/ pasitera) ☐gouvernement_____

17. Si vous avez besoin de conseil concernant des grandes décisions dans votre vie, qui demandez-vous ? (raha mila fanampia amy fandraisa fanampaha-kevitra lebe nareo, iza ty olo anontaninareo)

a. Donnez le nom d´une personne s´il vous-plait (azafady, ia ty anara olo): _____

b. relation avec vous (inonao olo io): ☐ chef du village (sefo-pokontany) ☐ famille (fianakavia) ☐ amsi (nama) ☐ chef spirituelle (tangalamegna/ pasitera) ☐ autre (hafa):_____

18. Etes-vous membre d´une association/organisation (nareo va anaty fikambana)?

☐non (aha) ☐association (fikambana) ☐coopérative (fiaraha-miasa) ☐groupe religieux (resakafinoana)

a.Si oui, laquelle? (Raha eka, ino ty anara)_____

b.Activités principales ? (ino ty asa ataonareo) _____

III Innovation existants

19. Qu´est-ce qu´il y a de nouveau dans votre vie comparé à il y a 5/10/ 20 ans? (nisy raha vaovao va tamy ty fiainanao raha oharina tamy 5/ 10/20 tao lasa) ?

a.☐**rien du tout** (tsy nisy)

b.☐**Matérielle agricole** (fitaova fambolea, ino avy)? _____

Où avez-vous l´obtenu (taia ty naazoanareo ty fitaova) ? _____

Quel est l´avantage (Ino tombontsoa areo)? _____

c.☐**Semences/variétés** (tabiry, ino aby)? _____

Où avez-vous l´obtenu (taia ty naazoha azy)? _____

Quel est l´avantage (Ino tombontsoany)? _____

d. ☐**Plantes** (introduit/nouveau) (zava-maniry nampidiry/vaovao)

_____

Où avez-vous l´obtenu (taia ty naazoanareo azy)? _____

Quel est l´avantage (Ino tombontsoany)? _____

e. ☐ **Pesticides,** (fanafody ampiasa amy vokatra, ino avy)**?** _____

Où avez-vous l´obtenu (taia ty naazoanareo azy)? _____

Quel est l´avantage (Ino tombontsoany)? _____

f.☐**Outils d'amélioration pour la fertilité du sol** (fitaova fanatsara ty tany, ino avy) ?

_____

Où avez-vous l´obtenu (taia ty naazoanareo azy)? _____

Quel est l´avantage (Ino tombontsoaareo)? _____

g. ☐**Autre** (hafa, inoavy)?

_____

Où avez-vous l´obtenu (taia ty naazoanareo azy)? _____

Quel est l´avantage (Ino tombontsoany)? _____

IV. Perception des innovations-1) fumier, 2) arrosage et 3) légumes

1) Fumier

Certaines personnes disent que l'ajout du fumier de zébu dans leurs champs/jardins améliore leurs cultures. D'autres personnes ont essayé, mais les cultures ne poussent pas mieux - même si l'incorporation et le transport du fumier dans les champs demandent pas mal de travail. Nous-mêmes, nous ne savons pas si l'application du fumier est une bonne idée ou pas. C'est pourquoi nous voulons connaître vos idées + expériences concernant l'application du fumier sur les cultures (misy olo mivola fa mahasoa voly ty fampiasa zezika. Nisy hafa koa nagnohatra nampiasa zezika fe tsy nitiry soa ty voliny, na dia nandany fotoa sady nanabe ty asany. Ndre izahay koa tsy mahay na mahasoa voly na tsia ty fampiasa zezika ; ka tianay ho hay koa ty hevitrinao asa manao akory).

20. Certaines personnes nous ont dit que l´application du fumier dans leurs champs augmente leurs récoltes. D'autres ont rapporté que le manioc /maïs n´a pas poussé mieux

(Misy ty olo sasany mivola fa nampitombo ty vokatriny ty fampiasa zezika. Ty hafa ndraiky mivola fa tsy nampitiry soa ty balahazony noho bele ty fampiasa zezika).

a.Connaissez-vous des personnes qui ont déjà utilisé le fumier dans leurs champs (efa nisy olo mampiasa zezika va tetoao)?

☐non(aha)☐oui, famille (eka, longo) ☐oui, village (fokontany)☐oui, région (faritra)

b.Si oui, qu´est-ce qu´il disent (ka ino ho asan –drozy)? _____

_____

21. Que pensez-vous, quand quelqu'un incorpore le fumier de zébu dans leurs champs (Ino ty eritreritrinareo, laha misy olo mampiasa zezika amy ty baibony) ?

_____

_____

22. Si vous n´utilisez pas du fumier, pourquoi pas (nareo tsy mampiasa zezika, fa manino)?

☐l'avantage n´est pas claire pour moi (tsy haiko ty tombontsoany)

☐pas de moyen de de transport (tsy misy fitaova hitantera azy) ☐je ne sais pas où trouver (tsy haiko hoe aia ty ahita azy)

☐utilisation de fumierest « fadi » (fady ty fampiasa zezika) ☐je ne possédé pas assez de quantité (tsy ampy ty ahy)

☐autre (hafa): _____

23. Si c'est vrai que vous utilisez le fumier, pourquoi (raha mampiasa zezika nareo, ino ty antony)?

_____ _____

2) Irrigation (Arrosage)

24. Concernant l´eau et vos cultures, est-ce que vous êtes d´accord qu´il y a :

a.assez d'eau dans les puits, alors je pour (maro ty rano am-bovo, afaka anondraha ty voly traka)	☐tout˙fait d´accord ☐d´accord ☐ moyen ☐ pas d´accord ☐pas du tout d´accord
b.problèmes de transport de l´eau (olana amy fitondrana rano)	☐tout˙fait d´accord ☐d´accord ☐ moyen ☐ pas d´accord ☐pas du tout d´accord
c.assez de main d´œuvre pour le transporter (misy afaky mitatitra rano)	☐tout˙fait d´accord ☐d´accord ☐ moyen ☐ pas d´accord ☐pas du tout d´accord
c.des conflits avec des voisins si j´utilise l´ eau de puits (manjary hampialy amy fokonolo laha mampiasa rano amy vovo)	☐tout˙fait d´accord ☐d´accord ☐ moyen ☐ pas d´accord ☐pas du tout d´accord
d. problèmes avec l´accès à l´eau (sarotra va ty ahitava rano)	☐tout˙fait d´accord ☐d´accord ☐ moyen ☐ pas d´accord ☐pas du tout d´accord
	☐tout˙fait d´accord ☐d´accord☐ moyen ☐ pas d´accord ☐pas du tout d´accord

25. Avez-vous déjà planté des cultures *autre que manioc, mais, sorgho etc.* qui doivent être arrosé, p. ex des tomates, carottes (efa namboly karazam-boly tondraha reny va nareo)?

☐oui(eka) ☐non (aha)

a.Si oui, lesquelles (raha eka, ino aby)? 1._____ 2._____ 3._____ 4._____

26. Si vous arrosiez vos cultures, comment transporteriez-vous l´eau (laha manondraka voly nareo, ino ty handesa azy)?_____ _____

3) Légumes

27. Savez-vous comment cuisiner des légumes (mahay miketriky traka va nareo)?

☐oui (eka) ☐ non (aha)

28. Mangez-vous des légumes crues comme salade (mihina traka manta manahaky salady reny va nareo)?

☐oui (eka) ☐ non (aha)

29.Y-a-t-il un repas traditionnel dans votre région ou les légumes sont utilisés (misy fomba fiketreha laoky misy traka va nataon'olobe taloha tany tamy tana areo tetoa) ?

a. Si oui, quel est le nom (raha eka, ino ty anara sakafo)? _____

b. Ingrédients (ino iaby ty fangarony):

_____ _____ _____

30. Quelles légumes préférez-vous concernant son gout (Ino ty traka tena tia areo):

1._____ **2.**_____ **3.**_____ **4.**_____ **5.**_____

La plantation de légumes est mieux réussie (p.ex.des oignons, des carottes ...) pendant la saison sèche, donc il nécessite l'arrosage. De plus, certaines personnes utilisent le fumier du zébu ou des chèvres pour son amélioration. En outre, les légumes doivent être protégés contre le soleil et les animaux (Amy asotry ty tena mahasoa ty fambolea traka, kanefa tsy maintsy mila tondraky. Misy koa ty olo sasany mampiasa taim-bala :omby na osy mba hahasoa azy. Sady tokony arova amy masoandro sy ny biby ty voly traka).

31. Quelle est votre impression, est-ce que c'est facile à faire ou difficile (mora va ty manao azy sa sarotra) ?

☐ très simple ☐ simple ☐ moyen ☐ pas simple ☐ pas du tout simple

32. Etes-vous sûr que vous pouvez réussir à faire pousser des légumes de cette façon (araky eritreritrinao, mety hampitiry soa ty voly traka va io)?

☐ très sure ☐ sure ☐ moyen ☐ pas sure ☐ pas du tout sure

33. Si vous planteriez des légumes, est-ce que vous les utiliseriez plutôt pour manger ou bien pour la vente (traka hambolea io hohany sa havarotra) ?

☐ vent(havarotra) ☐ autoconsommation (hohany) ☐ les deux (ireoroa) ☐don´t know (tsy haiko)

34.Où vendriez-vous des légumes (aia ty hamarota areo ty traka areo)?

☐ village (an-tanà) ☐marché locale (ambazary) ☐hotelsAmbola/Anakao (hotely) ☐Tuléar (Toliara)

35. Qui des personnes suivantes *approuvent* la plantation des légumes, (ia amy ty olo manaraka retoa ty manaikyty fambolea traka)

a. époux/épouse (valy)

☐approuve tout à fait ☐ approuve ☐moyen ☐approuve pas ☐approuve pas du tout

b. enfants (anaky)

☐approuve tout à fait ☐ approuve ☐moyen ☐approuve pas ☐approuve pas du tout

c. amis(nama)

☐approuve tout à fait ☐ approuve ☐moyen ☐approuve pas ☐approuve pas du tout

d. voisins(mpiara-monina)

☐approuve tout à fais ☐ approuve ☐moyen ☐approuve pas ☐approuve pas du tout

e. autres villageois (hafa):

☐approuve tout à fais ☐ approuve ☐moyen ☐approuve pas ☐approuve pas du tout

36. Si vous planteriez des légumes, quel serait le désavantage pour vous (laha mamboly traka, ino iaby ty lafy ratsiny)?

_____

37. Si vous planteriez des légumes, quel serait l'avantage pour vous (laha mamboly traka, ino iaby ty tombotsoany) ?

_____

38. Qu'est-ce qui peut-vous convaincre de planter des légumes (Ino ty mety hahasarika anao hamboly traka)?

_____

39. Si vous avez déjà planté des légumes, ou si vous avez déjà vu chez d'autres personnes, est-ce que vous pensez qu'ils demandent beaucoup de (lafa namboly traka anao na efa nahita olo namboly traka, araky eritreritrinao, mety mila/mandany) :

a.Temps pour la préparation de l'enclos : enlever les sables, clôturer, mettre du fumier, (fotoa fanamboara vala)	☐tout`fait d´accord ☐d´accord ☐ moyen ☐ pas d´accord ☐pas du tout d´accord
b.temps pour la récolte (fotoa ty fanangonam-bokatse)	☐tout`fait d´accord ☐d´accord ☐ moyen ☐ pas d´accord ☐pas du tout d´accord
c.mains d´œuvres (mpiasa)	☐tout`fait d´accord ☐d´accord ☐ moyen ☐ pas d´accord ☐pas du tout d´accord
d.couts monétaires (p.ex. des semences/matériel) (vola)	☐tout`fait d´accord ☐d´accord ☐ moyen ☐ pas d´accord ☐pas du tout d´accord
e.quantités / consommation d´eau (rano maro)	☐tout`fait d´accord ☐d´accord ☐ moyen ☐ pas d´accord ☐pas du tout d´accord
f.risque d´échec (misy atahora)	☐tout`fait d´accord ☐d´accord ☐ moyen ☐ pas d´accord ☐pas du tout d´accord
g.possibilités de vente (mety avily)	☐tout`fait d´accord ☐d´accord ☐ moyen ☐ pas d´accord ☐pas du tout d´accord

40. Pour planter des légumes, on pourrait trouver des semences p. ex. à Tuléar, comment aimeriez-vous les obtenir (laha hamboly traka anao, misy tabiry ohatra any Toliara any, ataonao akory ty ahazoa tabiry io)?

☐ acheter moi-même à Tuléar (viliako any Toliara any)
☐ acheter sur un marché local, pas loin de chez moi (viliko an-tsena any)
☐ acheter dans une association villageoise (viliko amy fikambana an-tana etoa) (ass. de femmes etc.)
☐ si je dois les acheter, je ne plante pas (ndra viliko, tsy hamboleko)
☐ demander un ami de les amener (maniraka olo anday azy bakany)

Pour les questions suivantes, dites s´il vous plait si vous êtes *tout à fait d´accord, d´accord, moyen pas d´accord ou pas du tout d´accord.*

41. Si je cultive des légumes y compris l'application d'engrais et de l'arrosage, mon statut social sera différent qu'avant (laha mamboly traka asia zezika noho tondraha zaho, mety hiiova ty fiainako) .

☐tout à fait d´accord ☐d´accord ☐moyen ☐pas d´accord ☐ pas du tout d´accord

a.Dans quel sens (miova manao akory)? _____ _____

b.Comment va votre statut changer si la cultivation est un succès ou un échec (ino ty ahaiza azy na hihasoa na hiharaty ty fiainanao).

---

42. Je pense que les jardins potagers peuvent améliorer ma sécurité alimentaire, si par exemple la production des autres cultures est faible (laha mamboly traka raho mety tsy ho lany ty haniko etoa).

☐tout à fait d´accord ☐d´accord ☐moyen ☐pas d´accord ☐ pas du tout d´accord

43. Je pense que les légumes peuvent être une source de revenu qui peut contribuer à mon bien-être (mety hampidi-bola ty fambolea traka).

☐tout à fait d´accord ☐d´accord ☐moyen ☐pas d´accord ☐ pas du tout d´accord

44. Je voudrai planter des légumes, mais je ne vais pas utiliser du fumier (zaho te hamboly traka fe tsy te hampiasa zezika).

☐tout à fait d´accord ☐d´accord ☐moyen ☐pas d´accord ☐ pas du tout d´accord

45.Je ne sais pas vraiment combien d'eau il faut donner aux plantes (tsy haiko ty habe ty rano anondraha azy).

☐tout à fait d´accord ☐d´accord ☐moyen ☐pas d´accord ☐ pas du tout d´accord

46. Je ne sais pas vraiment quand les plantes sont près à récolter (tsy haiko marina hoe ombia traka io vao azo halaina).

☐tout à fait d´accord ☐d´accord ☐moyen ☐pas d´accord ☐ pas du tout d´accord

47. Je ne sais pas vraiment combien de fumier on doit ajouter dans le sol (tsy haiko marina hoe, firy ty habe ny zezika afangaro amy tany io).

☐tout à fait d´accord ☐d´accord ☐moyen ☐pas d´accord ☐ pas du tout d´accord

48. Ca serait facile pour moi d´organiser le transport du fumier (tsy sarotra ty fitantera zezika io).

☐tout à fait d´accord ☐d´accord ☐moyen ☐pas d´accord ☐ pas du tout d´accord

49. Si je vais utiliser le fumier, ca va couter chère pour moi (mety ho lafo ty fampiasa zezika).

☐tout à fait d´accord ☐d´accord ☐moyen ☐pas d´accord ☐ pas du tout d´accord

50. L´utilisation du fumier est ***fadi*** chez nous (fady ty fampiasa zezika)

☐tout à fait d´accord ☐d´accord ☐moyen ☐pas d´accord ☐ pas du tout d´accord

51. Le fumier pu et ca me dérange (tsy mety amiko fa mantsy raha io).

☐tout à fait d´accord ☐d´accord ☐moyen ☐pas d´accord ☐ pas du tout d´accord

52. Le fumier pu et ca dérange mes voisins (halan'olo marigniky baiboko toy zeziko io fa mantsy).

☐tout à fait d´accord ☐d´accord ☐moyen ☐pas d´accord ☐ pas du tout d´accord

53. Si ma récolte ne serait pas «suffisante» sur un premier essai, je n'essaierais pas de nouveau (raha tsy mahampy ty vokatro amy ty voalohany ty, tsy mavita sasy raho).

☐tout à fait d´accord ☐d´accord ☐moyen ☐pas d´accord ☐ pas du tout d´accord

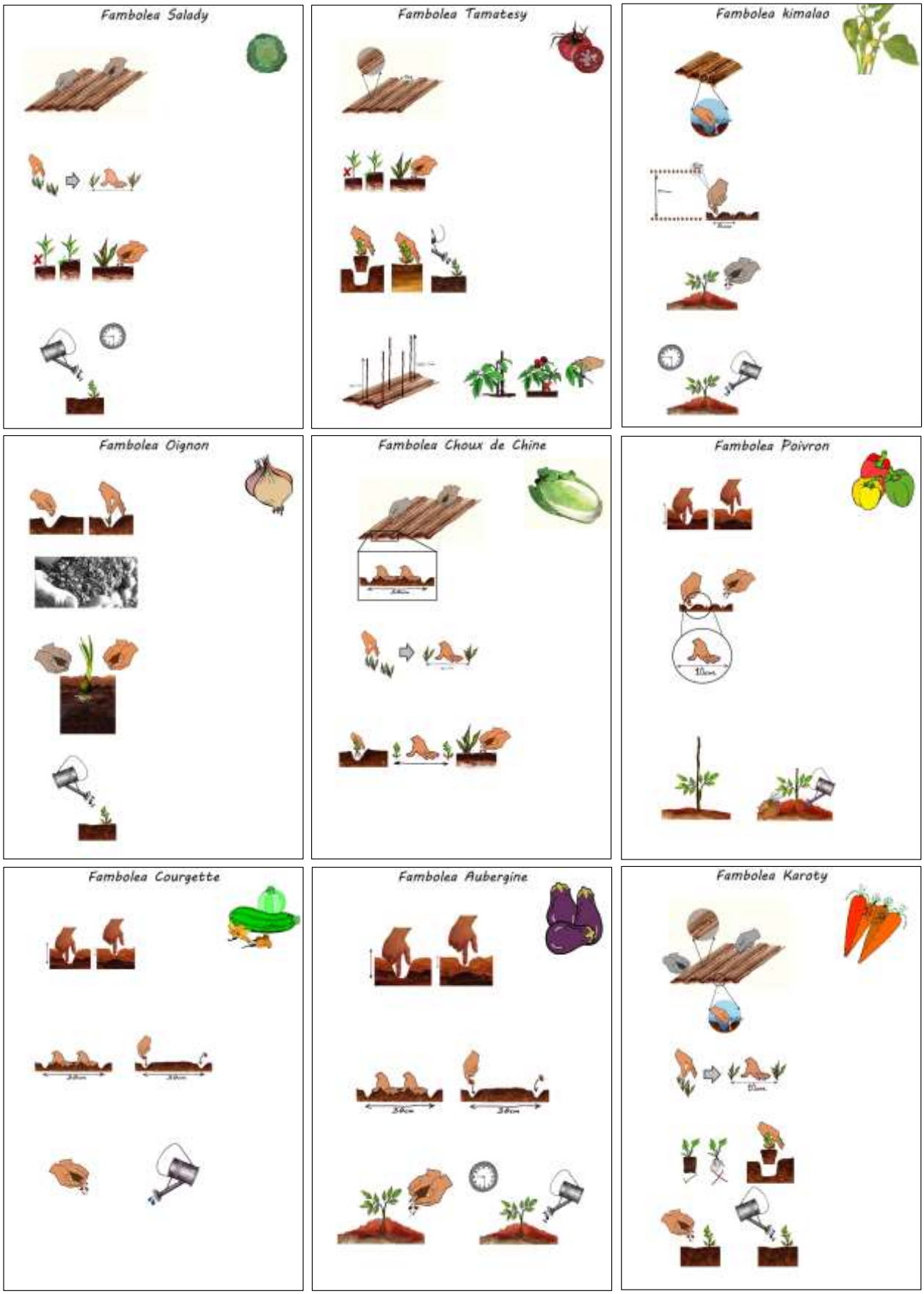
54. Si ma récolte ne serait pas «suffisant», j´essaierais une autre fois avec une technique différente (raha tsy mahampy ty vokatro amy ty voalohany ty, hagnoatry fomba fambolea hafa koa raho) ?

☐tout à fait d´accord ☐d´accord ☐moyen ☐pas d´accord ☐ pas du tout d´accord

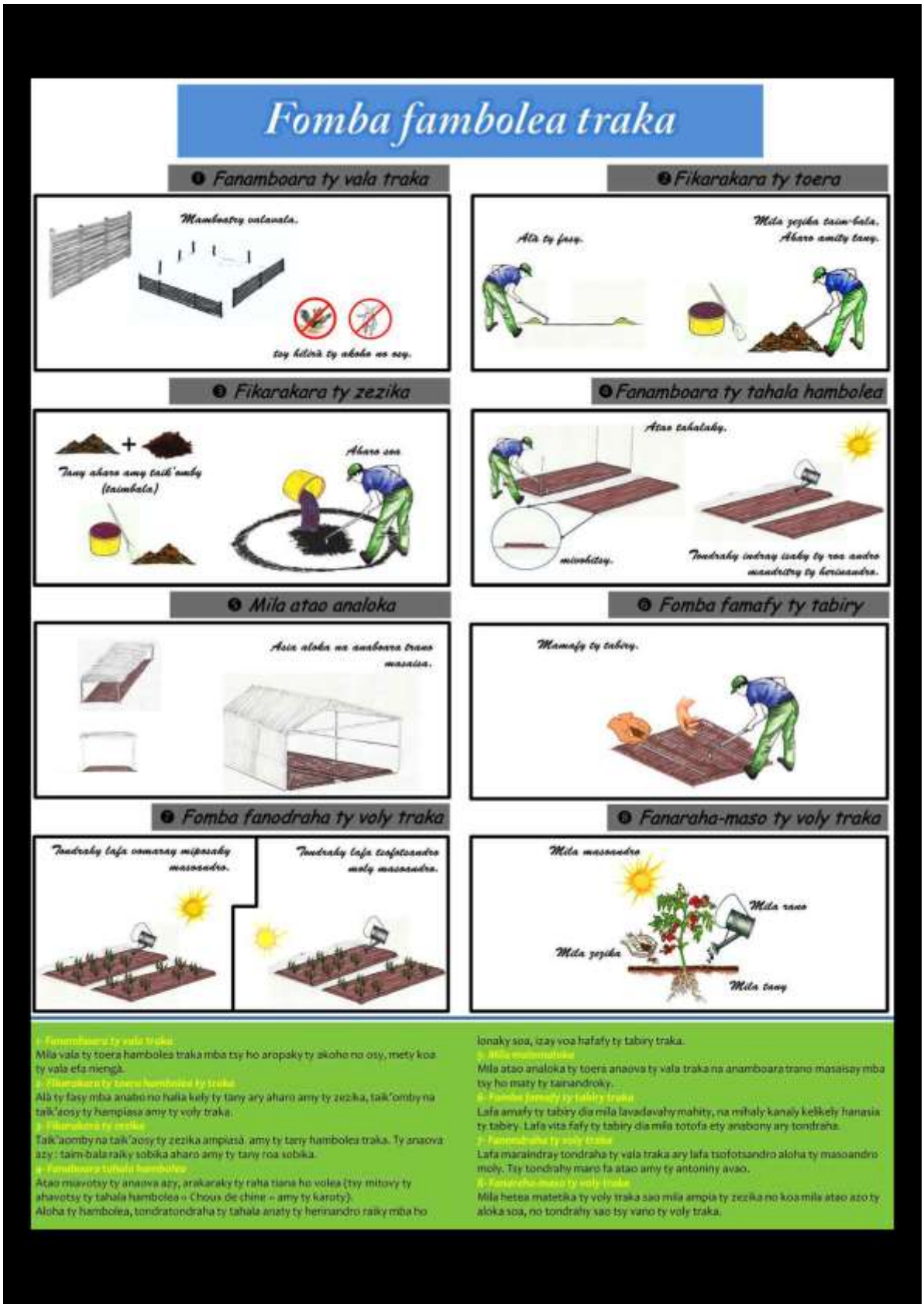
55. Si les jardins marchent bien sur une petite échelle, je vais aggrandir mon jardin et cultiver plus (laha soa ty famboleako amy ty voalohany ty, hitariko vala io noho hamboly maro raho).

☐tout à fait d´accord ☐d´accord ☐moyen ☐pas d´accord ☐ pas du tout d´accord

Annex 4: Vegetable gardening instructions



Annex 5: Advertisement for vegetable seeds



1- Fanamboara ty vala traka
Mila vala ty toera hambolea traka mba tsy ho aropaky ty akoho no osy, mety koa ty vala efa niengà.

2- Fikarakara ty toera hambolea ty traka
Alà ty fasy mba anabò no halà kely ty tany ary aharo amy ty zezika, taik'omby na taik'aosy ty hampiasa amy ty voly traka.

3- Fikarakara ty zezika
Taik'aomby na taik'aosy ty zezika ampiasà amy ty tany hambolea traka. Ty anaova azy : tsim-bala raiky sobika aharo amy ty tany roa sobika.

4- Fanaboara tahala hambolea
Atao miavotsy ty anaova azy, arakaraky ty raha tiana ho volea (tsy mitovy ty ahavotsy ty tahala hambolea « Choux de chine » amy ty karoty).
Aloha ty hambolea, tondratondraha ty tahala anaty ty herinandro raiky mba ho lonaky soa, izay voa hafafy ty tabiry traka.

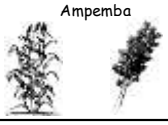
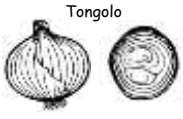
5- Mila matetika
Mila atao analoka ty toera anaova ty vala traka na anamboara trano masaisay mba tsy ho maty ty tainandroky.

6- Fomba famafy ty tabiry traka
Lafa amafy ty tabiry dia mila lavadavahy mahity, na mihaly kanaly kelikely hanasia ty tabiry. Lafa vita fafy ty tabiry dia mila totofa ety anabony ary tondraha.

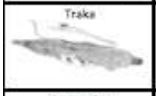
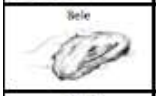
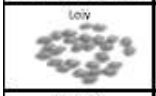
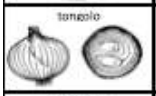
7- Fanondraha ty voly traka
Lafa maraindray tondraha ty vala traka ary lafa tsofotsandro aloha ty masoandro moly. Tsy tondrahy maro fa atao amy ty antoniny avao.

8- Fanaraha-maso ty voly traka
Mila hetsa matetika ty voly traka sao mila ampia ty zezika no koa mila atao azo ty aloka soa, no tondrahy sao tsy vano ty voly traka.

Annex 6: Pictograms

Code_____ Nom:_____ Journal NO:_____ Enqueteur:_____ date:_____	Miava 	Mampiasa zezika 	Mamboly 	Mila voly 
Bahalazo 				
Traka 				
Ampemba 				
Bele 				
Bajiry 				
Lojy 				
Voatavo 				
Antaka 				
Voatavaio 				
Traka 				
Tongolo 				
Antsamby 				

		100		200		500		1 000		2 000		5 000		10 000	
		☺	☹	☺	☹	☺	☹	☺	☹	☺	☹	☺	☹	☺	☹
Fitsetsana															
Omby															
Aondry															
Akoho															
Aasy															
Mila kata															
kajakoja an-trano															
Fanafody / Fisanasana															
Drala hafa															
Fizahan-tany/orinasa/asa tanana															
Fomban-drazana															

														
	☺	☹	☺	☹	☺	☹	☺	☹	☺	☹	☺	☹	☺	☹
Sarclage 														
application d'engrais 														
semis 														
récolte 														
manger 														
														
	☺	☹	☺	☹	☺	☹	☺	☹	☺	☹	☺	☹	☺	☹
Bahalazo 														
Traka 														
Ampemba 														
Bele 														
Batary 														
Loiv 														
Voatavo 														
Antake 														
voatabia 														
traka 														
tongolo 														
Antsambu 														

Annex 7: Household cluster description, frequencies and sampling weights for regional extrapolation. Sampling weights of the cluster (strata) were calculated through: $W_i = [(n_i / N) / (s_i / S)]$; where: n_i= is the number of HH in strata i (absolute frequency in population), N= is the total number of HH in the sampling frame (N=507), s_i= is the size of the sample having elements belonging to strata i, (absolute frequency in stratified sample); S= is the size of the sample (N= 150)

Cluster	Cluster description	Absolute freq. in population	Relative frequency in population %	Absolute frequency in stratified sample	Relative frequency in stratified sample%	Sampling weight for extrapolation
1	Traders	91	17.95	18	12	1.50
2	Livestock-rich	31	6.11	18	12	0.51
3	Fishers	54	10.65	0	0	0.00
4	Wage workers	25	4.93	18	12	0.41
5	Normal agriculturalists	131	25.84	18	12	2.15
6	Forest-resource dependent	88	17.36	18	12	1.47
7	Innovative HH*	87	17.16	60	40	0.42
All		**507**	**100**	**150**	**100**	

Annex 8: Recall survey covering the lean season, 12/2013-05/2014

Baseline WP7 rétroactif pour les dernières 6 moins, 2014/2015

1. **Combien d´heures-est-ce que vous avez depensé pendant les dernières 6 moins concernant les activités suivants (et avec combien de personnes)?**

Culture	Heures depensé + N° de personnes											
	semis	N° Pers	Somme	sarclage	N° Pers	Somme	Labourage du sol	N° Pers	Somme	Récolte	N° Pers	Somme
1. Bahalazo												
2. Tsago												
3. Ampemba												
4. Bele												
5. Bajiry												
6. Lojy												
7. Voatavo												
8. Antake												
9. Voatabia												
10.Traka												
11.Tongolo												
12.Antsamby												
13. Kapiky												
14. Cacahuete												

2. **Combien avez-vous depensé (en Ariary) et/ou gagné pour les activités suivants:**

Mois	sarclage		applic. d´engrais		Semis		Récolte	
	+	-	+	-	+	-	+	-
Janvier								
Février								
Mars								
Avril								
Mai								
Juin								
Somme	____	____	____	____	____	____	____	____

3. Combien avez vous depensé pour le matériel agricole, engrais et des pesticides?

Mois	Matériel		Engrais		Pesticides	
	Lequel?	Ariary	Lequel?	Ariary	Lequel?	Ariary
Janvier						
Février						
Mars						
Avril						
Mai						
Juin						
Somme		———		———		———

4. Combien avez-vous depensé pour la nourriture?

Culture	Janvier	Février	Mars	Avril	Mai	Juin	Somme
1.Bahalazo							
2.Bahalazo d.							
3.Tsako							
4.Bele							
5.Lojy							
6.Voatavo							
7.Bajiry							
8.Ampemba							
9.Antake							
10.Mody							
11.Voatabia							
12.Traka							
13.Tongolo							
14.Antsamby							
15.Kapiky							
16.Cacahuette							

5. Combien avez-vous gangé avec la nourriture?

Culture	Janvier	Février	Mars	Avril	Mai	Juin	Somme
1.Bahalazo							
2.Bahalazo d.							
3.Tsako							
4.Bele							
5.Lojy							
6.Voatavo							
7.Bajiry							
8.Ampemba							
9.Antake							
10.Mody							
11.Voatabia							
12.Traka							
13.Tongolo							
14.Antsamby							
15.Kapiky							
16.Cacahuette							

6. **Combien de bétails est-ce que vous avez vendu et acheté pendant les dernières 6 moins? Combien d´argent est-ce que vous avez depensé et gagné avec les bétails? Combien d´animaux ont était volé?**

Bétails	No vendu	Argent gagné	No acheté	Argent depensé	No Volé
Zébu					
Chièvre					
Mouton					
Poulets					

7. **Concernant coutume, qu´est-ce que vous avez donné et recu pendant les dernières 6 mois?**

Bétails	**No recu**	**No donné**	**No acheté**	**Argent depensé**
Zébu				
Chièvre				
Mouton				
Poulets				
Argent	**Somme recu**		**Somme donné**	
Ariary				
Autre:_____				

8. **Économie non-agricole: Concernt les activités non agricoles, combien avez-vous recu et depensé pour les choses suivantes?**

Quoi	**Somme recu +**	**Somme depensé -**
Transport		
Bois de chauffage		
Industrie		
Artisanat		
Médecine & éducation		
Consommation (alcohol, cigarettes, batteries etc.)		
Argent envoyé à/par la famille		

9. Nourritoure récu des ONG

Oui □ non □ ,

a. si oui, quoi_____ et combien _____?

Questions pour WP2/Wp7 : Sécurité des semences

10. Concernant les 5 années passés, combien de fois est-ce qu´il y avait de la sécheresse, c´est à dire que la récolte était mauvaise?

□1 □2 □ 3 □ 4 □ 5 fois

11. Comment jugez vous les récoltes que vous avez eu dans les 5 années dernières ?

2009	☐tout à fais suffisant	☐suffisant	☐moyen	☐pas suffisant	☐pas du tout suffisant	☐pas répondu
2010	☐tout à fais suffisant	☐suffisant	☐moyen	☐pas suffisant	☐pas du tout suffisant	☐pas répondu
2011	☐tout à fais suffisant	☐suffisant	☐moyen	☐pas suffisant	☐pas du tout suffisant	☐pas répondu
2012	☐tout à fais suffisant	☐suffisant	☐moyen	☐pas suffisant	☐pas du tout suffisant	☐pas répondu
2013	☐tout à fais suffisant	☐suffisant	☐moyen	☐pas suffisant	☐pas du tout suffisant	☐pas répondu
2014	☐tout à fais suffisant	☐suffisant	☐moyen	☐pas suffisant	☐pas du tout suffisant	☐pas répondu

12. Comment jugez-vous les 5 années passés concernant le degré de la sécheresse?

2009	☐très sec	☐sec	☐moyen	☐ pas sec	☐pas du tout sec	☐pas répondu
2010	☐très sec	☐sec	☐moyen	☐ pas sec	☐pas du tout sec	☐pas répondu
2011	☐très sec	☐sec	☐moyen	☐ pas sec	☐pas du tout sec	☐pas répondu
2012	☐très sec	☐sec	☐moyen	☐ pas sec	☐pas du tout sec	☐pas répondu
2013	☐très sec	☐sec	☐moyen	☐ pas sec	☐pas du tout sec	☐pas répondu
2014	☐très sec	☐sec	☐moyen	☐ pas sec	☐pas du tout sec	☐pas répondu

13. Est-ce que vos cultures ont était touché par des insectes (p.ex criquets), des maladies ou sécheresse ? Si oui, sur quelles cultures et combien a était détruit environ (%) ?

Culture	**Type de dégâts**				**Combien a était détruit %**				
	criquets	**maladies**	**Sécheresse**	**Autre**	**100-80%**	**80-60%**	**60-40%**	**40-20%**	**20-0%**
1. Bahalazo	☐	☐	☐	_____	☐	☐	☐	☐	☐
2. Bahalazo.d. douce	☐	☐	☐	_____	☐	☐	☐	☐	☐
3. Tsako	☐	☐	☐	_____	☐	☐	☐	☐	☐
4. Bele	☐	☐	☐	_____	☐	☐	☐	☐	☐
5. Lojy	☐	☐	☐	_____	☐	☐	☐	☐	☐
6. voatavo	☐	☐	☐	_____	☐	☐	☐	☐	☐
7. Bajiry	☐	☐	☐	_____	☐	☐	☐	☐	☐
8. Ampemba	☐	☐	☐	_____	☐	☐	☐	☐	☐
9. Antake	☐	☐	☐	_____	☐	☐	☐	☐	☐
10.Mody	☐	☐	☐	_____	☐	☐	☐	☐	☐
11. Voatabia	☐	☐	☐	_____	☐	☐	☐	☐	☐
12. Traka	☐	☐	☐	_____	☐	☐	☐	☐	☐
13. Tongolo	☐	☐	☐	_____	☐	☐	☐	☐	☐
14. Antsamby	☐	☐	☐	_____	☐	☐	☐	☐	☐
15. Kapiky	☐	☐	☐	_____	☐	☐	☐	☐	☐
16. cacahuete	☐	☐	☐	_____	☐	☐	☐	☐	☐

14. Concernant les plantes que vous poussez, combien de fois avez-vous semé cette année?

Culture	Fois semé
1. Bahalazo	
2. Bahalazo d.	
3. Tsako	
4. Bele	
5. Lojy	
6. voatavo	
7. Bajiry	
8. Ampemba	
9. Antake	
10.Mody	
11. Voatabia	
12. Traka	
13. Tongolo	
14. Antsamby	

15. Quelles sont les variétés le plus important pour votre sécurité alimentaire?

Culture	Variété 1	Variété 2	Variété 3
1. Bahalazo			
2. Bahalazo.d.			
3. Tsako			
4. Bele			
5. Lojy			
6. voatavo			
7. Bajiry			
8. Ampemba			
9. Antake			
10.Mody			
11. Voatabia			
12. Traka			
13. Tongolo			
14. Antsamby			
15. Kapiky			

16. Comme on a vu que dans cette saison la récolte était mauvaise pour plusieurs ménages, est-ce que vous avez des membres dans votre ménage qui sont migré, p.ex. en ville?

□Oui □non, si oui

a. qui ?_____(père, fils..)
b. ou est-il parti ?_____(Tuléar, Tana)
c. pour faire quoi?_____(travailler dans l´industrie..)

17. Si vous avez semé plusieurs fois, est-ce que les stocks des semences étaient assez que vous aviez eu à la maison?

Culture	Oui	Non
1. Bahalazo	☐	☐
2. Bahalazo	☐	☐
3. Tsako	☐	☐
4. Bele	☐	☐
5. Lojy	☐	☐
6. voatavo	☐	☐

7. Bajiry	☐	☐
8. Ampemba	☐	☐
9. Antake	☐	☐
10.Mody	☐	☐
11. Voatabia	☐	☐
12. Traka	☐	☐
13. Tongolo	☐	☐
14. Antsamby	☐	☐
15. Kapiky	☐	☐
16. cacahuettes	☐	☐

18. Est-ce que les stockages des semences étaient suffisants dans votre village cette année?

Culture	**Oui**	**Non**
1. Bahalazo	☐	☐
2. Bahalazo	☐	☐
3. Tsako	☐	☐
4. Bele	☐	☐
5. Lojy	☐	☐
6. voatavo	☐	☐
7. Bajiry	☐	☐
8. Ampemba	☐	☐
9. Antake	☐	☐
10.Mody	☐	☐
11. Voatabia	☐	☐
12. Traka	☐	☐
13. Tongolo	☐	☐
14. Antsamby	☐	☐
15. Kapiky	☐	☐
16. cacahuettes	☐	☐

19. Est-ce que les stockages des semences étaient suffisants sur votre marché le plus proche?

Culture	**Oui**	**Non**
1. Bahalazo	☐	☐
2. Bahalazo	☐	☐
3. Tsako	☐	☐
4. Bele	☐	☐
5. Lojy	☐	☐
6. voatavo	☐	☐
7. Bajiry	☐	☐
8. Ampemba	☐	☐
9. Antake	☐	☐
10.Mody	☐	☐
11. Voatabia	☐	☐
12. Traka	☐	☐
13. Tongolo	☐	☐
14. Antsamby	☐	☐
15. Kapiky	☐	☐
16. cacahuettes	☐	☐

20. Si non, ou est-ce que vous avez achète les semences manquant?
Lieu :_____ Distance :_____ □km _____□heures

21. Est-ce que la qualité des semences que vous avez acheté a changé comparé à avant ?

Culture	Oui	Non	Comment jugez vous-la qualité ?
1. Bahalazo	☐	☐	☐ très bonne ☐ bonne ☐ moyen ☐ mauvaise ☐ très mauvaise
2. Bahalazo.d.	☐	☐	☐ très bonne ☐ bonne ☐ moyen ☐ mauvaise ☐ très mauvaise
3. Tsako	☐	☐	☐ très bonne ☐ bonne ☐ moyen ☐ mauvaise ☐ très mauvaise
4. Bele	☐	☐	☐ très bonne ☐ bonne ☐ moyen ☐ mauvaise ☐ très mauvaise
5. Lojy	☐	☐	☐ très bonne ☐ bonne ☐ moyen ☐ mauvaise ☐ très mauvaise
6. voatavo	☐	☐	☐ très bonne ☐ bonne ☐ moyen ☐ mauvaise ☐ très mauvaise
7. Bajiry	☐	☐	☐ très bonne ☐ bonne ☐ moyen ☐ mauvaise ☐ très mauvaise
8. Ampemba	☐	☐	☐ très bonne ☐ bonne ☐ moyen ☐ mauvaise ☐ très mauvaise
9. Antake	☐	☐	☐ très bonne ☐ bonne ☐ moyen ☐ mauvaise ☐ très mauvaise
10.Mody	☐	☐	☐ très bonne ☐ bonne ☐ moyen ☐ mauvaise ☐ très mauvaise
11. Voatabia	☐	☐	☐ très bonne ☐ bonne ☐ moyen ☐ mauvaise ☐ très mauvaise
12. Traka	☐	☐	☐ très bonne ☐ bonne ☐ moyen ☐ mauvaise ☐ très mauvaise
13. Tongolo	☐	☐	☐ très bonne ☐ bonne ☐ moyen ☐ mauvaise ☐ très mauvaise
14. Antsamby	☐	☐	☐ très bonne ☐ bonne ☐ moyen ☐ mauvaise ☐ très mauvaise
15. Kapiky	☐	☐	☐ très bonne ☐ bonne ☐ moyen ☐ mauvaise ☐ très mauvaise
16. cacahuettes	☐	☐	☐ très bonne ☐ bonne ☐ moyen ☐ mauvaise ☐ très mauvaise

22. Est-ce que les prix des semences ont augmentés dans les dernières 6 moins?

Culture	Oui	Non	Prix bas	Prix haut
1. Bahalazo	☐	☐		
2. Bahalazo.d.	☐	☐		
3. Tsako	☐	☐		
4. Bele	☐	☐		
5. Lojy	☐	☐		
6. voatavo	☐	☐		
7. Bajiry	☐	☐		
8. Ampemba	☐	☐		
9. Antake	☐	☐		
10.Mody	☐	☐		
11. Voatabia	☐	☐		
12. Traka	☐	☐		
13. Tongolo	☐	☐		
14. Antsamby	☐	☐		
15. Kapiky	☐	☐		
16. cacahuettes	☐	☐		

23. Est-ce que vous avez prix des crédits pour acheter des semences cette année ?
Si oui, combien et pour quelles semences ?
1._____ Ar____ 2._____ Ar____ 3._____ Ar____
4._____Ar____ 5._____Ar ____

24. Si oui, qui vous a donné un crédit ?

☐amis ☐famille ☐ ONG ☐autre :_____

25. Est-ce que vous avez récu des semences des ONG? Si oui lesquelles , combien et comment jugez vous la qualité?

Culture	Quantité	Qualité
1.		☐ très bonne ☐ bonne ☐ moyen ☐ mauvaise ☐ très mauvaise
2.		☐ très bonne ☐ bonne ☐ moyen ☐ mauvaise ☐ très mauvaise
3.		☐ très bonne ☐ bonne ☐ moyen ☐ mauvaise ☐ très mauvaise
4.		☐ très bonne ☐ bonne ☐ moyen ☐ mauvaise ☐ très mauvaise
5.		☐ très bonne ☐ bonne ☐ moyen ☐ mauvaise ☐ très mauvaise

26. Dans les 5 dernières années, est-ce qu il y a des nouvelles variétés que vous plantez ?

a. Si oui, lesquelles et quelle est la source

Culture	**source**	**Comment jugez vous la performance de cette culture ?**
1.		
2.		
3.		
4.		
5.		
6.		
7.		

27. Combien de semences est-ce qu´il vous faut pour planter sur la taille de 1 ha ?

Culture	**Quantité**	**kg**	**kapok**
1. Bahalazo		☐	☐
2. Bahalazo.d.		☐	☐
3. Tsako		☐	☐
4. Bele		☐	☐
5. Lojy		☐	☐
6. voatavo		☐	☐
7. Bajiry		☐	☐
8. Ampemba		☐	☐
9. Antake		☐	☐
10.Mody		☐	☐
11. Voatabia		☐	☐
12. Traka		☐	☐
13. Tongolo		☐	☐
14. Antsamby		☐	☐
15. Kapiky		☐	☐
16. cacahuettes		☐	☐

28. Est-ce que vous avez réduit votre consommation de nourriture dans les dernières 6 moins ?

Oui □ non□

29. Combien de repas est-ce que vous et vos enfants mangez par jour au cours de l´année?

	Juin-Aout-2013	Septembre-décembre 2013	Janvier-Mars 2014	Avril-Juin 2014
Adolescents				
Enfants				

30. Si vous avez eu des problèmes concernant votre sécurité alimentaire, est-ce que vous avez aussi collecté des plantes sauvages (cactus, yam etc.) ?

□Oui □non

a. Si oui, lesquelles et ou ?

Quoi	**Lieu (p.ex. foret)**
1.	
2.	
3.	

31. Qui décide quelles cultures sont poussées sur vos champs ?

☐chef du village ☐chef spirituelle ☐Père ☐mère ☐fils le plus âgé ☐fille le plus âgé

☐grand père ☐grand mère autre :_____

32. À votre avis, comment pourrait on améliorer votre système de l´agriculture ?

_____
_____
_____
_____

Annex 9: Recall survey covering entire 2014

Baseline WP7 rétroactif pour les dernières 12 moins, Janvier- fin décembre 2014

1. Comment jugez-vous vos récoltes de l´année dernière ?

Culture	0=pas planté	1=très bonne	2=bonne	3=moyen	4=mauvaise	5=très mauvaise
1.Bahalazo	☐	☐	☐	☐	☐	☐
2.Tsako	☐	☐	☐	☐	☐	☐
3.Bele	☐	☐	☐	☐	☐	☐
4.Lojy	☐	☐	☐	☐	☐	☐
5.Voatavo	☐	☐	☐	☐	☐	☐
6.Bajiry	☐	☐	☐	☐	☐	☐
7.Ampemba	☐	☐	☐	☐	☐	☐
8.Antake	☐	☐	☐	☐	☐	☐
9.Mody	☐	☐	☐	☐	☐	☐
10.Voatabia	☐	☐	☐	☐	☐	☐
11.Traka	☐	☐	☐	☐	☐	☐
12.Tongolo	☐	☐	☐	☐	☐	☐
13.Antsamby	☐	☐	☐	☐	☐	☐
14.Kapiky	☐	☐	☐	☐	☐	☐
15.Cacahuettes	☐	☐	☐	☐	☐	☐

2. Combien avez vous produits dans l´ année dernière?

Culture	Quantité	Unité
1. Bahalazo		☐ kap de graine ☐gobelet ☐kg ☐sac ☐panier ☐charrette
2. Tsako		☐ kap de graine ☐gobelet ☐kg ☐sac ☐panier ☐charrette
3. Ampemba		☐ kap de graine ☐gobelet ☐kg ☐sac ☐panier ☐charrette
4. Bele		☐ kap de graine ☐gobelet ☐kg ☐sac ☐panier ☐charrette
5. Bajiry		☐ kap de graine ☐gobelet ☐kg ☐sac ☐panier ☐charrette
6. Lojy		☐ kap de graine ☐gobelet ☐kg ☐sac ☐panier ☐charrette
7. Voatavo		☐ kap de graine ☐gobelet ☐kg ☐sac ☐panier ☐charrette
8. Antake		☐ kap de graine ☐gobelet ☐kg ☐sac ☐panier ☐charrette
9. Voatabia		☐ kap de graine ☐gobelet ☐kg ☐sac ☐panier ☐charrette
10.Traka		☐ kap de graine ☐gobelet ☐kg ☐sac ☐panier ☐charrette
11. Tongolo		☐ kap de graine ☐gobelet ☐kg ☐sac ☐panier ☐charrette
12. Antsamby		☐ kap de graine ☐gobelet ☐kg ☐sac ☐panier ☐charrette
13. Kapiky		☐ kap de graine ☐gobelet ☐kg ☐sac ☐panier ☐charrette
14. Cacahuete		☐ kap de graine ☐gobelet ☐kg ☐sac ☐panier ☐charrette
15. Autre : _____		☐ kap de graine ☐gobelet ☐kg ☐sac ☐panier ☐charrette

3. **Combien avez-vous dépensé (en Ariary) et/ou gagné pour les activités suivantes dans l´année dernière:**

Mois	sarclage		applic. d´engrais		Semis		Récolte	
	+	-	+	-	+	-	+	-
Somme	____	____	____	____	____	____	____	____

4. **Combien avez vous dépensé pour le matériel agricole, engrais et des pesticides dans l´année dernière?**

Mois	Matériel		Engrais		Pesticides	
	Lequel?	Ariary	Lequel?	Ariary	Lequel?	Ariary
Somme		____		____		____

5. **Combien avez-vous dépensé pour la nourriture dans l´année dernière?**

Culture	Somme
1.Bahalazo	
2.Tsako	
3.Bele	
4.Lojy	
5.Voatavo	
6.Bajiry	
7.Ampemba	
8.Antake	
9.Mody	
10.Voatabia	
11.Traka	
12.Tongolo	
13.Antsamby	
14.Kapiky	
15.Cacahuettes	

6. **Combien avez-vous gagné avec la nourriture dans l´année dernière?**

Culture	Somme
1.Bahalazo	
2.Tsako	
3.Bele	
4.Lojy	
5.Voatavo	
6.Bajiry	
7.Ampemba	
8.Antake	
9.Mody	
10.Voatabia	
11.Traka	
12.Tongolo	
13.Antsamby	
14.Kapiky	
15.Cacahuettes	

7. **Combien de bétails est-ce que vous avez vendu et acheté pendant les dernières 12 moins? Combien d´argent est-ce que vous avez dépensé et gagné avec les bétails? Combien d´animaux ont était volé?**

Bétails	No vendu	Argent gagné	No acheté	Argent dépensé	No Volé
Zébu					
Chèvre					
Mouton					
Poulets					

8. **Comme on a vue dans les donnés du pictogrammes, vous avez vendu _____ zébu pour _____Ariary et _____ chèvres pour _____Ariary**

9. **Quelles types d´animaux avez vous vendu et pourquoi?**

Bétails	**Age**	**Sexe**	**Prix Ariary**	**Raison de vente**
Zébu_1		☐Masculin ☐Féminin		☐ achéter de la nourriture ☐ coutume ☐ autre :_____
Zébu_2		☐Masculin ☐Féminin		☐ achéter de la nourriture ☐ coutume ☐ autre :_____
Zébu_3		☐Masculin ☐Féminin		☐ achéter de la nourriture ☐ coutume ☐ autre :_____
Zèbu_4		☐Masculin ☐Féminin		☐ achéter de la nourriture ☐ coutume ☐ autre :_____
Zébu_5		☐Masculin ☐Féminin		☐ achéter de la nourriture ☐ coutume ☐ autre :_____
Chièvre_1		☐Masculin ☐Féminin		☐ achéter de la nourriture ☐ coutume ☐ autre :_____
Chièvre_2		☐Masculin ☐Féminin		☐ achéter de la nourriture ☐ coutume ☐ autre :_____
Chièvre_3		☐Masculin ☐Féminin		☐ achéter de la nourriture ☐ coutume ☐ autre :_____
Chièvre_4		☐Masculin ☐Féminin		☐ achéter de la nourriture ☐ coutume ☐ autre :_____
Chièvre_5		☐Masculin ☐Féminin		☐ achéter de la nourriture ☐ coutume ☐ autre :_____

10. Concernant coutume, qu´est-ce que vous avez donné et reçu pendant les dernières 12 mois?

Bétails	No reçu	No donné	Argent dépensé
Zébu			
Chèvre			
Mouton			
Poulets			
Argent	**Somme recu**	**Somme donné**	
Ariary			
Autre:_____			

11. Économie non-agricole: Concernant les activités non agricoles, combien avez-vous reçu et dépensé pour les choses suivantes dans l´année dernière?

Quoi	Somme reçu +	Somme dépensé -
Transport		
Bois de chauffage		
Industrie		
Artisanat		
Médecine & éducation		
Consommation (alcool, cigarettes, batteries etc.)		
Argent envoyé à/par la famille		
Travail sur les champs		

12. Nourriture reçue des ONG ?

Oui □ non □

a. si oui, quoi_____ et combien _____en Unité_____?

13. Comme on a vu que dans cette année la récolte était mauvaise pour plusieurs ménages, est-ce que vous avez des membres dans votre ménage qui sont migré, p.ex. en ville?

□Oui □non, si oui

a. qui ?_____(père, fils..)
b. ou est-il parti ?_____(Tuléar, Tana)
c. pour faire quoi?_____(travailler dans l´industrie..)

14. Est-ce que vous avez prix des crédits pour acheter de la nourriture cette année ?
Si oui, pour quelles nourriture et combien?
1._____ Ar_____ 2._____ Ar____ 3._____ Ar____

4._____Ar_____ 5._____Ar ____

15. Si oui, qui vous a donné un crédit ?
□amis □famille □ ONG □autre :_____

16. Quelle était votre source de revenue le plus important dans l´année derniére ?

_____

17. Combien de personnes ont travaillé sur vos champs l´année dernière?

Group d'Age	Membres de la famille	
	Masculin	Féminin
0-8		
9-15		
16-55		
56 et plus		
Total		

18. Combien de bétails possède votre ménage il y a un an et aujourd´hui ?

Bétails	**Il y a un an**	**Aujourd´hui**
Zébu		
Chèvre		
Mouton		
Poulet		

Annex 10: Opuntia survey

Enquête sur *raketa*

Code :_____ Nom : _____ Village :_____

I. Accès et droits de propriété

1. Avez-vous des ***raketa*** à l´entourage de vos champs ? Oui □ Non □
2. Estimez, combien de plantes est-ce que vous avez dans les haies à l´entourage de vos champs ?_____de plantes
3. Avez-vous planté les ***raketa*** vous mêmes /ou qn. de votre famille ?
   Oui □ Non □
4. Si les plantes appartiennent á vous, qui a l´accès à ces plantes, c´est à dire qui a le droit de récolter des fruits ?_____
5. Est-ce que c´est pareil pour le reste des plantes, p.ex. les feuilles ? Qui a le droit de les récolter ?
   □ pareil □ pas pareil:_____
6. Est-ce que ces règles sont respectées dans votre communauté ? Oui □ Non □
   a. Si non, qu´est –ce qu´il y a comme violation concernant les règles ?

   _____
7. Est-ce que ces règles sont aussi respectées par des étrangers ? Oui □ Non □
   a. Si non, qu´est –ce qu´il y a comme violation concernant les règles ?

   _____
8. Avez-vous aussi du raketa d´ailleurs des champs et ses entourages ?
   Oui (1) □ Non (0)□, a. Si oui, ou ? □en village □à coté de la maison □en brousse
9. Est-ce que les règles concernant l´accès à ces plantes-lá sont respecté par (a) les villageois? Oui □ Non □ et (b) les étrangers ? Oui □ Non □
   c. Si non, qu´est –ce qu´il y a comme violation concernant les règles ?

   _____
10. On voit souvent qu´il y a aussi du ***raketa*** sauvage, qui a les droits d´usage là-bas ?

    _____ _____
11. Quelles sont les variétés du raketa qui poussent chez vous ?

Variété	Couleur (fruit)	Période de fruit	
		De (mois)	Jusqu´ à (mois)
1.			
2.			
3.			
4.			
5.			
6.			

   a. Si c´est plus en totale, combien de variétés, est-ce qu´íl connaît ?_____ variétés
12. Quelles sont les variétés de raketa le plus important pour alimentation :
    1. _____ 2._____ 3._____
13. Quelles sont les variétés de raketa le plus important pour les zébus :
    1. _____ 2._____ 3._____

14. Quoi d´autre est-ce que vous faites avec les raketa (p.ex. médecine, matériel de construction) ?

1. _____ 2._____ 3._____

15. À partir de quel âge est-ce que les plantes commencent à donner des fruits ?

_____ans

II. Saisonnalité et utilisation

16. Dans quelle période collectez-vous les fruits de raketa ?

Entre_____ et_____(mois)

17. Dans quelle moins collectez-vous le plus ?_____

18. Dans la période de soudure (*kere*) combien de fois mangez-vous du raketa?

_____ fois ☐ par semaine ☐par jour

19. Combien de pièces mangez-vous à chaque fois ?entre____et _____pièces dd

20. Prenez-vous aussi des repas ou il n´y a que du raketa ? Oui ☐ Non ☐

21. Combien de fois par mois ? _____fois

22. Est-ce que la consommation du raketa cause des problèmes de santés ?

Oui ☐ Non ☐

Si oui, lesquelles (a. adultes). :1._____ 2. _____ 3. _____

b. Enfants : 1._____ 2. _____ 3. _____

23. Est-ce que vous vendez aussi du raketa ? Oui ☐ Non ☐

24. Quelles sont les parties que vous vendez ?

Parties	Prix Max	Mois	Prix Min	Mois

25. Combien vendez-vous (ménage entier) par an?____ pièces pour _____ Ariary (somme)

26. Quelle est la proportion entre l´autoconsommation et la vente du *raketa* que vous collectez ? _____% d´alimentation _____% de vente

Note pour l´enquêteur : la somme doit être 100%

27. Combien est-ce que le raketa contribue a votre alimentation en totale ?

_____%

III. potentiel du marché

28. Avez-vous vendu les graines à l´ami de Ndrina? ☐oui ☐non

29. Quand? entre _____et_____

30. Pourquoi avez vous - ou n´avez-vous pas vendue des graines ?

a. Si oui :_____

b. Si non: _____

Note pour l´enquêteur : Si la réponse est non, sautez 22-28

31. Comment avez-vous récolté les graines?

_____

32. Combien avez-vous vendues chaque anné? _____kg

33. Quel était le prix ?_____Ariary/kg

34. Comment jugez-vous le prix que vous avez reçu ?

☐ tout à fais satisfaisant ☐ satisfaisant ☐moyen ☐ pas satisfaisant ☐ pas du tout satisfaisant

35. Combien de temps faut-il pour collecter un kg de graines ?_____heures

36. Comment jugez-vous la main d´œuvre nécessaire pour séparer les graines ?

☐ bcp de main d´œuvre nécessaire ☐ quelque main d´œuvre nécessaire ☐ moyen ☐ pas bcp de main d´œuvre nécessaire ☐ pas du tout bcp de main d´œuvre nécessaire

37. Qu'est-ce que vous avez faites avec les restes des fruit ?_____

38. Si vous mangez les fruits du raketa, est-ce que c´est simple de séparer et collecter les graines ?

☐ très simple ☐simple ☐ moyen ☐ pas simple ☐pas du tout simple

39. Qu´est-ce que vous faites normalement avec les graines ?_____

IV. risques, opportunités et conflits potentiels

Imaginez qu´il y aurait une association qui achèterait les semences de raketa chez vous pendant toute l´année.

40. Quels sont les risques et les conflits potentiels que vous voyez dans votre communauté?

1._____
2._____
3._____

41. Quelles sont les opportunités que vous voyez ?

1._____
2._____
3._____

42. Quels sont les types de ménages qui profiteraient le plus de la vente des semences?

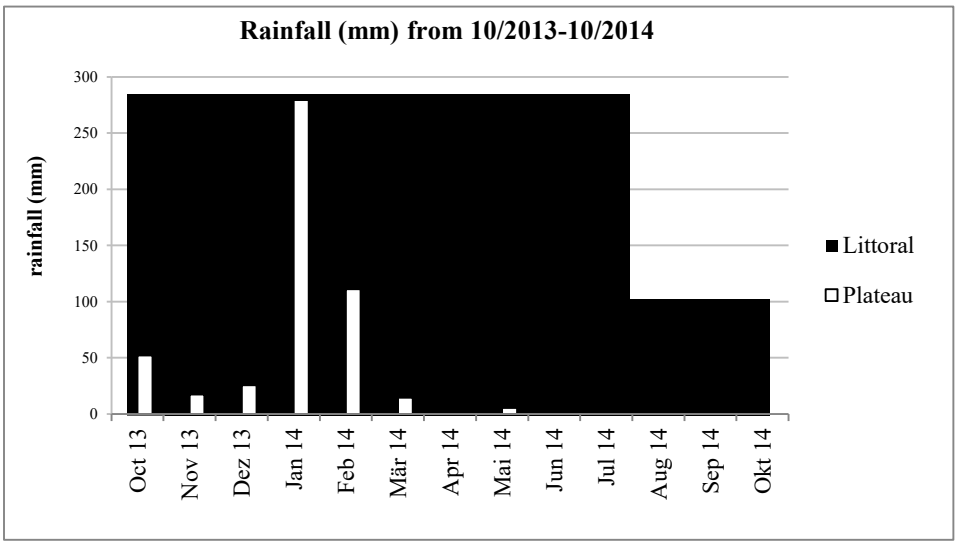
1._____
2._____
3._____

43. Pensez-vous que cette vente pourrait être une source de revenu lucrative pour vous ?

☐ très lucrative ☐ lucrative ☐ moyen ☐ pas lucrative ☐ pas du tout lucrative

44. Combien serait un prix satisfaisant pour vous pour un kg de graines ?_____Ariary/kg

Annex 11: Rainfall in the study region, Source: CNA 2015



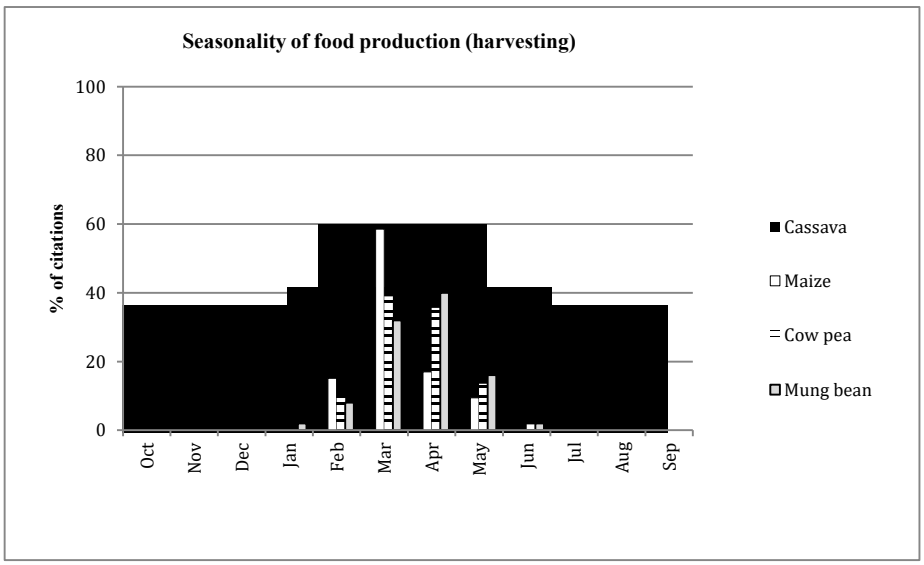
Annex 12: Household cluster description, frequencies and sampling weights for regional extrapolation (entire 2014; N= 140),. Sampling weights of the cluster (strata) were calculated through: $W_i = [(n_i / N) / (s_i / S)]$; where: n_i= is the number of HH in strata i (absolute frequency in population), N= is the total number of HH in the sampling frame (N=507), s_i= is the size of the sample having elements belonging to strata i, (absolute frequency in stratified sample); S= is the size of the sample

Cluster	Cluster description	Absolute freq. in population	Relative frequency in population %	Absolute frequency in stratified sample	Relative frequency in stratified sample%	Sampling weight for extrapolation
1	Traders	91	17.95	17	12.14	1.48
2	Livestock-rich	31	6.11	15	10.71	0.57
3	Fishers	54	10.65	0	0.00	0.00
4	Wage workers	25	4.93	16	11.43	0.43
5	Normal agriculturalists	131	25.84	18	12.86	2.01
6	Forest-resource dependent	88	17.36	16	11.43	1.52
7	Innovative HH*	87	17.16	58	41.43	0.41
All		**507**	**100**	**140**	**100**	

Annex 13: Proportion of dry-wet and shell-seed proportions and local units for surveyed crops (Source: Proportion factors from Hanisch (2015), conversion factors to local units= own data)

Crop	Proportion (pod/seeds)	Proportion (dry/wet)	Pod sack (kg)	Seed sack (kg)	Oxcart (kg)	Basket (kg)	Kapok (kg)
Mais	0.7	0.7	8.0	3.8	21.3	1.8	0.2
Peanut	0.6	0.8	*	6.1	21.8	1.6	0.3
Loyi	0.7	1	4.5	3.7	47.9	0.7	0.3
Millet	0.7	1	*	1.,7	65.0		0.3
Antsamby	0.6	1	*	3.4	45.9	0.6	0.2
Sorghum	0.8	0.9	*	2.2	32.9	1.7	0.2
Antake	0.7	1	*	8.8	39.1	1.6	0
Voanjabory	0.8	0.9	*	7.6	*	1.3	0.2
Cassava	*	0.4	4.7	1.2	143.2	1.7	*

Annex 14: Seasonality of food production, Source: Coral 2014



Annex 15: Curriculum Vitae

Curriculum Vitae

Angaben zur Person

Vorname\Nachname	**Hendrik Philip Hänke**
Adresse	Gneisenaustrasse 59, 10961 Berlin
Telefon	+49(0)3060058915 Mobil 01577-8965396
E-Mail	hendrikhaenke@gmail.com
Geburtsdatum	22/10/1984
Kinder	Samuel Richter (10 Jahre alt)

Tätigkeit	Promotion in dem BMBF Projekt: Nachhaltige Landnutzung in Süd-West Madagaskar (SuLaMa), Abteilung "Umwelt-und Resourcenökomie", Universität Göttingen
Genauere Tätigkeit	1. Eine umfassende Längsschnittstudie zur Ernährunssicherheit und dem Haushalts-Einkommen von Kleinbauern 2. Eine interdisziplinäre Studie zur sozial-ökologischen Resilienz der lokalen Bevölkerung und der natürlichen Umwelt 3. Eine botanisch-ökonomische Studie zum Potential von lokaler Katusfeigen *(Opuntia spp.)* Ölgewinnung 4. Versicherungsfunktion von Vieh während Ernteausfällen
Zeitraum	09/2012- 04/2016
Tätigkeit	Berater für das Umweltprogramm der GIZ in Südwest Madagaskar
Genauere Tätigkeit	Studie zur Verbesserung von Einkommensmöglichkeiten für rurale Haushalte während der „Hungersaison" in SW Madagaskar
Zeitraum	10-2014-12-2014
Tätigkeit	Mitarbeit in dem Forschungsprojekt „*Human dimensions behind the regreening of the Sahel in Africa*" des Stockholm Resilience Centers, Feldforschung in Burkina Faso im Rahmen der Masterarbeit
Genauere Tätigkeit	Historische Analyse des Baumbestandes (1960-2011) und eine Studie über die Landnutzungsänderung durch Satellienbildanalyse, Waldinventur, Interviews und partizipative Geographie. Stipendienfinanzierung durch das Stockholm Resilience Centre
Zeitraum	05/02/2010- 20/04/2010
Tätigkeit	Praktikum in der sozial-ökologischen Forschungsgruppe „Marktbasierte Instrumente für Ökosystemleistungen" an der Berlin-Brandenburgischen Akademie der Wissenschaften
Genauere Tätigkeit	Teilprojekt „ Bäume in der Agrarlandschaft als Biodiversitäts-Hotspots" (mit Dr. Tobias Plieninger) am Beispiel von Kohlenstoff-Sequestrierung durch Feldgehölze, gemeinsame Feldforschung in dem „Biosphärenreservat Oberlausitzer Heide- und Teichlandschaft"
Zeitraum	05/02/2010- 20/04/2010
Tätigkeit	Studie über die natürliche Regeneration der Berber-Zypresse (*Tetraclinis articulata*) im Al Hoceima Nationalpark (Marokko) in Kooperation mit der lokalen NGO „*Réseau des ONG's de Développement au Parc National d'Al-Hoceima (RODPAL)*"
Genauere Tätigkeit	Feldforschung, floristische Inventuren in dem gesamtem Nationalpark, quantitative Bestandsaufnahme des natürliches Vorkommen der Berberzypresse, Landnuztungskartierung, GIS Auswertung

Zeitraum	21/07/2008 - 21/10/2008
Tätigkeit	Sozio-ökonomische Studie über das Management des Dja Biospärenreservates in Kamerun in Kooperation mit der nationalen NGO *„Alternatives Durables pour le Développement (ADD)"*, Teilnahme am Asa-Programm (GIZ) und Stipendienfinanzierung durch die GIZ
Genauere Tätigkeit	Feldforschung, sozio-ökonomische Begutachtung, quantitative und qualitative Interviews, direkte Observation im Rahmen des Zusammenlebens mit Ureinwohnern, GIS Auswertung, „stakeholder analysis"
Zeitraum	10/05/2007 - 27/05/2007
Tätig	Zoologisch-wildbiologisches Praktikum im Bialowiesza Nationalpark in Polen

Schul- und Berufsbildung

Zeitraum	15/08/2010 - 01/06/2012
Bezeichnung der erworbenen Qualifikation	Master of Science (M.Sc.) in „Ecosystems, Resilience and Governance of Social-Ecological Systems" an dem „Stockholm Resilience Centre" (einer Kooperation des Bejier Instituts für ökologische Ökonomie, des Stockholmer Umwelt-Instituts und der Stockholm Universität) Notenschnitt : excellent (1,1)
Zeitraum	15/09/2006 - 15/07/2010
Bezeichnung der erworbenen Qualifikation	B. Sc. in „International Forest Ecosystem Management" an der Hochschule für Nachhaltige Entwicklung Eberswalde, mit den Schwerpunkten Waldökologie, Forstwirtschaft, Naturschutz und Entwicklungszusammenarbeit Titel Bachelorarbeit : Sozio-ökonomische Studie über das Management des Dja Biospärenreservates in Kamerun (Gutachter: Prof. Dr. Martin Welp) Note Bachelorarbeit: excellent (1,3)
Zeitraum Bezeichnung der erworbenen Qualifikation	01/08/1997 - 01/06/2005 Erlangung der allgemeinen Hochschulreife am Friedrich-Ebert-Gymnasium in Berlin Leistungskurse: Französisch, Deutsch
Zeitraum	01/08/1991 - 15/06/1997
Bezeichnung der erworbenen Qualifikation	Grundschulabschluss an der Teltow-Grundschule in Berlin-Schöneberg

Sprachen

Muttersprache	Deutsch

Sonstige Sprachen

	Verstehen				Sprechen				Schreiben	
	Hören		Lesen		An Gesprächen teilnehmen		Zusammenhängendes Sprechen			
Englisch	C1	sehr gut	C2	sehr gut	C1	gut bis sehr gut	C1	gut bis sehr gut	C2	sehr gut
Französisch	C1	gut bis sehr gut	C1	gut bis sehr gut	C2	sehr gut	C2	sehr gut	C1	gut bis sehr gut

Referenzniveau des gemeinsamen europäischen Referenzrahmens für Sprachen

Sprachzertifikate	DELF Diplom A-C (Diplôme d´Études en Langue Française), TOEIC (Test of English for International Communication)
IT-Kenntnisse und Kompetenzen	Sehr gute MS Office Kenntnisse (Word, Excel, Access, Power Point). Sehr gute Statistik Kenntnisse,

	z.B. SPSS. Erfahrung mit der Verarbeitung von sehr großen Datenbanken.
Auslandsaufenthalte (> 2 Monate)	Madagaskar (3* 4 Monate), Burkina Faso (2 Monate), Kamerun (3 Monate), Marokko (4 Monate), Schweden (6 Monate), Australien (3 Monate), Mexiko (2 Monate)
Auszeichnungen	Stockholm Resilience Centre Stipendiat (2011) GIZ Stipendiat (2008) ASA-Programm Alumnus (http://www.asa-programm.de)

Annex 16: Declaration of authorship **(**Eidesstattliche Erklärung)

E r k l ä r u n g e n

1. Hiermit erkläre ich, dass diese Arbeit weder in gleicher noch in ähnlicher Form bereits anderen Prüfungsbehörden vorgelegen hat.

   Weiter erkläre ich, dass ich mich an keiner anderen Hochschule um einen Doktorgrad beworben habe.

   Göttingen, den 12.2.2016

   .....
   (Unterschrift)

2. Hiermit erkläre ich eidesstattlich, dass diese Dissertation selbständig und ohne unerlaubte Hilfe angefertigt wurde.

   Göttingen, den 12.2.2016

   .....
   (Unterschrift)