SuLaMa

Participatory research to support sustainable land management on the Mahafaly Plateau in southwestern Madagascar

Final report

(01.01.2011 – 31.12.2016)

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SUSTAINABLE LAND MANAGEMENT

DLR Projektträger

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Partners

University of Hamburg, University of Kassel,
University of Marburg, Brandenburg University of Technology Cottbus-Senftenberg,
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In collaboration with

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Executive Summary

The transdisciplinary project SuLaMa has been part of the international research programme 'Sustainable land management' funded by the German Federal Ministry of Education and Research (BMBF) with the aim of understanding the interactions and interdependencies between land management, climate change and ecosystem services for the development of practical solutions for sustainable land use together with stakeholders.

SuLaMa, which ran over six years and ended in 2016, was located on the Mahafaly Plateau in Southwestern Madagascar. This part of the country comprises a unique dryland with high endemic biodiversity, but is also one of Madagascar's most disadvantaged regions in terms of economy and climate. The human population is growing rapidly, and people suffer from recurring droughts lasting one or more years – and persistent poverty. The inhabitants survive on pastoralism and agriculture, but their current practices simultaneously contribute to deforestation and land degradation. As people depend heavily on natural resources, especially during lean times, natural ecosystem conservation is essential to support their livelihoods.

The challenge on the Mahafaly Plateau is to conserve this hotspot of global biodiversity while providing subsistence for the local population. Thus, SuLaMa was developed in close collaboration with national authorities and universities in Madagascar, with the goal of developing stakeholder-based solutions for improved land management, while maintaining the natural ecosystem – along with its biodiversity and services for human well-being. To reach these objectives, SuLaMa combined expertise in the fields of agronomy, socio-economics, global change and natural resources management with the know-how of regional implementation partners. SuLaMa focussed on a research area of 7,500 km^2, which included three main study villages and the National Park.

Due to the generally low level of education in Madagascar there is a special need for capacity building and knowledge transfer. In this context, research topics were always addressed through 'tandems' comprising one Malagasy and one German student. This promoted mutual trust and understanding. SuLaMa used a participatory approach, including everyday research with local people as well as regular community workshops, which helped to take local culture and traditions into consideration when formulating research topics and development concepts. Workshops were held at all levels, ranging from village meetings to workshops with the regional government and international stakeholders. In this way, diverse stakeholders were given a voice.

To gain insight into complex interactions of land use activities and to examine future trends, SuLaMa developed spatially-explicit simulation models. Furthermore, two databases were implemented: one online data source and one on-site database. The latter was established to provide information on demand to regional stakeholders. Apart from these decision support tools, SuLaMa helped formulate practical methods of improved land management – including techniques and approaches in the fields of agriculture, forest management and biodiversity conservation. Promising methodologies for knowledge transfer to the communities were 'comic-strip narratives' illustrating recommendations for improved practices as well as 'role-playing games'.

Over the six year endeavour, all major milestones and objectives were achieved, though a flexible approach was adopted and SuLaMa was not averse to modifying its work plan. Mainstreaming methodology – including the establishment of long-term monitoring to be continued by Malagasy universities, schools and development organisations – was one of SuLaMa's major achievements in terms of ensuring post-project sustainability. Furthermore, SuLaMa's findings were integrated into a regional landscape management plan, coordinated by a partner NGO on-site, which will help to ensure long-term application of the project's outcomes.

The early involvement of local people in the project process as well as the permanent presence of project representatives, living on-site, can be seen as one key to the successful implementation of SuLaMa's ideas. The project's participatory approach and the close collaboration with different stakeholder groups were innovative aspects, and these can serve as a model for similar research and development activities in the future.


Tobias Feldt

Chapter 1

Introduction

1.1 The Mahafaly Plateau in Southwestern Madagascar

Madagascar is among the poorest countries in the world, with more than 77% of the population estimated to live on less than US$ 1.90 per day (World Bank, 2016). It faces severe development challenges combined with declining natural resource productivity. The island nation has a human population of 23.6 million, growing at 2.7% annually (United Nations Development Programme (UNDP), 2015). Southwestern Madagascar belongs to the most economically disadvantaged regions of the island – with the highest observed food insecurity (WFP and UNICEF, 2011; Noromiarilanto, 2016). This has led to regular food aid interventions in the past. Food insecurity has been aggravated by political instability and the lack of state functionality, especially during the period after the political coup in 2009, which led to many development agencies suspending their funding to the country until the democratic elections of 2013.

The project SuLaMa ('Participatory Research to Support **Su**stainable **La**nd Management on the Mahafaly Plateau in Southwestern **Ma**dagascar') ran for six years from 2011 to 2016. Funded by the BMBF (German Federal Ministry of Education and Research), SuLaMa has been part of the international research programme 'Sustainable land management, Module A', which aimed to contribute to the understanding of the interactions and interdependencies between land management, climate change and ecosystem services, and the development and implementation of stakeholder-based solutions for sustainable land use practices. Together with 11 other regional projects, SuLaMa fell under the umbrella of the scientific coordination programme GLUES (see Chapter 8). SuLaMa was strategically located in one of the most unique drylands on earth, home to a large number of endemic plants and animals – Madagascar's Mahafaly Plateau and its nearby coastal plain (Figure 1). The region faces the simultaneous problems of reconciling conservation of a prominent hotspot of global biodiversity with sustainable subsistence land use. The majority of the local population survive on pastoralism and agriculture on marginal land. Local people depend, to a very high degree, on natural resources and they have very few means to cope with losses of these critical resources and their services. The whole interrelated system is threatened by human population growth, over-utilization of natural resources such as increased cutting of natural forests – as well as climate change. Unsurprisingly, this non-sustainable land use has led to severe deforestation, endangered endemic animal and plant species, and decreased living standards. This makes research on sustainable land management particularly relevant and urgent.

1.2 SuLaMa's evolution

SuLaMa evolved as a joint German–Malagasy initiative following the original request for a project on sustainable land management and biodiversity conservation by Malagasy authorities. From the initial expression of interest, presented by the Ministry for Environment, Forest and Tourism, and the National Park Agency together with the University of Hamburg on the '*Needs and assets for biodiversity observation systems in Madagascar as a basis for sustainable land use management and conservation of ecosystem functions and services*' at a BMBF-organized conference in Spier, South Africa, in 2008, the project changed its focus from biodiversity monitoring and conservation to research that could contribute directly to the development of land use management plans. It was therefore intended that existing or new agencies, experienced in the implementation of development schemes, could become interested and involved, and follow up the results from SuLaMa's research that were relevant to their activities.

In this context, the Mahafaly Plateau and its vicinity represent a focal region for conservation and development initiatives. It is part of the *Atsimo-Andrefana* region that addresses the conservation of Madagascar's 'spiny forest ecosystem' (*Ala Maiky*). The existing programmes and projects on-site provided the background for SuLaMa's research activities, manage-

ment framework and planning. Apart from taking advantage of conceptual synergies, SuLaMa was set up to complement the spatial arrangement of the existing projects by filling neglected regional gaps. Before the project commenced, neither the consequences of the different forms of land use, nor the opportunities and constraints for the ecosystems' diversity, functions and services had been adequately studied or documented, especially not in a participatory manner with local communities.

1.3 SuLaMa's approach to meet the objectives

Based on this situation, the aims of the project were to assess the socio-ecological system of the Mahafaly region by analysing the interdependencies and interactions between major land use options, biodiversity and ecosystem services and functions (ESS/F) and to develop stakeholder-based solutions for the reconciliation of biodiversity conservation and the maintenance and enhancement of ESS/F with economic land management.

To accomplish these project aims and the demands of the funding call, SuLaMa defined the following objectives:

1. Evaluation of relevant ESS and development of methods for their analysis and valuation (suitable for long-term monitoring)
2. Analysing the dependence of ESS/ESF on biodiversity, climate change and land management via functional and quantitative studies
3. Modelling of different land use scenarios (alternative land use forms vs. business as usual) over time and space
4. Identifying trade-offs and synergies between different forms of land use (food production, climate and biodiversity protection, etc.) that take special account of ESS/ESF
5. Developing socio-economic tools for consideration of ESS/F in land management

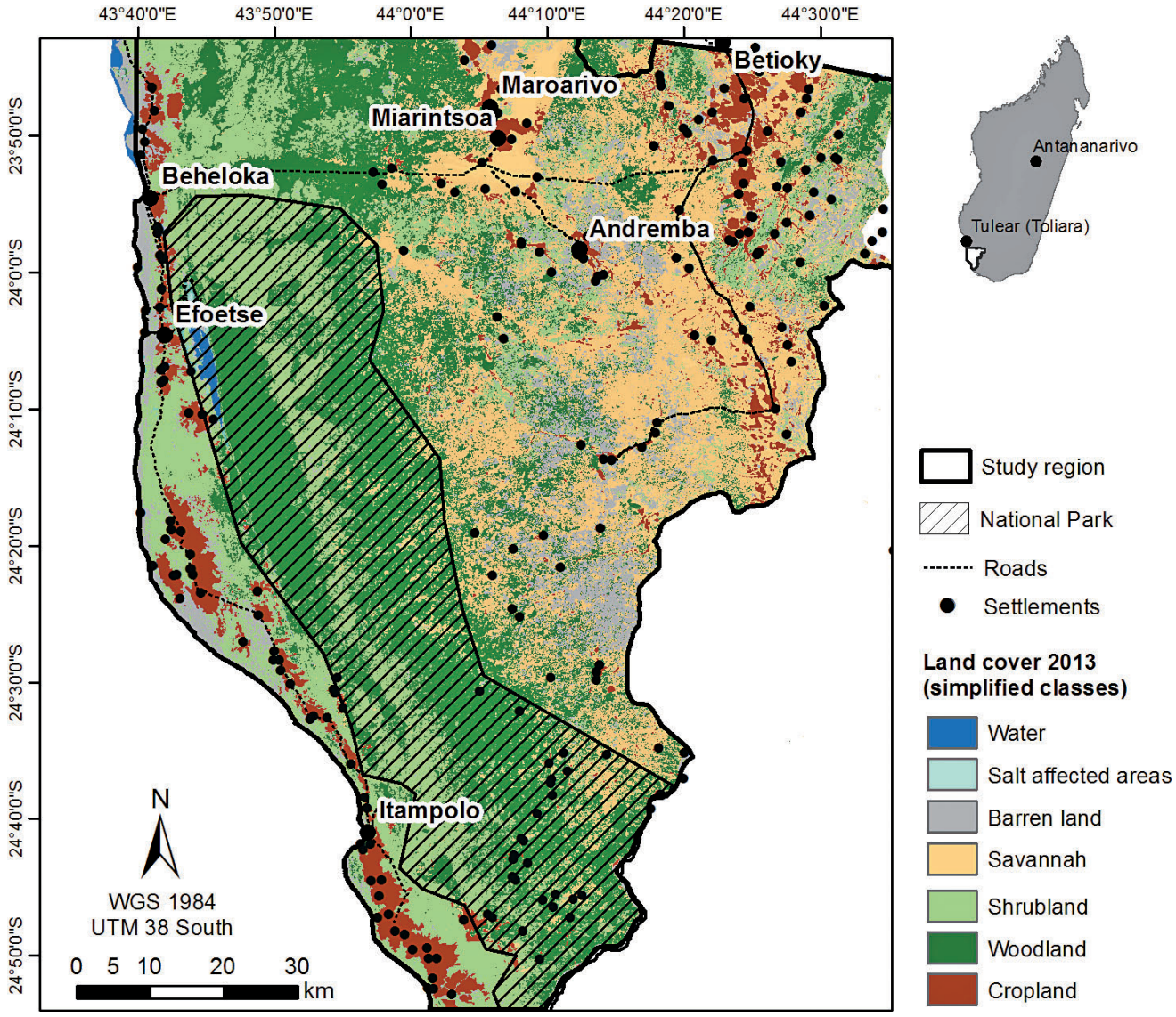

Figure 1: Study area in the Mahafaly region of southwestern Madagascar.

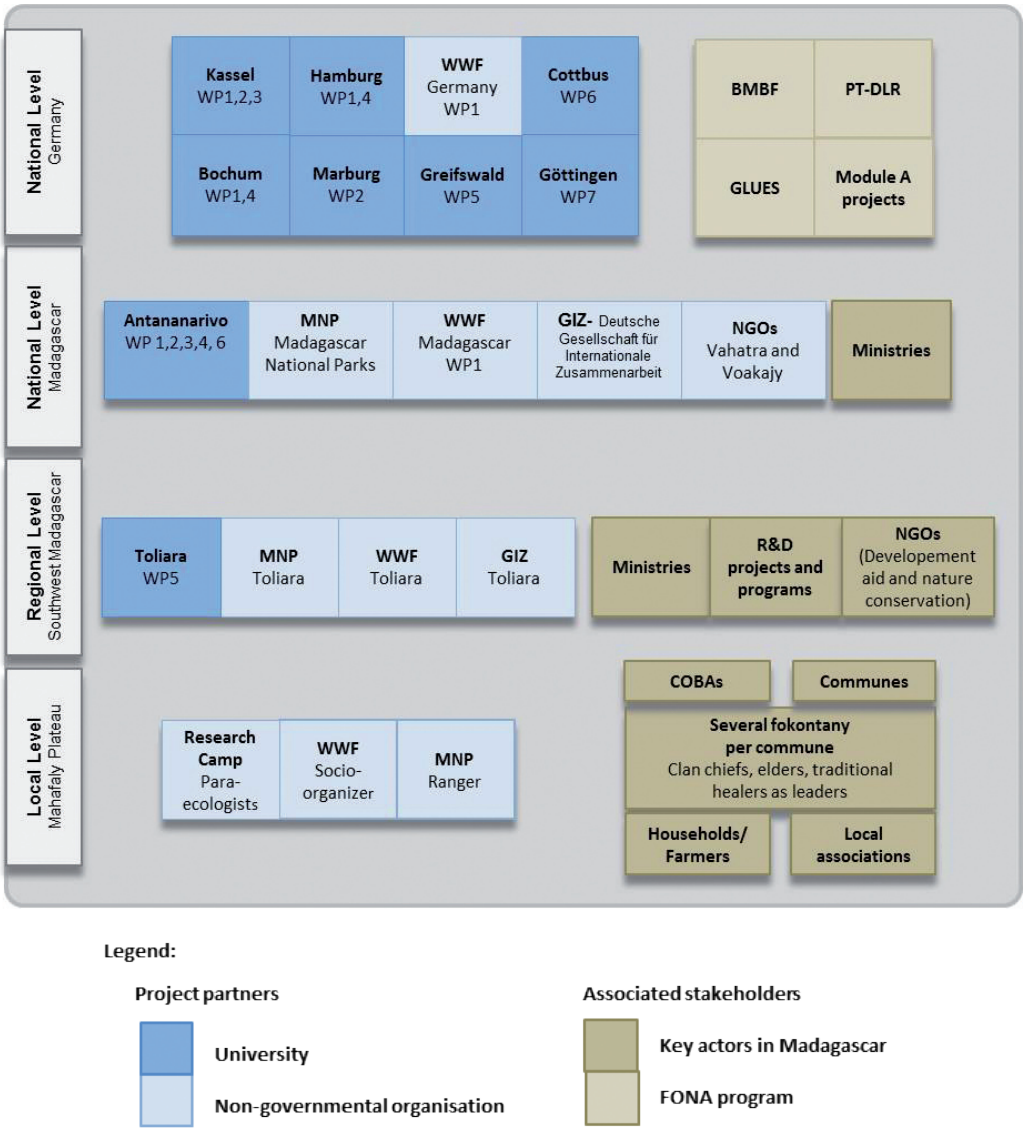

Figure 2: SuLaMa's structure with German and Malagasy project partners and associated key actors in Madagascar.

To achieve the desired results, SuLaMa used a transdisciplinary approach, combining the know-how of international and regional development and conservation organisations with the scientific expertise of 9 different universities in Germany and Madagascar. Apart from the universities of Antananarivo and Toliara, the WWF Madagascar, the Madagascar National Park Agency, the GIZ-PGM, and the NGOs Vahatra and Voakajy were contract partners of SuLaMa on the Malagasy part. Over the course of the project, the SuLaMa consortium grew to 14 Malagasy and German partners (Figure 2).

The project was organised in seven subprojects (i.e. work packages = WPs) including researchers from Malagasy and German universities as well as staff/members from the regional partner institutions (see also Annex 10.5). WP1 covered project management, coordination, communication, land use modelling and data management, WP2 was dedicated to agronomy, WP3 focused on animal husbandry, WP4 covered natural ecosystems and functions, WP5 targeted socio-governance, WP6 focused on economics, and WP7 covered agricultural economics. The project was supplemented by a hydrogeological component in 2014. The coordination unit of WP1 guaranteed logistics and infrastructure in the study region, the implementation of a harmonized methodology, a consistent project data base, joined surveys and inquiries, and the organization of regular meetings and workshops, which fostered the synergies between all workpackages (researchers and partner institutions) and associated stakeholders and enabled the final project synthesis (Figure 3). As an effective road map for the project consortium, SuLaMa generated a work plan with 15 overarching milestones that integrated specific objectives and contributions of all disciplines/work packages and partners involved (see Chapter 7).

The assessment of the socio-ecological system comprised a variety of strategies and studies. As a baseline, the project used the data gained by a participatory survey in 2011 (MARP: Méthode Accéléré Rural et Participative: similar to 'Rapid and Participatory Rural Appraisal' – see Chapter 2.2.4). These

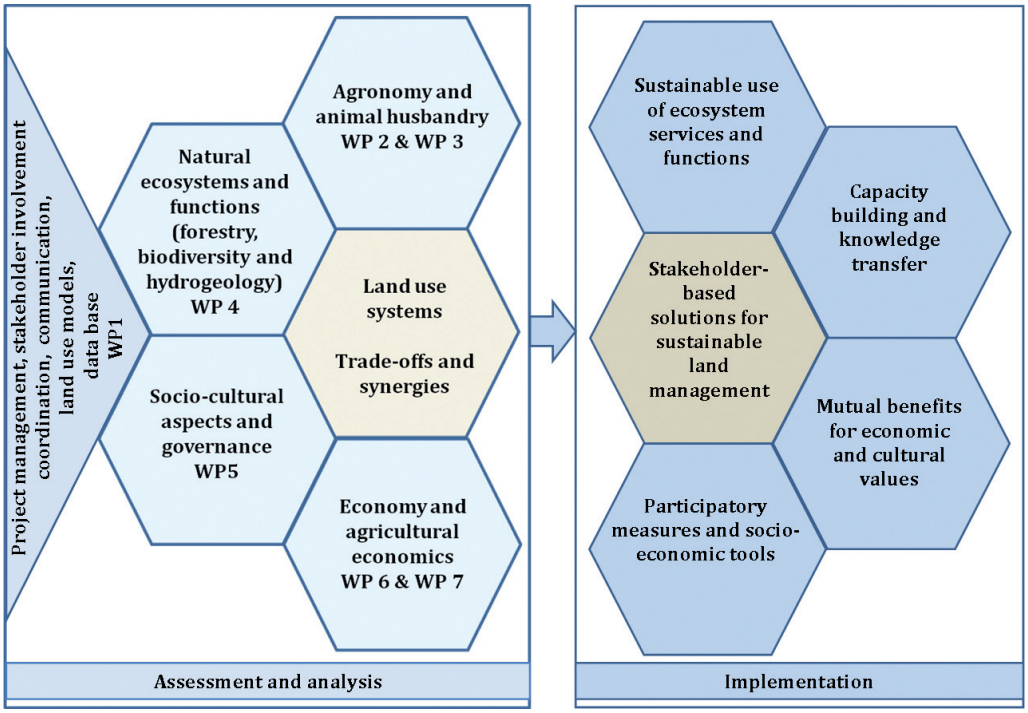

Figure 3: Cooperation of workpackages for the assessment, analysis and implementation of sustainable land management.

baseline data were supplemented by further surveys, field experiments, inventories and interviews conducted as disciplinary and interdisciplinary research in collaboration with partners and local stakeholders. A substantial number of the methods were conceptualised as participatory approaches. The transdisciplinary character of SuLaMa can be considered as the major achievement, as it enabled the implementation of techniques and approaches, which held strong prospects of being continued well beyond the project's timespan.

1.4 How to read this document

This report illustrates SuLaMa's achievements from 2011 to 2016. The project outcomes are in full compliance with the goals of the proposal, the working plan/milestones set by the consortium in 2011, the requirements in the call for proposals of the funding initiative 'Sustainable Land Management' for Module A (August 24th, 2008), and the auxiliary conditions outlined in the funding decision (November 26th, 2010).

In this context, the focus of the report lies particularly on implementation-oriented results and those assessment strategies, structures, approaches and techniques that have good prospects for future continuation. The report describes the performance of the project consortium as a whole and of the different scientific disciplines, and illustrates the achievements by presenting:

- a stakeholder analysis and appropriate communication and involvement tools with a special focus on participatory measures (Chapters 2.1 and 2.2);
- the current status on the Mahafaly Plateau describing briefly and concisely the challenges and social-ecological frame conditions (Chapter 3.1);
- key findings and recommendations in the fields of natural resources, livelihoods and food security, and socio-governance and their relevance for implementation and/or project work (Chapters 3.2–3.4);
- land use models as decision support tools for regional land management planners (Chapter 4);
- products, approaches and techniques that are implemented in the study region and have good prospects for long-term application (Chapter 5);
- highlights and challenges that arose over the duration of the project (Chapter 6);
- the successful completion of the project milestones according to the overarching work plan, as well as necessary modifications of tasks (Chapter 7.1, 7.3, and 7.4);
- reflections on the overall project performance with a special focus on the integration of subprojects (Chapter 7.2); and
- the interactions with GLUES and other projects of Module A (Chapter 8).

Chapter 2

Stakeholder analysis and involvement

2.1 Stakeholder analysis

The fact that SuLaMa evolved as a Malagasy–German initiative facilitated local stakeholder involvement since the project was able to participate within the already existing network established by regional and local partners (such as the WWF). However, for effective research, and especially the implementation of locally accepted land use alternatives, it was crucial to develop a comprehensive stakeholder involvement strategy.

SuLaMa's stakeholder involvement strategy included an initial detailed stakeholder analysis of relevant actors at all levels, as well as the development of specific stakeholder communication strategies for the different groups. In this context, SuLaMa put a firm emphasis on the early and continuous involvement of local individuals and communities in the research process, in order increase the probability of successfully combining scientific know-how with traditional knowledge, and to identify solutions that focused not simply on short-term relief aid.

In Madagascar, a multitude of conservation and development organizations are active. The southwestern part of the country has been a focal region for various programmes and projects in the past, while representation by the Malagasy government was virtually absent. To gain an overview, and handle the complex stakeholder landscape, a 'spectrum stakeholder analysis' was conducted. The aim of this analysis was to understand the stakeholders' objectives and interests in the research region, and to evaluate their influence on and possible contribution to the project's activities. SuLaMa adopted two strategies to identify stakeholders on the ground (local and regional level) and those acting as drivers and actors at the regional, national and international level. As a first step, the project identified stakeholder groups who used natural resources and/or made decisions regarding access to them. In a second step, stakeholders were categorised and the relationships between stakeholders were investigated. At a higher level (national and international) the project asked known actors (GOs and NGOs) about collaborators and contacted them. In sum, it became clear that a large number of organizations were/are involved in the development of land use practices on the Mahafaly Plateau. A living document – with currently about 90 entries – exists. Below are the key stakeholders, classified according to their status.

As an active and influential environmental NGO in the project region, the WWF constituted a direct partner supporting the project with logistics, local knowledge, stakeholder dialogue and management planning. For the latter, SuLaMa's results and recommendations were integrated into the 'landscape approach' (see Chapter 5.4.4), a sustainable land management concept for the whole Mahafaly Plateau and adjacent regions. Another key partner of SuLaMa was the national agency, Madagascar National Parks (MNP; formerly ANGAP), that manages the Tsimanampetsotse National Park (as one focal research site in the study area) and closely cooperates with the local population in co-management and community-based management. As important academic stakeholders, the Universities of Toliara and Antananarivo were direct partners of SuLaMa. Additionally, SuLaMa collaborated with the universities of Tamatave and Fianarantsoa, which were participants (together with the two other universities) in the annual summer school programme, organized by the NGO Vahatra. The NGOs Vahatra and Madagascar Voakajy (involved in the biodiversity research) were also direct project partners, as they supported research topics, capacity building and knowledge transfer. SuLaMa itself represents a stakeholder in this category. Further academic stakeholders existed mainly in form of Research and Development (R&D) projects.

Apart from WWF, a number of predominantly French NGOs from the conservation and development sector, as well as the German development agency (GIZ), work in the area in order to improve food security and conserve the natural heritage. Among the United Nation agencies, the UNDP was deeply involved in improving access to water, while the World Food Programme (WFP) implements a

food security programme and supports a food security alert system. Apart from SuLaMa, the main projects active in the region (called SLM and COGESFOR) were also implemented by the WWF, which facilitated the coordination of activities. The PGE-M (Programme Germano-Malgache pour l'Environnement; implemented by GIZ) acted as a political advisor for decentralized resource management and protected area management, and was also an associate partner of SuLaMa. Furthermore, there are programmes of the World Bank operational in the area such as the FID (Fonds d'Intervention pour le Developpment), which finances infrastructure, and PSDR (Projet au Soutien du Développement Rural), which supports farmer organizations.

Due to the coup d'etat in 2009, the involvement of national governmental stakeholders at the beginning of the project was extremely problematic since changes in legislation and staff were unpredictable. Moreover, many political departments were not functional between 2009 and 2013. Nevertheless, with the official presidential election in 2013/2014, most of the ministries became functional again, and during meetings and workshops with governmental authorities from 2013 onwards, SuLaMa's ideas and recommendations were met with great interest.

With respect to the involvement of political stakeholders, local and regional governments constituted the most important contacts for the project. In the southwestern region, these included the Betioky and Toliara II districts at the regional level, and the communes of Beheloka, Maroarivo, Meantake, Masiaboay, Beahitse and Itampolo at the communal level. Moreover, decentralized state services such as the Environment and Forests Regional Directorate (Ministry of Environment) and the Rural Development Regional Directorate (Ministry of Agriculture) were in close contact with SuLaMa as they participated on the regional communication platform (see Chapter 2.2.2) and at several project workshops. The autonomous state agency 'National Agricultural Research Center' (FOFIFA) represented another actor involved in improving cropping systems.

Local organizations have the potential to create ownership and anchor sustainable land management techniques within the local population. Those organizations working in the agricultural and ecological field were especially key stakeholders for the SuLaMa project. Farmers' organizations are often affiliated to the *Maison des paysans*, which provides them with services in partnerships with the *Centre de Services Agricoles*, an autonomous body of the Ministry of Agriculture. AICPM (*Association Inter Communale du Plateau Mahafaly*) is an umbrella structure that supports local associations and reinforces the existing environmental rules. It consists of the mayors of five communes, and develops environmental rules, the so-called *dina*, to reinforce existing legislation – for example regarding bush fires, slash-and-burn practices and rules governing endangered species.

With respect to natural resources, the committees for co-management in the Tsimanampetsotse National Park, the COSAP (*Comité d'Orientation et de Soutien à l'Aire Protégée*) and the CVO (*Comité de Vigilance Opérationnelle*), as well as the committees for community-based management in the buffer zones of the park, COBA/VOI (*Communauté de Base/ Vondron'Olona Ifotony*), play an important role in the development of sustainable land use. The 22 COBAs were created with support from a regional NGO to implement a community-based management initiative in the buffer zone of the National Park. Appropriately, their goal is to promote sustainable use of natural resources, and to foster the regeneration of the forest. Community-based natural resource management can be seen as a promising approach for biodiversity conservation and the sustainable use of the ecosystem's goods and services. Thus, the COBAs represented important stakeholders for SuLaMa.

In the economically marginalized region where most people's mainstay is subsistence farming, trade plays only a minor role. Nevertheless, commerce constitutes an important income source for some rural households. Small local businesses have an interest in innovation – and in improving their income sources. In this context, the project investigated innovations in terms of agricultural techniques in collaboration with farming households.

Local authorities were further important partners and contacts of the project. Since the state has only very limited influence in most communities, traditional leaders collaborate closely with state representatives of the *fokontany* (*chef/president*) in terms of making local decision-making. Furthermore, the clan elder and the traditional healer hold important and influential positions. The individual farming and herding households and families were found to be those most closely involved with land use strategies in the area, while simultaneously being the group most affected by the consequences of their actions. This stakeholder group was identified as the most important project partner, in that it was able to profit directly from engagement in mutual learning, training in innovative resource management practices, and benefits most from increased awareness about environmental challenges.

Following the stakeholder analysis, and taking the political insecurities during the first project period into account, SuLaMa's key stakeholders primarily comprised conservation and development actors, national and regional academics as well as local communities and individual households.

2.2 Stakeholder communication and involvement tools

2.2.1 Starting point

Immediately after the project initiation in 2011, the SuLaMa team visited all organisations involved in the project's activities in Madagascar. The objectives were to outline the final programme, to discuss the consequences of the political instability for the project, and to prepare the first joint workshop / field trip for all partners involved. While the consequences of the political situation were quite dramatic, the fact that SuLaMa represented one of the very few funding options for Malagasy counterparts – and the fact that the project had been developed as a joint Malagasy–German initiative from the very beginning – was much appreciated and led to a very warm welcome from all parties involved. During a second fact-finding trip to the research area on the Mahafaly Plateau with Malagasy and German representatives from all working packages, the team identified study sites for baseline surveys and developed appropriate data collection strategies.

2.2.2 Stakeholder communication platform

As a project partner and initiator of many further R&D projects, WWF Madagascar facilitated the stakeholder networking and communication. SuLaMa revived a regional stakeholder communication platform, named the '*Sous-cluster allimentaire*', to ensure and improve the interaction with various stakeholders and further R&D projects in the study region. The platform allowed the different organisations, institutions and programmes active in the region to discuss and share work plans, new achievements, experiences and scientific knowledge. Encouragingly, representatives of the Ministries of Agriculture and Environment participated. It also helped SuLaMa and other projects to identify synergies concerning research and implementation activities on the Mahafaly Plateau, avoiding possible replication of activities. In this context, two major achievements of SuLaMa were *(1)* the initiation of an improved R&D project communication and coordination in the region, and *(2)* the updating of planning tools (conservation strategy, monitoring and research plans) to support other projects working on the Mahafaly Plateau (e.g. various WWF projects, ACF, GIZ and MNP). Additional to the stakeholder communication platform, the project organized regular workshops and meetings with partners and stakeholders.

2.2.3 Tandem approach and summer schools

SuLaMa's concept for enhanced capacity building at the academic level followed the 'tandem approach' in which students from German and Malagasy universities closely collaborated as counterparts within scientific disciplines, and jointly conducted assessments and analyses. To foster the connection among university-based research and the Mahafaly region, and to build capacity in terms of scientific fieldwork, SuLaMa organised annual interdisciplinary summer schools in Madagascar in cooperation with the NGO Vahatra. Here, students from three Malagasy universities (Antananarivo, Fianarantsoa and Toliara) learned different field research methods and techniques. The excursions served not only to enhance the implementation of knowledge on an institutional level, but also as a foundation for the development of community-based conservation monitoring, which is envisaged to be a long-term programme for the whole region. Furthermore, the SuLaMa team offered regular courses and seminars in field methods, GIS and statistical analyses that were given at the Universities of Antananarivo, Fianarantsoa, Tamatave and Toliara.

2.2.4 Participatory approaches with local communities

To foster the communication between researchers and local stakeholders, and to mediate a better understanding among their differing perceptions, the project collaborated from the beginning with locally recruited community liaison agents, namely socio-organizers and 'para-ecologists'. Both acted as multipliers of ideas and fostered continuous information transfer from/to the communities. While the socio-organizers provided not only a communication but also a cultural link between scientists and rural communities, the para-ecologists supported experimental research and received training on standardized monitoring and interview techniques. Another important aspect that helped the project to gain mutual trust and foster collaboration between researchers and communities was the long-term engagement of Malagasy and German researchers in the field. Most researchers lived from some months up to several years in the study region, and this helped them to gain deeper insights into the local culture and to understand – and acquire – traditional knowledge. The long-term engagement of researchers also allowed adaptation of measures and planning in accordance with social or environmental changes over the project course. Agronomists were able to conduct field experiments and feedback workshops together with people from rural commu-

Figure 4: Villagers participating at a workshop of the MARP (Méthode Accéléré Rural et Participative) survey in 2011 (photo: Jutta Hammer).

nities. SuLaMa's socio-organizers organized regular workshops for these communities in order to inform them about the projects' outcomes and solutions about sustainable land use. Moreover, excursions to the National Park with pupils and teachers were part of the awareness-raising programme. The fact that research results were communicated by non-scientific mediators who lived in the area fostered trust among the local population, and contributed to the understanding and acceptance of alternative techniques.

A central goal of SuLaMa's stakeholder involvement strategy was to integrate local voices and perceptions into the research process in a participatory and interdisciplinary way. In the work with local people, community workshops proved their value as a well-accepted communication channel. The participatory approach also included assessment strategies with local people, such as ethnopedological surveys and soil mapping.

Apart from 'everyday research' in terms of joint field experiments and surveys, three overarching project workshops with rural communities facilitated the communication between researchers of different disciplines and local land users. These were the MARP survey and workshop in 2011, the village feedback workshop in 2014 and the final village workshop in 2015.

The baseline study called MARP (*Méthode Accéléré Rural et Participative*) was conducted in the initial project phase (SuLaMa, 2011; in Liniger et al., 2017, www.wocat.net/). The specific objectives were *(a)* to build a link between German and Malagasy researchers from different disciplines, *(b)* to train them in the MARP methodology, *(c)* to understand the broad outlines of local subsistence strategies, and *(d)* to explore the diversity of social and environmental situations in the Mahafaly Plateau region.

Local people were a central part of the process that defined relationships between land, resource use and local socio-culture (Figure 4). The common experience not only fostered mutual learning between project members and the local population but also the communication between researchers of different disciplines and universities. The findings regarding both the socio-economic and socio-cultural systems helped to sharpen the research goals within the project. A series of additional participatory appraisals have been conducted on the Mahafaly plateau after completion of the MARP, in order to broaden the scope of analyses. The same methodology was used, although semi-structured interviews were given priority over other tools. These 'post-MARP' surveys were conducted in three *fokontany* of the littoral, and two *fokontany* of the savannah area. These surveys mostly confirmed the conclusions of the MARP, but also provided more details of the functioning, sustainability and performances of local cropping systems. Furthermore, they enabled a better understanding of interactions between the Tsimanampetsotse National Park area and adjacent local farming systems.

Role-playing games were designed in order to understand and discuss the livelihood strategies of different household types and villages in the research region (see Chapter 4.6). Participants assumed fictitious roles and simulated their annual subsistence decisions. In the framework of the game, players learned about the consequences of their decisions and discussed strategies in scenarios of drought and cattle theft. The data derived helped researchers to understand decision making patterns, and therefore assisted them to validate their models. Besides, the process stimulated local people to reflect on their current land use system. Overall the insights fostered a common understanding of the interdependency between climate, ecosystem services (in particular cultural ecosystem services), and land management.

Chapter 3

Key findings and recommendations for sustainable land use on the Mahafaly Plateau

3.1 The current status of the social-ecological system on the Mahafaly Plateau

3.1.1 Frame conditions and challenges

The Mahafaly Plateau covers approximately 800,000 ha and includes the Tsimanampetsotse National Park (220,000 ha), numerous sacred forests, and community forests. The actual study area comprised four communities in two different ecozones, namely a coastal area in the west and a limestone plateau in the east, both characterized by pastoralism and agriculture on marginal land, and severe states of degradation. By means of SuLaMa's first participatory, transdisciplinary survey in 2011, the MARP study, the team selected the specific study sites and villages on the basis of important criteria including representative land use management activities, region-specific use of ESS/F, the possibility of alternative land use options, comparability of different habitat types, sufficient infrastructural conditions, and accessibility of study sites. Based on the SuLaMa assessments – including the MARP study and further project observations (village and household surveys, inventories etc.), we present, in the following section, an overview of the socio-ecological frame conditions and most relevant drivers the project found that lead to the fragile economic situation of local households.

The semi-arid climate in the region is highly volatile (e.g. between 1995 and 2009, annual rainfall varied by 40%; WFP and UNICEF, 2011) with recurrent droughts and occasionally significant damage caused by heavy cyclones in wetter years, further exacerbated by locust outbreaks. The remote area's infrastructure is poorly developed and is completely lacking in electrification and clean water. Professional medical care is almost absent and expensive, and educational opportunities are limited. The political instability over the last few years has led to increased security problems, and especially to high risk of livestock theft. Furthermore, transportation and the access to markets beyond the immediate vicinity are limited. Consequently, the local population relies largely on subsistence in a marginal and high-risk environment: families are thus very dependent on natural resources for supplementary food, fuel wood, construction material, health care, and as a basis for supplementary income activities.

In the project area, the majority of the local population belongs to three different ethnic groups: the Vezo, the Tanalana and the Mahafaly. As the Vezo are mostly restricted to coastal villages with fishing and trade as their main economic activities, the project focused on the villages inhabited by the Mahafaly (plateau area) and the Tanalana ethnics (both coastal and plateau areas) because their societies rely mainly on agropastoralism, the most common form of land use by rural communities in southwestern Madagascar. Typically, villages are surrounded by a belt of privately owned crop fields and commonly used pastures of differing vegetation types (grassland savannah, woodland savannah, shrubland, forest etc). The principle livestock species are zebu cattle, goats and some sheep. Livestock not only serve as an economic good but also play a crucial role in the culture of both the Mahafaly and the Tanalana.

In general, people herd livestock to different grazing lands each day. Besides daily movements, there are also seasonal relocations of herds for several months from their village of origin. In case of the traditional transhumance of the Tanalana livestock from the coastal villages, the herds (mainly cattle) are taken to the plateau at the beginning of the rainy season to exploit the savannah, and to take advantage of the brief period of available surface water. As soon as the waters begin to dry up, the herds are taken back to the coastal area which provides water year-round and, recently, is safer in terms of cattle raiding. After the onset of political instability following the coup d'état, a novel seasonal movement was triggered, the so-called 'inverse transhumance' during which herds originating from

the plateau are taken to the coastal area during times of high risk of cattle raids on the plateau (see Ratovonamana et al., 2013; Feldt and Schlecht, 2016; Goetter, 2016 for details). Moreover, the depletion of resources in the coastal area due to the increased exploitation of fodder leads to a herd movement termed 'vertical transhumance', during which herds are displaced within the coastal area to cope with local fodder shortage. During both the transhumance and the inverse transhumance movement, the herds are obliged to use tracks across the Tsimanampetsotse National Park (which are also used to access daily pasture by the herders) despite this being illegal.

Although the climatic and edaphic properties differ among the coastal area and the plateau (lower precipitation and quarternary sand dunes in the littoral zone; higher precipitation and a mosaic of different soil types of tertiary origin on the plateau), the labour-intensive agricultural techniques using hand tools are very similar. Cassava is the main staple crop and is often planted in a mixture with maize and cowpeas. There is also cultivation of sweet potato, melons, groundnuts, sorghum and pearl millet. Two main types of rainfed crop cultivation systems exist: *(i)* short-term slash-and-burn fields usually established deep inside forest remnants that are planted for a few years with maize ('*hatsaky*') then left to recover, and *(ii)* permanent fields on relatively fertile soils surrounding the villages which are fenced and cultivated for many years with alternating fallow and cropping periods ('*baiboho*') (Brinkmann et al., 2014; Noromiarilanto et al., 2016). Farmers own, on average, 2.1 ha of fields: the vast majority of these fields (>96%) is owned under traditional rights without a formal land title.

The low-input/low-output cropping system is often not sufficient to achieve food security amongst smallholder farmers (Noromiarilanto et al., 2016). Neither plough utilisation nor manure fertilisation are common; virtually no pesticides are used and all soil treatments and weeding are performed manually. The unfavourable soil conditions as well as the harsh climate (low and erratic rainfall, high frequency of droughts, strong winds and passing of cyclones) in combination with crop pests (especially locust plagues) and crop diseases lead to an extremely challenging environment for the cultivation of crops (Faust et al., 2014, Hanisch et al., 2015). As the rains in the area are highly volatile and no irrigation is applied, a considerable proportion of the crops often wilts and dies before the harvest in dry years, or at best harvest quality and quantity suffer. On most soil types, the cropping methodology causes a depletion of plant nutrients that eventually necessitates fallowing of the field after several years of cultivation. The farmer then either establishes a new field using slash-and-burn techniques to clear new land, or returns to re-cultivate fallowed fields. In order to establish a new field, part of the common forest is assigned to an individual from the village in accordance with the village community customs ('*fokonolona*'). Cultivation practices depend on the soil fertility and water availability. If the fields are inherited, the current users will follow the cropping cycle of their ancestors.

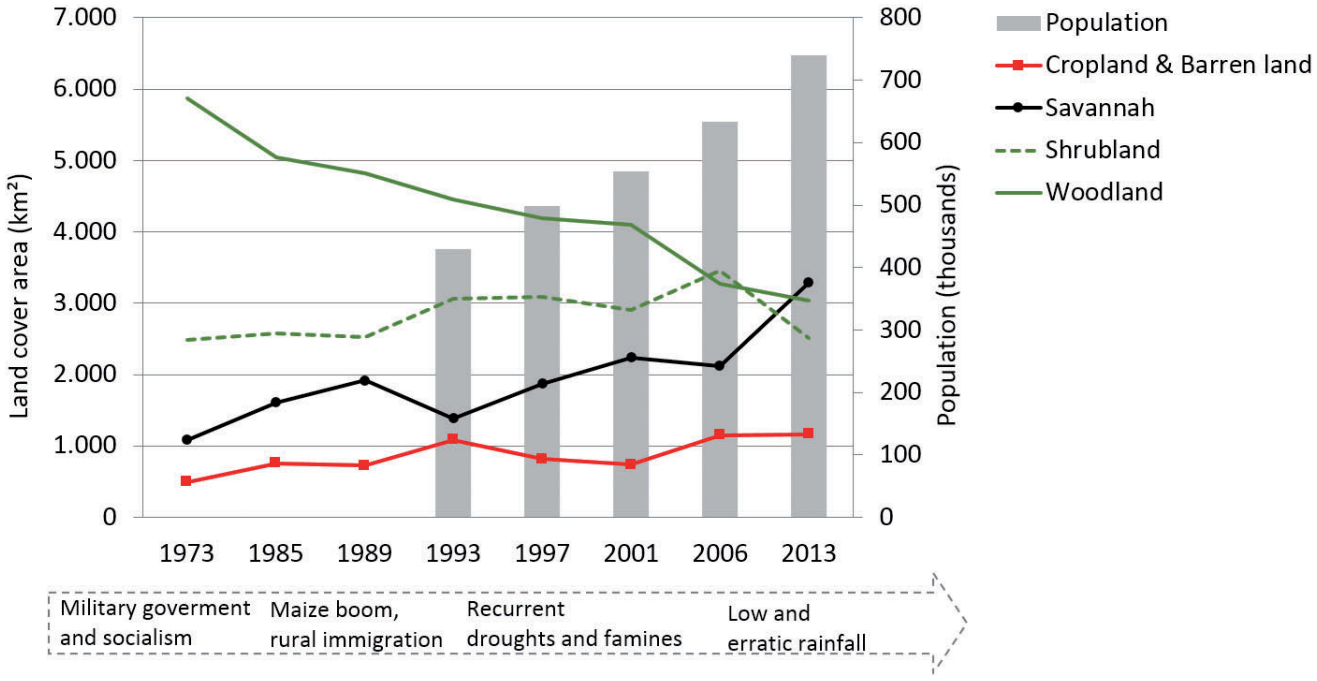

Figure 5: General trends of land cover changes from 1973 to 2013 for the whole study region and population trends from 1993 to 2013 for the three districts (Betioky-Sud, Toliara II and Ampanihy in SW Madagascar).
Classes were simplified in the following way: forest = classes 7, 8 and 9; savannah = classes 4 and 5; cropland and barren land = classes 10 and 3. The dynamic of the land use system was investigated by analysing the processes and causes of land use changes (source: Brinkmann et al., 2014).

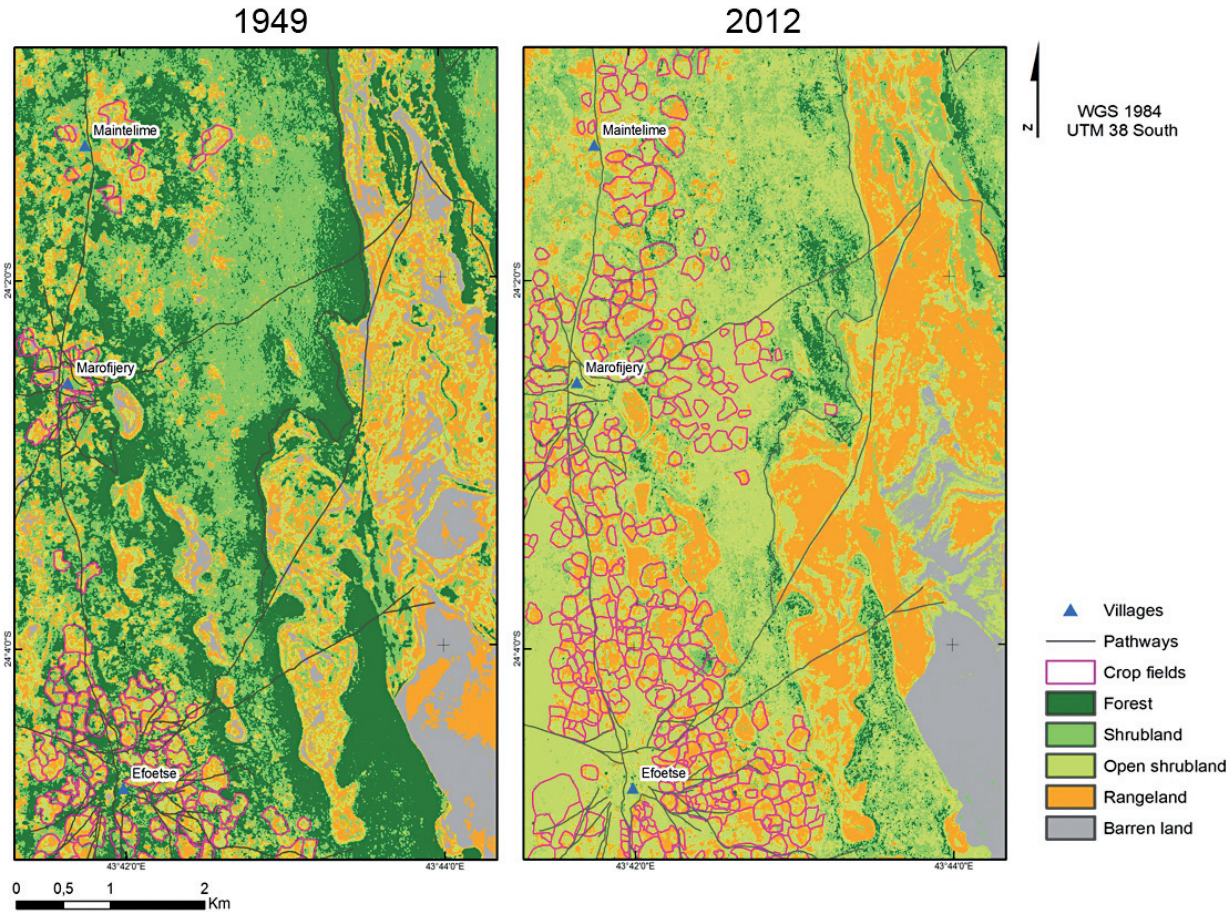

Figure 6: Land use changes from 1949 to 2012 in the littoral zone.

3.1.2 Land use and land cover changes (LULCC)

These agricultural practices have led to the development of a cultural landscape where villages are characterized by a mosaic of crop fields in different stages – currently cultivated fields, temporarily fallow fields and completely abandoned land – surrounded by pastures of differing grazing intensities. The traditional land use practices with the continuous extension of crop fields has led to very considerable deforestation of the region. Over the past 40 years, forest losses have amounted to 45%, resulting in the development of savannah and associated forest fragmentation (Figure 5). Deforestation has been most acute in remote locations, close to small, recent settlements that are poorly connected to infrastructure and main markets.

The correlation analysis for the entire observation period (1973–2013) indicates a strong relationship between deforestation rate and the biophysical factors of altitude, distance from the National Park, distance from the road, initial woodland status and the area of cropland in 2013. Deforestation mostly increases with higher altitude, and greater distance to both the main road and the National Park border. The relative explanatory power of the predictor variables has changed over time, indicating modifications in the general causes and processes of deforestation. The causes of this diffuse deforestation pattern in the Mahafaly region changed through space and time, but one major driver is the slash-and-burn agriculture often practiced by farmers from neighboring regions seeking for new land to cultivate.

A detailed analysis of land use changes revealed that the cropland area increased up to 40% in the villages from 1949 to 1966. In the littoral zone, several cropland areas in the western part were abandoned due to poor soil conditions, while cropland expansion occurred in the eastern part near the National Park border (Figure 6). Since then, pressure on available land resources and ecosystem services increased dramatically with the highest deforestation rates on the plateau, where most woodlands were transformed to savannah. A socio-economic analysis revealed increasing slash-and-burn agriculture from 1960 to 1980 caused by a cash crop boom involving maize (Noromiarilanto, 2016).

3.2 Biotic resource management and conservation

The high deforestation rate in the Mahafaly region translates into a direct threat to the local population, as their livelihood support regime depends strongly on benefits from forest ecosystems and the basic ecological processes behind them. However, for

some ecosystem services, the local population has no strategy to utilize them in a sustainable manner. Madagascar's forest management is in the process of decentralization, giving more responsibilities to local communities for their own forests. Relevant aspects of the community forests are registered by community monitoring programmes. These programmes include, but are not specifically targeted towards, biodiversity monitoring – as this is not a priority for the communities. To develop such strategies as part of an overall sustainable management plan, a better understanding of the spiny forest ecosystem and related services and benefits was essential. Thus, SuLaMa's aims in the field of natural resource management were the assessment and analysis of the forest ecosystem and its implication for local livelihoods. The following sections provide an overview of the most important services and benefits supplied by the spiny forest ecosystem, as well as results and recommendations for sustainable forest management and biodiversity conservation.

3.2.1 The spiny forest ecosystem and its benefits for people

The natural habitat of the Mahafaly Plateau constitutes spiny forest, and harbours the highest level of plant endemism both at the generic (48%) and species (95%) level in all Madagascar. Forests influence microclimate, regulate water flow, reduce wind erosion, function as bio-regulators (e.g. by providing habitats to pollinators for crops), and play an important role in climate change mitigation. Furthermore, the local population uses a huge variety of wild crops, plants and fruits for their livelihood, especially during times of crop failures. Wild yam and medical plants belong to the most important non-timber forest products (NTFPs), as they contribute directly to the food security and health of the local population. In an ethnobotanical survey (Andriamparany et al., 2014), six endemic species of wild yam were identified as potential food resources on the plateau (out of 22 species recorded in the south-western region). Yams are mostly consumed as a supplement to the daily quantity of cultivated staple foods when these are scarce, but sometimes they constitute the main staple, especially in the villages near forest areas, where daily collection is possible. As production of wild yams is amongst the key ecosystem provisioning services, cultivation of wild yam species appears to be a major opportunity to decrease the pressure on the wild population (see Chapters 3.4.2 and 5.3.1).

Apart from wild yam species, medicinal plants also play a vital role for the people. SuLaMa identified 221 plant species that are used by the local population for themselves – or for their livestock. These plants are used to treat 46 different ailments in people and livestock, of which the most common were digestive disorders, muscular skeletal problems and cosmetic uses for women (Andriamparany et al., 2014). Most of the medicinal plants used by the local population are of local origin (95%) while the rest are bought or imported from the nearest town, or from neighbouring regions. The majority of the plant species are collected in forest areas (82%), and only 14% of the species are cultivated. The remainder are typically collected in fallow land, shrubland or grassland (Andriamparany, 2015). This emphasizes the extraordinary importance of forests for local medical care. Although the majority of the plants used are endemic to Madagascar (68%), exotic plants or plants that have a large worldwide distribution are used as well.

The MARP and the village baseline survey in 2012 and 2013 revealed that a large number of animal species occurring on the Mahafaly Plateau are consumed to enhance the diet of local people. Animals hunted include guinea fowl, wild pigs, tenrecs and tortoises. In fact hunting is prohibited in the core area of the national park and in sacred forests, but is nevertheless carried out due to a lack of control mechanisms and staff capacity. The radiated tortoise (*Astrochelys radiata*) suffers especially from overexploitation for bush meat and illegal trade, resulting in a continuous decline of the population. The species is also the symbol of Madagascar's southern ecosystem and a 'must-see' for tourists. Thus, the radiated tortoise represents a clearly defined model for conflicts of interest between individual income from bush meat, illegal trade and community development in terms of tourism.

The spiny forest ecosystem of the Mahafaly Plateau also supplies livestock fodder. Simultaneously, some of these plant species are cultivated or left undisturbed around agricultural fields to serve as fodder during the dry season. 133 plant species were identified as being consumed by livestock, including 13 species of major importance for animal nutrition (Feldt et al., 2015). Free roaming cattle graze inside the National Park, which increases forest damage, especially in terms of young forest regrowth. During the recent years of political instability, the forest also served as protection against cattle raiders, adding a new component to the forest's ecosystem service (Götter, 2016).

A further important ESS is the provision of woody plants for construction or energy purposes. Certain tree species are used as construction materials for houses or coffins, as fuel wood, which is the main energy source for cooking, or for the production of charcoal. An example of an important multipurpose tree species is the tamarind (*Tamarindus indica* L.), which provides food and traditional medicinal products, and is

also used for traditional ceremonies and other cultural practices. Although tamarind is important for people's livelihoods and considered as sacred in the Mahafaly region, it is one of the most widely used species for charcoal production, leading to its overexploitation. Charcoal is an important income-generating activity, sold in local markets as well as being transported to Toliara for sale (Ranaivoson et al., 2015; Ranaivoson et al., 2017; see also Chapter 2.4.2).

Many traditions and customs are linked with natural forests, plants and animals, and are essential components of the Malagasy culture. The ecosystem services provided by plants influence social and cultural life as well as the health of the local population. Specific plant or animal species are used as remedies or protection in rituals and cults. In the local custom, they also strengthen the cohesion between the local population and supernatural beings. As already noted, they are used as traditional medicine too. When applied by traditional healers, these natural resources are believed to help many individual and common needs. Besides rituals, specific plant or animal parts are also necessary to produce fetishes and talismans (see Chapter 3.3.1). Respect of taboos is a fundamental element of the Tanalana belief system. Among the taboos that affect natural resources are taboo animals, sacred and cursed trees, and other plant species. Furthermore, there are taboos associated with places – for example grazing areas, wells, tombs, forests, and caves (Tahirindraza, 2015).

Tourism is a further example of an important ecosystem service. While resources for human consumption are the most relevant goods from the forest currently, the native biodiversity itself has the potential for adding value through the development of tourist activities. Apart from the beauty of the landscape and its unique vegetation, the value of the region as a tourist attraction depends on charismatic animal species ('flagship species'), as identified in Madagascar National Park's Action Plan for Tsimanampetsotse (MNP, 2013).

3.2.2 Sustainable forest management

Sustainable forest management (SFM) is a promising approach to promote long-term conservation of the forest ecosystem and its biodiversity, and thereby to generate and maintain ESS for present and future generations. For this, SuLaMa investigated the spatial and temporal development of forest structure, biomass and carbon stocks, and forest productivity. Moreover, charcoal production practices were examined together with the importance of this activity for the local economy. For each topic, a short overview of the results was produced. The results were taken as a basis for assessing the potential for SFM, restoration activities, REDD+ and sustainable charcoal production, in order to reduce pressure on forest resources.

Forest characteristics

The analyses of forest structure revealed the great importance of a small number of pachycaulous species, which are characterised by a disproportionately thick stem for their height, and few branches. Although these pachycaulous species only amounted to 50 trees ha^{-1} (total mean tree density: 630 trees ha^{-1}), they contributed more than 46% to the basal area of all trees in the natural forest (on average 4.5 m^2 ha^{-1} of a total basal area of 9.7 m^2 ha^{-1}). Most trees in the dry forests that were investigated were found in lower diameter classes and only few large trees were registered. This represents a typical diameter distribution for natural forests in the tropics. Even though trees with diameter at breast height (DBH) greater than, or equal to, 15 cm only represented 4.8% in terms of the number of trees, they accounted for 47.1% of the basal area within the forest. In addition, diameter classes of 25–30 cm and above were almost entirely represented by the few pachycaulous species. The mean height of all trees was 3.65 m (maximum height: 7.5 m), which is low compared to other tropical dry forest ecosystems.

Forest biomass and carbon stocks were calculated applying allometric biomass functions (specific to pachycaulous and non-pachycaulous species) to collected forest inventory data (Plugge et al., 2015). Overall, the allometric calculations resulted in an extremely low mean tree volume of 25.7 ± 5.7 m^3 ha^{-1}, a mean biomass of 14.4 ± 3.2 t ha^{-1} and a carbon stock of 7.9 ± 1.8 t C ha^{-1}. There was a significant difference among the plots within and outside the National Park, with the tree volume (and consequently also biomass and carbon stocks) within the protected area being more than 54% higher than outside.

To extrapolate the results to the landscape level, ground data were used in combination with remote sensing data to create spatially explicit models and maps of forest parameters and biomass estimations (Figure 7): these contributed to the SuLaMa land use modelling process SEALM (see Chapter 4.2).

We calculated annual tree growth rates based on data of subsequent forest inventories as an indicator of natural forest productivity. Across all species, the increase of DBH was 0.26 cm $year^{-1}$, but differed to a great extent between pachycaulous species (0.55 cm $year^{-1}$) and non-pachycaulous species (0.17 cm $year^{-1}$). The differentiation between the growth rates of these two species groups is important for the assessment of the potential for sustainable forest use, as pachycaulous species are not used for fuel or construction due to their low wood density. Therefore, the relatively low growth rate of 0.16 cm $year^{-1}$ for non-pachycaulous

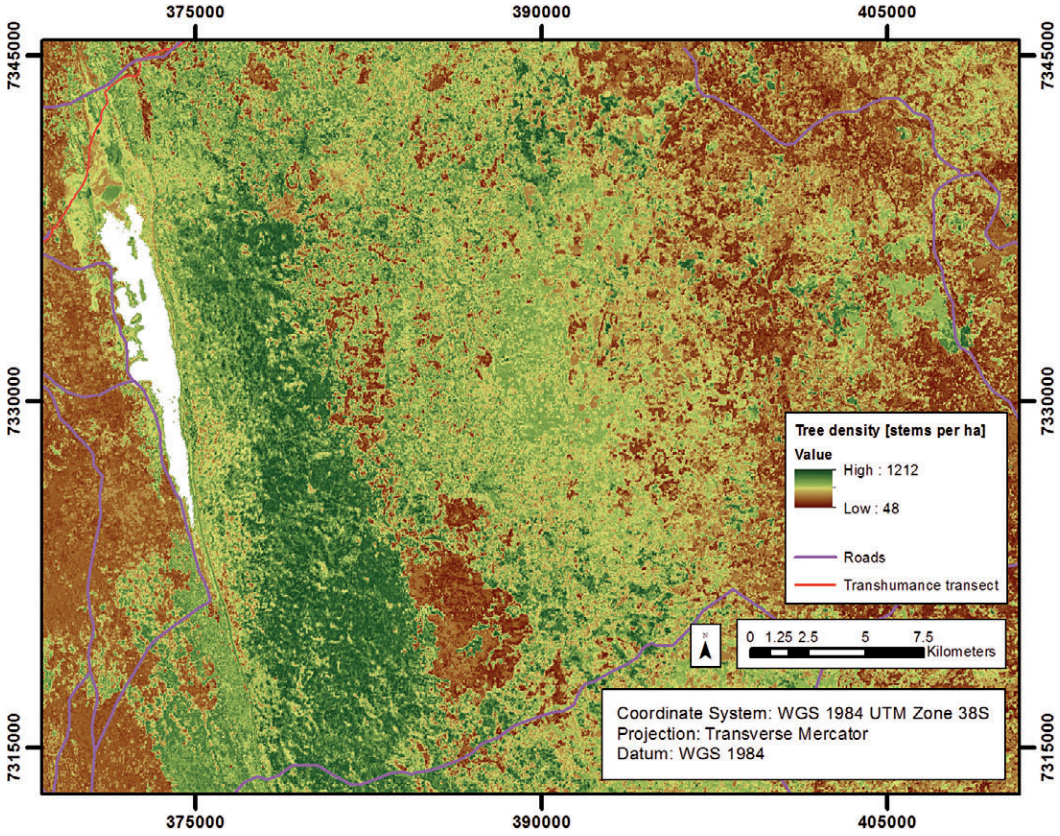

Figure 7: Map of tree density [stems ha^{-1}] created using Random Forest models.

species, which comprise around 90% of all tree species found in the natural forest but are almost non-existent in larger diameter classes (see above), seems to be the most appropriate value for planning sustainable yields.

To examine the influence of climate on diameter growth, hourly measurements of the circumference at breast height of three tree species of differing wood densities were carried out using electronic high-precision band dendrometers. The data revealed highly species-specific reactions to rainfall events. For example, the pachycaulous species *Delonix adansonioides* increased its stem diameter up to 3–4 mm within two months following high-intensity rainfall events, and then remained stable. In contrast, the stem diameter of *Cedrolopsis gravei* increased up to 6 mm within only few weeks after heavy rainfalls, but then decreased to its original size over the following months. Even erratic low-intensity rainfalls resulted in diameter increases of 0.5–1.5 mm followed by equally high decreases within one week. As the intra-annual DBH variability may exceed the actual DBH growth (see above), the time of measurement with respect to rainfall events can have a huge influence on the estimation of growth rates based on forest inventory. If calculations of potential yields are based on overestimated growth rates, this may lead to unsustainable forest management. This information is relevant for all those who carry out forest monitoring in the study region such as COBAs, NGOs, and state agencies.

Potential for sustainable forest management and REDD+

The fundamental principle of SFM is to use only as much of the forest resources as will be naturally and regularly replaced by the forest ecosystem. In that regard, the combination of low stocks and low growth rates of non-pachycaulous species results in very low potential for the sustainable harvest of woody resources. Additionally, the conversion of natural forest to agricultural land (Brinkmann et al., 2014) diminishes the forest resources available in the study area. This also indicates that the present strategies of community-based forest management, which up to now have been considered promising to secure long-term sustainable wood provision for the local population, are probably inadequate. The regional situation therefore renders the implementation of SFM plans difficult if they are to contribute simultaneously to the long-term conservation of the forest ecosystem and the provision of wood and NTFPs for the local population. To alleviate this situation, the potential for forest restoration and reforestation activities was tested on-site (see Chapter 5.3.2).

Madagascar is considered to be a prime target country for REDD+ ('Reducing Emissions from Deforestation and Forest Degradation'; UNFCCC, 2015) and different stakeholders consider it as a promising approach to contribute to the protection of the natural forests in the study region. One important

aim of SuLaMa was therefore the estimation of the economic potential for REDD+ of the dry forests in southwestern Madagascar.

REDD+ focuses on forest carbon stocks as a mean to calculate economic incentives for forests. According to this parameter, the above-ground carbon stock of 7.9 t C ha^{-1} in the Tsimanampetsotse National Park is very low compared to other Malagasy forest ecosystems: for example Asner et al. (2012) estimated above-ground carbon stocks of 99.5 t C ha^{-1} for humid forests in northern Madagascar, with many undisturbed forests holding more than 140 t C ha^{-1}. This indicates that carbon-based payments for ecosystem services (PES) such as REDD+ only have limited potential to provide incentives to protect the unique dry forest ecosystem of the Mahafaly region, as the emphasis of REDD+ activities is orientated towards forests ecosystems that store high amounts of carbon. Nevertheless, as REDD+ is a national approach it should encompass all forest types of Madagascar, and benefits from REDD+ do not necessarily need to be invested at the same location as they were earned. Therefore, whether carbon-low dry forests of the Mahafaly region will benefit from REDD+ compensations or not depends closely on the political will and interpretation of the safeguards, such as conservation of biodiversity, permanence and avoidance of leakage aligned to REDD+. For example, REDD+ compensations could be used for an alternative PES scheme that encourages biodiversity conservation instead of a sole focus on the prevention of carbon emissions. Such a PES scheme could then take advantage of the Measuring, Reporting and Verification (MRV) system and the strengthening of the forest policies and tenure rights through the REDD+ mechanism.

Investigation of charcoal production

Household interviews and field inventories for biomass estimation showed that charcoal production plays an important role in income generation, particularly during lean periods and in villages close to roads or the sea, with 95% of production destined for the city of Toliara (Ranaivoson et al., 2017). Producers gain very low prices for this charcoal: only 10–20% of the market price in Toliara. The production level tripled between 2000 and 2012 (Waeber et al., 2015) and the consequence is increasing pressure that threatens natural forest resources and the occurrence of tree species which are specifically targeted for charcoal production. Due to their high caloric value, tamarind trees are one of the main species used for charcoal production (SuLaMa, 2011). From 2004/2005 to 2012, wood biomass losses of tamarind trees ranged from 12 to 90%, and this was mainly caused by charcoal production and expansion of agriculture. The traditionally sacred status of the tree is apparently insufficient to secure its conservation in the Mahafaly region (Ranaivoson et al., 2015).

Potential for sustainable charcoal production

The WWF project 'COGESFOR' and the NGO 'Association Partage' had already investigated charcoal production in the eastern region of the Mahafaly Plateau. In some villages, local people were trained in the improvement of carbonization techniques in order to improve charcoal yield. Points of sale for 'improved charcoal' were made, and a checkpoint of forest products (notably charcoal) was installed in Betioky: but these systems are not yet functional. To successfully conserve the tamarind population in the study region, it is recommended to establish tamarind plantations in villages as well as raising the perceived value of tamarinds by enhancing its contribution to people's diet through the promotion of more elaborate processing and marketing of tamarind fruits (Ranaivoson et al., 2015). For charcoal production, the use of other, more abundant, tree species with rapid growth, such as *Acacia bellula* in the coastal zone and *Albizia polyphylla* on the plateau, is recommended in order to reduce the pressure on tamarind populations. Furthermore, reforestation measures (which are already based on alternative and faster growing tree species), charcoal production quotas and implementation of more efficient carbonization techniques (based on the technique adopted by CIRAD: Caramcodec) are recommended. The work already started by the project COGESFOR and Association Partage should be further supported and enhanced.

3.2.3 Biodiversity conservation

Assessments of biodiversity components were designed to support the priorities defined by the regional action of Madagascar National Parks (MNP, 2013). The overarching priority is to maintain the integrity of the park and its biotic components. To provide necessary information to park authorities, SuLaMa conducted research on *(i)* ecological needs and population development of selected flagship species for conservation and tourism, *(ii)* land use effects on animal and plant communities, *(iii)* suitable monitoring systems, and *(iv)* ways of integrating local communities into conservation activities within the context of landscape conservation and development.

Flagship species of the southwest

Regional flagship species for conservation and tourism are the radiated and the spider tortoises (*As-*

trochelys radiata, *Pyxis arachnoides*; Hammer, 2013), a mongoose (*Galidictis grandidieri*, Marquard et al., 2011) restricted to Tsimanampetsotse National Park, blind cave fish (Rasoloariniaina et al., 2016), flamingos – and of course the lemurs (e.g. Bohr et al., 2011; Kobbe et al., 2011; Rakotondranary et al, 2010) that represent a primatological 'must' in Madagascar for tourism. As part of the objectives of biodiversity monitoring and the evaluation of habitat and environmental characteristics required by the endemic fauna, baseline data was compiled, and long-term monitoring of flagship species and their health in the spiny forest ecosystem was initiated.

The radiated tortoise (*Astrochelys radiata*; Figure 8) is one of most popular tourist attractions in the region. However, it also serves as important cash income for the local human population when sold on the regional food market – and through the international pet trade. A standardized long-term inventory within Tsimanampetsotse National Park has been established to assess the population dynamics of the species. The densities of radiated tortoises differ widely, but seem to be influenced more by poaching than responses of the species to alterations in habitat. Tortoises tolerate a large variety of situations, including habitat degradation without measurable changes in home range size and body condition. The impact of habitat degradation on tortoises is difficult to evaluate because tortoises encountered in such habitats are likely to be taken by local people for consumption or trade. Thus, population density estimates of tortoises cannot be interpreted in an ecologically meaningful way as long as the extent of tortoise collection is not known. With respect to the relevance of poaching of this species, socio-economic benefits of the capture and trade of tortoises for the local people and biodiversity marketing have been explored in detail. It is not yet clear what proportion of the animals is sold for consumption and how many end up in the pet market. But given a price of € 3–8 per animal, the income is substantial.

In collaboration with SuLaMa, the Malagasy NGO Voakayj assessed the utilization of tortoises as bushmeat in Toliara, using covert monitoring of public rubbish dumps in Toliara. 1,913 carapaces of radiated tortoises were discarded following evisceration between June 2010 and January 2014 – and this was just at the monitoring sites within the city of Toliara. There was notable spatial and temporal variation, with some evidence of peaks in carapace dumping during May–June and October–December. A single rubbish dump, near the artisanal fishery landing beaches, accounted for 93% of the carapaces observed. Within a single month (February 2012) eight tonnes of dried tortoise meat were confiscated by the police: this corresponds to about 25,000 tortoises (Castellano et al., 2013; Ganzhorn et al., 2015; Manjoazy et al., submitted; Ronto et al., submitted).

Figure 8: Flagship species of the southwest: The radiated tortoise (*Astrochelys radiata*) (photo: Jutta Hammer).

Programmes for long-term monitoring to be implemented by the national park management have been established for other flagship species, such as spider tortoises, mongooses and mouse lemurs (Rakotondriamanga et al., 2009; Raktondranary et al., 2010; Marzec, 2013; Steffens, 2016). Furthermore, water characteristics have been measured in relation to blind cave fish and flamingos, as water properties and quality seem to play an important role in the presence or absence of these species (Rasoloariniaina et al., 2015, 2016; Rasoloariniaina, 2016).

With respect to ecosystem-health, deviations from the natural fluctuations within the overall equilibrium could be measured by parasite loads of several endemic species such as lemurs and tortoises. Parasite loads increased with increasing degradation of the original habitat. Some of the parasites are also potential pathogens that can affect people and their livestock, emphasizing the importance of intact ecosystems under the 'one health' concept (Ehlers et al., 2016).

Land use effects on biodiversity

The species composition of bird communities changed markedly between habitat types related to land use. The bird surveys revealed substantial hunting pressure on birds along the route of transhumance (Randriamiharisoa et al., 2015). Since birds are important seed dispersers, and biodiversity is of the greatest interest to international tourists in the region, hunting birds compromises the sustainability and future development of tourism.

The overall species richness of reptiles was negatively affected by human-induced land cover changes (Figure 9); namely a reduction in forest and vegetation cover. There is a threshold of woody vegetation cover at about 10–30% of remaining vegetation in the landscape after which reptile species richness decreases markedly. Thus the retention of woody

vegetation to a particular degree is likely to stabilize reptile species richness in the landscape. The same applies to mouse lemurs (Nopper et al., 2017a; Nopper, 2017; Steffens, 2016).

Anthropogenic woody structures such as hedges along agricultural fields work equally well, and therefore can play an important role in maintaining high reptile species richness. Consequently, they could serve as links among remnant natural forests, and may enhance connectivity in the landscape used by people. Yet hedges are poor in terms of endemic plant species. Thus, to entirely protect species diversity, the protection of contiguous forest habitat and forest remnants within the agricultural matrix remains essential, as there are also species restricted to forests. It is notable that the study area harbours a highly diverse and abundant fossorial reptile fauna on cultivated sites.

Invertebrate communities showed various responses to different types of land use systems. Crop fields had reduced diversity of the invertebrate species analysed at the landscape level, while local richness remained unaffected. Plant species richness decreased with grazing pressure and agricultural activities. Since grazing pressure increases during the dry season, grazing mostly affects woody species, since herbs are no longer available. In contrast to the bush encroachment due to grazing in mainland Africa, grazed areas in southwestern Madagascar contain fewer woody plant species than areas not used by livestock. Plant phenology monitoring in terms of assessing the onset of specific phenophases (young leaves, flowering and fruiting) between years is an established tool for monitoring the effects of climate change; for example in special 'phenological gardens' in Europe and around the world. In total, 1,337 individual woody plants from 111 species were monitored biweekly in different parts of the region. Phenological data are now available from 2007 to 2016 and will allow the tracking of environmental change, with important consequences for ecosystem services, such as fruit or honey production (Ratovonamana et al., 2011, 2013).

Application of the 'Natura 2000' concept for maintaining corridors between protected areas

Protected areas are essential for long-term conservation of biodiversity. Yet protected areas alone will not suffice. Additionally, there is a need to increase the biodiversity value in the landscape used by people. Therefore, it is important to establish and maintain a network of suitable structures across the anthropogenic matrix. This can be provided by hedges, forest fragments and community managed forests (Nopper et al., 2017a, 2017b; Nopper, 2017). Structural heterogeneity in the human used landscape can maintain high species richness. Species decline show predictable patterns from pristine to degraded forests and on to agricultural fields. Leftover structures in pasture and agricultural land, such as hedges or remnant forest patches maintain high biodiversity that decreases significantly only in the most degraded areas. While anthropogenic land use systems cannot harbour all of the endemic species of the region, they could be designed in such a way as to act as corridors between native forests and buffer zones around protected areas.

At present, agroforestry systems with woody perennial vegetation integrated into cultivated areas and grazing sites are the most promising way of reconciling biodiversity conservation, agriculture, fallback food during times of crop failure, and other ESS derived mainly from natural forest ecosystems. For this, a concept that mimics 'Natura 2000' in Europe is envisaged. This consists of blocks of natural forests, linked by suitable corridors crossing a landscape where anthropological land use dominates. This component of a larger implementation scheme is planned to be integrated into the WWF's landscape approach and will be extended in collaboration with the 'Beza Mahafaly' project.

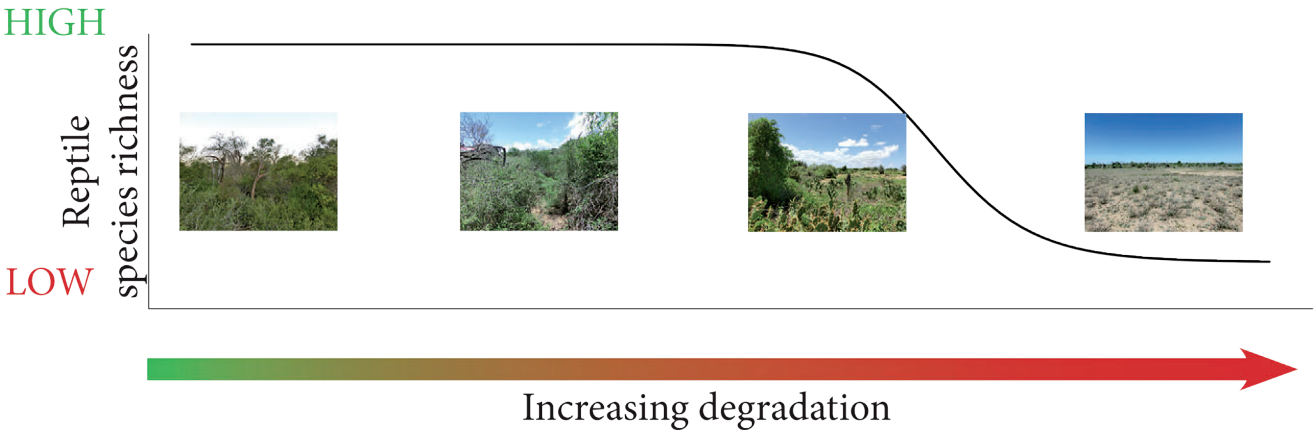

Figure 9: Decreasing reptile species diversity with increasing degradation from intact forest to open landscapes.

Payment for ecosystem services (PES)

The potential of payments for ecosystem services (PES) schemes for effective nature conservation is a controversial issue, especially in the context of forest conservation (TEEB, 2010). On the Mahafaly Plateau, as in many developing countries, the costs of forest preservation are borne by the local land users, who are often poor, but the benefits in terms of biodiversity conservation and carbon sequestration accrue – at least to some extent – to the global community. Thus, PES schemes often function in a way where funds financed by tax payers or donors in developed countries are used to compensate local land users for preserving the forest (Engel et al., 2008, TEEB, 2010). SuLaMa explored three selected PES design issues in the context of poverty both on the demand and supply side of an ecosystem service.

The first issue deals with the question of whether to include distributive goals in the design of PES. To identify the preferences for distributive goals on the side of potential ES-payers in the form of citizens in developed and developing countries paying through donations or taxes, the project team carried out a survey (a 'choice experiment') among citizens of the German city of Cottbus and the Malagasy city of Antananarivo (Randrianarison and Wätzold, 2016). They were asked about their willingness-to-pay to support the preservation of the endangered endemic dry forest in southwestern Madagascar, and whether they cared about the distribution of the money among the local population. The finding was that a distribution where poorer ES-providers received more money than the other providers was preferred over an equal distribution of payments. Furthermore, the respondents' willingness-to-pay for forest conservation was negatively affected if information on the distribution of payments was not available. This calls for integrating distributive goals in the design of PES – at least to some extent.

The second issue questioned the relevance of the time of receipt of payments for ES providers. It is common practice to give payments to the ES-providers at a specific time of the year. In many local contexts, including the Mahafaly region, the choice of the timing of payments can have a significant impact, especially if the potential providers are poor, depend on subsistence agriculture, and food supply fluctuates seasonally. To test this, a choice experiment survey was carried out among local households: however instead of specifying a PES-scheme, a hypothetical case was cited where migrants send remittances to these households (Randrianarison et al, submitted). It was found that the time when the money is received matters significantly to the respondents, and on average they are happy receiving less money overall as long as they receive it in months when they need it most. Hence, it is suggested that in areas like the Mahafaly Plateau, giving payments to ES-providers at a time where food is scarce can lead to greater benefits than giving payments at a time where food is ample, in particular if savings possibilities are limited due to a lack of financial infrastructure. This may enhance the attractiveness of PES schemes to local communities and improve their livelihoods.

Third, the economic benefit of forest degrading activities in the Mahafaly region, especially clearing land for agriculture through slash-and-burn, and charcoal production, were explored. If forest conservation is to be socially feasible, these benefits must be outweighed by the ESS provision of standing forests. The team explored whether benefits for forest degrading activities could be outweighed by payments for carbon credits in a potential REDD+ project. Moreover, a review of actual costs and benefits of forest protection for Madagascar was provided, which led to the insight that local people making land use decisions need to profit more from the high benefits provided by Madagascar's forests to the global community (e.g. carbon sequestration and biodiversity protection; Neudert et al., 2016b).

Tourism and eco-tourism in the Tsimanampetsotse National Park

Tourism has been identified as a form of land use with enormous potential to improve local income. Yet, apart from the beauty of the landscape and its unique vegetation, the value of the region as tourist attraction depends on charismatic animal species ('flagship species'), as identified in Madagascar National Park's Action Plan for Tsimanampetsotse (MNP, 2013). In 2014, the WWF initiated a study aimed at analyzing the potential of the region for eco-tourism activities. In order to support this study, the SuLaMa project collected information on existing and/or potential natural and cultural tourist attractions through conducting semi-structured interviews with tourists coming to the coastal area adjacent to the Tsimanampetsoptse National Park – and to the park itself. Tourists mentioned a number of problems that hinder tourism in and around the park. Amongst others, there was apparently a lack of informative material. Neither the National Park management nor hotels provide sufficient information on the natural and cultural attractions. As a first step to improve the information on natural aspects, SuLaMa developed flyers, brochures and guides (see Annex 10.2) on important endemic animals and plants of the National Park area. They were distributed in the tourism centre in Toliara, and the MNP office at the Tsimanampetsoptse National Park entrance.

Further important issues for tourists were the insufficient infrastructure and the poor education of the local guides in terms of language skills and specific knowledge of species. By tackling these problems, the region could be more attractive to tourists. Local inhabitants of the region have recognized the present and future economic income possibilities that these natural attractions might provide to them. The management of the Tsimanampetsoptse National Park has already offered some jobs to local people within the tourist sector (e.g. as local guides). To reinforce local capacity, SuLaMa initiated a joint monitoring programme for the project's para-ecologists, who are familiar with the most important plant and animal species and corresponding monitoring techniques, and are also, as inhabitants of the area, the most capable mediators for knowledge transfer to other local people such as local MNP guides. Long-term monitoring for mongooses and reptiles is now carried out by local para-ecologists in collaboration with Madagascar National Parks.

Regional database and community-based monitoring

The results of long-term population monitoring studies in the Tsimanampetsotse National Park and degraded areas used by people are being integrated into the regional data base hosted by the WWF. It includes a special section on biodiversity components (Figure 10). The database was established and designed according to the needs and interests of local and re-

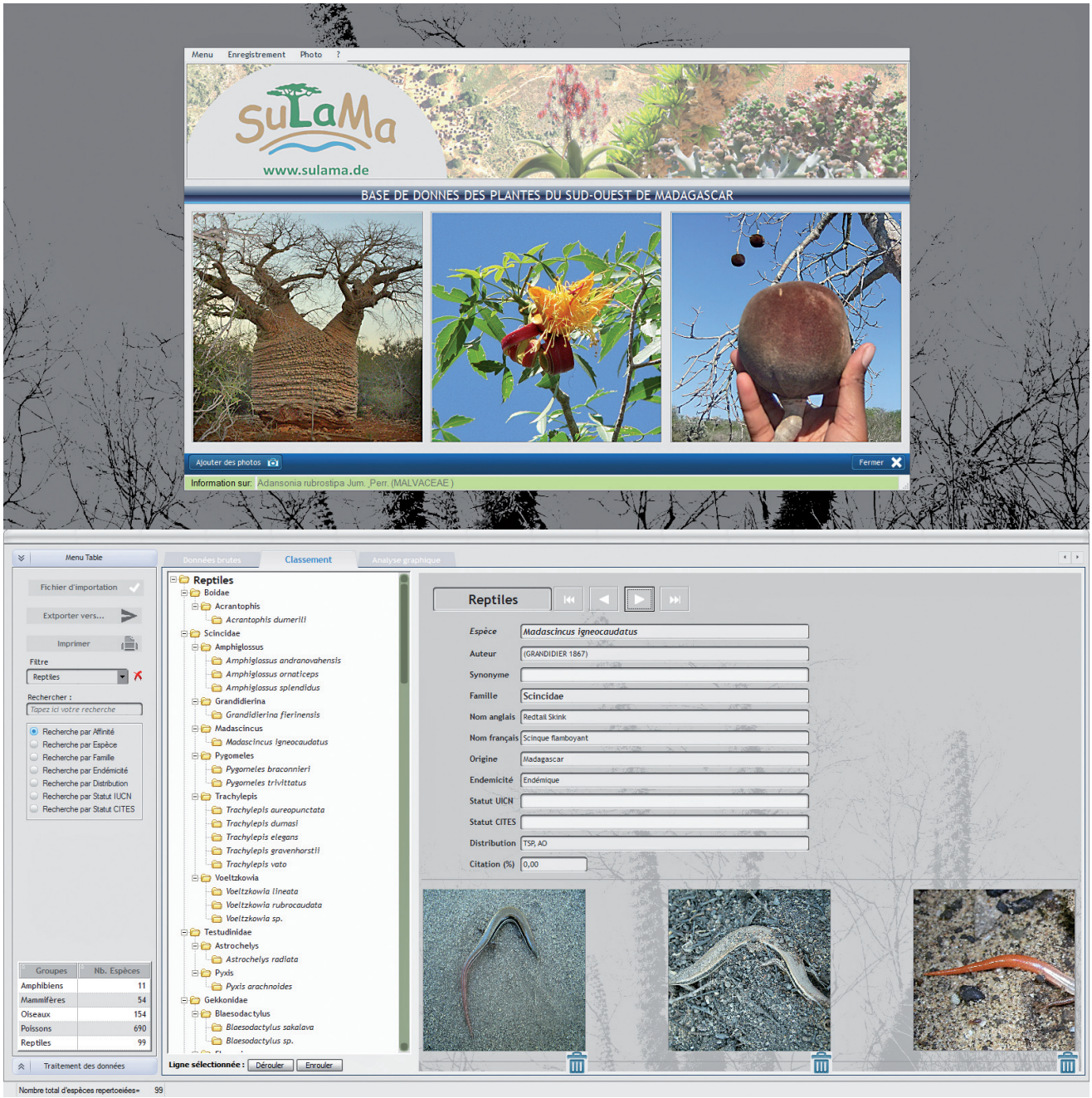

Figure 10: SuLaMa's data base on regional plant and animal species.

gional stakeholders and partners. For MNP, for example, the data compiled regarding flagship species and population dynamics represents a valuable baseline for further monitoring. In this context a programme for long-term data collection and training on biodiversity monitoring techniques involving MNP staff and local communities was developed and implemented (Nopper et al., 2017b; in Liniger et al., 2017). The community-based monitoring and the database are described in more detail in Chapter 5.3.4 and 5.4.3.

3.3 Socio-cultural frame conditions

3.3.1 Traditions, customs, norms and values

In the Mahafaly region, decisions about natural resource use for people's livelihoods are driven by local traditions and customs, norms, and values, which are also referred to as 'institutions'. Spirituality is also of great significance to the communities' culture. Local people believe in a strong connection of place and spirit, so that taboos and sacred places play an important role in the use of, and access to, land and natural resources. Furthermore, resource use and many other aspects of local life are framed by local knowledge systems and a specific traditional social and ethnic structure that determines conflict resolution mechanisms, hierarchies, allegiances, and pacts. Numerous conservation and development interventions have been implemented in the region, yet with little success. This is due to the fact that knowledge about these socio-cultural frame conditions is deficient, and it points to a lack of common understanding between science-based experts, external decision-makers, and local populations. This knowledge gathered in the project's studies (with a focus on the Tanalana group) was crucial for the understanding of the socio-ecological system and a precondition for the involvement of local stakeholder groups as well as a cooperation that respects social and cultural diversity. Furthermore, we analysed examples of how the local society and its institutions have changed over time, as besides the traditional aspects of local life, the society is currently in a process of socio-economic transition.

Social and ethnic structure and local governance

Among the Tanalana, the family is the smallest organizational unit consisting of the father, mother, and several children who are integrated into a larger group, the lineage. These units compose the clan. Families, lineages and clans have several elders. The Tanalana are a federation of clans reigned by the traditional institution called *hazomanga* and identified by the earmark of their cattle called *vilo*. The term *hazomanga* is used as term for the holy pale – a wooden rod that is erected at sacred sites, where rituals are carried out – for the clan or lineage origins, for a particular knife that is used to accomplish sacrifices, and as the name of the lineage or clan chief. The Tanalana society consists of eleven different clans, each one with its own *hazomanga* and respective zebu earmark.

According to historical narratives, three great Tanalana patriarchs who originate from the Androy and Anosy region founded the society along the coast of the Mahafaly region. They received land in exchange for services rendered to the king and indigenous people at that time, such as healing the disabled daughter of the king, saving a livestock herd, and killing a monster in the Mahafaly region. In the course of years, the Tanalana welcomed newcomers to their society, but still perceive themselves as the first settlers and masters of the land.

Elders are responsible for taking decisions in Tanalana society. Conflicts are negotiated at various levels: that is within the family circle, at the lineage or clan level or in a wider frame at *fokontany*, commune, district, or court level. In general, local people prefer to resolve problems locally at family, lineage, clan, *fokontany*, or commune level and avoid the regional court. Which level is chosen also depends on the availability of charismatic specialists in conflict resolution. Special skills are necessary to resolve conflicts and problems, including knowledge of customs, myths, the history of lineages and clans, and the relationships of the parties in conflict.

Spirituality

Tanalana believe in the existence of invisible authorities who strongly influence their socio-economic and cultural life. Tanalana worship different kinds of supernatural powers: God, nature spirits, recently deceased people, and their ancestors. Communication with these powers happens through dreams, trance, and prayer. Both good and bad events in society are traced back to the will of these beings. Local communities seek to build and keep a long-lasting relationship with these divinities by honouring them through rituals. Rituals are performed for various reasons such as requests (e.g. for offspring or health), praising, and purification in case of transgression of social rules or sorcery – among others.

To avoid divine punishment, people seek to respect their ancestors' rules such as taboos, ancestral patrimonies and respect of older relatives and parents. Taboos can be defined as a religious system of interdictions which dictate that an object or a person is

considered sacred or unclean. In the local dialect, the word *faly* means both taboo and sacred. Taboos affect almost every socio-economic and cultural sphere in the society. Some of the information sources claimed that these taboos are of divine origin, while others attributed their origin to the nature spirits. Others again stated that taboos come from the ancestors or are recommended by traditional healers. Though some taboos are only valid for a single individual, lineage, clan or ethnic group, others are universal. Tanalana are convinced that mankind cannot live without supernatural assistance. To secure this assistance fetishes are planted in or around the house or in the livestock corral, and talismans are worn around people's necks, chests or wrists. These fetishes and talismans have several functions: protection, healing, support of wishes, and the prevention of bad destiny. Both fetishes and talismans are produced by the diviner-healer after practicing the art of divination with plant seeds.

Knowledge systems

Knowledge systems identified in interviews with Tanalana can be grouped into the following categories: ecological knowledge, knowledge that is related to natural resource use, knowledge of names, and a knowledge-belief interconnection. While ecological knowledge comprises knowledge of ecological processes, which is applied especially with respect to agriculture, people also have knowledge about natural resource use. This implies knowledge about which resources are used to achieve which purpose and how. Besides, Tanalana know an enormous range of vernacular names of plants and trees. Furthermore, in interviews people mentioned the names and their origins of various places/locations illustrating their mental images of the landscape. Tanalana knowledge relates to their belief system. Tanalana know, for example, where nature spirits reside and how they live. Practices and knowledge is based on the ancestors' experiences and the knowledge they left behind, such as the interpretation of environmental signs and signals. Knowledge also relates to local taboos. Analysis shows that Tanalana's knowledge is very rich and comprehensive, especially in regard to the environment (Fritz-Vietta, accepted).

Transition of local institutions

Today, the local institutional setting in the Mahafaly region presents a potpourri of traditional rules and norms co-existing with adapted versions or recently emerged institutions which often overlap or even contradict. This has several impacts on local livelihoods: the ongoing social transition has led to the emergence of 'new customs' that are however not well adapted to the overall economic situation. For example, the people's annual spending for participating in exorbitant funeral feasts are constantly increasing, presenting a heavy economic burden for many. Thereby, the actual social exchange far exceeds the traditional customs and social duties fixed by traditional norms which are furthermore found to differ according to the people's economic situation.

It is evident that the funereal dynamics are driven and amplified by competition for fame through big presents, and the fear of gossip and social shame in this public setting of 'see and be seen' on the other hand. Furthermore, the social transition benefits the adaptation capacity of individuals, but challenges cooperation and collective action at village level. The individual adaptation capacity is witnessed by the cattle raiding problem on the plateau fostering a transhumance movement of herds from the plateau to the coastal plain (Goetter, 2016). It is found that mental models of kinship between Tanalana and Mahafaly people, as well as the social norms of hospitality, guest rights and duties are crucial for the transhumance movement. However these are interpreted differently by Tanalana and Mahafaly village communities, as well as by individuals. As a result, some people are not able to participate in the adaptive transhumance movement. The study also reveals that the cattle raiding problem has led to an environment of mistrust, and through this a general transition in these mental models and social norms. Guest rights (for example regarding free access to natural resources) are today more conditional on kinship relations, and interpretations of kinship have become more restrictive.

Challenges regarding collective action and cooperative adaptation at community level are shown by SuLaMa's study on the spontaneous individual privatization of the *samata* fodder tree (*Euphorbia stenoclada*) and the local attempts to curtail this process (Goetter and Neudert, 2016). In contrast to the former open access situation, today three different types of private property rights regarding *samata* have become widely socially accepted. The new community rules (*dina*) and rules at commune-level aimed at regulating this privatization by fixing maximum sizes for private enclosures per person have not been, however, successfully implemented and enforced. This is mainly due to strong bargaining power on the side of the privatizers, paired with a lack of power and collective action by local communities, and second, a specific local ideology regarding the legitimation of resource appropriation which is strongly shaped by a cultural background of few traditional restrictions to individual natural resource use and privatization. Furthermore, *samata* has become a local cash crop, and selling harvesting rights has become a new livelihood strategy that people do not want to legally curtail.

3.3.2 Socio-cultural issues and project design

The results from studies on local social and ethnic structures, institutions, modes of governance, knowledge and spirituality were subsequently integrated into the conceptualisation of participatory surveys, workshops for feedback and implementation strategies.

These formed the basis for the development of locally adapted and accepted techniques. For example, the project was able to identify socio-cultural aspects that foster innovation and possible transitions towards sustainable land use such as specific taboos and spiritual meanings of places and natural resources. To capture and then diffuse this knowledge among external actors who work in the region, leaflets on taboos and clan structures (see Annex 10.2) were developed and distributed at the final conference in Toliara in September 2015. Moreover, the project developed a checklist addressing external actors in the region. The checklist provides necessary advice for the design of implementation products and activities according to the demands of their target groups and the contexts in which they are relevant and usable.

The thorough comprehension of modes of local governance twinned with the insights on local communities' coping capacities to challenges such as resource scarcity, political instability and market transition are important with regard to the design of future projects in the region. Together with SuLaMa's studies on households (see Chapter 3.4.1) our socio-cultural studies also provide a sound view of the relationship between poverty and people's strategies regarding income and expenditure against the background of societal constraints.

3.4 Livelihoods and food security

3.4.1 Socio-economic aspects of rural households

In the Mahafaly region, households are generally very poor and have to manage their livelihoods in a very variable and uncertain environment. Securing survival, stabilising income and ensuring food security are very important concerns of local households, and they mainly draw on agriculture, livestock keeping, other natural resources, as well as other non-farm income sources to earn their livelihoods. In the following sections different aspects of livelihoods are explored, as well as reflections on potential pathways to improve the situation of local households.

Household characteristics and decisions

Household analyses provide important background knowledge for developing adequate solutions and evaluating the impact of these proposed measures. In addition to participatory baseline surveys, the project investigated the socio-economic situation of 665 rural households in the Mahafaly region to learn about current livelihood strategies (Neudert et al., 2015). On the Mahafaly Plateau the average age of the population is only 19 years, and the educational level is low. 73% of people above 18 years are illiterate, and more than 80% had not received formal education. Education proved to be an important determinant of whether households take up non-farming activities or not. Farm-households conduct a wide range of income-generating activities, and combine subsistence and cash income for their livelihoods. In addition to arable farming and livestock keeping, this includes the use of natural resources (e.g. collection of naturally growing food plants; ocean products including fish) or remittances from non-farming activities (e.g. trade, handicrafts, salaried work). Due to the arid climate of the study region and natural recurring disasters households frequently have to cope with crop failures. Thus, many households combine multiple income sources in order to secure a more stable income. Six different livelihood strategies can be distinguished (Neudert et al., 2016a):

(1) **Arable farmers** obtain the overwhelming share (more than 70%) of their household revenues from crops, while other sources of revenue play only a minor role.

(2) **Poultry keepers / arable farmers** earn nearly equal shares of their revenue from crops and poultry, and also rely heavily on the collection of food plants. These households are poor and in most cases they do not have livestock. The collection of wild food is a typical strategy for times when crop yields are not sufficient. This indicates that these households struggle to fulfil their basic needs not only during crop failures, but also in years with relatively good harvests.

(3) **Goat keepers / arable farmers** rely strongly on goat keeping, but obtain approximately one third of their revenues from arable farming.

(4) **Zebu cattle keepers / arable farmers** also rely on cropping but predominantly earn revenues from their cattle. These households belong to the wealthier group in the region. Livestock can be sold to satisfy daily needs and used for cultural reasons, e.g. for funerals and marriages. Moreover, livestock perform the important function of buffering income gaps after crop failures.

(5) **Non-agricultural and agricultural workers/ arable farmers** get more than half of their revenues from non-agricultural activities and agricultural wage work, but also obtain one fifth of their revenue from arable farming. In most households within this group, at least one member is well educated.
(6) **Ocean product collectors/fishers** base their livelihoods on the ocean and draw on the collection of ocean products and fishing for the overwhelming share of their revenues. They obtain only approx. 16% of their revenues from farming. They are mainly members of the Vezo Sakalava ethnic group.

Monitoring of market prices

In addition to collecting household-level data, the project team carried out regular monitoring, every two weeks, of market prices for crops, other food plants and livestock at five markets during 2013 and 2014. It was found that prices for crops, especially, vary widely, being lowest at harvest time and highest during lean times. Furthermore, prices for maize and beans may double directly after rainfall events in November–February as people need to buy seed material from the market. As local people sell crops mainly directly after harvest to obtain cash, they receive comparably low revenues. Thus, households could increase their revenues by storing crops directly after harvest and selling them during lean times. This could be enabled by micro-credit schemes. Prices for goats show the opposite pattern of price seasonality (i.e. prices are highest at harvest time and lowest during lean times), but the price differences are generally lower than for crops. For zebu cattle, almost no price seasonality was observed. Thus, price developments mirror the capital storage function of live animals in the household portfolio.

Seasonality and food security

Chronic food insecurity, as well as seasonality in food production and income generation, represents the major challenge for the rural population. Food production has two peaks (annual crops from March to May, and cassava in July and August). However, self-produced food production is insufficient; e.g. during 2014 households produced, on average, only 21% of their minimum dietary energy requirements. Project surveys further confirmed that the majority of farmers only have enough food from April to October, and a general food shortage occurs from mid-October to the end of March. Following the harvest periods closely, food expenditures decreased from March to May and from August to September in 2014. One to two months after the cassava harvest, food expenditure increased steadily and reached a maximum in November–March (Figure 11a). Most respondents stated that they were cash-constrained throughout roughly half the year, mirroring precisely the seasonal patterns of food self-sufficiency (Figure 11b). However, 30% of respondents stated that they were cash-constrained throughout the whole year. The longitudinal survey revealed that households on average earned ~€23 from crop sales in 2014, but spent more than ten times as much for food purchases (~€250 on average). Given that most households lack cash savings, farm households had to use a range of non-farm income sources to cope with this situation. However, the main non-farm income source was the sale of livestock indicating the lack of alternative income sources.

Income generating activities for farmers during the lean period

With regard to the feasibility of alternative income generating activities, the German Malagasy Environment Programme (PGM-E / GIZ) mandated a study by SuLaMa during the lean period. With the idea of combining sustainable management of natural resources and sustainable development of the local human population, two participatory workshop series were conducted in selected target villages in the Mahafaly Plateau to identify and evaluate promising income activities to generate additional revenue during the lean period. The purpose of this study was to reduce food insecurity and to improve livelihoods by creating alternative sources of income (ASI) particularly during the 'lean period' which ranges from 4 to 7 months a year, depending on rainfall patterns.

Ten ASIs were identified and were proposed for implementation in the Mahafaly villages. Each ASI was assessed according to its feasibility in relation to different contexts, namely profitability, feasibility and environmental impact. The analysis from these factors allowed the team to classify and prioritize the identified ASIs. Of these ten ASIs, poultry farming was prioritized, particularly by women, followed by planting and storage of sorghum, storage of cassava, storage of groundnuts, construction of storage facilities, domestication of wild yams, the introduction of agricultural inputs/tools shops, goat breeding, as well as handicraft, carpeting and basket weaving.

However, these ASIs are not well-suited to small and vulnerable farmers. Only poultry breeding, cultivation and storage of sorghum, the domestication of wild yam, goat farming and basket weaving are profitable activities for poor and asset-poor farmers, according to our analysis. On the contrary, storage of cassava and groundnuts, construction of warehouses and setting up input/tool shops only benefit large

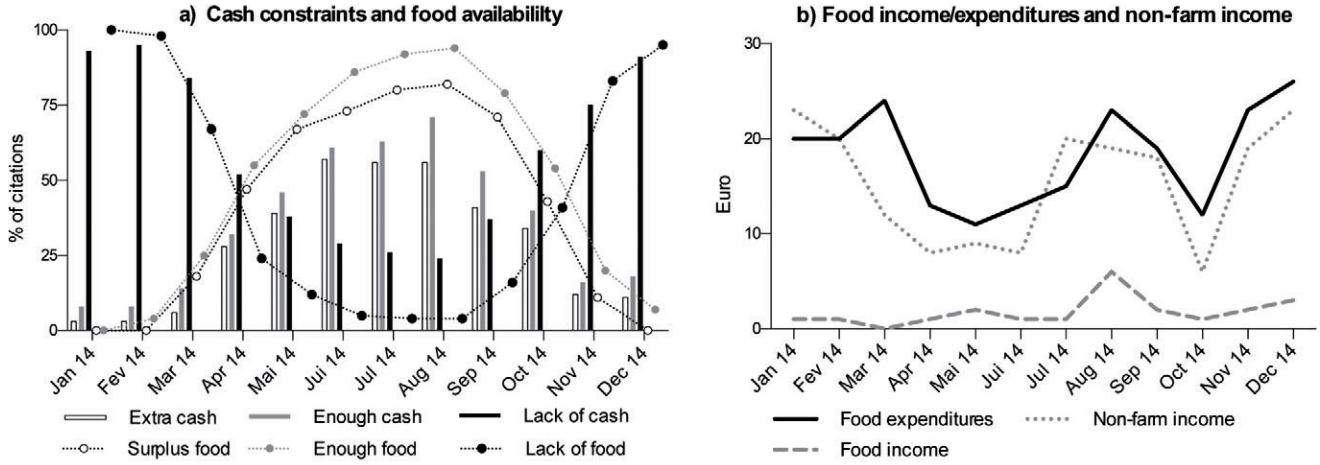

Figure 11: (a) Cash constraints and food availability based on market participation survey; (b) Average food income, expenditure and non-farm income in 2014 based on a longitudinal survey, sampling weights applied, N=140 (Hänke, 2016).

producers or better-off households, as they require initial capital. Small farmers could only benefit from such activities if they work in family or community fields, while establishing communal regulations and sharing the harvest.

Potential of prickly pear cactus oil

With respect to the survey results regarding the necessity of suitable non-agricultural income sources, the potential of *Opuntia* seed oil production was assessed as an income alternative. Cacti of the *Opuntia* genus are abundant in the region, particularly as hedges on private farmland. From the seeds of its fruit, high-priced seed oil can be extracted. To investigate its economic potential, the project carried out an inventory of *Opuntia* in farmers' hedges, and estimated the amount of seed oil that could be produced per household, based on field sampling and laboratory analysis. To assess the socio-economic impact of a potential large-scale project of regional *Opuntia* seed oil production, the team 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 very important socio-economically, and contribute >50% to total food intake during periods of food shortage (hunger season). 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 spinier, and their fruits are virtually inedible due to the much higher seed content. The combination of low nutritional value and high seed content suggests promising seed oil production potential for these latter varieties. We found that each household could produce ~14 kg of the respective *Opuntia* spp. seed oils. To avoid remaining competition risks between human nutrition and the commercialisation of local *Opuntia* seeds, sourcing strategies should exclusively target the fruit of the high seed varieties.

Relevance of data for project goals and stakeholders

The analysis of the different livelihood strategies led to a more detailed understanding of the wealth variation and livelihood decisions. There is a complex set of challenges – many of which relate to a fundamental lack of water, drought and seasonality – that hinders sustainable agricultural intensification and perpetuates the extreme poverty in the region. While interventions are certainly needed to counter and compensate for the lack of food and the cash constraints identified in more than six months of the year, investments in the agricultural sector might not, however, be the only solution. Agricultural activities are only seasonally feasible, highly risky, and the biophysical settings limit any agricultural upgrading in the area, as water is insufficient and soil fertility is low (Hanisch, 2015). Also, climate change projections for southern Madagascar show an increase of extreme weather events such as cyclones and prolonged droughts (Tadross et al., 2008; Usman and Reason, 2004), suggesting that rainfed farming will become even more difficult in the future. Due to this fact, a large number of donors and NGOs are present in the region, mainly running agricultural *food-for-work* programmes. So far, no sustainable agricultural intensification nor yield improvements have proved to be successful (Hanisch, 2015; UNICEF, 2011).

In order to tackle these challenges, non-agricultural income sources will be crucial, particularly those that can be generated outside of the two food production peaks. Hence, concerning interventions with the goal of reducing livelihood vulnerability, an income diversification strategy should be promoted, which will improve farmers' resilience in coping with both seasonality and crop failure. Therefore, more emphasis on alternative

income sources – other than livestock and cropping – is necessary. Particular focus should be placed on developing income alternatives that target the poorest among the local households, who have low education and nearly no capital for investments.

The household baseline data and market monitoring data were integrated into the regional database for decision support, and can be thus useful for NGOs exploring income alternatives. Moreover, it is planned to use the data as a foundation of an early warning system for food security by regional NGOs, based on market prices for staple products. Household and market monitoring data was also provided for the modeling work under SuLaMa.

3.4.2 Agriculture

Improving cropping systems

Due to dwindling land resources and low soil fertility coupled with population growth, intensification of cropping systems in the Mahafaly region is urgently needed. SuLaMa thus aimed at identifying constraints and opportunities, and field-testing promising cropping and cultivation system alternatives in farmers' fields. As a major opportunity for cropping system intensification manure was identified, as it is an unused resource, readily available to most farmers. Likewise, charcoal residue, which is available in the study area after charcoal production, can be used as a soil amendment (technically termed 'biochar') and has the potential to improve soil characteristics and crop yields, as has been demonstrated in studies from other semi-arid regions. However, little is known about the performance of traditional and newly introduced cropping systems in this area. Against this background, the effects of manure and charcoal amendments were assessed on cassava yields – as well as estimating the contribution of further factors limiting cassava yield in the study area. To investigate the effects of manure on maize, sorghum and millet yields, the SuLaMa team installed demonstration trials on farmers' fields in different villages. Furthermore, in the coastal area where groundwater is available throughout the year, the potential to diversify income and diet through irrigated vegetable cultivation with manure and charcoal amendments during the dry season was investigated.

Regarding the application of manure and charcoal amendments on cassava, the experiments showed that manure did not affect yields in the first year, but led to tuber yield increases of 30–40% after three years in a continuously cropped field with low soil fertility. Charcoal did not affect yields across the whole trial period. However, infection with cassava mosaic virus significantly affected yields of all treatments and led to tuber yield depression by up to 30%. Plant stands were significantly reduced, presumably due to the occurrence of dry spells and poorly adapted planting material. These results indicate that availability of high quality and better adapted cassava planting material, limited water availability and management issues are the main factors limiting cassava yield in the study area. Nutrients applied in the form of 2.5 t ha^{-1} local livestock manure would be sufficient to replace nutrients extracted by cassava tubers and biomass at current yield levels (Hanisch, 2015). Regarding the effects of manure on cereals, control yields on the plateau plots ranged between 0–0.4 t ha^{-1} for maize, and 0.1–0.7 t ha^{-1} for sorghum, while yields on manured plots were increased by 50–200% (Figure 12). The demonstration plots in the coastal zone did not yield any harvestable products due to significant dry spells occurring during the season.

For vegetable production, manure and charcoal amendments on carrot and onions did not affect yields. However, shading decreased carrot yields by 33% in the first year and enhanced yields by 65% in the second year, while onion yields were raised by 148% and 208% under shading in the first and second years, respectively. Shading and quality of seeds significantly affected the carrot yield in the third year, and increased the yield by 55% and 62%, respectively. Manure increased carrot yields by 20% during the third year but the effect was not statistically significant.

Seed germination experiments revealed that salinity of irrigation water as well as quality of seed significantly reduced germination rates, leading to particularly low plant stands in onion plots. Time of storage could be one of main factors that decrease seed viability. Taking into account local and regional market prices, returns to labour under the obtained yield and management system were highest for carrot cultivation under shade in the second year, with a total of approximately € 3. Returns were often negative in the case of shaded plots due to costs for shading material, and generally too low to justify commercial production.

SuLaMa's results from fertilization trials with manure suggest that livestock manure currently available in village livestock corrals may be of too low quality to be used by farmers due to the long storage period under unfavourable conditions. Manure used in the studies had C:N ratios of up to 33:1, and the low or lack of yield increasing effects of manure application may be due to N immobilization after application (Hanisch, 2015). Hence, appropriately stored and composted manure should be used in future investigations of the fertilization potential of local manure. Moreover, due to relatively low livestock densities, manure is currently not available in sufficient amounts in the study area to be the sole source for cropland fertilization. The absence of significant manure effects further confirm

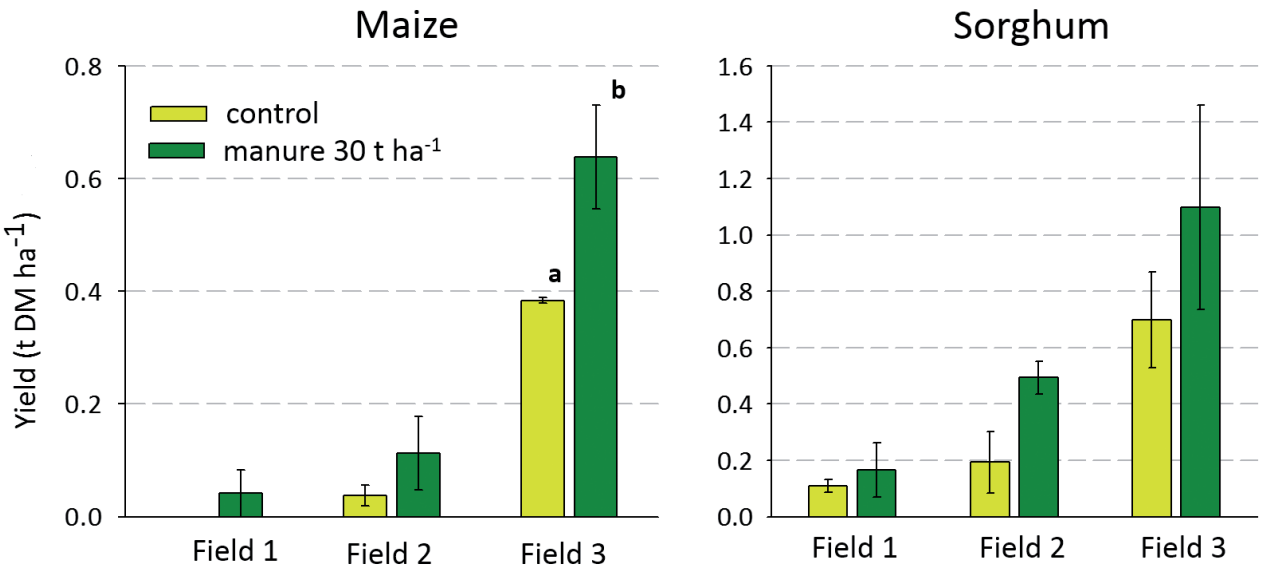

Figure 12: Maize and sorghum grain yields on the plateau in three trial fields in 2012/2013.

that there is a need to access adapted and high quality plant material to enable yield increases and efficient use of soil fertility enhancing amendments, under the constraints of limited water availability.

Regarding irrigated vegetable production, the project recommends further investigation of the observed multiple constraints (salty well water, local seed quality) as well as possible promising techniques to overcome them (e.g. seed priming), which have been identified but not yet sufficiently tested on-site. In this context, local NGOs and communities continue the established experiments in the coastal zone, in sites which will also be used as a seedling nursery. Simultaneously, several projects have started to test and implement vegetable growing in villages on the plateau and to train households in composting livestock manure and household waste to improve the availability and quality of organic fertilizer for homegardens. Composting in this dry environment with low biomass production merits more research in order to be able to give local people better management recommendations.

Cultivation of yams

Domestication of wild germplasm and in situ conservation of wild populations may contribute to counteracting the devastating effects of high harvesting intensity on the existing wild yam populations in the region. The project, therefore, investigated the relative regenerative abilities of six wild yam species (*Dioscorea alatipes*, *D. bemandry*, *D. fandra*, *D. soso*, *D. ovinala* and *D. nako*) as well as the agronomic performance of the wild yam species *D. alatipes* and a local variety of *D. alata*.

The results suggest that regeneration of yam species is possible in pots and in situ as well as under field conditions. For field cultivation of yams, a manure application rate of 20 t ha^{-1} is recommended for *D. alata*. Regeneration of local wild yams was better using the perennial crown of the tuber than mini-sets from wild yams. The regeneration performance depends on specific edaphic conditions, while *D. fandra* and *D. soso* grew on different soil types (calcareous, ferralitic, and sandy soils), the other species preferred only one soil type, which is their original soil in the forest (Andriamparany et al., 2015).

Yam cultivation on the Mahafaly Plateau is complicated by the high labour input for mini-set production and the difficulties in finding appropriate yam seeds. However, cultivation of yams is an option to reduce the pressure on wild yam populations and to contribute to a diversification of cultivated crop species. The possibilities for yam cultivation in the research area (*D. alata* as well as wild species) is currently being assessed by WWF under multiple management options to be able to give specific recommendations for the local management practice. A corresponding large-scale project has been started (see Chapter 5.3.1). In close cooperation with the WWF, SuLaMa tested the agronomic performance of two wild yam species (*D. alatipes* and *D. fandra*) on different soil types (original soil, rich soil, soil from field crops). The results suggests that apart from the good performance on original soils, wild yams grow well under rich soil leaving room to improve the agronomic performance by soil amendments.

3.4.3 Livestock and grazing management

The importance of livestock

Livestock, and in particular cattle, play a significant economic, cultural, and social role for local communities. Until today, the region's agropastoral groups still

keep large herds of extensively farmed zebu cattle and small ruminants. However, livestock farmers have to face several constraints such as seasonal water and forage shortages, but also epizootic diseases and an escalating number of violent conflicts related to livestock raiding. At the same time, the importance of animals as symbols of wealth and prestige still leads to the widespread belief among development agencies that livestock keeping contributes little to food security or other livelihoods of the rural population, while posing a serious threat to the region's environment. Against this background, the major drivers of pastoral dynamics, the reproductive performance of local livestock, opportunities for economic development, and future potential for rural development were all studied.

Seasonal movement and diet

It was found that across seasons, grazing cattle and goats covered longer distances on the plateau and were found further away from the settlements than those from the coastal plain. Seasonal water shortage has been confirmed as a key constraint on the plateau while livestock keeping along the coast is more limited by dry season forage availability. However, recent security issues and land use conflicts with local crop farmers are gaining importance and force livestock owners to adapt their traditional grazing management, resulting in spatio-temporal variation of livestock numbers and in the impending risk of local overgrazing and degradation of rangelands (Ratovonamana et al., 2013; Feldt and Schlecht, 2016; Goetter, 2016).

While cattle largely relied on grasses as the principal component of their diet, goats had a stronger preference for ligneous (woody) vegetation. The nutritive value and digestibility of the natural forage, as well as its abundance in the coastal zone, substantially decreased over the course of the dry season and emphasized the importance of supplementary fodder plants, in particular *Euphorbia stenoclada* (samata, Figure 13). This succulent tree species was found to be of qualitative and quantitative importance in the region's coastal area, offering energy and water at times when nearly no other fodder is available (Ahlers et al., 2016). However, the ongoing unsustainable utilization and overexploitation of its wild stocks may raise the pressure on the vegetation and pasture resources within the nearby Tsimanampetsotse National Park (Feldt, 2015).

The progeny history interviews with livestock breeders revealed higher market dynamics than expected, especially for zebu cattle, resulting in annual contribution margins of € 33 per head of cattle and € 11 for a goat (Feldt et al., 2016). Improved feeding could support substantial herd expansion and productive offtake rates, whereas improved culling would stabilize livestock numbers and concomitantly increase monetary herd output. However, this would be clearly limited by the region's restricted carrying capacity and cultural constraints.

Our results illustrate the highly extensive and resource-driven character of the livestock system in the Mahafaly region, with herd mobility being a central element to cope with seasonal shortages in forage and water However, additional key drivers and external factors increasingly affect migration decisions and grazing management, leading to a risk of local overgrazing and overexploitation of natural pasture resources. At the same time, it hampers the region's agronomic development, which has not yet been fully exploited. The situation therefore demonstrates the need for practical improvement suggestions and implication measures, such as the systematic afforestation of supplemental forage plant species in the coastal zone and stronger integration of animal husbandry and crop production, to sustain the traditional livestock system without compromising peoples' livelihoods – while at the same time minimizing the pastoral impact on the area's unique nature and environment.

Cultivation of alternative livestock fodder

As previously mentioned, the *samata* tree is the most important dry season fodder of the coastal area, particularly for zebu cattle. Although the villagers traditionally fostered the dominance of *samata* by constantly removing other plants, the supply is shrinking as the *samata* stocks are today degraded throughout the region, with a severity gradient from south to north. Besides the resulting problems in fodder (both quantity and quality) wildlife, livestock and people also suffer from the diminished shade the trees supply. According to the locals, the degeneration is due to lower precipitation rates, but also overexploitation of *samata* (Goetter and Neudert, 2016), being a result of an increased demand. There is also the diminished supply, fostering unsustainable cutting techniques which cause poor regrowth or even the death of the trees. A survey of trees on different sample plots verifies that besides cutting at the branch level, cuts at the apical meristem and at the trunk are also common – and these can kill the tree. Thus, the mortality rate of cut trees is up to 22%, although in 45% shoot regeneration takes place. The regeneration problem is also illustrated by a deficiency in young individuals (Goetter et al., 2015).

The problem of diminished supply is also related to the situation under which the villagers have started to privatize the historically common pool of *samata* stocks. The private *samata* stocks are unequally distributed among the villagers, as the privatization followed a 'first-come-first-served' process. Today, *samata*

Figure 13: Feeding of samata (*Euphorbia stenoclada*) to zebu cattle in a village of the coastal zone (photo: Johanna Götter).

has become a regional cash crop with a rapid increase in prices. Thus, many herders are obliged to use the remaining common stocks, which are often heavily overused and thus lower in quantity and much worse in quality than the private stocks. Moreover, the villagers' habit of multiplying the *samata* on private land by digging up naturally occurring 'wildings' (seedlings) from the bush, reduces the biomass and regeneration of the wild stock and thus contributes to its degeneration. The increased demand is a result of changes in the movement of herds on the coastal plain and on the plateau. The coastal zebu herds were accustomed to stay under transhumance on the plateau during the rainy season, but the herders now prefer to return to the coast after only a few weeks to avoid cattle thieves on the plateau. Their early return of the herds leads to the early use of *samata* resources. Also, because of cattle thieves, many plateau farmers began to move their herds to the coast in the dry season, meaning that many more animals have to be fed with the *samata* (Goetter, 2016, Goetter and Neudert, 2016).

The main problem of the *samata* cultivation in the past was that the villagers had no knowledge of how to multiply the trees for mitigating the pressure. The *samata* naturally reproduces sexually by germination and vegetatively by shoot rejuvenation. The project experimented with the artificial propagation of *samata* by germination and cuttings in the natural environment, testing the local variety of *samata* with different pre-treatments and factors such as shade, hormones and different substrates (red sand, calcareous soil or white sand). Considerable success with good survival and growth rates were obtained with non-hormone-treated cuttings planted in white sand under full sun. As the artificial multiplication with cuttings is also faster in comparison to germination, and technically easy, it is the preferable propagation method. The multiplication technique with cuttings does not demand much material or technical knowledge, but only some general practical knowledge and simple skills. Providing the villagers with knowledge about multiplication is thus a promising approach to help the regional animal husbandry to survive and protect the ecosystem from further depletion. As the multiplication is – compared to other species – relatively easy and besides regular watering the small trees do not need much care, *samata* can not only be multiplied in formal nurseries, but by the villagers themselves. In this context the SuLaMa team and WWF Madagascar started community workshops for the cultivation of *samata* and community tree nurseries (see Chapter 5.3.3).

Chapter 4

Land use models and scenarios as decision support tools

4.1 The need to understand relationships

For the design of nature conservation and sustainable management strategies, landscape managers and policy makers need to understand the underlying relationships of land use and land cover changes (LULCC) as well as deforestation processes (Kates et al., 2001), both generating many environmental problems from local to global scales. This is particularly true for southwestern Madagascar where the rate of total deforestation over the last decades has been extraordinarily high (Brinkmann et al., 2014) and where food insecurity is a serious problem, as local people depend to a very high degree on natural resources to sustain their livelihoods.

4.2 SEALM – SuLaMa Empirical Agent-based Land-use Model

To gain insight into the complex interactions and feedbacks between land use activities and ecosystem services, and to inform decision makers of possible future trends under different scenarios, SuLaMa developed a spatially-explicit simulation model (SEALM – SuLaMa Empirical Agent-based Land-use Model). The specific aims were *(i)* to identify hotspot areas of LULCC and landscape fragmentation in space and time, *(ii)* to explore smallholder farmers' coping strategies to food insecurity and *(iii)* to simulate possible future trends in the land use system and the effects of these trends on the environment, household economy and food self-sufficiency. For the technical implementation, an agent-based modelling approach (ABM) was applied in Netlogo (Wilensky, 1999) based on the empirical data of all SuLaMa work packages.

SEALM consists of different types of entities (Figure 14), which include the landscape ('patches', see below), households and global variables ('globals'). For the parameterization of entities, a wide range of data was used, incorporating social surveys, high-resolution remote sensing (Selsam et al., 2017) and field-based validation data. Households represent the individual farm households characterized by their state variables, which capture the livelihood capitals and assets derived from socio-economic surveys. The landscape is depicted by congruent land pixels ('patches') corresponding to GIS-layers of institutional and biophysical spatial state variables, such as land use, soil-quality, crop yield, field age and owner. Forest patches are additionally characterized by spatial state variables related to the forest use potential (e.g. biomass stock, growth rate), which are parameterized based on remote sensing and forest inventory data. Global variables such as population dynamics, climate conditions, protection of forest resources, and general conditions of crop management (fallow period, use of fertilizer) are driving forces that directly affect the state variables and household activities.

During model initialization, the user can select the state variables (landscape and households) of three different villages (Efoetse, Andremba or Miarintsoa), which will then be used for the simulation. The spatial extend of the model comprises the village area and its surroundings (100 km^2). The user can also change the global variables in the user interface at will to simulate multiple scenarios (e.g. population increase or different crop management strategies).

As growth and yield of crops in the study region closely depend on precipitation, SEALM includes a climate module which simulates rainfall regimes over the simulation period of 30 years that are characteristic of future climate projections from IPCC/CMIP5 AR5 (IPCC, 2014). To downscale and regionalize those projections and to subsequently generate stochastic rainfall data which serve as an input for the crop module, we employed a tool developed by Jones and Thornton (2013). SEALM imports random iterations of these simulated rainfall data from one of four user-selected global greenhouse gas concentration scenarios (Representative Concentration Pathways (RCPs)) during model initialization. Furthermore, an option to force the occurrence of multi-year droughts can be activated by the user to examine the influence of extreme climate events (e.g. caused by ENSO) on model outcomes.

Simulations are performed along discrete time steps, following a yearly cycle, which includes sequential steps with patch-based processes, and ends after 30 years. For each simulated year, different processes related to land use are initiated by household agents, which can be summarized as ex-ante planning (decisions on investment and land use activities), crop cultivation (field extension, planting, weeding, harvesting) and ex-post planning (decisions on coping strategies). Household resources, energy requirements and labour availability change at the beginning of each year, according to the corresponding population increase. The core mechanism of the household agent is energy budget accounting to fulfil food self-sufficiency. For every simulated year each household tries to satisfy its members' energy requirements by a mixture of different activities such as crop cultivation, animal husbandry, off-farm activities and various coping strategies. Crop cultivation is dynamic, and crop yields are calculated for each simulated year based on production functions, which take into account management activities, soil quality and climatic conditions.

For each time step, households may use different adaptation mechanisms to avoid food insecurity and increase household income; increase or reduce the area of cultivated land depending on available capital and energy requirements, change the allocation of their agricultural fields, and change their coping strategy according to the availability of livestock, farm-income and capital. The household decision-making process was mainly simulated using a heuristic approach, which takes inputs from the household profile, its perceived landscape information, and data from other household agents. Through land-use activities the household agents modify their environments resulting in LULCC. Simulation outputs are spatio-temporally explicit land-use and land cover maps, which are used to analyse habitat fragmentation, changes in forest area and biomass stocks and basic socio-economic indices such as food self-sufficiency, crop yield, household income, Gini coefficient, availability of fuel and construction wood and coping strategies.

SEALM provides a tool to better understand human–environment interactions and LULCC processes. The baseline scenario showed that the detected trends in LULCC indicate a strong increasing pressure on available land resources in the study region, which is reflected in high deforestation rates and fragmentation of the remaining forest. However, a decline is expected in deforestation rates in the future, since the peak has already been reached in the past, where deforestation was a result of interactions between complex political, social and ecological processes (Brinkmann et al., 2014). For the majority of households, the daily calorie intake was insufficient and the results revealed that due to various biotic and

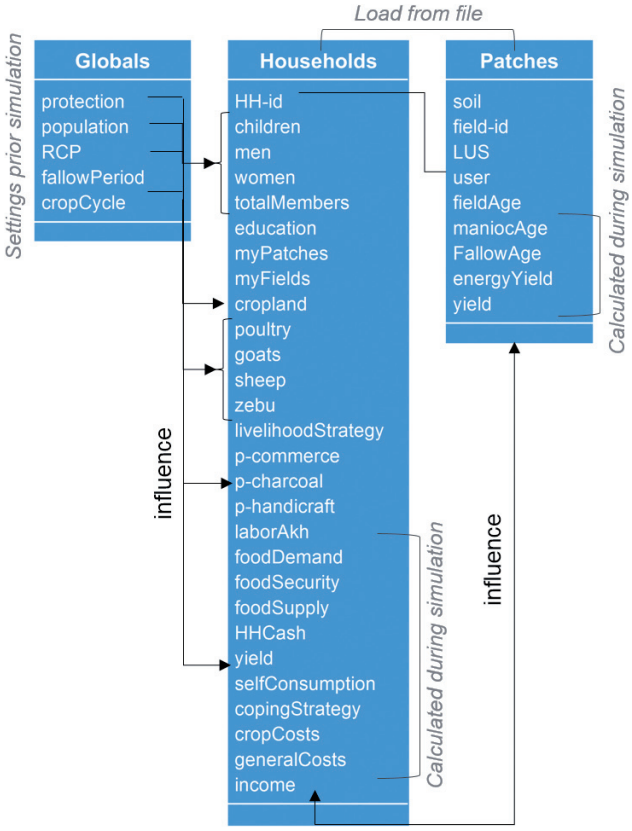

Figure 14: Entities and parameters of SEALM.

abiotic constraints, the agricultural production of annual cultivated food crops provided, on average, only up to 64% of people's diets (Noromiarilanto, 2016). However, Malagasy farmers will most likely continue to practice the traditional low-input agriculture, including slash-and-burn cultivation techniques, as long as alternatives and other promising crop cultivation techniques are lacking, and space to grab land is available. Thus, one potential solution to food insecurity and deforestation is to provide local communities with improved agricultural techniques, which enhance soil fertility and incorporate drought resistant crop varieties. However, due to the high climate-induced risk in crop production, enhancing access to off-farm income opportunities is equally important in order to fulfil food security in the long-term.

4.3 Forest model

To simulate and quantify the changes in forest biomass stocks due to forest growth and the extraction of forest products, a forest model was developed and integrated into SEALM. For model initialization and parametrization, remote sensing data and forest resource assessments were used, which focused on forest area, tree species diversity, growing stock and increment (Chapter 3.2.2). The related forest wood volume was estimated by linking field plot measurements with remote sensing data utilizing Random

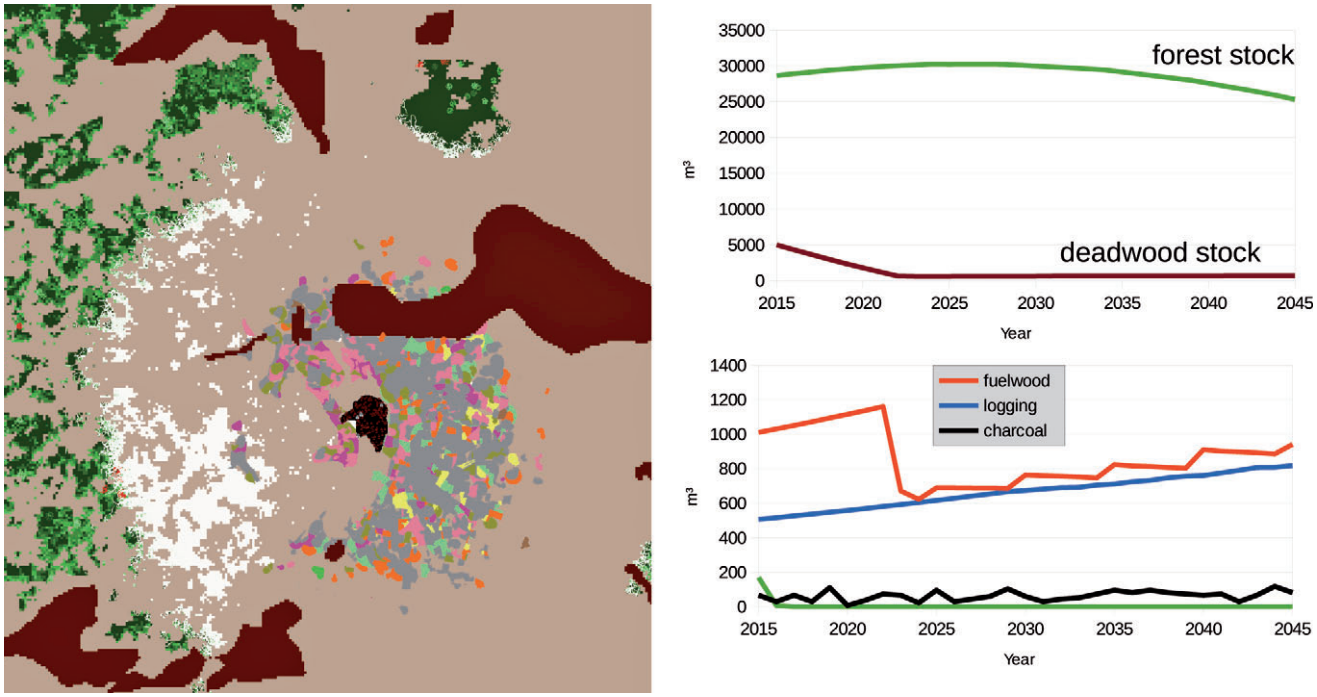

Figure 15: Development of forest stocks next to the village of Miarintsoa in the baseline scenario assuming annual consumption of 0.8 m³ wood for cooking and 0.4 m³ wood for construction. Left - forest living stock in simulation year 15, dark green high to light green low stocks and white total forest degradation. Right top - annual development of living and above ground forest stocks. Right bottom - annual forest production for different types of uses.

Forest classification. Procedures simulating forest dynamics and the extraction of timber were developed based on available field data and complementary literature. Forest dynamics were described by the increment in growing stock, occurrence of deadwood and annual decomposition rates. Biomass stocks of local less-touched forest reflect the regional stocking potential. A constant production of dead wood was assumed. The total timber demand was calculated based on average per capita demand for fuel wood and household demand for construction timber.

For the case study conducted in the vicinity of Miarintsoa village, scenarios were identified that differ in wood demand as well as forest management strategies. Figure 15 presents general trends in forest stock and forest products within the landscape next to the village of Miarintsoa for the baseline scenario. This scenario is parametrized by an annual timber demand of 0.8 m³ for cooking per capita and 0.4 m³ for construction per household, which estimates the current timber consumption pattern. After the simulation period of 30 years, the baseline scenario results in a 12% reduction of initial carbon stocks, after a period of increasing stocks in the first simulation decade. Forest land close to the village was degraded intensively while remote forest biomass stocks slowly increased. After 6 years, the demand for fuelwood cannot be satisfied by the available deadwood pool within in the modelling area, and thus imports are required. Population growth, coupled with current timber and wood fuel extraction, are identified as the major drivers of forest degradation. In contrast, a scenario of intensive forest use revealed that increased timber extraction quantities (1.2 m³ construction timber and 0.8 m³ fuel wood) will lead to total degradation of the 1,233 ha of forest area in the study area within 19 year. After 12 years, fuel wood needs to be imported in this scenario.

4.4 Livestock model

Grazing and browsing may not only alter the overall productivity of rangeland plant communities, but also their composition in terms of abundance and diversity through selective consumption of different plant species. To analyze the sustainability and productivity of different grazing and herd management strategies with special consideration of the effect of future climate scenarios, a spatially explicit, dynamic, ecological model has been developed applying techniques of agent-based modeling (Fust and Schlecht, 2017), which is a component of SEALM.

Due to the complexity of the processes and their respective representations in the model, the model structure and its development were handled in a number of submodules. The vegetation submodule represents the condition of the rangeland habitat in terms of resource availability and distribution. Since the purpose of the model was to simulate the use of foraging resources by herbivores, it was important to also incorporate, beside the plant organism-intrinsic factors, the key parameters related to the nutritive status and value. Based on field measurements of herbaceous

biomass and remote-sensing based vegetation indices, the above-ground biomass was evaluated and mapped for the study area. By analyzing yearly time-series of these vegetation indices, time-sensitive gradients and seasonal patterns in biomass availability were assessed and approximated to simulate the temporal dynamics in biomass availability of rangeland vegetation. For the most important rangeland vegetation types, averaged values for digestibility were evaluated and overall digestibility was analyzed and extrapolated for the study area. Accordingly, temporal gradients and seasonal patterns in digestibility were translated into corresponding time-sensitive functions, thus simulating maturation and re-growth of the vegetation.

The herbivore submodule includes all livestock-related processes, simulation of animal behavior, metabolic implications, movements, etc. Because of their economic and ecological importance in the study region, the model focuses on the effects of grazing by cattle. Thus, the model adopted the principle of optimal herbivore foraging that is premised on energy maximization. The herbivore submodule simulates the movements and the corresponding energy costs and gains through free grazing in high temporal and spatial resolution. Based on different simulated herding management strategies, daily grazing itineraries were calculated and the daily energy balances accumulated over many years.

Results indicate that organic digestibility of the forage material is of particular importance for the long-term sustainability of the livestock production systems of villages on the plateau, while forage biomass received only a restricting parameter at elevated stocking levels during lean periods. Live weights of the individual animals exhibited seasonal changes of up to 20%, mostly influenced by the management strategy and precipitation scheme involved. These preliminary findings reveal that dynamic herd and grazing management adaptation has the potential to alleviate the pressure on rangelands in the study region.

4.5 Hydrogeological model

4.5.1 Assessment of water availability

The provision of water is an essential ecosystem service on the Mahafaly Plateau. However, its scarcity in the region is one of the most important limiting environmental factors for the improvement of livelihoods. The Mahafaly region is characterized by low precipitation, and freshwater is a rare good. Surface water occurs almost exclusively during the rainy season and is of rather poor quality (salty, muddy, insufficient sanitary conditions) – people and animals share the use of ponds and puddles. Moreover, especially in drought years, there are high risks of crop failure due to low water availability. These problems are aggravated by an overall decline in precipitation and an increased variability of rainfall between years: both have been documented over the last decade, possibly due to climate change effects. The subterranean water system below the limestone plateau is assumed to hold substantial potential for communities, not only as drinking water for humans but also to improve agro-pastoral activities (and also other sectors like ecotourism). In this context the assessment of the groundwater reserves and their dynamics plays a decisive role. The provision of water through important plant species like baobab (*Adansonia* spp.) in the Mahafaly region plays also a role. This species is adapted to drought condition and has the potential to store large quantities of water, which have served the inhabitants of the area during dry periods in the past.

Livestock benefit also from water stored in fruits and forage plants (e.g. in *raketa*/*viro* (*Opuntia* spp.). Although several governmental institutions and NGOs have been working on the development of sustainable water management plan for the region in the past, only little information about the groundwater system and its potential as a sustainable water source was available. To address the freshwater problem in the region and to investigate the potential of groundwater as a sustainable water resource, SuLaMa started a hydrogeological study in collaboration with the University of Bochum, the WWF Madagascar, 'Action contre la faim (ACF)' and the Malagasy NGO 'SOARANO' in 2014. The goal was the development of a regional hydrogeological model and consequent recommendations for localized water resources utilisation as a basis for future water management. Due to the poor water quality all over the region, the hydrogeological study was supplemented by a chemical and bacterial analysis investigating different kinds of typical locations for water supply (Rasoloariniaina et al., 2015). All data were fed into the regional data centre in Toliara as basis for a future monitoring on water availability. The long-term data collection will be presumably conducted under the aegis of WWF.

The hydrogeological models were developed for the local and the regional scale. The regional scale hydrogeological model, which comprised the area between the Onilahy and the Linta River with an extent of ~40,000 km^2 was developed based on rough estimates and information from literature (e.g. Besairie, 1946; Aurouze, 1957; Guyot, 2002; Batelaan et al., 2003; Andre et al., 2005; Dworak, 2014). The local scale hydrogeological models were developed for selected SuLaMa project villages and their surrounding area (100 km^2) based on field investigations including about hundred wells characterized in terms of geometry, groundwater level and electrical conductivity.

The regional hydrogeological model of the Mahafaly Plateau is dominated by four major hydrogeological units: the low permeable fractured crystalline basement, the high permeable karstic plateau including localized intermediately permeable perched aquifers on top, the intermediately permeable porous aquifer within the paleo-channel of Itomboina (an ancient dry floodplain) and the intermediate permeable porous coastal aquifer (Figure 16). Groundwater flow is roughly directed from the central crystalline basement to the coastal aquifer, to finally discharge into the Mozambique Channel. Groundwater levels are shallow in the crystalline basement. In the area of the Mahafaly limestone plateau, groundwater levels in the karstic aquifer are estimated to be at a depth of 50 m – 150 m below ground. In this area, only the perched aquifers which lie on top of the karstic aquifer provide shallow, and therefore accessible, groundwater levels. Within the channel of Itomboina, the depth to the groundwater level displays an east to west gradient and is shallow only in the western area (close to the village of Maroarivo). In the coastal sandy aquifers, the groundwater levels are again shallow and easy to access. Regional groundwater recharge is about 40 mm year^{-1} in the crystalline basement, about 1 mm year^{-1} in the area of the plateau and up to 100 mm year^{-1} in the coastal area. An additional water resource consists of rainwater catchments (called *sihanaka*) built by local people all over the inhabited area of the Mahafaly Plateau. They contain large volumes of fresh water collected during the rainy season, and are hence independent of the local groundwater situation. In general, they provide water only during the rainy season and are used by the local people for daily drinking, cooking and washing as well as for watering livestock. After a period of about two months, the *sihanakas* fall dry due to consumption, evaporation and infiltration.

Local hydrogeological models show a marked variability amongst the different target villages of the SuLaMa project. The water resources on the plateau are scarce, as the major karstic aquifer is only accessible through deep drilling and pumping operations. In contrast, the perched aquifers are easily accessible, but they are relatively small and localized. As an example of the latter, SuLaMa studied the aquifer that is located close to the village of Andremba. The aquifer is recharged during the rainy season, as displayed by an annual hydrograph measured in one of the local hand dug wells. During the rainy season peak, the groundwater level rises up to surface elevation, and then drops gradually to a level of about 10 m below ground surface in the dry season. The latter behaviour is due to leakage into the deeper hydrogeological system and simultaneous extraction of up to 20 m^3 day^{-1}. The village of Miarintsoa is located north of Itomboina at the edge of the Itomboina channel, where no perched aquifers are present. The depth of the channel structure that is filled with continental sediments cutting into the Eocene layers is not known in detail, but estimates within the large-scale hydrogeological model suggest the groundwater level to be 10 m below the surface. Due to the low groundwater level, no well exists in Miarintsoa, and the local population uses a rainwater catchment (*sihanaka*) during the rainy season for water supply. The *sihanaka* usually dries up after a period of about two to three months. During the rest of the year, the local population is dependent on water sources outside the village area, mainly from the perched aquifer in the village of Maroarivo (see above). The annual water level fluctuations in the coastal area were studied in the typical village of Efoetse, which demonstrates shallow groundwater levels throughout the year. Consequently, the groundwater is easily accessible to the population, but the high electrical conductivities of up to 22,000 µS cm^{-1} indicate high salt concentrations due to salt water intrusion from the ocean.

4.5.2 Potential for future water management

The multi-scale modeling approach unravelled the hydrogeology of the SuLaMa area as very heterogeneous. As a consequence, water resources are distributed very ununiformly in the SuLaMa area and reliable groundwater management plans are recommended to be developed in a site-specific way. Nonetheless, the challenges differ between the actual plateau and the littoral area, and both cases demand different management approaches. In the real plateau area water is scarce in the dry season, and it is only local perched aquifers that serve as water resources. The limits of the latter are individual and closely depend on groundwater recharge, geometry and hydrogeological characteristics. As an example, for the target village of Andremba, the study showed that livestock water demands (20 m^3 day^{-1}) are withdrawn from the local perched aquifer throughout the year. The study found that this amount of water can be provided by the local perched aquifer as long as annual precipitation is not significantly reduced by climate change. It was also found that a possibly increased water withdraw (max. 40 m^3 day^{-1}) during the rainy season is feasible without pronounced effects on the water resources in the dry season. Increased water production during the rainy season can serve for irrigated agriculture or for water storage in tanks as an additional water resource for the dry season.

In the coastal zone, water is easily accessible throughout the year, as groundwater levels are shallow. However, freshwater resources are limited by

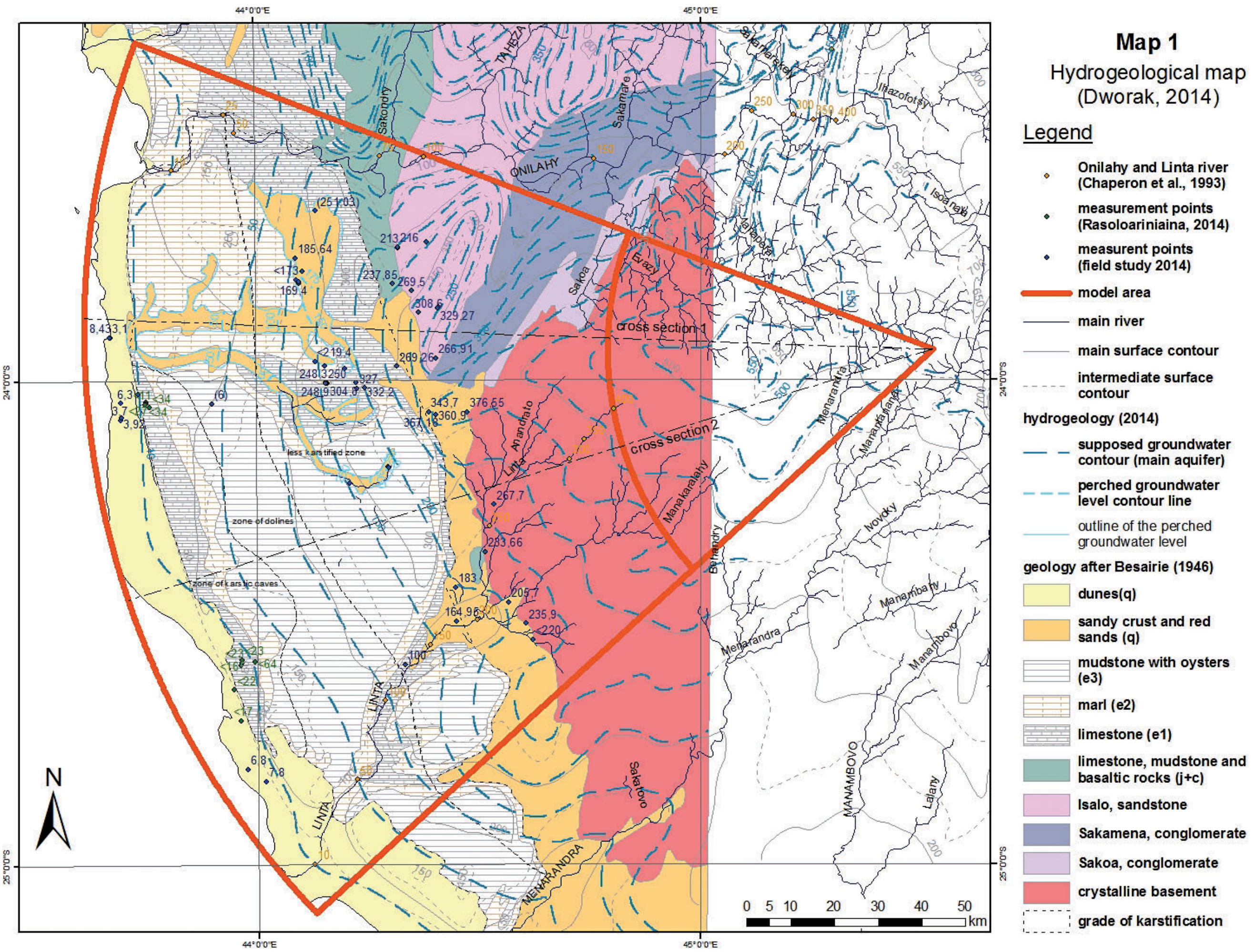

Figure 16: Map of the hydrogeological large-scale model showing the different geological units together with groundwater levels for the model area (Dworak, 2014).

groundwater recharge, hydrogeological characteristics and proximity to the ocean. For sustainable water resource management in the littoral, mapping and modeling of the salt–freshwater interface is needed. Therefore, a quantitative hydrogeological survey is recommended, together with hydrogeological modeling for the villages. Using the target village of Efoetse as an example, our study showed that the recent groundwater production has already pushed the fresh–salt water interface close to the locations of withdraw. As consequence the water produced at Efoetse is already quite salty. It is a mixture of seawater and groundwater. A higher production of water in Efoetse would force the fresh–salt water interface closer to the location of the wells, which would result in even higher salt concentrations. In case more water is needed it is recommended to produce it further inland and transport it to Efoetse. As an alternative, desalinisation of the water might be an option.

Even though the hydrogeological conditions are very variable, water quality is low throughout the SuLaMa area. We found the pH being neutral to slightly alkaline and within the permissible limits of WHO and Malagasy standards. Electric conductivity and total dissolved solids were very high and above the permissible limits in the coastal plain, moderately high in the park and low on the plateau. The concentrations of nitrogen components (NH_4, NO_3 and NO_2) were high in the rainy season, with the highest concentrations in wells. Phosphate concentration was high throughout the study area. Total coliforms, *Escherichia coli*, *Salmonella* spp. and *Vibrio* spp. were present throughout the study area year-round, representing a serious health hazard. Their concentrations were not correlated with any physicochemical characteristics in any systematic fashion that would allow the use of the physicochemical characteristics as a proxy for microbial contamination. Poor sanitary conditions are the principal causes of water contamination – and that could be reduced substantially by simple behavioural changes of the local human population (Rasoloariniaina et al., 2015). To this end SuLaMa organized meetings in the villages to raise awareness about improved water hygiene. This included practical demonstrations and the distribution of brochures showing people to use different sources for human drinking water, livestock watering, bathing, cooking and washing.

4.6 Participatory scenario development: Role-Playing Games

After comprehensive research was completed within the disciplines, role-playing games were designed to validate the system understanding and discuss scenarios with the local population. Employing this methodology, participants simulate real-life decisions on a spatial scene by using visualizing material. Two participatory simulation games were designed and tested in SuLaMa's village workshops 2014: The 'Livelihood Game' and the 'Livestock Game'. Both games were aimed at validating the decision-making processes of different household types. During the Livelihood Game, participants assume the role of one of four household types in the village, differing in resources and composition. A satellite map of the village and its surrounds, with mapped field contours, allows participants to locate their houses and fields. The fictitious households are asked to plan their annual subsistence decisions in terms of agricultural activities, animal husbandry and off-farm activities over the course of one year. Each decision is visualized by pictured cards, colours and symbols. At the end of a year, revenues and expenses are distributed among the players. As cultural conventions influence the decision-making process, players picked so-called 'destiny cards' symbolizing funerals, sacrifices or other unplanned events. After two years, participants reflected on their life quality, their free time and education of the children. In the following two years, the scenario of a drought cycle leading to harvest failure was simulated. Participants developed and discussed coping strategies around this situation.

The Livestock Game seeks to understand and discuss the herders' decisions on grazing grounds, fodder and water supply. As decisions on grazing grounds vary throughout the year, the game covers the time span of one single year with three seasons. Players are given roles with different herd sizes and they locate their corrals and grazing grounds on the satellite map (Figure 17). While fodder is still abundant at the end of the rainy season, fodder becomes increasingly scarce over the course of the year. The herders adapt their grazing grounds and decide to use supplementary fodder accordingly. After simulating one 'normal' year, a scenario of cattle raiders (*malaso*) is simulated in the second year. The workshops were held in two villages in the coastal zone and two villages located on the Mahafaly Plateau. The games were facilitated by the Malagasy socio-organisers, who were familiar with the regional dialect. Workshop participants lived in the villages, and were currently practicing the main activities, farming and livestock keeping. Two groups worked simultaneously in each of the four villages. Each group was composed of twelve participants, so that 96 participants took part in the workshops in total.

Figure 17: Livestock game: workshop participants in Andremba localize their grazing paths and grounds on a village map, July 2014 (photo: Jacques Rakotondranary).

Chapter 5

Implementation of results and recommendations: techniques, approaches and strategies with good long-term prospects

5.1 Linking research to practice

Beyond contributions to the scientific debate, the central aim of SuLaMa was to link SLM research to practice – namely in the form of improvements to local livelihoods, farming practices and conservation of the natural ecosystem. During its last three years, the project thus focused on the development of implementation products and strategies based on research findings and stakeholder interests. Results and recommendations from the scientific disciplines were incorporated into three main implementation sectors; namely *(i)* practical techniques and approaches for local people and NGOs, *(ii)* databases and models as decision support tools for international, national and regional stakeholders, and *(iii)* knowledge transfer and capacity building for regional universities, local schools and communities. Long term application will be ensured through the interconnection of the three sectors (Figure 18). The products and strategies were discussed and improved in collaboration with political actors, development associations and external scientists during a number of workshops. In particular, results and recommendations for action in the field of agricultural sciences, environmental education, conservation of biodiversity, and sustainable forest management were widely appreciated. Several approaches and techniques are being implemented or further tested by regional partners, programmes and stakeholders. A particularly important achievement has been the high level of acceptance of the project and its outcomes by the village communities, who praised their integration and the participatory project structure – including at the closing conference. Hence, it is envisaged that there will be a good chance of success in terms of independent implementation of the results and recommendations by local communities. Since the official elections in 2013, political consoli-

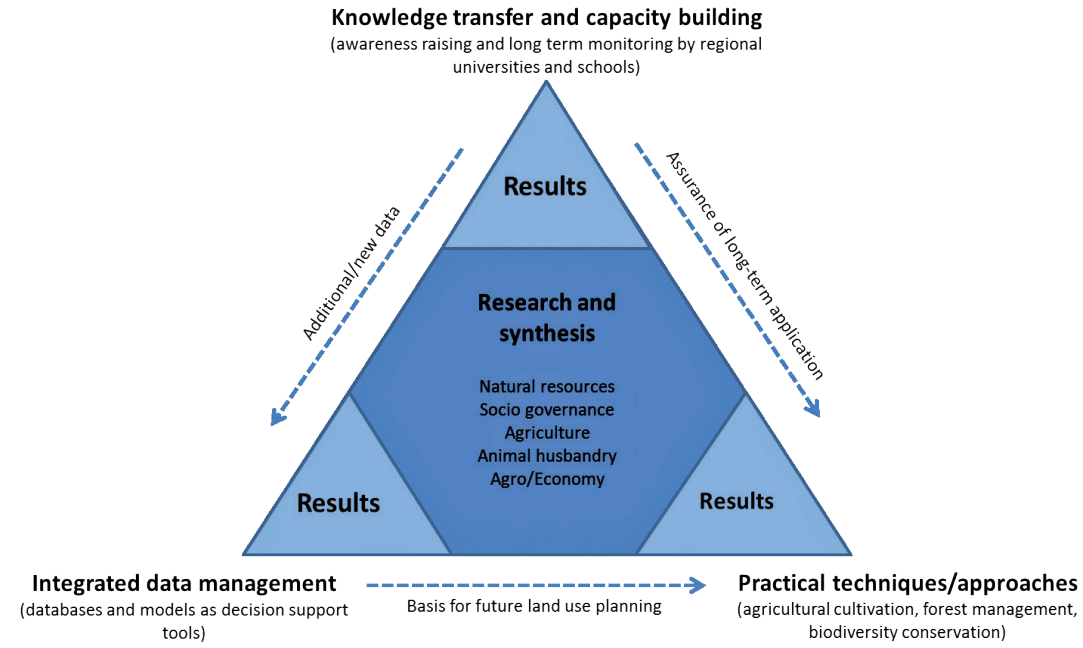

Figure 18: Linking research to practice in the Mahafaly Plateau region.

dation seems to be taking place, following a number of years of political instability. Thus, the probability of long-term integration of SuLaMa outcomes into regional politics has substantially increased.

However, projects with a limited funding period often face the problem that achievements that are not explicitly realized in terms of concrete implementation may cease to have any impact after the end of the project period. Thus, apart from the implementation of action strategies, the establishment and enhancement of capacity building structures, knowledge transfer, stakeholder networks and a publicly available database were SuLaMa's priority tasks. This was aimed at ensuring the accessibility of results and data beyond the actual project lifespan, and to provide a reliable basis for activities and research of third parties in the future (Figure 18). Some of the concepts presented were developed by SuLaMa and partners; others represent recently initiated measures or strategies such as the 'landscape approach' and the 'IST curriculum', which SuLaMa supported by providing data and scientific results, as well as practical and theoretical recommendations.

5.2 Product development strategy

From 2014 to 2016, SuLaMa focussed on the final product development, the scientific presentation of project findings and the support of implementation activities including agricultural and agroforestry techniques, awareness-raising workshops and data integration. In close collaboration with partners and stakeholder (farmers, rural communities, NGOs, universities and state agencies) and based on research results, SuLaMa developed several products for sustainable land management. For joint product development, the project organized several meetings and workshops in Madagascar. In May 2015, a workshop on stakeholder-based product development (following the concept of the first successful product workshop in November 2014) took place in Toliara. Here, the most promising recommendations and solutions were finalized after validation with stakeholders, partners and sub-project leaders. All products were presented at the final SuLaMa conference, which took place in Toliara in September 2015. Many of these recommendations are currently being implemented. The success, or need for further refinement of SLM approaches and techniques, can be reported to the project team via various communication tools (platforms, meetings on site or by mail). In this context, the practice-oriented NGOs and project partners in the region are particularly important agencies and mediators.

Additionally, in cooperation with all work packages, the relevant results and recommendations of the SuLaMa project were compiled in a compendium. It was handed over to the stakeholders and project partners during the final conference in Madagascar. The participants of the conference were explicitly asked for feedback in order to optimize the most relevant deductions and recommendations according to the requirements of the stakeholders. The products in the forms of reports, flyers, brochures etc. that were developed within the framework of the project are publically available for download on the SuLaMa homepage (www.sulama.de) (see Annex 10.2).

At the end of the project period, SuLaMa presented the recommended techniques and approaches for sustainable land management to the local population during the final village workshops. They took place in two of the four main study villages, with 171 residents of these and surrounding villages participating. The feedback given by the local population was very positive; the participatory approach of the project, which had ensured continuous involvement of local people in the research and implementation process, was especially appreciated. In addition to these overarching workshops, regular village meetings for awareness-raising were conducted during the implementation period from 2014 to 2016 (Chapter 5.5.3).

5.3 Implementation of techniques and approaches in the fields of agriculture, forest management and biodiversity conservation

Indigenous uptake of innovative cropping techniques can be difficult to evaluate in the short-term, as farmers' participation often depends on food donations or payments while impact assessment of interventions are commonly absent. In summary, instead of focusing on yield, alternative cropping systems have to be more resilient to recurring shocks than traditional systems: and this would be ideally assessed through a long-term approach by integrating the results of numerous approaches and organisations. In this context SuLaMa, in collaboration with different stakeholders, selected and promoted three promising techniques in the fields of agriculture, agroforestry and livestock management with particular potential for long-term application. Furthermore, a biodiversity monitoring programme has been developed in collaboration with the National Park Agency and communities. These techniques and approaches are currently being further tested and implemented by regional partners.

5.3.1 Use and cultivation of yams

In villages distant from the forest, wild yams (*Dioscorea* spp.) supplement the staple foods (cassava and maize) when these are scarce. Moreover, especially in the villages near forest areas where daily collection is possible, wild yams may even become a staple itself. However, the populations of wild yam are scarce and mainly located in restricted areas of open spiny forests and dry spiny forest thickets, where overharvesting, combined with unsustainable harvest methods, threatens the population. In this context, it is important to raise awareness about the sustainable harvest of wild yam tubers, particularly in villages near forest areas, by replanting the crown of the tubers in the soil. This action will not only ensure the regeneration of tubers but will also reduce soil degradation that occurs due to the holes left after harvesting. To raise environmental awareness and more easily communicate recommendations for sustainable harvest techniques of wild yam, the project started to design comic-style illustrations of visual narratives showing two contrasting scenarios of sustainable and unsustainable harvest techniques. This was later combined with field workshops with local communities, especially in villages near forests areas (e.g. Ampotaka in 2015) or in remote areas where high wild yam harvest intensities were recently registered (e.g. Bealintany in 2016). Regular monitoring of wild yam collecting sites are necessary in the future to evaluate the impact of those changes on the existing wild yam population.

Domestication of wild germplasm and in situ conservation of wild yams may contribute to counteract the devastating effects of high harvesting intensities on the existing populations in this region. However, yam cultivation on the Mahafaly Plateau is complicated by lack of know-how, the high labour input for mini-set production and the difficulties in finding appropriate yam seeds. In cooperation with the WWF, the possibilities for yam regeneration and cultivation (*D. alata* as well as wild species) were further assessed and implemented under multiple management options to provide specific recommendations to villagers on the Mahafaly Plateau. With respect to villagers' needs for additional information, field workshops were organized with local communities (Figure 19) and with scholars to give technical support, not only regarding yam cultivation but also on agricultural techniques, such as making compost. One of the management strategies in 2016 was cultivating yams in homegardens. For this, about 3,000 seed yams were grown in nurseries managed by local communities in seven villages. The sprouted yam mini-sets were later transplanted into the homegardens of local households and in school gardens. The homegardens were a success in terms of agriculture innovation in this area (through the use of compost, manure, rich soil from under Tamarind trees, use of waste water for regular watering) and it was greatly appreciated by the local communities.

Figure 19: Field workshop on yam regeneration in a local community-based nursery (photo: Jessica Andriamparany).

5.3.2 Forest restoration and reforestation activities

Forest restoration and reforestation are promising approaches to alleviate impacts of forest degradation and deforestation. To foster their implementation and adaptation by local and regional stakeholders (e.g. MNP, WWF, GIZ, COBAs), SuLaMa first developed guidelines (see Annex 10.2) that show in detail the relevant technical knowledge needed, as well as the preconditions for the successful reforestation of dry zones – based on a comprehensive literature review. It was made clear that the success of reforestation is closely dependent on the understanding of a complex mixture of socio-economic and political prerequisites on the one hand, and a sound knowledge of site-specific ecosystem functioning and species ecology and phenology on the other.

In a subsequent step, the project team assessed the readiness for implementing reforestation activities. For this, expert group discussions were carried out with local stakeholders to discuss the availability of areas suitable for reforestation attempts. Stakeholders agreed that degraded and abandoned agricultural fields have the potential to be used as reforestation sites. For these areas, the project team then applied a landscape level diagnostic to evaluate the presence of 27 relevant key success factors for the study region that have been found to increase the likelihood of successful restoration activities (Hanson et al., 2015). Knowledge about the presence/absence of these factors can help to prioritize future interventions of regional stakeholders for reforestation activities. Through expert group discussions, it was found that 12 key factors of the 27 were already in place in the study region, for example 'generation of economic, ecological and social benefits' through reforestation activities (see also Chapter 3.2.2) while six were only partly fulfilled, for example laws that 'restrict the clearing of remaining natural forests' exist, but are poorly enforced. Nine however had not yet been addressed at all, for example the lack of coordination among institutions, ministry agencies and other stakeholders at the regional level.

Furthermore, the team initiated and developed — in cooperation with local stakeholders — an experimental design for the development of reliable techniques to produce planting material of native tree species. The timely initiation of such experiments is of great importance, as restoring abandoned land requires ecological knowledge that can only be gained through long-term studies. The results of those trials will therefore serve as a valuable basis for future reforestation and rehabilitation projects in the study

Figure 20: Cultivation of samata (photo: Gertin Randrianabinina).

area by organisations such as MNP,WWF and local associations. Activities included the collection of seeds from local trees and the development of systematic documentation of experiment outcomes and lessons learnt. SuLaMa moreover developed a new nursery layout with local partners to ameliorate the drainage conditions as well as an experimental germination design assessing different nursery conditions (intensity of sunlight and shade) and frequency and type of watering. The aim was to identify best practices for seedling production of different species under the harsh environmental conditions of the study region (especially the high salinity of water used for irrigation). The field trials were developed and designed so that they could easily be adapted by local and regional stakeholders (e.g. MNP, WWF, COBAs) to examine other factors (e.g. type of soil). This aspect was especially important for continuation of these experiments beyond the project duration.

5.3.3 Cultivation of the fodder tree *samata* (*Euphorbia stenoclada*)

The propagation of *samata* via cuttings does not demand much material or technical knowledge besides some general practical knowledge and basic skills. Providing the villagers with this knowledge was thus a promising approach in supporting animal husbandry and to prevent the ecosystem from further degradation. As the multiplication is – compared to other species – relatively easy and besides regular watering, the young trees do not need much care, *samata* can not only be multiplied in standard nurseries, but also by the villagers themselves. In collaboration with the WWF, SuLaMa started a first *samata* community nursery in April 2015 together with the village community of Ampotaka and the local COBA (Figure 20). By September 2015, five nurseries (with 3,000 trees) were established, three of them together with village communities (Efoetse, Marofijery, Ankilibory), and the other two in cooperation with the teachers of local primary schools planting *samata* in school gardens (Ambola, Maromitilike). The nurseries are predominantly of a demonstration character, meaning that they do not mainly aim to increase the supply of *samata* fodder, but to display to the local population that multiplication is possible and easy to practice. Furthermore, a workshop with around 20 villagers from three *fokontany* took place in May 2015 at the experimental plot in Efoetse. The young trees resulting from the multiplication experiments were shown and the multiplication technique developed was explained in detail.

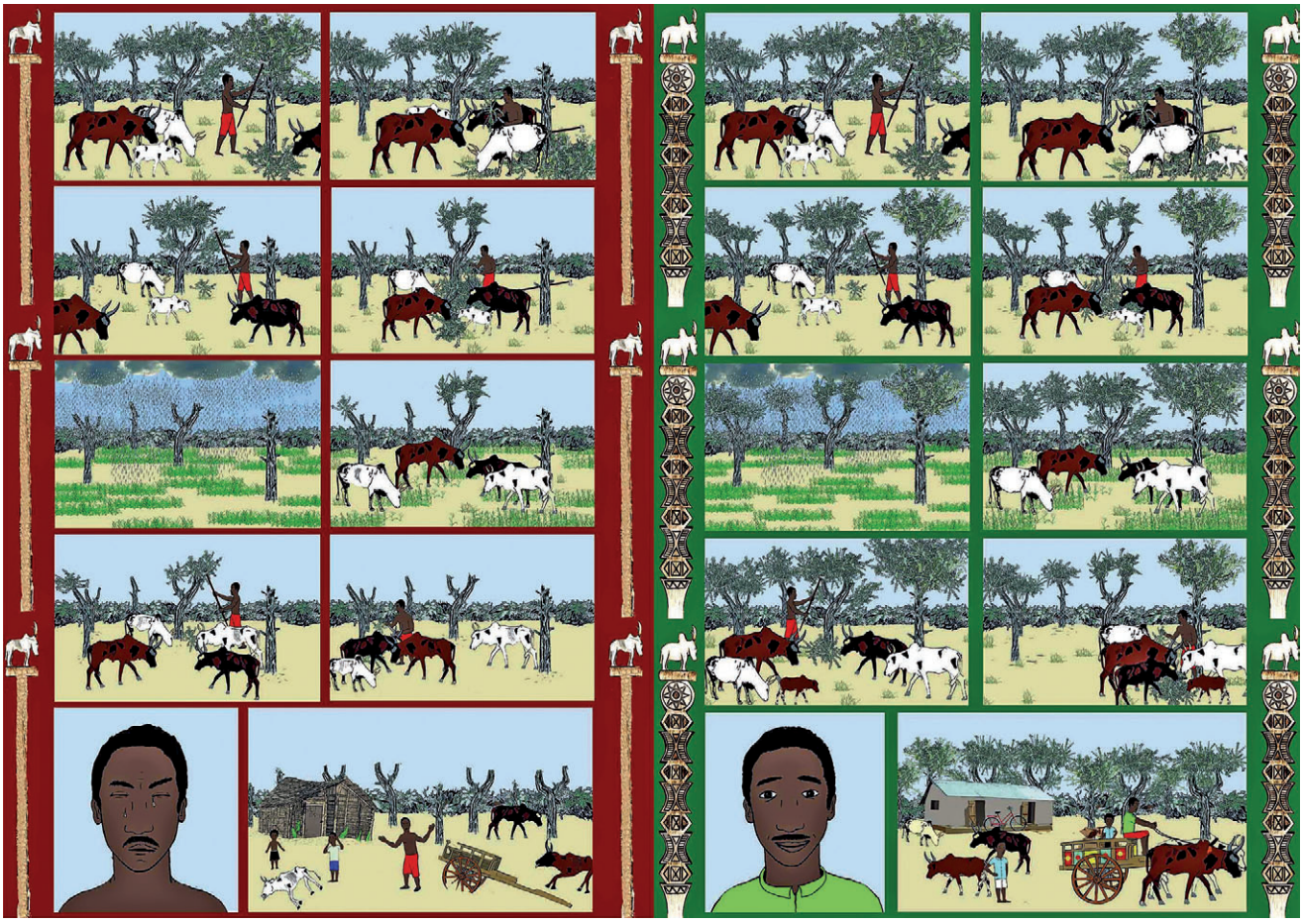

Figure 21: Comic strip showing unsustainable cutting of samata stocks (left), and the recommended technique (right). (David Weiss).

Figure 22: MNP staff during a training workshop for biodiversity monitoring (photo: Yedidya R. Ratovomanana).

Figure 23: A para-ecologist during a reptile monitoring exercise (photo: Joachim Nopper).

To promote more sustainable pruning techniques, a corresponding comic strip was produced (Figure 21). This comic illustrates that heavy cutting leads to re-growth problems, resulting in diminished fodder supply and, in the long run, problems in sustaining livestock herds. On the other hand, more selective pruning can have positive effects on the herds' health and size. Besides awareness-raising and facilitating multiplication at the local level, documents were prepared in French and English describing technical details of the multiplication, paired with an illustration of the problem of *samata* degradation and the potential of the multiplication approach (in: Liniger et al., 2016; see Annex 10.2). In this way, it is hoped to draw the attention of development organizations to the degradation problem and to promote *samata* multiplication. Additionally, documentary films were produced by WWF, WOCAT and SuLaMa with similar aims and content.

5.3.4 Community-based biodiversity monitoring

Environmental and biodiversity monitoring are among the key tasks of the Madagascar National Park authority. Up to present, effective monitoring over the whole area (Tsimanampetsotse National Park and the surrounding areas), however, has been hampered by the lack of MNP staff and the lack of integration of local people. Employment of local staff from villages surrounding the National Park (so-called 'ecoguards') was identified as a possible approach that could compensate for the lack of MNP personnel, and would also ensure communication of monitoring results to the local population. A first concept for a long-term monitoring programme was compiled in collaboration with WWF and MNP in 2015. A central part of this approach is the training of ecoguards together with local MNP staff and para-ecologists, who have been working in the SuLaMa project, and are proficient in monitoring techniques. Methods were developed jointly with WWF and MNP to fulfil the requirements for standardized biodiversity monitoring that can be easily applied by local staff and community-based assistants. To familiarize para-ecologists and MNP staff with the approach, a first training workshop was held in the Tsimanampetsotse National Park in late 2015 (Figure 22). A project was successfully launched and mainstreamed in mid-2016. Under this initiative, standardized monitoring of birds and reptiles in collaboration with MNP staff and local communities took place in the National Park and in 5 COBAS, respectively, in November 2016 (Figure 23).

5.4 Data integration and data management

5.4.1 Methods of managing data

SuLaMa guaranteed future access to project results and the integration of findings into regional SLM through *(i)* a concept for long-term data collection in collaboration with the regional university, local schools, and para-ecologists, *(ii)* the set-up of a regional database for stakeholders, *(iii)* the integration of project data into an overarching management plan for the complete Mahafaly region, and *(iv)* the provision of project metadata on an international level via online databases.

5.4.2 Long-term data collection through the regional university, local schools and para-ecologists

After two consecutive years of natural disasters including locust invasions, droughts and cyclones, the regional food security cluster has suggested the revival of a regional food security early warning system (*Système d'alerte précoce* – SAP). This continuous monitoring of food security indicators aims at enabling timely and ef-

ficient responses to disaster, as well as informing more strategic long-term interventions. Since 2014, SuLaMa supported the data monitoring system by providing socio-economic information and access to project equipment, such as weather stations for the collection of environmental indicators (rainfall and temperature). In this context, members of the regional communication platform developed an additional approach in 2015 that engages local schools, in collaboration with the University of Toliara, to regularly collect key indicator data, such as local market prices and rainfall, as part of classroom activities.

This approach offers advantages of cost-efficiency and continuity of data collection, as well as advantages for teachers in integrating real-world data and its relevance into the curriculum (e.g. in maths and geography). University students, in collaboration with the regional association, Maison des Paysans, and WWF's Toliara office are being trained to manage the collecting and organizing of data into the regional database as well as disseminating data and results of analyses to the wider stakeholder community. Curriculum implementation and data collection began in September 2015. SuLaMa supported the approach with scientific expertise, the involvement of former SuLaMa field assistants, students and the funding of workshops. Future ongoing training and supervision of students, teachers and technicians is planned to be continued by the University of Toliara, the WWF and the NGO 'Big red earth'. Since 2012 the para-ecologists have regularly monitored selected biodiversity components within the National Park (such as abundance and occurrence of key and indicator species). Monitoring activities were, and still are, coordinated from the research camp hosted by the University of Hamburg. The collected data are currently being integrated into the regional database hosted by the WWF, and serve not only the food security alert system but also the development of the long-term biodiversity monitoring programme. The National Park agency can also use the data for a continuous update on population size and distribution of endangered species.

5.4.3 Regional database for stakeholders

Most of the information compiled on past and current projects is not available through modern library services that focus on English, peer-reviewed references, while reports by NGOs or GOs, books and monographs often not available: the so-called 'grey literature'. As a result, many projects start out from scratch and are unaware of the existing documented knowledge. In cooperation with scientific and managing organizations (i.e. University of Toliara, WWF, MNP) – thus based on

Figure 24: Regional data base for partners and stakeholders in Madagascar.

the specific demands of project partners and regional stakeholders – SuLaMa developed a 'Regional Database' hosted by the WWF office in Toliara. It provides available knowledge about former and current research and development activities of local and regional organisations as well as SuLaMa's socio-economic and environmental data, and makes it transparent to partners and interested stakeholders (Figure 24). A joint database was one of the most important structures in the environmental context that was missing in Madagascar so far. It was vitally needed to serve as a source for information that would otherwise be lost. It provides references for future fieldwork and the development of management plans, and is therefore useful for all stakeholders who regularly carry out research or development projects in the region (GOs and NGOs). In the future, the database will serve as a drop-in-centre to make information on socio-economic and biodiversity aspects available to stakeholders upon request.

5.4.4 Integration of data into an overarching management plan – The 'landscape approach'

The 'landscape approach' of the WWF aims at integrating all conservation and development projects in the region in order to establish a comprehensive management plan that reaches beyond the study area. Since 2013, SuLaMa has contributed to the landscape approach by providing socio-economic and spatial data analyses, land use models, maps, GIS tools, long-term monitoring measures and recommendations. The strategy helps to reach decisions about the advisability of particular interventions, and to facilitate the planning and implementation of R&D activities across the whole Mahafaly region. Data management and GIS will be continued beyond the official project period and may serve further conservation and SLM projects as an infor-

mation base. The landscape approach thus provided a unique possibility for SuLaMa to contribute to an overarching management plan supported by many projects. Instead of focusing on the development of a suitable plan solely for the study area, the landscape approach ensures a sustainable management concept for the whole Mahafaly region.

5.4.5 Online databases – GBIF, WOCAT and SENVIS

To assure accessibility of the project results and data beyond the local and regional stakeholders, SuLaMa published articles in peer-reviewed journals and made the project's biodiversity information universally available by adding the data to the **Global Biodiversity Information Facility database (GBIF)**, which can be retrieved online (www.gbif.de). Furthermore, SuLaMa has submitted several contributions to the **WOCAT database** (on: www.wocat.net). These include techniques, approaches and instructional videos, e.g. on the MARP-Survey, Comic-style illustrations, *samata* cultivation, Biodiversity Monitoring and Role-playing games (in: Liniger et al., 2017; see Annex 10.2).

The project also established the **SuLaMa Environmental Information System (SENVIS)**, which is an information and database platform that provides disciplinary data of the project, e.g. climate data, survey data, metadata on scientific disciplinary data and literature, as well as geospatial data. SENVIS uses a Web-GIS application to provide geospatial data of different formats (e.g. satellite images, aerial photographs, land cover maps, land use and soil maps for three different village areas). The data can be accessed online (http://www.sulama.de or http://senvis-maps.sulama.de/) and different functionalities allow the user to browse spatial data, show metadata and attributes of the different layers, measure areas and distances and print a map of the region of interest. SENVIS is being continuously updated until the end of the project in December 2016. SuLaMa also provided an off-line version (DVD) for local stakeholders, which includes all SuLaMa products (e.g. reports, flyers, maps). Specifically, SENVIS consists of the following components:

a) ***Metadata Information System***
For the disciplinary data collected by the different work packages a metadata information system was established to facilitate interdisciplinary cooperation. Metadata summarizes and structures existing information regarding the disciplinary research activities, and provides background information about the scientific data collected within the SuLaMa work package. The metadata includes a short description of the data collected, the person responsible and work package, data type information, sampling and measurement methods, the availability and processing of the data, the study area and location and down-/upload functionalities for raw data (ACCESS database, Excel sheets, pdf, etc.). Each work package was responsible for the provision and revision of its own metadata.

b) ***Literature database***
This summarizes all relevant publications on research topics, which might be of interest to the SuLaMa research team. Due to limited user rights of some journal publications, this was mainly designed for internal usage within the SuLaMa group, but the final SENVIS version offers an updated and open-access version of the literature database, only including freely available articles and reports as well as project publications if possible (in other cases the abstracts are presented).

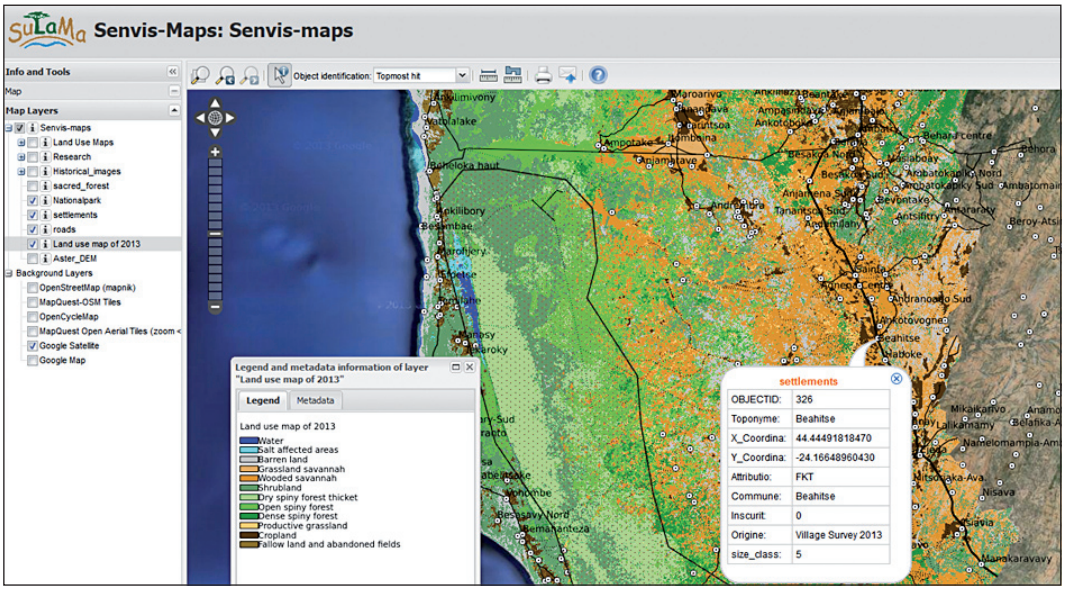

Figure 25: Screenshot of a map created with SENVIS.

c) ***Web-based GIS application (SENVIS Map Server)***
The Web GIS application was established using the open source QGIS Web Client, which is based on OpenLayers, GeoExt and ExtJS that makes use of QGIS specific WMS extensions. It can be used for a variety of different web mapping applications and provides a data model and web-based interfaces for displaying, navigating and querying OGC compliant map services and helps to manage, organize, protect and monitor map services, users and applications. Different functionalities allow the user to browse spatial data, show metadata and attributes of the different layers, measure areas and distances and print a map of the region of interest (Figure 25). GoogleEarth and GoogleMaps information can be displayed in the background.

5.5 Knowledge transfer and capacity building

5.5.1 The need for capacity building

As remarked on the communication platform and during several meetings and workshops with stakeholders and partners at the beginning of the research phase, there was (and still is) a special need for capacity building of villagers through participatory methods, as well as of local extension workers and researchers, to assure continued support to the farmers in long-term on-farm trials. SuLaMa therefore started to intensify the capacity building and knowledge transfer at regional universities and in rural communities as described in the following sections.

5.5.2 Regional universities

The tandem approach and the annual summer schools with regional universities was a successful strategy to involve academic stakeholders and to enhance capacity building in Madagascar. It could potentially serve as a general approach for further research projects. Another important cooperation activity in terms of capacity building involved the Institut Supérieur de Technologie (IST) situated at the University of Toliara. The IST offers a three-year programme in agricultural sciences, but at the beginning of the project, this programme was very theoretically oriented; that is the students had little practical experience. This department, founded in 2011, is relatively young and necessitates a strong education base and continuous link to regional stakeholders for students to become an asset for agricultural development in the region. As students graduating at the IST will in the future represent a major group of potential employees for Malagasy and international organizations and institutions working in the sector of agriculture and development in the south-west, a more practical approach would be essential.

In this context SuLaMa supported the development of a concept for an 'Applied Research' module in order to strengthen and/or introduce essential competencies. Furthermore, a strong link is being established with the regional stakeholder group 'Cluster Sécurité Alimentaire Sud-Ouest', which clusters the above mentioned partners and other projects, to be able to continuously integrate SuLaMa's, as well as the other organizations', research and development activities and results into the curriculum. The module includes group working, learning and implementation of scientific methods and statistical know-how, computer engineering and communicational skills. Furthermore it allows testing and application of agricultural techniques, starting dialogues with relevant stakeholders (NGOs, projects, programmes of the conservation and agricultural sector), identifying interesting and relevant research questions, developing adequate experimental designs for data collection and analysis. The communication between students and villagers during the field experiments and associated workshops are seen as an especially important step towards sustainable implementation of alternative land use techniques. The goal is the aggregation of knowledge and a more coordinated extension of research output into the south-west, including the Mahafaly Plateau, as well as the long-term capacity building of villagers to manage their common resources. In 2015, the concept for the integration of practical components into the existing IST study programme was developed with local partners (WWF, University of Toliara) and interested stakeholders (NGOs and other participants of the regional discussion platform). The initial workshops and experimental trials were started in June and December 2015, respectively.

Apart from the regular courses at universities, SuLaMa offered a training course for Malagasy scientists and WWF staff on the application of agent based models using NETLOGO (www.nelogo.com). During the course, basic knowledge on scenario development as a future decision-making support tool was imparted. The transferred know-how can be used to integrate project results, e.g. outcomes of the study on the cultivation of local yams varieties, into the SuLaMa land use model (SEALM) in order to simulate the cultivation of yams as a further land use option, and to allow it to be evaluated economically.

5.5.3 Awareness-raising workshops

During the projects' implementation phase, SuLaMa's researchers and socio-organizers conducted several

initiatives for awareness-raising in the study villages. This included regular information meetings on sustainable techniques and approaches developed in the fields of agriculture, animal husbandry, and the use of natural resources. To this end SuLaMa's recommendations on SLM techniques were presented via practical demonstrations and with the help of comic style illustrations and brochures. In cooperation with the NGO, ABC Domino (an organisation dedicated to establishing private schools), the socio-organizers established self-organized school gardens in the coastal area through which teachers, parents and students can learn about improved cultivation techniques based on results and recommendations provided by SuLaMa and partner organizations. The school garden concept will be continued by WWF and ABC Domino. Regarding future research and assistance in the SLM sector, SuLaMa's socio-organizers, as well as para-ecologists can provide their knowledge/services to other regional or local stakeholders (e.g. to the National Park Agency for biodiversity monitoring, to development aid organizations, or other managing organizations active in the region).

5.5.4 Comic-style illustrations

To communicate scientific results and recommendations on sustainable land management, and ensure knowledge transfer from scientific experts to local people, comic-style illustrations of visual narratives were designed for environmental education purposes (Figure 26). Comic (i.e. cartoon) illustrations were prepared to show the impact of different land use techniques on the environment and local livelihoods using two contrasting stories/scenarios: a 'worst case' scenario of unsustainable land use techniques that were often applied by local inhabitants, and an example of a 'best case' scenario based on an alternative, recommended, sustainable land use option. To keep the story simple and understandable, the focus was on key messages, which could be easily transformed into visual narratives – and technical details were left aside. Based on the research on the diversity and local use of forest resources and sustainable land use techniques in animal and crop husbandry, key messages and recommendations, which were easy to implement, were formulated. Two examples of over-utilized natural resources and an example of a so-far neglected soil improvement technique were chosen for comic-style illustrations and transformed to visual narratives: *(i)* sustainable harvesting practice of wild yams (*Dioscorea bemandry*), *(ii)* composting manure and its application to improve soil fertility and yield in homegardens, *(iii)* sustainable utilization of the succulent tree *Euphorbia stenoclada* (*samata*) as supplementary forage for livestock.

5.6 Scientific audience and public relations

Stakeholder communication also included the presentation of results to scientific audience and the broad public. SuLaMa's scientific results were presented in publications and at several conferences and workshops (see Chapter 9.1, Annex 10.3). The project participated in conferences covering climate change, desertification and biodiversity conventions (i.e. UNCCC COP17, UNCCD COP11, UNCCD COP12, and the UNCBD COP13). A list with articles in popular scientific journals can be found under www.sulama.de and in Chapter 9.1. In 2013, a documentary of SuLaMa's work, with a focus on cultural aspects and natural conservation (entitled: '*Auf Expeditionsreise nach Madagaskar – Ökosystem in Not*'), was broadcast on German and French ARTE TV. It gave SuLaMa the opportunity to reach interested people outside the scientific community. From April to July 2015, the Zoological Institute at the University of Hamburg hosted an exhibition called '*Participatory research for the development of sustainable land use alternatives in Madagascar*'. The goal of the exhibition was to use multiple media to give the public an understanding of both the unique biodiversity of Madagascar and current research aspects.

Figure 26: Comic-style illustrations of visual narratives designed by David Weiss (left); local children reading the comic on sustainable harvesting of wild yam (right; photo: Katja Brinkmann).


Johanna Götter

Chapter 6

Challenges and highlights

6.1 Political circumstances

SuLaMa was faced with the challenge of political instability in Madagascar, especially during the first project period from 2011 to 2013. The crisis in 2009 provoked unforeseeable changes in legislation and the presence of local authorities. Due to the political situation, international government funding was reduced and some key persons from the Malagasy partners involved in the project design had to be dismissed, which affected our collaborators, such as MNP, WWF and GIZ in Madagascar. Due to the international sanctions and interrupted budgets for development aid between 2009 and 2013, the situation for Madagascar's population (especially for the rural communities) became even more alarming (e.g. increasing food prices, declining infrastructure, insufficient medical care). One serious problem that emerged from the political instability was an increase in crime in many parts of the island, especially in the southern region. In particular, the increased theft of cattle caused not only security issues, but also incalculable social and economic problems. This also negatively affected the tourism sector (MNP data, 2013).

In addition to the political crisis, the fact that governance structures are generally relatively weak in the region, and their de facto power to enforce land use regulations is low, hinders the implementation of those approaches that require a legal framework. As a consequence, what is required are research recommendations that work at the community-based management level, or with individual farmers. All the more important is the involvement of local land users and non-governmental organizations in order to learn about their problems and advancements and to foster long-term communication between the different parties. It was a specific challenge to integrate the various levels and interests of these stakeholders into the project's research and implementation process.

Despite, and perhaps partially because of, the dramatic political situation, the fact that SuLaMa had been developed as a joint Malagasy–German initiative from the very beginning was keenly acknowledged and led to a very warm welcome from all parties involved. As one of only a few international projects being active in the study region during the political crisis, the project played a major role in developing and maintaining the network of stakeholders in the region. It is encouraging that by now most of the ministries are functional and many development agencies and programmes have restarted their work. That could be clearly seen during the final conference of SuLaMa in Toliara, where state agencies emphasised their interest in joint future research and development activities.

6.2 Communication, expectations and perspectives

A common challenge for R&D projects is certainly that people often look for a quick way to gain grants or aid through the project and then (if successful) to prioritize the project over other organisations working in the same area. Thus, it was important to introduce the project in a way that it was not perceived as a source of 'handouts'. One of the major challenges during SuLaMa's project time was to enable and keep a constant exchange between researchers and the local population despite different languages (although French is an official language the majority of the rural population speaks Malagasy – and in different dialects), cultures and perspectives. In this context, the work of the socio-organisers from WWF Toliara was excellent and essential for the work in the villages to explain the benefits for the villagers from cooperation and to act as a cultural link.

It is important to note that not only the perspectives of politicians, local land users and scientists on land management related problems differ to a large extent. The perspectives also can vary considerably among scientists from different research areas and nationalities (in SuLaMa's case, Malagasy and German). It was thus a crucial to find ways for the integration of

differing perspectives to reach an on-going transdisciplinary dialogue, and thereby avoiding a sole western top-down perspective concerning sustainability and biodiversity conservation.

6.3 Regional coordination of research and development activities

A further challenge was to handle the complexity of existing interventions in the study region. Stakeholders and regional authorities continuously remarked that there was a need for better coordination between actors and documentation of ongoing interventions to improve decision-making. Most organizations and institutions active in research and development of land use practices on the Mahafaly Plateau work under parallel hierarchies, which makes the coordination of their activities problematic. This is especially true of the agricultural sector, which has been a major focus of several NGOs as it is the main activity for subsistence and income for the majority of the people. The challenging frame conditions regularly throw the population back to a dependence on food and seed relief aid. Many organizations have the same focus, such as the dissemination of seeds and development of alternative cropping practices, with various forms of farmer participation and training. There is an increasing effort to coordinate activities across these various organizations, but so far this often only focuses on short-term responses to disaster to tackle the neediest communities, while coordination, or a common principle in the testing and dissemination of particular agricultural techniques, is lacking.

Though the regional communication platform certainly helps to identify synergies in development strategies, effective coordination of the various activities in the study area remains difficult. However, it was very encouraging that so many regional state agencies, NGOs, projects and programmes participated regularly on the platform and in the several project workshops. This demonstrated interest in SuLaMa's work and stressed the willingness of regional stakeholders to jointly evolve long-term solutions for better-coordinated sustainable land management and nature conservation. In this context, the establishment of the regional database, the integration of project data into an overarching landscape management concept and the implementation of capacity building programmes by SuLaMa was much appreciated by all parties involved.

6.4 Remoteness, infrastructure and climatic conditions

Logistics represented a challenge due to the remoteness, and because of the unfavourable infrastructure and extreme weather events. As a consequence, some time frames and topics of sub-projects required adjustments compared to the initial application (see Chapter 7.4). The remoteness of the research area and climate (i.e. cyclones, wind, dust, salt) sometimes lead to difficulties in transport of people, and the handling of material, and required back-up organisation and flexible planning. Due to the poor infrastructure within the research area (condition of roads, lack of sanitary facilities within the villages, health issues, etc.) working conditions in the field were difficult and always demanded thorough preparation. Thus, the organisation of the fieldwork was especially challenging, not only for students but also for the coordination team. During the first period of the project there were some problems concerning the purchase of important items (cars, field equipment etc). However, the good collaboration with the WWF in Toliara solved many logistic problems, as it offered a joint project-office and supported research activities in the field (through cars from the WWF car pool, purchase of campsite equipment, reservation of accommodation, etc.).

Besides the consequences of the political 'seesaw', the unpredictable and harsh climate was one of the major problems for the team, especially with respect to experimental field work. In 2013 a heavy cyclone ('Haruna') destroyed thousands of houses and damaged crops (mainly maize). An extreme locust invasion followed the intense rainfall brought by the cyclone, resulting in the worst outbreak for 17 years. The locust plague became a major concern, due to the passage of several swarms through the Mahafaly Plateau, which destroyed vast areas of crops – and also many experimental field plots (Figure 27).

The challenging frame conditions including different languages, cultures, and perspectives, demanded a certain openness and flexibility from all parties involved, as project aims had to be re-interpreted, discussed anew or even completely altered during the course of the project. The situation required substantial flexibility from project planning and management.

Figure 27: Locust swarm arriving in a village on the Mahafaly Plateau (photo: Johanna Götter).

6.5 Special highlights

A particular highlight was the group spirit of SuLaMa between Malagasy and German partners – who, as we have noted, collaborated closely. The work with PhD counterparts in all work packages facilitated constant exchanges of perspectives and rendered research easier for both sides. This became especially visible during the various workshops held in Madagascar in which German and Malagasy PhD students participated. Furthermore, the annual interdisciplinary field school run by zoologists (Vahatra), botanists and social scientists (SuLaMa-staff) was a great success. SuLaMa developed a positive image in Madagascar, and as a result, the project received many requests for participation and extension of the programme.

The collaboration with partners and stakeholders in the form of product development and implementation was a particular highlight. The regional project partners supported the SuLaMa not only with advisory, but also with technical, administrative, logistical and staff support. Furthermore, they clearly stated their interests and role in the ongoing land use transformation process and hence enabled a focused investigation of current and future problems for the dry forests of southeastern Madagascar.

The workshops with local communities (MARP, RPGs and final village workshops) were further major highlights since they were conducted and implemented jointly by the various disciplines and partners. The MARP formed a basis for the subsequent project work in the field and introduced SuLaMa's ideas and objectives to local stakeholders. The MARP and RPGs were instrumental to understand the production system and the social situation in the research area. They had a significant, positive, impact on the communication and mutual understanding between the different work packages and their specific research aspects. The community workshops fostered the development of team spirit and a common idea of SuLaMa's vision by all participants to improve land management on the Mahafaly Plateau.

The success of the project was mainly due to mutual trust between the local communities and long-term engagement of researchers. Communications of the results by non-scientific mediators was the key for the understanding and acceptance.


Tahiry Randrianoson

Chapter 7

Project performance and reflection

7.1 Work plan fulfilled

The project successfully achieved all project milestones according to the work plan set by the consortium in 2012 – as presented in Table 1. In the following sections the SuLaMa team reflect on the role of the sub-projects, responses and amendments to the reviewers' feedback from the evaluation in 2012, modifications of the working programme due to new insights into the socio-ecological system and/or changes in external drivers such as political and climatic constraints – but also personnel changes, and last unintended and unexpected consequences. Additionally to the official project time from 2011 to 2015, one extra year was granted by the BMBF in order to continue the implementation and final outreach of the projects' results, techniques and approaches.

7.2 Integration of sub-projects (workpackages)

The management of a multi-faceted project is a complex challenge of organizing, communication and planning. One core activity of SuLaMa was thus the organization of regular meetings and workshops in order to align and harmonize activities within the project and amongst the different disciplines. In Germany and Madagascar, workshops were convened twice a year, giving researchers from different work packages the opportunity to jointly discuss next steps and define common goals. The tandem approach and the joint research sites for all project members fostered exchange between Malagasy and German researchers irrespective of their work disciplines. Both aspects facilitated the development of interdisciplinary projects such as the cultivation of alternative livestock fodder plants; a multi-cross approach that involved the knowledge and engagement of all WPs.

In particular, the community workshops (MARP, RPG) were designed to be interdisciplinary approaches, linking research tasks amongst all sub-projects. Both events were perceived as important milestones where German and Malagasy researchers met personally and had time to set their research in an interdisciplinary context. The MARP survey formed a very good basis for all subsequent collaboration activities. It was implemented and conducted jointly by nearly all German and Malagasy PhD students and Post-Docs, and had a positive impact on the communication and mutual understanding between the different work packages and their specific research aspects. The MARP fostered the development of team spirit and a common concept of SuLaMa's vision by all participants.

During the status workshop with all partners in Germany in 2013, it became clear that SuLaMa had to strengthen even more the communication among project disciplines in order to integrate the various contributions into the projects' overall aims, especially in respect to the implementation period. To this end a logical framework was developed to define, monitor and evaluate activities, outputs, purpose and goals of the single disciplines into an overarching framework. Furthermore, product development workshops were organized in Germany and Madagascar where the team defined products for different topics (agriculture, forestry, stakeholder processes, knowledge management), listed possible target groups in Madagascar, and determined the respective contributions and responsibilities of all work packages and researchers. The established communication strategies served all participants as platforms to coordinate their work plans, to form task groups, to facilitate information exchange, and to provide scientific publications, results and other materials. The strengthened exchange between project members led to trust-based and efficient cooperation among sub-projects and the successful cohesion and performance of the consortium as a whole.

All work packages contributed to the modelling approach with data provision and integration as well as with different sub-modules of the land use model. This included units for livestock, forest, households and hydrogeology. The baseline and household surveys provided baseline information for all sub-projects on the household characteristics in the research area,

Table 1: Overview of project work plan and milestones.

Year	2011 I				2012 II				2013 III				2014 IV				2015 V				2016 VI			
Quarter	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
1. Set-up of SuLaMa's administrative, technical and staff structure																								
2. Selection and establishment of study sites completed and inter- and transdisciplinary research activities started (MARP completed)																								
3. Structures for continuous stakeholder involvement and capacity building established																								
4. Continuous cooperation with GLUES established																								
5. Participatory GIS and collection of relevant spatial information on land-use started																								
6. Baseline survey II / Household survey completed																								
7. Development of storyline concepts with stakeholders																								
8. SENVIS 1.0 established																								
9. Analysis of ESS/F of current land use types and inter- / extrapolation of indicators completed																								
10. Development of scenarios and conceptual modelling framework completed																								
11. Identification of criteria and development of approaches for trans-regional upscaling land management options with stakeholders completed																								
12. Implementation phase																								
13. Participatory measures for a concerted integration of proposed land management and knowledge transfer developed and discussed with decision makers																								
14. Management plan for sustainable land use developed																								
15 Final outreach																								

and formed the basis for the RPG workshop and the household module in the SEALM. Moreover, interdisciplinary studies and field trials were carried out. Agronomists and agro-economists worked together in innovation experiments on vegetable cultivation in gardens, and manure application in combination with more drought tolerant maize varieties. When researching local institutions and governance, social scientists and economists collaborated closely and triangulated their results. In the end, data from all sub-projects were integrated into the land-use models, which were validated in a participatory way.

7.3 Responses to reviewers' feedback

In 2012, a major external project evaluation took place. The committee of reviewers generally praised the project for being well-rooted in the study region. However, it was critical of the fact that the ecosystem services concept had not yet been applied sufficiently and ecosystems services and functions in the Mahafaly region had not yet been assessed systematically at that time. In response to this feedback, SuLaMa worked intensely on the topic. In a SuLaMa-ESS workshop in Hamburg the 'stepwise-approach' (Förster et al., 2013) was used to structure and reduce the complexity of assessments by focusing on situations where ESS information had a direct impact on decision-making. Furthermore, a detailed report on ecosystem services and functions of the regional ecosystems was produced taking the results of the MARP survey and supplementing inventories into account (listed in Annex 10.2). The study revealed that livelihoods in the Mahafaly region intimately depend on the ecosystem services supplied by natural and agro-ecosystems. Biophysically, the region is characterized by unique ecosystems and species, of which many are endemic to the area and used for a wide variety of purposes. These ecosystems continue to deliver provisioning services, regulating services, supporting services and cultural services required for the well-being of the local population. However, arid climatic conditions resulting in water scarcity, poor soil quality, low and unreliable crop yields, combined with population growth, and the increasing demand and conversion of dry forest to agricultural and pasture lands leading to deforestation, are aggravating the depletion of ecosystem functions and services delivered by the region. But although the maintenance of ecosystem services and goods in the region remains a challenge, SuLaMa's findings, recommendations and implementation initiatives can be seen as promising tools for the preservation of the ecosystem services.

Another recommendation was that the ecosystems' resilience should be analysed more intensely, and features or aspects of ecosystems that maintained or even increased their resilience should be identified. In this context, the project analyzed the complex interactions of the social-ecological system, and provided scenarios to estimate the pressure on available land resources in the study region, reflected in past and current deforestation rates and fragmentation of the remaining forest. Many of SuLaMa's techniques and approaches that were or are in progress to be implemented were developed in order to reduce pressure on the natural ecosystems and thus improve resilience to stresses such as climate change and population growth. These strategies include, amongst others, sustainable collection methods of wild crops (e.g. yams) and their domestication, plantations of alternative livestock fodder, reforestation activities, community-based monitoring of natural resources, etc.

In regard to the stakeholder analysis, the reviewers claimed that the analysis should go beyond a mere identification of stakeholders at different levels. Rather, stakeholders should be assessed regarding their influence and interaction with other stakeholders. In response to this criticism, the stakeholder analysis was deepened (see Chapter 2.1). Stakeholders were categorized and a communication and partnership strategy was determined. It became obvious that the key stakeholders in the region were conservation and development actors as well as traditional authorities and local communities, and academic stakeholders in Madagascar.

Following the recommendations of the evaluation in 2012, SuLaMa added a new component in agricultural economics to the research programme. This additional work package (WP7: Agro-economics) under the University of Göttingen investigated innovation processes. The reviewers remarked further that the classical experimental multifactor design for agricultural trials were as not ideal for the project region as experimental fields and planting material were non-homogeneous. It was therefore recommended to adopt a more simple demonstration strategy directly on the fields of farmers to foster ownership and motivation among local land users. After the evaluation, farmer field schools were implemented and the new work package including a PhD position was integrated into the project. The task of the new work package was to investigate agricultural innovation processes in the research region. In collaboration with WP2, the work package conducted innovative experiments on vegetable cultivation in gardens and manure application, in combination with more drought-tolerant maize varieties.

Regarding the PES scheme, the reviewers commented that the complicated, spatially targeted PES scheme as envisaged in the proposal was not suitable for the region as poverty, diversity of ethnic groups instability and security make a system of defined payments to specific stewards of ESS difficult. Here, the original task was changed into an analysis and development of three selected innovative PES design issues in the context of poverty both on the demand and supply side of an ecosystem service (see Chapter 3.2.3).

The midterm evaluation in 2014 reflected that particularly the capacity enhancement including the tandem-approach and the IST cooperation was a promising approach to build an interface between science and practice. Furthermore, the intense evaluation of underlying assumptions at the beginning of a project (i.e. through the participatory rural appraisals at the start of SuLaMa) can be seen as a crucial step regarding the implementation of the further project design.

7.4 Reconsidered or cancelled activities

Though having clear objectives, SuLaMa followed a flexible project design, which was modified during the course of the project. The MARP survey in particular, and the evaluation in 2012 helped to adapt and concretise the research designs of the individual work packages. Three major changes to the original work plan are exemplified here:

- The research and implementation periods cannot be considered as completely separate temporal units. Some research activities had to be postponed, modified or discussed anew, for example due to new insights, identified data gaps, new cooperation options or personnel changes, and thus could not be finished until 2013. On the other hand, some implementation projects were already initiated before 2014.
- As planned in the proposal and working programme (Table 1), SuLaMa aimed at developing a management plan regarding sustainable land use for the project area. However, the cooperation with conservation and development stakeholders on-site revealed a multiplicity of strategies and projects. As SuLaMa's duration was limited to five years, it was found more sensible to offer the project's findings and recommendations to existing long-term programmes in the region. In this context the landscape approach of the WWF offered a unique opportunity to integrate SuLaMa's results and data into comprehensive regional SLM planning. The landscape approach is intended to coordinate implementation of activities across a whole landscape, cooperating with a multitude of stakeholders and combining results from different programmes and projects.
- In 2014 SuLaMa added a hydrogeological component to the project. Although small-scale irrigation projects were originally planned in the proposal, the water issue became more complex than expected. The problem with the limited availability of water was underestimated before the project start, so the envisaged irrigation projects had to be implemented by WWF. In response to the misjudgement of the freshwater problem, especially in terms of improving agro-pastoral systems, the work plan was supplemented with a hydrogeological component in 2014. For SuLaMa's own irrigation experiments the results came too late, but for a variety of stakeholders the information gathered will be helpful, since it demonstrates the limited potential of groundwater as freshwater reservoirs and underlines the necessity of desalinisation plants for the coastal area.

7.5 Unintended and unexpected consequences and outcomes

Some implementation potentials evolved from topics, which were not considered to be relevant at first. A good example is the *samata* fodder tree that was not on the agenda of R&D projects, neither among the SuLaMa researchers – nor other local organizations. However, the trials and workshops on *samata* cultivation evoked great interest among local communities. In some villages people asked proactively to plant *samata* tree nurseries and organized the care of the nurseries themselves.

Adjustments of the typical project design were necessary to enable real co-production of knowledge together with local stakeholders and relevant research according to local needs: for example an exploratory pre-phase of research projects before fixing tasks, research questions and approaches of individual disciplines. In theory, the combination of research and implementation activities in a transdisciplinary setting is promising. However, it might be more efficient for future projects to closely cooperate with development aid agencies (e.g. GIZ) during all project phases (definition of research objectives, research activities and implementation). These aid agencies should then be ready to adopt the jointly developed measures for long-term implementation.


Jacques Rakotondranary

Chapter 8

Collaboration with GLUES and other regional projects

An important achievement during the first project phase was the establishment of the continuous co-operation with the scientific coordination project GLUES. SuLaMa participated in GLUES-organized workshops over the whole project period. The very good collaboration between the coordination teams of SuLaMa and GLUES facilitated the exchange and transfer of information for the organization of joint events and products. Bilateral meetings with the GLUES teams for data integration, stakeholder work, science policy interface and public relations and SuLaMa took place regularly. SuLaMa provided material for public and scientific outreach, for example the presentation of SuLaMa's objectives and results through GLUES at international conferences and conventions (UNCCC, UNCCD, UNCBD) and the GLUES webpage (quarterly letter, programme description, see also under http://nachhaltiges-landmanagement.de/en/scientific-coordination-glues/). Jointly developed outreach products included a scientific portrait and video clip of SuLaMa's work were jointly developed, as well as several contributions to the LAMA conference in February 2016.

Furthermore, the integration of SuLaMa's spatial data into 'Medium-Term Projections' and 'Long-Term Scenarios' developed by GLUES was an important task. Other emphases were placed on the integration of project results into decision-making (i.e. science policy interface) and the work with local and regional stakeholders. Moreover, there was discussion about suitable tools and approaches for the ESS assessment in two ESS-workshops, thereby focussing directly on SuLaMa's specific problems/solutions, stakeholder perspectives and information needs in decision-making. The workshops organized by GLUES offered platforms for exchange and discussions with participants of other LAMA projects, for example concerning the possibilities of international outreach under the framework of UN conventions.

SuLaMa also contributed to a cross-project publication in Ecology and Society on the issue of ecosystem services assessment for informing land use decisions under the lead of Johannes Förster (UFZ/GLUES; Förster et al., 2015). Besides SuLaMa, several other projects from the Sustainable Land Management Programme Module A (i.e. LEGATO, COMTESS, SuMaRiO, and INNOVATE) participated in the joint publication. Currently, SuLaMa project results are being integrated into an ESS metadatabase design that will provide relevant information on quantitative indicators for the assessment of ESS/F. To support the GLUES/WOCAT process (under which GLUES identified a partner with long-term and extensive experience in documenting SLM – i.e. WOCAT), SuLaMa participated in the development of the GLUES/WOCAT book on Sustainable Land Management (Ligener et al., 2017), and submitted several techniques and approaches as well as instructional videos to the WOCAT database (see Annex 10.2). The collaboration with other projects included joint publications, sharing experiences and findings, and exchange on transdisciplinarity and stakeholder involvement tools. The excellent cooperation amongst the projects will permit future joint proposals and research including the knowledge gained from more than six years of experience in SLM on a global level.

Chapter 9

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Chapter 10

Annex

10.1 Acronyms and Abbreviations

ABM	Agent-Based Modelling approach
ACCESS	Alliance Center for Collaboration, Education, Science, and Software
ACF	Action Contre la Faim
AICPM	Association Inter communale de Plateau Mahafaly
ANGAP	Madagascar National Parks = MNP
ASI	Alternative Sources of Income
BMBF	Bundesministerium für Bildung und Forschung
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour Développemente
COBA	Communauté de Base
COGESFOR	Sustainable Resource Management for the Conservation of Regional Biodiversity Hotspots (WWF Project)
COP	Conference of the Parties
COMTESS	Sustainable Coastal Land Management: Trade-offs in Ecosystem Services (FONA Module A Project)
COSAP	Comité d'Orientation et de Soutien à l'Aire Protégée
CVO	Comité de Vigilance Opérationnelle
DBH	Diameter at Breast Height
ESS	Ecosystem Services
ESS/F	Ecosystem Services and Functions
FFEM	French Facility for Global Environment
FID	Fonds d'Intervention pour le Developpement
FOFIFA	National Agricultural Research Center
FONA	Forschung für Nachhaltige Entwicklung
GBIF	Global Biodiversity Information Facility database
GEF	Global Environment Facility
GIS	Geoinformation Systems
GIZ	Gesellschaft für Internationale Zusammenarbeit
GLUES	Global Assessment of Land Use Dynamics, Greenhouse Gas Emissions & Ecosystem Services (FONA Module A Project)
GO	Governmental Organisation
INNOVATE	Interplay among multiple uses of water reservoirs via inNOVative coupling of substance cycles in Aquatic and Terrestrial Ecosystems (FONA Module A Project)
IST	Institut Supérieur de Technologie
KfW	Kreditanstalt für Wiederaufbau
LAMA	Sustainable Land Management
LEGATO	Land-use intensity and Ecological Engineering – Assessment Tools for risks and Opportunities in irrigated rice based production systems (FONA Module A Project)

LULCC	Land Use and Land Cover Changes
MARP	Méthode Accélérée de Recherche Participative
MGA	Malagasy Ariary
MNP	Madagascar National Parks = ANGAP
MRV	Measuring, Reporting and Verification
NGO	Non-Governmental Organization
NTFP	Non-Timber Forest Product
OGC	Open Geospatial Consortium
PES	Payments for Ecosystem Services
PGM-E	Programme Germano-Malgache pour l'Environnement
PRA	Participatory Rural Appraisal
PSDR	Projet au Soutien du Développement Rural
QGIS	Quantum Geographic Information System
R&D	Research and Development
RCP	RDA (Radar Data Acquisition) Control Processor
REDD+	Reducing Emissions from Deforestation and (Forest) Degradation(+)
RPG	Role-Playing Games
SAP	Système d'Alerte Précoce
SEALM	SuLaMa Empirical Agent-based Land-use Model
SENVIS	SuLaMa Environmental Information System
SFM	Sustainable Forest Management
SOARANO	Malagasy NGO on Water Management
SLM	Sustainable Land Management
SuLaMa	Participatory research to support sustainable land management on the Mahafaly Plateau in southwestern Madagascar (FONA Module A Project)
SuMaRiO	Sustainable Management of River Oases along the Tarim River (FONA Module A Project)
TEEB	The Economics of Ecosystems and Biodiversity
UFZ	Helmholtz-Zentrum für Umweltforschung
UNCBD	United Nations Convention on Biological Diversity
UNCCC	United Nations Climate Change Convention
UNFCCC	United Nations Framework Convention on Climate Change
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme (PNUD in French)
UNICEF	United Nations International Children's Emergency Fund
UNPF	United Nations Population Fund
VOI	Vondron'Olona Ifotony
WFP	United Nations World Food Programme
WHO	World Health Organization
WOCAT	World Overview of Conservation Approaches and Technologies (Switzerland)
WP	Work package
WWF	World Wide Fund for Nature

10.2 Products and WOCAT contributions

10.2.1 Non peer-reviewed articles, reports, manuals, brochures, leaflets and flyers

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10.2.2 WOCAT contributions

Contributing authors from SuLaMa to: Liniger HP, Mekdaschi Studer R, Moll P, Zander U (2017) Making sense of research for sustainable land management. Centre for Development and Environment (CDE), University of Bern, Switzerland and Helmholtz-Centre for Environmental Research GmbH – UFZ, Leipzig, Germany.

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Kobbe S, Kübler D, Nopper J	University of Hamburg, Germany
Brinkmann K, Feldt T	University of Kassel, Germany
Fricke R	University of Marburg, Germany

Database with SLM technologies and approaches by SuLaMa.

SLM technology/ approach		code	Common name
SLM Technology	Goetter, Johanna Madagascar	T_MAD002en	Sustainable propagation of the fodder tree *Euphorbia stenoclada* ('samata')
SLM Approach	Maren Wesselow Madagascar	A_MAD002en	Role-Playing Games in Natural Resource Management
SLM Approach	Tobias Feldt Madagascar	A_MAD003en	Increasing environmental awareness using comic-style illustrations as a visual communication tool
SLM Approach	Nadine Fritz-Vietta Madagascar	A_MAD004en	Rapid and Participatory Rural Appraisal Study (MARP)
SLM Approach	Joachim Nopper Madagascar	A_MAD005en	Participatory monitoring and evaluation of long-term changes in ecosystems

Videos showing SLM technologies and approaches by SuLaMa.

Title	Description
La culture durable de l'arbre fourrager Samata à Madagascar	The video shows the sustainable use and technique of multiplication of cuttings of the samata tree (*Euphorbia stenoclada*) with the objective of the long-term supply of more fodder for livestock to reduce the pressure on natural vegetation. Produced by SuLaMa and WOCAT.
Des jeux de rôle pour la gestion des ressources naturelles	The video explains how two role-playing games are used to understand and to discuss the decisions of small-scale farmers in Madagascar. While in the first game, farmers simulate their livelihood decisions in 'normal' times and in times of drought, the second game focuses on livestock decisions in view of seasonal fodder scarcity and cattle raiders. In preparation.

10.3 Conference contributions

10.3.1 Talks

2016

Andriamparany J: Role of yam species and medicinal plants for food self - sufficiency and farmers' livelihoods in SW Madagascar. Sustainable Land Management – Final Conference 2016, Berlin, Germany.

Brinkmann K: Agent - based modelling of subsistence agriculture and land cover changes in SW Madagascar. Sustainable Land Management – Final Conference 2016, Berlin, Germany.

Englert A, Brinkmann K, Kobbe S, and Buerkert A: Dynamics of Small-Scale Perched Aquifers in the Semi-Arid South-Western Region of Madagascar and Implications for the Sustainable Groundwater Exploitation. AGU Fall Meeting 2016, San Francisco, USA.

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Goetter JF: Informal institutions and development through the lens of New Institutional Anthropology – an illustration from rural Madagascar. '3rd Witten Conference on Institutional Change 2016', Witten/Herdecke, Germany.

Kübler D: REDD+ in a landscape context – the SuLaMa Project. SICSS Blockseminar 2016, KlimaCampus Universität Hamburg, Germany.

Neudert R, Hänke H, Barkmann J, Wätzold F: Surviving in a fragile environment – Livelihood challenges and strategies of households in semi-arid south-western Madagascar. Sustainable Land Management – Final Conference 2016, Berlin, Germany.

Nopper J: Effects of land use practices on biodiversity in dry southwestern Madagascar. Sustainable Land Management – Final Conference 2016, Berlin, Germany.

Prill L, Kübler D: Tropische Wälder im Spannungsfeld zwischen Übernutzung und Nachhaltigkeit – Lösungsansätze am Beispiel Madagaskars. Deutsche Aktionstage Nachhaltigkeit 2016, Hamburg, Germany.

Wesselow M, Fritz-Vietta N, Kobbe S, Rakotomalala D, Brinkmann K, Ratovonamana Y, Ratsimbarison R, Stoll-Kleemann S: Different Methods for Different Purposes – Experiences with participatory methods in the SuLaMa research project. Sustainable Land Management – Final Conference 2016, Berlin, Germany.

2015

Barkmann J, Hänke H, Hanisch S, Feldt T: Sticking to the digging stick: Resilience traps perpetuate poverty in southwestern Madagascar's Mahafaly Region. Deutscher Kongress für Geographie 2015, Fachsitzung: LN-FS-13. 2.10.2015. Humboldt Universität, Berlin.

Englert A, Dworak L, Robertin J: Hydrogeological Survey at the SuLaMa Project Site – Southwest Madagascar, invited talk at the Institute of Environmental Assessment and Water Research (IDAEACSIC) 2015, Barcelona, Spain.

Goetter JF: From open access to a regime of mixed common- and private property: Indigenous appropriation and regulation of the fodder tree *Euphorbia stenoclada* in southwest Madagascar. 15th Biennial Global Conference IASC, Edmonton, Canada.

Hänke H, Barkmann J: Insurance function of livestock: farmer´s coping capacity with regional droughts in south-western Madagascar. Annual Meeting of the Association of American Geographers in Chicago 2015, USA.

Kübler D, Plugge D, Ratovonamana Y: Seasonal stem diameter dynamics in a tropical dry forest. GTÖ 2015, Zurich, Switzerland.

Kübler D: REDD+ in a landscape context – the SuLaMa Project. SICSS Blockseminar 2015, KlimaCampus Universität Hamburg, Germany.

Randrianarison HS: Are buyers of ecosystem services willing to consider distributional impacts? Results from a choice experiment in Antananarivo, Madagascar. Workshop on Non-Market Evaluation (WONV) 2015, Nancy, France.

Thielsen K, Stoll-Kleemann S: What can conservationists learn from local rule negotiation processes? National Park Tsimanampetsotse in Southwestern Madagascar. Tropentag 2015, Berlin, Germany.

Wesselow M, Stoll-Kleemann S: Role-Playing Games in Land Use Research – Experiences from the Mahafaly Plateau in Madagascar. Tropentag 2015, Berlin, Germany.

2014

Andriamparany J, Brinkmann K, Buerkert A, Jeannoda V: Role of local knowledge in the use of medicinal plants in SW-Madagascar. Tropentag 2014, Prag, Czech Republic.

Fust P, Feldt T, Schlecht E: Agent-based modelling of transhumant cattle herd movements in Southwestern Madagascar. Tropentag 2014, Prag, Czech Republic.

Goetter JF: Struggling for Regulating the Appropriation of Local Commons: The Case of Fodder-Trees at the Tanalana-People in Southwestern Madagascar. IASC 3rd European Meeting 2014, Umea, Sweden.

Kübler D: Prediction of forest structure parameters in a tropical dry forest in the southwest of Madagascar using remote sensing imagery. GTÖ 2014, Freising, Germany.

Kübler D: REDD+ in a landscape context – the SuLaMa Project. SICSS Blockseminar 2014, KlimaCampus Universität Hamburg, Germany.

Markova-Nenova N: The importance of equity in the design of PES schemes. Global Land Project Open Science Meeting 2014, Berlin, Germany.

Nopper J, Brinkmann K, Ganzhorn J: How changes in land cover affect reptile diversity in south-western Madagascar. GfÖ 2014, Hildesheim, Germany.

Nopper J, Lauströer B, Ganzhorn J: Einfluss von Landnutzung auf die Diversität von Reptilien im Südwesten Madagaskars. BfN, Internationale Naturschutzakademie Insel Vilm, Germany.

Wätzold F: PES for the poor? The preferences of buyers. BIOECON Conference2014, Cambridge, UK.

2013

Barkmann J, Hänke H: Markets for the poor: long-term adoption of agricultural innovations via spontaneous economic activity. Sustainable Land Management – Status Conference 2013, BMBF, Berlin, Germany.

Brinkmann K: Ernährungssicherung auf dem Mahafaly Plateau – Maniok, Yams und innovative Landnutzungsstrategien. Sustainable Land Management – Status Conference 2013, BMBF, Berlin, Germany.

Feldt T, Antsonantenainarivony O, Fust P, Schlecht E: Escaping insecurity through increased livestock herd mobility – a sustainable strategy? Tropentag 2013, Stuttgart, Germany.

Fricke R: Effects of ecosystem degradation on plant and animal biodiversity in the Mahafaly plateau, SW Madagascar. Open Landscapes 2013, Hildesheim, Germany.

Ganzhorn JU: Turning Madagascar upside down. Open Landscapes 2013, Hildesheim, Germany.

Ganzhorn JU, Plugge D, Kobbe S, Ratovonamana YR, Rakotomalala D: Beziehungen zwischen Landnutzungspraktiken und Biodiversität. Sustainable Land Management – Status Conference 2013, BMBF, Berlin, Germany.

Goetter JF, Neudert R: Haushaltsentscheidungen bezüglich Viehhaltung unter sich verändernden ökologischen und sozialen Bedingungen in der Mahafaly-Plateau-Region, Madagaskar. Sustainable Land Management – Status Conference 2013, BMBF, Berlin, Germany.

Kobbe S, Nopper J, Ratovonamana YR, Rakotomalala D, Braskamp E, Lauströer B, Marzec S, Randiamiharisoa LO, Raonizafinarivo S, Ganzhorn JU: Changes of vertebrate species distribution in response to different forms of land use on the Mahafaly Plateau in Southwestern Madagascar. GTÖ 2013, Vienna, Austria.

Paulsch C, Rumbauer C, Falk T, Jürgens N, Mubyana-John T, Plugge D: Implementing UNCCD objectives – experiences from research projects in China, Madagascar and the Okavango region. 11th session of the Conference of the Parties to the United Nations Convention to Combat Desertification 2013, Windhoek, Namibia.

Ratovonamana YR: Plant phenology of Madagascar dry spiny forest in relation to recent climate change. Open Landscapes 2013, Hildesheim, Germany.

Thielsen K: Decision making processes in natural resource management among the Tanalana (Southwest Madagascar). Open Landscapes 2013, Hildesheim, Germany.

Thielsen K: Decision making processes in natural resource management in south-west Madagascar. Sustainable Land Management – Status Conference 2013, BMBF, Berlin, Germany.

2012

Nopper J, Braskamp E, Lauströer B, Mananjara FH, Ganzhorn JU: Habitat affinities and population characteristics of reptiles from arid south-western Madagascar. World Congress for Herpetology 2012, Vancouver, Canada.

Plugge D: REDD+ in a landscape context – the SuLaMa Project. SICSS Blockseminar 2012, KlimaCampus Universität Hamburg, Germany.

2011

Neudert R, Goetter JF: Institutionelle Herausforderungen des Designs eines Zahlungssystems für ökologische Leistungen. Workshop Neue Institutionenökonomie 2011, BTU Cottbus, Cottbus, Germany.

10.3.2 Poster

2016

Englert A, L Dworak, Rasoloariniaina J, Brinkmann K, Kobbe S, Buerkert A: Hydrogeology in The South-West of Madagascar – A Multi-Scale Approach. Sustainable Land Management – Final Conference 2016, Berlin, Germany.

Goetter JF, Antsonantenainarivony O, Rabemirindra H, Randriamampionona SJP, Randrianambinina G, Schlecht E, Wätzold: Drivers of overuse and degradation of the important fodder tree *Euphorbia stenoclada* in southwest Madagascar and approaches for mitigation. Sustainable Land Management – Final Conference 2016, Berlin, Germany.

Feldt T, Fust P, Ahlers F, Schlecht E, Antsonantenainarivony O, Ramananoro FM, Edmont R, Rakotoarimanana V: Interrelatedness of grazing livestock with vegetation parameters against the background of political instability in the Mahafaly region, southwestern Madagascar. Sustainable Land Management – Final Conference 2016, Berlin, Germany.

Fritz-Vietta N, Mbola MM, Tahirindraza HS, Thielsen K, Wesselow M, Marikandia LM, Stoll-Kleemann S: The role of cultural values to the Tanalana people from the Mahafaly Plateau region, south-west Madagascar. Sustainable Land Management – Final Conference 2016, Berlin, Germany.

Krüll A, Fricke R, Opgenoorth L, Brandl R: Head, Shoulders, Knees & Toes – Functional diversity of carabid beetle assemblages along a land-use gradient, Mahafaly Plateau, southwest-Madagascar. GFÖ 2016, Marburg, Germany.

Kübler D, Olschofsky K, Prill L, Plugge D, Ranirison A, Köhl M: Assessing the potential for sustainable forest management of a dry forest ecosystem in south western Madagascar. Sustainable Land Management – Final Conference 2016, Berlin, Germany.

SuLaMa: Madagascar: Protecting nature to survive. Poster on progress achieved towards the Aichi Biodiversity Targets. 13th meeting of the Conference of the Parties to the Convention on Biological Diversity 2016, Cancun, Mexico.

Wesselow M, Stoll-Kleemann S: Role-Playing Games – eine partizipative Methode für die Forschung und das Management von natürlichen Ressourcen. Future Earth Summit 2016, Berlin, Germany.

2015

Englert A., L. Dworak, J. Rasoloariniaina, K. Brinkmann, S. Kobbe, A. Buerkert Hydrogeology in The Semi-Arid South-West of Madagascar – a Multi-Scale Approach. AGU Fall Meeting 2015, San Francisco, USA.

Faust, S, Hanisch, S, Buerkert, A, Joergensen, RG: Soil Properties under Manured *Tamarindus indica* in the Littoral Plain of South-WesternMadagascar. Tropentag 2015, Berlin, Germany.

Fritz-Vietta N, Tahirindraza HS, Stoll-Kleemann S: Local people's knowledge about land use activities in the Mahafaly plateau region, southwest Madagascar. Tropentag 2015, Berlin, Germany.

Goetter JF, Antsonantenainarivony O, Rabemirindra H, Wätzold F, Schlecht E: Degradation of the succulent fodder tree *Euphorbia stenoclada* in southwest Madagascar and approaches for improved management. Tropentag 2015, Berlin, Germany.

Plugge D, Kübler D, Rakotomalala Y: Meeting the demand of local populations by purposeful sustainable dry forest management – understanding growth patterns of heavily used tree species. 3rd Scientific Conference to the UNCCD 2015, Cancún, Mexico.

2014

Antsonantenainarivony O, Rabemirindra H, Rakotoarimanana V, Edmond R, Brinkmann K, Schlecht E: Regeneration and biomass production of *Euphorbia stenoclada* in the coastal plains of Southwestern Madagascar. Tropentag 2014, Prag, Czech Republic.

Fanambinantsoa N, Faramalala MH, Buerkert A, Brinkmann K: Dynamics and drivers of land use changes in Southwestern Madagascar during the past 60 years. Tropentag 2014, Prag, Czech Republic.

Feldt T, Neudert R, Schlecht E: Reproductive and growth performance of extensively managed goat herds in Southwestern Madagascar. Tropentag 2014, Prag, Czech Republic.

Kübler D, Köhl M: Prediction of forest structure parameters in a tropical dry forest in the southwest of Madagascar using remote sensing imagery. Forest Change 2014, Freising, Germany.

Ranaivoson T, Rakouth B, Buerkert A, Brinkmann K: Analysis of biomass production of Tamarind trees and their role in local communities of south-western Madagascar. Tropentag 2014, Prag, Czech Republic.

2013

Andriamparany J, Jeannoda V, Brinkmann K, Buerkert A: The potential of wild yams to improve food security on the Mahafaly Plateau in Southwestern Madagascar. Tropentag 2013, Stuttgart, Germany.

Andriamparany R, Opgenoorth L, Andrianarimisa A, Brandl R, Buerkert A, Hanisch S, Fricke R: Manure and charcoal effects on soil faunal activity in irrigated vegetable gardens in South-west Madagascar. Tropentag 2013, Stuttgart, Germany.

Antsonantenainarivony O, Rakotoarimanana V, Edmond R, Schlecht E: Grazed vegetation types near Tsimanampetsotsa National Park in Southwestern Madagascar. Tropentag 2013, Stuttgart, Germany.

Brinkmann K, Schaeper W, Fanambinantsoa N, Buerkert A: Acquisition of RGB and NIR photographs from Unmanned Airborne Vehicles (UAVs) for crop and land use monitoring. Sustainable Land Management – Status Conference 2013, BMBF, Berlin, Germany.

Fanambinantsoa N, Faramalala MH, Buerkert A, Brinkmann K: Use of remote sensing data to assess crop yields and food security on the Mahafaly Plateau, SW Madagascar. Tropentag 2013, Stuttgart, Germany.

Fricke R, Luck M, Opgenoorth L: Habitat degradation shapes biodiversity patterns of plants and ants in South-west Madagascar. Tropentag 2013, Stuttgart, Germany.

Ganzhorn JU: Trading endangered species as an ecosystem service for habitat and species conservation in Madagascar´s spiny forest. GTÖ 2013, Vienna, Austria.

Gérard A, Ganzhorn JU, Carriére SM, Kull CA: The role of non-native plant species for nature conservation in Madagascar. Open Landscapes 2013, Hildesheim, Germany

Hanisch S: Agricultural innovations in cropping systems of semi-arid Southwestern Madagascar under multiple ecological and socio-economic constraints. Tropentag 2013, Stuttgart, Germany.

Holzmann S, Plugge D, Köhl M: Developing strategies against land degradation and desertification: a heatmap for priority intervention areas in sub-Sahara Africa. UNCCD 2nd Scientific Conference 2013, Bonn, Germany.

Lauströer B, Braskamp E: Impact of land use types on the richness and composition of reptile communities in Southwestern Madagascar. Open Landscapes 2013, Hildesheim, Germany.

Lauströer B, Braskamp E, Mananjara F, Rakotomalala D, Ratovonamana YR, Nopper J, Kobbe S, Ganzhorn JU: Impact of land use types on the richness and composition of reptile communities in southwestern Madagascar. GTÖ 2013, Vienna, Austria.

Marzec S, Hammer J, Mananjara WR, Rasoma RVJ, Ranivoarivelo S, Ganzhorn JU: Impacts of habitat types and land use on tortoises (*Pyxis arachnoides*, *Astrochelys radiata*) in Southern Madagascar. GTÖ 2013, Vienna, Austria.

Neudert R, Wätzold F, Randrianarison H, Goetter JF: Foregone benefits of reducing deforestation in southwestern Madagascar. 10th biennal conference of the European Society for Ecological Economics 2013, Lille, France.

Nopper J, Atrefony F, Kasola C, Fisy L: Response of reptiles to short-term changes in habitat characteristics in Tsimanampetsotsa National Park. Open Landscapes 2013, Hildesheim, Germany.

Nopper J, Ratovonamana, YR, Rakotondranary J, Rakotomalala D, Marzec S, Lauströer B, Braskamp E, Randriamiharisoa LO, Raonizafinarivo S, Kobbe S, Ganzhorn JU: Impacts of land use on the biodiversity of vertebrates in Southwestern Madagascar. GFÖ 2013, Potsdam, Germany.

Ranaivoson T, Rakouth B: Allometric equations for timber stock and stem biomass estimation of Phanerophytes in dry forests on the Mahafaly Plateau, Madagascar. Tropentag 2013, Stuttgart, Germany.

Randriamiharisoa LO, Raonizafinarivo S, Raherlialao MJ, Ranivo J, Rakotondravony D, Wilmé L, Ganzhorn JU: Impact of land use types on the richness and composition of bird communities in Southwestern Madagascar. GTÖ 2013, Vienna, Austria.

Randriamiharisoa LO, Ranirison A, Raherilalao MJ, Rakotondravony D, Wilmé L, Ganzhorn JU: Effects of transhumance on the richness and composition of bird communities in Tsimanampetsotse National Park. Open Landscapes 2013, Hildesheim, Germany.

Ranirison A, Ratovonamana Y, Plugge D, Holtzman S, Faramalala M, Roger E: Influence of transhumance on spatio-temporal dynamic of forest cover in Southwestern Madagascar. Open Landscapes 2013, Hildesheim, Germany.

Raonizafinarivo S, Randriamiharisoa LO, Raherilalao MJ, Ranivo J, Rakotondravony D, Wilmé L, Ganzhorn, JU: Bird communities in different anthropogenic habitats in southwestern Madagascar. Open Landscapes 2013, Hildesheim, Germany.

Rasoloariniaina JR, Raminosoa N: Physicochemical and bacteriological quality assessment of the water resources in the Mahafaly Plateau, Madagascar. Tropentag 2013, Stuttgart, Germany.

Ronto WM, Rakotondravony D, Ganzhorn JU: Thermoregulation behavior of radiated tortoise. Tropentag 2013, Stuttgart, Germany.

2012

Fritz-Vietta, N: Sustainable Land Management in Madagascar (SuLaMa) – What Does Inter- and Transdisciplinary Research Need to Learn? International conference Planet under Pressure 2012, London, UK.

Thielsen K, Tahirindraza HS, Mampiray MM, Fritz-Vietta N, Stoll-Kleemann S: Taboos in natural resource management. Statuskonferenz Nachhaltiges Landmanagment 2013, BMBF, Berlin, Germany.

2011

Neudert R, Mewes M, Wätzold F, Goetter JF: Challenges of designing a PES-Scheme in south-western Madagascar. Payments for Ecosystem Services and their Institutional Dimensions – International Conference on Payments for Ecosystem Services 2011, IED, Civiland, Berlin, Germany.

10.4 List of PhD, Master and Bachelor thesis

List of PhD thesis

Work package	Name	Title
WP1: Coordination	Dr. Noromiarilanto Fanambinantsoa	Déforestation, occupation des terres et évaluation de la sécurité alimentaire en utilisant la télédétection et le système d'information géographique en région Mahafaly, Toliara, Madagascar
WP2: Agronomy	Dr. Susan Hanisch	Improving cropping systems of semi-arid south-western Madagascar under multiple ecological and socio-economic constraints
	Dr. Jessica Andriamparany	Diversity, local uses and availability of medicinal plants and wild yams in the Mahafaly region of south-western Madagascar
	Dr. Tahiry Ranaivoson	Impacts écologiques et aspects socio-économiques de la production de charbon de bois dans la région Mahafaly, sud-ouest de Madagascar
	Roger Andriamparany	Effects of soil fauna – Bait-Lamina and litter bag experiments
	Roman Fricke	Biodiversity of terrestrial invertebrates on the Mahafaly Plateau (SW Madagascar) in relation to land use type and land use
WP3: Animal husbandry	Dr. Tobias Feldt	Interrelatedness of grazing livestock with vegetation parameters and farmers' livelihoods in the Mahafaly region, Southwestern Madagascar
	Dr. Ononamandimby Antsomamtenainarivon	Groupements végétaux pâturés du Plateau Mahafaly (Sud-Ouest de Madagascar): Identification des espèces fourragères et parcours naturels du bétail
	Pascal Fust	High-resolution spatiotemporally dynamic model of herbivory impact in Mahafaly region, Madagascar
WP4: Natural Ecosystems & Functions	Dr. Jean Robertin Rasoloariniaina	Aspects quantitatifs, qualitatifs et ichtyologiques des eaux souterraines de la région Mahafaly, Sud-ouest de Madagascar
	Dr. Joachim Nopper	Effects of land use on reptile diversity in southwestern Madagascar
	William Ronto	Influence of different types of land use and of overexploitation on the population dynamics of the radiated tortoise (*Astrochelys radiata*)
	Amadou Ranirison	Transhumance and spatiotemporal dynamic of Tsimanampetsotsa vegetation, southwest Madagascar
WP5: Stakeholder-Processes & Cultural Values	Katinka Thielsen	Process of decision and interest negotiations of local stakeholder in the context of use of natural resources in the Tsimanampetsotsa national park in southwest Madagascar
	Hémery Stone Tahirindraza	Spiritual and traditional meaning of ecosystem services on the Mahafaly Plateau: surroundings of the Tsimanampetsotsa park
	Mampiray Miandrito Mbola	Social and natural capital in the service of a sustainable development of the Tanalana society (southwest Madagascar)
WP6: Economy	Johanna Goetter	Institutional change in the Mahafaly region

Work package	Name	Title
	Henintsoa Randrianarison	The relationship between conservation and poverty reduction in the design and implementation of PES schemes – experiences from Madagascar
WP7: Agricultural Economics	Dr. Hendrik Hänke	Livelihoods on the edge: farming household income, food security and resilience in resilience in southwestern Madagascar

List of Master (M.Sc.) and Bachelor (B.Sc.) thesis

Work package	Name	Title
WP1: Coordination	Linda Dworak (M.Sc.)	Hydrogeological survey at the SuLaMa project site in SW Madagascar
	Lea Spelzhausen (B.Sc.)	Comparison of different classification systems for the valuation of ecosystem services
WP2: Agronomy	Sybille Faust (M.Sc.)	Effects of Tamarindus indica and manure on seed germination, mineralization rate and microbial properties of sandy soils of south-western Madagascar
	Fenohaja Babarezoto Soavit (M.Sc.)	Inventaire floristique des mauvaises herbes (adventices de culture) et des espèces recouvrantes: cas du système de culture traditionnel du Plateau Mahafaly
	Anna Krüll (M.Sc.)	Species richness and functional diversity of ground beetles and darkling beetles in relation to land use in the littoral region of the Mahafaly Plateau, Madagascar (pending)
	Marvin Luck (B.Sc.)	Open range and long legs ground-dwelling ant assemblages in traditional land-use systems on the Mahafaly Plateau (south-western Madagascar)
	Andre Böckers (B.Sc.)	DNA barcoding and phylogeny of termites along a transect on the Mahafaly Plateau
WP3: Animal husbandry	Frauke Ahlers (M.Sc.)	*Euphorbia stenoclada*: occurrence and use as a fodder in south-western Madagascar
	Fidgerald M. Ramananoro (M.Sc.)	Études comparatives du comportement au pâturage et d'itinéraires de petits ruminants dans la région Mahafaly Sud-Ouest de Madagascar
	Herinavalona A. Rabemirinra (M.Sc.)	Reproduction et production de biomasse d'*Euphorbia stenoclada* Baill. (Samata) dans le Plateau Mahafaly (Sud-Ouest de Madagascar)
	Lisa M. Frank (B.Sc.)	Beurteilung der Verwendung von Fotofallen zur Bestimmung der Weidenutzung eines Naturschutzgebietes: Beweidungsdruck im Nationalpark Tsimanampetsotsa
WP4: Natural Ecosystems & Functions	Enzo Braskamp (M.Sc.)	Effects of land use on reptile communities in the littoral forests of south-western Madagascar
	Balten Lauströer (M.Sc.)	Reptile communities along a gradient of anthropogenic influence around the village of Andremba on the Mahafly plateau, southwestern Madagascar

Work package	Name	Title
	Olinga Päplow (M.Sc.)	Concept for a sustainable management of *Astrochelys radiata* (Shaw 1802)
	Julian Ehlers (M.Sc.)	Tick infestation of endemic tortoises in southwest Madagascar and investigation of tick-borne pathogens
	Anna Vorländer (M.Sc.)	Development of different forest management strategies for dry forests in South Western Madagascar
	Ranja Andriantsoa (M.Sc.)	Étude des parasites gastro-intestinaux des testudines *Astrochelys radiata* et *Pyxis arachnoides arachnoides* et des carnivores *Galidictis grandidieri* et *Canis lupus familiaris* dans le parc national Tsimanampetsotsa
	Sylwia Marzec (M.Sc.)	Studie der Populationsdichte und Populationsstruktur in verschiedenen Habiten von Spinnenschildkröte (Pyxis arachnoides) und Strahlenschildkröte (Astrochelys radiata) auf zwei räumlichen Skalen
	Franck Hermé Mananjara (M.Sc.)	Effects of land use systems on the occurrence of fossorial reptiles
	Jean Luck R. Ravoavy Randrianasolo (M.Sc.)	Parasites gastro-intestinaux des zébus et des chèvres du Plateau Mahafaly, dans la région du Sud-ouest de Madagascar
	Soafara Raonizafinarivo (M.Sc.)	Effets de l'agriculture et du pâturage sur la communauté d'oiseaux dans la région du Parc National de Tsimanampetsotsa
	Lalatiana O. Randriamiharisoa (M.Sc.)	Effets de bordure et de la piste de transhumance sur la communauté aviaire du Parc National de Tsimanampetsotsa
	Andriatsitohaina Ranaivojaona (M.Sc.)	Relationship between habitat structures and the occurrence of fossorial reptiles
	Harald Gross (B.Sc.)	Evaluation of Alternative Energy Sources for Firewood in the Mahafaly Region
WP5: Stakeholder-Processes & Cultural Values	Mahaleo Claude Razafindramonja (M.Sc.)	La gestion, l'accès et l'appropriation de la terre chez les agro-pasteurs Tanalana du Sud-ouest de Madagascar : Le cas des villages de Marofijery et de Miarentsoa
WP6: Economy	Sandra Serafin (M.Sc.)	Issues on implementing payments for ecosystem services projects in Madagascar: a comparative analysis
	Alexander Korff (M.Sc.)	Analyzing the experience of international tourists visiting Tsimanampetsotsa National Park to identify improvement potential and to increase the benefits to local communities and the environment
	Ester Vogt (B.Sc.)	International trade of endangered wildlife: economic assessment of trading schemes in the light of species conservation – The radiated tortoise (*Astrochelys radiata*) in Madagascar
	Amrei Aigner (B.Sc.)	The concept of payments for ecosystem services and examples from Madagascar
WP7: Agricultural Economics	Claudia S. Coral Guerra (M.Sc.)	Integration of smallholder farmers into agribusiness value chains under restrictive markets: the case of the Littoral-Mahafaly plateau transect in south-western Madagascar
	Lucile Manon (M.Sc.)	Cassava stock management by smallholder farming households in South-Western Madagascar – Agriculture, subsistence, market and cultural influence

10.5 The SuLaMa project – work packages, participants and contributing authors

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Non-Governmental Organizations (NGOs)

WWF (World Wide Fund for Nature) Germany and Madagascar

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10.6 List of Stakeholders in Madagascar

Stakeholder	Interest	Abbreviation	Form of involvement in SuLaMa
Local level			
Local governments			
Fokontanys (Chef/President Fokontany)	Local administration		Information, cooperation and decision making (steering committee), capacity building (beneficiary), dina application
NGOs			
Association des Vétérinaires Sans Frontières	Animal Husbandry, agriculture, animal health	AVSF	Information, cooperation (small ruminants husbandry, poultry, yams)
Action Contre la faim	Food security	ACF	Agriculture, water research (in collaboration with University of Avignon)
Centre Diocésain pour le Développement	Livelihoods	CDD	Agriculture
Local associations			
Communauté de Base (Community natural resources management groups)	Livelihoods	COBA	Cooperation and participation (pilot farmers) in research
Association Inter Communale du Plateau Mahafaly	Communication	AICPM	Information, cooperation and decision making (steering committee), capacity building (beneficiary)
Projects and programs from donors			
further R&D projects	(e.g. water, SLM, conservation)	SOARANO, COGESFOR, SLM, various other WWF projects	e.g. Water monitoring, land use alternatives, conservation and biodiversity monitoring
Economic operators			
Hotels (mainly in Anakao, Ambola, Toliara)	Tourism development		Tourism
Others			
Individual farming and herding families	Livelihoods		Cooperation and participation in trials
Small private businesses	Trade of wild and domesticated animals and crops (Example: Yam)		Information and cooperation
Schools (public and private)	Environmental education	ABC Domino, EPP school, Lycée	Knowledge transfer

Stakeholder	Interest	Abbreviation	Form of involvement in SuLaMa
Regional Level			
Regional governments			
Regional Districts (Betioky, Toliara II, and Ampanihy)	Administration		Information and decision making (steering committee)
Decentralized state agencies			
Direction Régional du Développement Rural	Rural development	DRDR	Agriculture, husbandry
Direction Régional de l'Environnement et Forêt	Natural resources management, monitoring of protected areas	DREF	Technical service for protected areas and natural resource monitoring
Direction régional du Tourisme et de l'Artisanat	Tourism	DRTA	Tourism
Direction Régional de l'Eau	Water resources management	DRE	Technical and institutional support for the project's implementation (partnership with WWF)
Regional Department of Meteo	Climate data		Information/data exchange (climate data, SLM modeling)
Regional departments (forest, health, education, agriculture, animal husbandry, water)	Administration, rural development		Information and decision making (steering committee), technical and institutional support for implementation
Autonomous state agencies			
Madagascar National Parks	Conservation	MNP	Information and decision making (steering committee), capacity building for management, eco-tourism development biodiversity monitoring, transhumance regulation (pasture)
Centre National de Lutte Antiacridienne	Locust control	CNA	Information/data exchange (climate data, SLM modeling)
Centre de Service Agricole (in partnership with DRDR)	Farmer support	CSA	Capacity building, farmers' technical supervision
Office Régional du Tourisme	Tourism development	ORTU	Tourism
NGOs			
WWF	Conservation and development	WWF	Protected area management, TGRN management, water resources management, energy/ wood programme, agriculture, livelihood, governance
Welthungerhilfe	Food security	WHH	Agriculture (programme for the Mahafaly Plateau starts 2014)
Arboretum d'Antsokay	Capacity building		Capacity building, sustainable tourism development

Stakeholder	Interest	Abbreviation	Form of involvement in SuLaMa
Association pour le Développment de l'Energie Solair	Solar energy initiatives/ promoting use of renewable energy sources	ADES	Sustainable forest management (sustainable charcoal production)
Universities			
University of Toliara	Capacity building		Research cooperation, summer school
Institute Supérieur de Technologie: Universites of Fianarantsoa (Program on Biodiversity and Environment) and Toliara (Agronomy)	Capacity building	IST	Research cooperation, summer school
Donor-sponsored Projects and Programmes			
Fonds d'intervention pour le développement	Food security	FID	Conservation (in cooperation with WWF)
Small Grant Programme/ Tany Meva fondation	Conservation, natural resources management	SGP/Tany Meva	Capacity building/knowledge transfer (in cooperation with COBAs)
Farmers' organizations			
Maison des Paysans	Agricultural development	MDP	Knowledge transfer
United Nations programmes			
World Food Programme	Food Security	WFP	Agriculture
Others			
Comité de Soutien aux Aires Protégées	Natural resources management	COSAP	Capacity building, monitoring measures (ecological and socio-economical)
National Level			
State departments			
Ministries of Agriculture, Environment and Forests, and Animal Husbandry	Research and Development		Information and decision making (steering committee), implementation and monitoring of new land use strategies, other options of involvement can be discussed
Autonomous state agencies			
National Center for Agricultural Research	Land use options	FOFIFA	Information and decision making (steering committee), implementation and monitoring of new land use strategies
Centre National de l'Eau, de l'Assainissement et du Génie Rural	Research (water)	CNEAGR	Information on groundwater resource availability and exploitation (in partnership with WWF)

Stakeholder	Interest	Abbreviation	Form of involvement in SuLaMa
Universities			
University of Antananarivo, University of Fiaranantsoa, University of Tamatave	Capacity building		Cooperation in all fields of research, summer schools
NGOs			
Vahatra	Research, capacity building		Knowledge transfer, information
Professionnels du Développement Solidaire	Water resources management	GRET	Hydrogeological modeling
Madagasikara Voakajy	Biodiversity conservation and sustainable use of resources		Biodiversity (flagship species) monitoring
Projects and programs from donors			
Fonds d'Intervention pour le Développement	Food security	FID	Information
Programme Germano-Malgache pour l'Environnent	Recourse and protected area management	GIZ/PGE-M	Information and decision making (steering committee), cooperation towards new land use strategies; natural resources management, agriculture, forest management, land management plan
International Level			
United Nations Development Programme	Development	UNDP	Information and decision making (steering committee), cooperation towards new land use strategies

10.7 Glossary of Malagasy terms

Ala Maiky	Programme of the WWF that addresses the conservation of Madagascar's 'spiny forest ecosystem'.
Baiboho	Permanent fields, which are fenced and cultivated for many years with alternating fallow and cropping periods.
Dina	Environmental rules to reinforce existing legislation – for example regarding bush fires, maximum sizes for private enclosures per person, slash-and-burn practices and rules governing endangered species.
Faly	Malagasy term for taboo or sacred.
Fokontany	Smallest administrative unit of rural Malagasy communities consisting of up to four villages and their associated hamlets.
Fokonolona	'Community', officially consisting of all members of a *fokontany* (administrative version), from a historical perspective consisting of all older members of a lineage/a clan (historical version); abbreviated as *fokonolo*.
Hatsaky	Traditional cultivation system of slash-and-burn: fields are usually established inside forest remnants and planted for a few years with maize, then left to recover.
Hazomanga	The term *hazomanga* is used as a term for the holy pale – a wooden rod that is erected at sacred sites, where rituals are carried out – for the clan or lineage origins, for a particular knife that is used to accomplish sacrifices, and as the name of the lineage or clan chief.
Samata	Malagasy term for *Euphorbia stenoclada*, an endemic succulent tree species, that is threatened by habitat loss and an important fodder plant for *zebus*; a number of individual trees is locally considered sacred.
Sihanaka	Rainwater catchment, used by the local population during the rainy season for water supply. The *sihanaka* usually dries up after a period of about two to three months.
Tanalana	One of three ethnic groups inhabiting the Mahafaly Plateau region. The *Tanalana* society consists of eleven different clans.
Vilo	A *vilo* is a cattle earmark indicating the affilation to a specific *Tanalana* clan.
Zebu	Malagasy humped cattle (*bos taurus indicus*), that play a significant economic, cultural, and social role for local communities.