



Assessment of food self-sufficiency in smallholder farming systems of south-western Madagascar using survey and remote sensing data



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ABSTRACT

Madagascar is among the countries with a very high level of poverty and food insecurity. This holds particularly true for the south-western (SW) region with its chronic food shortages. Information on crop production, food availability and coping strategies of smallholders to deal with food shortages are scarce but urgently needed to assess the local food security status for more effective land management planning and famine prevention. This study, therefore, investigated farmers' coping strategies and determined the food security index (FSI), the food self-sufficiency ratio (FSSR) and cassava self-sufficiency (CSS) at the household level in three typical villages of the Mahafaly region in SW Madagascar. To this end we used household consumption surveys, land use mapping, crop field measurements, allometric equations and canopy cover estimations from aerial photographs for cassava yield assessments. For the majority of sampled households the daily calorie intake was insufficient ($FSI < 1$) and the most frequent food insecurity coping strategies encountered were collection of wild food, off-farm activities and a reduction of meals. There was a high seasonal variation in food consumption, FSI and FSSR with different patterns on the plateau and in the coastal area. The main factors influencing FSSR were cassava yield, the livestock richness and landholding, whereas the number of off-farm activities determined FSI. Altogether, our results revealed that annual cultivated food crops provided up to 64% of people's diet. Cassava was the most important staple and played a key role for food self-sufficiency. However, cassava yields averaged only 0.69 t ha^{-1} and CSS ranged between 39 and 54%. Although there exists a high climate-induced risk in crop production, there is still room for improvements of agricultural techniques to enhance food self-sufficiency. However, enhancing access to off-farm income opportunities is similarly important to sustain local livelihoods in the long-term.

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1. Introduction

Food security exists “when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life” (World Food Summit, 1996). This definition points to the multi-dimensional aspects of food security including food sufficiency and availability, nutrient adequacy, cultural acceptability, safety, certainty and stability (Carletto et al., 2013; Coates, 2013). Sub-Saharan Africa is the most food insecure region of the world (FAO et al., 2014), having the lowest global Food Security Index (FSI) score after Asia and the Pacific region (The Economist Intelligence Unit, 2014). Madagascar is among the countries with a particularly high prevalence of undernourishment (FAO et al., 2014). At the national level its level of food insecurity amounts to over 50% (Minten and Barrett, 2006) with more than two-third of

the population consuming < 2133 cal per day (Dostie et al., 2002). This is particularly true for the Mahafaly region in south-western (SW) Madagascar (ACF, 2012; Sasson, 2012), which is the country's most economically and climatically disadvantaged environment (Minten and Barrett, 2006) with the lowest mean households food consumption scores (WFP and UNICEF, 2011). In 2009 $> 50\%$ of the region's inhabitants were affected by food insecurity (WFP, 2009) and 41.6% were seriously affected by chronic malnutrition (INSTAT, 2010) or “kere”, which is the local name for famine. People's livelihoods in the Mahafaly region are largely determined by crop and livestock husbandry, but the rainfed, subsistence oriented slash-and-burn agriculture is limited by the availability of water and nutrients throughout the year. Additional constraints are recurrent droughts, cyclones and locust infestation (Andriamparany et al., 2014; Brinkmann et al., 2014) making households especially vulnerable to chronic food shortages. Consequently, the local people depend to a high degree on natural resources and wild food (Andriamparany et al., 2014) to meet their daily needs. Information on the local food system, agricultural productivity, food self-

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sufficiency and coping strategies for food shortages are still lacking for this region (Dostie et al., 2002), but urgently needed to more effectively monitor the food security status for land management planning and policy making.

There are various methods to determine the status of food security at the household level whereby different indicators measure different aspects of the multi-dimensional phenomena (Jones et al., 2013; Carletto et al., 2013). Principal methods currently used by the World Food Programme (WFP) or other agencies are based on proxy indicators of food consumption, such as diet diversity, food frequency, or coping strategies (FAO and WFP, 2009). Another frequently used method relies on food expenditures or dietary intake that are commonly reduced to indicators of caloric sufficiency (Coates, 2013). Household whose daily calorie intake is greater or equal to the recommended daily calorie intake are regarded as food secure, whereas households with a daily calorie intake lower than the recommended daily calorie intake are considered food insecure.

Another indicator is food self-sufficiency defined as the ability of a household or region, to sustain its own requirement for food which can be measured at different levels (Coates, 2013). At the household level it determines the amount of households which can supply their food from their own production or reports the number of months of the year that households are food self-sufficient. Detailed information on crop yields and food production in the studied region is needed to measure food self-sufficiency. To monitor crop production, Geographic Information Systems (GIS) and remote sensing techniques combined with ground truth data from field measurements are valuable tools (Becker-Reshef et al., 2010; Oroda, 2001; Wu et al., 2010).

This study, therefore, aims to investigate crop production, food self-sufficiency and assess food security at the household level in the Mahafaly region using household consumption surveys, land use mapping, crop field measurements, allometric equations and remote sensing techniques in three selected villages along a topographic gradient. We focus on the seasonal variation in food availability and on households' strategies to cope with food shortages during the lean season. We hypothesized that the food security level of households varies between seasons and site conditions and highly depends on their socio-economic conditions.

2. Materials and methods

2.1. Study area

The study was situated in the Mahafaly region of SW Madagascar, and is characterized by semi-arid climatic conditions with an annual mean temperature of approximately 24 °C and irregular rainfall with an annual precipitation <500 mm (Battistini and Richard-Vindard, 1972). The area comprises the recently extended Tsimanampetsotsa National Park and a number of sacred and community forests. Based on existing village and households surveys (Andriamparany et al., 2014; Brinkmann et al., 2014; Neudert et al., 2015), three representative villages surrounding the National Park were selected (Fig. 1) to investigate the status of food security at the household level. To account for the variability of livelihood strategies, socio-economic and environmental conditions in the study region, we selected one typical village in the coastal zone and two villages in the inland plateau zone.

In the coastal area, the village Efoetse is mainly inhabited by “Tagnalana” and fishermen, locally called “Vezo”. Animal husbandry, crop cultivation and off-farm activities are important income generating activities. Similar to other coastal areas in the arid SW Madagascar, marine resources and small scale fisheries are particularly important for food security but fish consumption is very low

compared with other countries of the Eastern and Southern Africa-Indian Ocean (Kurien and Rios, 2013).

Miarintsoa and Andremba are situated on the plateau, where most of the inhabitants belong to the “Tagnalana” and “Mahafaly” ethnic groups. Here, farmers' livelihood depends predominantly on crop cultivation, animal husbandry and on the use of forest resources such as wood for charcoal and non-timber forest products (NTFPs). Permanent crop fields are established on sites with relatively fertile soils near the settlements and are locally called “Baiboho”. These Baiboho's are commonly cultivated for many years with alternating fallow and cropping periods, in contrast to the short-term slash and burn fields, which are only cultivated up to four years (Brinkmann et al., 2014). Hedgerows with “Raketa” (*Opuntia* spp.) are planted as fences around the fields in the coastal area. For the establishment of new fields or extensions, cultivation practices depend on the soil fertility and water availability. If the crop fields are inherited, the current users will follow the cropping cycle of their ancestors.

Typical cropping systems in this region are mixed systems with cassava (*Manihot esculenta* L. Crantz) as major crop, often combined with maize (*Zea mays* L.) and cowpea varieties (*Vigna* sp.). There exist also a few cultivations of sweet potatoes (*Ipomoea batatas* (L.) Lam.), sorghum (*Sorghum bicolor* L.), and millet (*Panicum miliaceum* L.). It was estimated that cassava provides 14% of all calories consumed in Madagascar, and in the southern region, its consumption is most important where it accounts for over 27% of caloric intake (Bergeron, 2002). Consequently, the most important staple in the Mahafaly region is cassava, followed by maize and cowpea as vegetable. Cassava tubers are usually harvested very late, after 12–20 months, mainly due to the low production under harsh environmental conditions where water and nutrients are strongly yield limiting. Bitter varieties of cassava are dried in the sun to store them for a longer time period, whereas sweet cassava varieties are consumed “fresh”, especially in the coastal area.

Besides agriculture, livestock is culturally and economically important in the study region (Neudert et al., 2015; Feldt et al., 2016). Despite high livestock numbers, systematic dairy production is lacking and livestock is more important as a status symbol and savings than as a food stock (Feldt et al., 2016). Meat consumption is limited to special occasions (particularly funerals) and to meet social obligations, whereby milk is only little consumed (Bergeron, 2002).

2.2. Household consumption survey

To determine the food security index, the food self-sufficiency ratio and household coping strategies, a household consumption and expenditures survey (HCES) was conducted in 2013 based on general guidelines (Maxwell and Frankenberger, 1992; Smith and Subandoro, 2007; Fiedler et al., 2012; Smith et al., 2014). To this end semi-structured household (HH) interviews were conducted in each village to gather general information on HH composition, HH income, crop and livestock husbandry and the type and frequency of strategies to cope with food shortages from 20 HHs of different wealth status (N = 60, Appendix A). We tried to exclude a bias due to insufficient sample size by selecting representative HHs using an existing larger HH survey in the study region conducted by Neudert et al. (2015). The interviews on food consumption were conducted every month with the female member in charge of cooking, supervising, and serving and included general information on HH typical diets, the quantity per food item and the sources of food (own production, collected, purchased, gifts, etc.) over a 7 day- recall period (Appendix B).

2.2.1. Food security index (FSI) and food self-sufficiency ratio (FSSR)

To estimate the food consumption and intake, four types of sources were differentiated: own production, collected, purchased

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