Abstract: The hunger gap (the annual period of hardship when most crops are growing but not yet ready for harvest) remains a reality for many smallholder farmers throughout the globe. With a population largely relying on agriculture, and high poverty and malnutrition rates continuously afflicting the country, farmers in Madagascar are particularly vulnerable to the impacts of the hunger gap, further putting pressure on already fragile ecosystems. Using a case study in the Alaotra region, we examine the seasonal trends of climate and agricultural resource dynamics, as well as characterize farmers’ experiences of and strategies used in response to the hunger gap, in order to assess how conservation may better consider the hunger gap to align its objectives with local needs. Results show that farmers are vulnerable to climatic events during a large part of the year, exacerbating the impacts of the hunger gap. The hunger gap appears to have varying degrees of impact on communities around Lake Alaotra, linked to factors such as road quality and agrarian structures—for example, land tenure and size of parcels—contributing to growing environmental degradation. We end by discussing various past and present responses aimed at improving the resilience of farmers of the Alaotra region, including improved accessibility, agricultural intensification, and conservation agriculture.

Keywords: food insecurity; hunger gap; seasonality; livelihood; adaptation; Madagascar
foundation of farmers’ livelihoods. In many tropical regions, there is an overlap between poor
smallholder farming communities and high biodiversity, putting many species at risk [8]. This
inevitably leads to conflicting interests between development and conservation, likely to exacerbate
with increasing change. A better understanding of seasonal trends and hardships, as well as existing
coping strategies, may help in managing these conflicts by guiding policies and measures that are
beneficial for both biodiversity and smallholder farmers.

Madagascar is of particular interest when considering the hunger gap, with close to 80% of
its population working in the agricultural sector and poverty levels remaining some of the world’s
highest [9]. The United Nation’s Millennium Development Goal 1, which focused on the eradication
of extreme poverty and hunger, was not met in Madagascar [10]. The proportion of the population living
in extreme poverty (under USD 1.25 a day) has increased over the last decades, growing from 67.1% in
1993 to 77.1% in 2013. Furthermore, the situation regarding food security has deteriorated, increasing
from 29.7% of the population in 1993 being below the minimum level of dietary energy consumption
to 32.5% in 2013 [11–13]. Factors such as population growth, political instability, global food price
fluctuations, and the increasing frequency of extreme climatic events further push Madagascar’s
population into precarious situations and exacerbate the annual impacts of the hunger gap [9,14,15].
These socio-economic realities have a strong impact on the island’s biodiversity and natural wealth.
Madagascar is home to a vast share of the world’s endemic species [16], many of which are currently
under intense pressure from human activity. Exploiting natural resources is a necessity for much of
the population, but this exploitation is having a profound impact on the island’s ecosystems [17].

Globally, much research on the hunger gap and the coping strategies employed by farmers have
been conducted [3,18–20]. Our study was interested in investigating the relation between these months
of hardship and the natural environment in order to explore potential implications of the hunger gap
for conservation. This was done through a local case study in the Alaotra-Mangoro region, where both
development and conservation stakes are high. Successful conservation requires an understanding
of the local people’s needs and hardships. Better understanding of local resource users’ realities
during the most difficult months of the year can inform (conservation) policy in order to help ensure
the long-term provisioning of ecosystem services. In order to assess how conservation may better
consider the hunger gap to align its objectives with local needs, the specific objectives of this study
were: (i) to identify and assess the seasonal trends of climate and agricultural resource dynamics and
(ii) to characterize farmers’ experiences of and strategies used in response to the hunger gap.

2. Materials and Methods

This study took place in the Alaotra-Mangoro region of Madagascar, in the north-east of the
island. It is one of the country’s main agricultural production areas and is home to the country’s
largest lake. This region is of national interest, both for its inland fisheries as well as for its role as
the country’s most important rice producer [21,22], contributing to its strong population growth by
attracting people from across the country [23]. Multiple changes are taking place in the region that
are felt strongly by the local population. These range from decreasing soil quality to increasing living
costs, covering all areas of the local population’s lives [24]. Data on fish catches show a decrease over
the last two decades [25], limiting an important source of protein that many rely on during the hunger
gap. An annual closed fishing season, currently from 15 October to 15 December, was introduced in
2002 to try and remediate this situation, as overfishing is believed to be the main driver [26].

Since the colonial era, there have been numerous top-down interventions and modernization
efforts in this agricultural system from investments into both major and micro-hydraulic infrastructures,
state farms, and agricultural development, amongst others [27,28]. Today, agriculture and fishery
remain the economic motors of the region [29], with most inhabitants performing multiple activities
to sustain their livelihood [30]. A third of farmers in the region do not own the land they cultivate,
instead having sharecropping arrangements with rich landowners [27,28,31].
Besides playing a key role in the country’s economy, the region’s high value biodiversity also makes it an important conservation area, being home to a number of endemic species, including the Alaotran gentle lemur *Hapalemur alaotrensis*, currently close to extinction [32,33]. This species depends on the marshes that surround Lake Alaotra, classified as a Ramsar site in 2003 and Alaotra Protected Area in 2015 [33,34]. The marshes have been shrinking over the years due to agricultural encroachment to make room for off-season cultivation, where rice fields are naturally irrigated by lake water year-round [21,32]. This requires the clearing of the marshes, i.e., the habitat of the Alaotran gentle lemur, despite the marshes’ status of protection [34].

The region’s climate is characterized by a hot rainy season from November to April and a cooler season the rest of the year with interspersed rainfalls. The average annual rainfall is between 950 and 1250 mm, with the maximum taking place in January [35]. These heavy rainfalls can be accompanied by cyclones, further leading to flooding, destruction of shelters, and a deterioration of soil quality due to heavy deposits [22,36].

This paper collates data from a variety of methods conceived for a larger project on the Alaotra region’s social-ecological system (SES), using a combination of participatory workshops, focus groups, and semi-structured interviews (Figure 1).

![Logical framework of the study.](image)

We chose three study sites around Lake Alaotra so that we could have a representation of each lakeshore as these vary substantially in terms of infrastructure, population pressure, and land use, including levels of marshland conversion and degradation (Figure 2). Andilana Sud, a village of 1074 people (2007) on the west shore of the lake, has 5700 ha of marshes that have largely been converted to rice fields, and it does not have a direct access to the lake [26]. Vohimarina, in the north and home to 1150 inhabitants (2017), has 300 ha of marshes that have been classified as showing low degradation [37]. Andreba Gare, in the south-east, had 5280 inhabitants in 2017 and encompasses 234 ha of intermediate-degraded marshes [26,37]. The secondary, paved, highway ‘Route Nationale 3a’ (RN 3a) runs along the west side of Lake Alaotra, giving access to Andilana Sud and Vohimarina, and the unpaved ‘Route Nationale 44’ (RN44) runs along its eastern side through Andreba Gare, with passage during the rainy season often being challenging to impossible.

An initial phase of fieldwork took place from April 2013 to February 2014, a second phase from June to September 2015, and a third phase from October to December 2016. The first phase focused on exploring the regional resource and climate dynamics, using a participatory modelling method to build a shared conceptual model of a social-ecological system [38]. This involved four full-day workshops with 35 participants in total, approached at respective village markets and invited to join the research sessions (see details in [39]). We selected the markets because these are the hubs of the villages and an important location visited by most farmers irrespective of their livelihood strategies. We assume to have an “average” representation of a village society, since all stakeholders use the market as...
a social interaction forum. During the first workshop, the main actors, resources, and dynamics that play a role in the changes of the marshlands were identified [39]. The second workshop served as verification of the model, further detailing the interactions between the system components, while the third and fourth workshop were realized in other regions with additional stakeholders. These validation workshops served to clarify inconsistencies and ensure validity for the whole Alaotra region. Six focus groups [40] \((n = 30)\) additionally allowed for the triangulation of the results [39]. Based on the dynamics identified and ranked by the stakeholders, a dynamics graph, where we addressed the annual cycles of the main resources and the climatic conditions influencing them, was developed together with the participants. The resulting graph was verified in the following sessions.

Figure 2. Study area at Lake Alaotra, with the location of the four intervention sites during the three phases of our research (see Figure 1) and the regional capital.

During the second phase, we conducted 80 exploratory interviews with farmers in Andreba Gare, gathering, through open interviews, information about their understanding of the hunger gap, daily activities during the different periods of the year, and information about crop cultivation, as well as interviewing local authorities (chef fokontany, the smallest administrative unit in Madagascar). As for the first phase, participants for phases two and three were selected on the basis of willingness to participate by approaching individuals at the market squares of the three sites. This explorative step allowed the development of the interview questions used as our main data-collection method.
The third phase began with the conduction of six focus groups, two in each site with either four men or four women, using seasonal calendars and livelihood monitoring calendars to document annual climatic and agricultural events that affect farmers’ livelihoods [41]. These took place during the annual fishing closure, before the hunger gap. Participants were therefore likely already anticipating the forthcoming months, potentially influencing their interview responses. We further conducted 123 semi-structured interviews (41 per site), covering participants’ definition of the hunger gap and changes in their experience of this period over the last decade, as well as its impacts and their coping strategies (see section Appendix B).

The research followed the ethical guidelines proposed by [42], with participants giving their prior consent to taking part in the study and their anonymity being respected. We coded the interviews using the software QSR NVivo (version 11) and tested for differences between sites by performing analysis of variance (ANOVA), Welch’s t-test, paired t-test, and cross tabulations (Fishers’s exact test and Chi-square test) using IBM SPSS (version 23).

3. Results

3.1. Resource and Climate Dynamics Surrounding Lake Alaotra

The workshops and focus groups allowed identifying the annual climatic and agricultural events that define farmers’ lives (Figure 3). The hunger gap extends from January to April. Few crops are ready for harvest, leading to shortages if the previous years’ stocks are exhausted. The rainy season, which begins in November and ends in April—with yearly variations—brings with it extreme climatic events such as cyclones and flooding that can cause damage to crops, shelters, and infrastructure, putting an additional financial strain on farmers. Hardships begin to ease when the rain diminishes, and crops become ready for harvest. Though all 12 months of the year can potentially be dedicated to rice production (Figure 3), only 15% of participants mentioned performing the illegal practice of off-season rice cultivation in the marshes.

![Figure 3. Annual resource and climatic dynamics in the Alaotra, co-developed with farmers and fishers throughout the region. The bottom section represents the fish dynamics, the middle section the different crop cycles, and the top section the key climatic events affecting agricultural production and infrastructure. The hunger gap represented by the hachured months between January and April coincides with the period of heavy rainfall, when most crops are growing and are not yet ready for harvest. The light grey months in the rice crop and rain cycles represent the fluctuating time of harvest depending on when the rainy season starts: If the rain begins in November/December, harvest will be due approximately in March. If the rain starts in January, harvest will be in April/May.](image-url)
The dry months preceding the rainy season bring with them a different set of challenges in the form of limited access to water. This is also the season of occurrence of fires. Fires can be bush fires as well as fires set in the marshes to clear the reeds and prepare the land for off-season cultivation. The exact time when the rain starts to fall, which varies yearly, will impact the annual yields, including those of off-season cultivations, as early rainfalls will increase the risk of inundation of these fields. Some participants stated that there is currently less rain, or that it is arriving later than it was ten years ago. Farmers depend on fishing to help bridge the hunger gap, as fish lay their eggs in October and quantities peak in March. Participants expressed that fish stocks still appear to be decreasing despite the annual two-month fishing closure put in place to increase the likelihood of juveniles reaching adulthood.

We found that there were significant differences in production areas and activities between Andreba Gare and the other villages. While Vohimarina and Andilana Sud were dominated by land owners who mostly grew rice, Andreba Gare had a much lower share of landowners and a correspondingly lower share of rice cultivators. Instead, they mainly cultivated onions, beans, and tomatoes. Close to a third of all landowners were also land tenants, and those did not own land either rent parcels (sharecropping or fixed-rent contracts) or work as daily labourers on others’ land. In all three sites, food security is preferentially achieved through the personal consumption of harvested rice rather than through the sale of cash crops (e.g., onions, tomatoes, peanuts). Though there was no significant difference between sites amongst participants of the questionnaire regarding age, household size, and gender, education differed significantly. Andilana Sud showed the highest mean years of education (8.5), followed by Vohimarina (7.6), and lastly Andreba Gare (6.3) (Table A1 in Appendix A).

3.2. Perceived Impacts of the Hunger Gap

Across the sites, the three most mentioned impacts of the hunger gap are (i) ‘insufficient quantity and/or quality of food’ and (ii) ‘financial difficulties,’ and (iii) ‘unemployment’, although an indirect impact resulting from the lack of jobs (Figure 4). “There is no work to be done, and even if we do find any the salaries are very low because the amount of available work is much less than the number of people looking for employment,” said Participant 110, Andilana Sud.

There were no significant associations between perceived impacts and sites, with people from all three villages appearing to have similar concerns. The hunger gap also affects people’s feeling of security, with participants mentioning that people are pushed to stealing: “The hunger gap increases insecurity, as people are desperate due to hunger and lack of money, so they steal from their neighbors,” said Participant 38, Vohimarina.

The stress of being unsure of having enough food affects not only adults but also children, some of whose parents stated that the stress leads to a deterioration of school results. Due to insufficient

![Figure 4. Impacts of the hunger gap, as mentioned by study participants from three villages around Lake Alaotra (percentages; n = 123).](image-url)
financial means, there is the lack of hygiene and spreading of diseases, exacerbated by the humidity and stagnant waters during the rainy season. The decrease in available produce further lead prices to increase on the market. As people have little money during this time, purchasing produce at the market is done sparingly, making it difficult for those selling to earn enough. The average daily income is halved during the hunger gap, from US$ 3.29 to US$ 1.45 (MGA10,545 to MGA4664, live market rate 1 November 2016). Comparing income between sites (Figure 5), although we do not observe a significant difference during the hunger gap at the $p > 0.05$ level, we do observe one for the rest of the year, with participants in Vohimarina having an average daily income 39% higher than those in Andreba Gare and 20% higher than those in Andilana Sud.

Figure 5. Average daily income between sites and between the hunger gap and the rest of the year ($n = 123$).

3.3. Coping with the Hunger Gap

Saving yields and/or money is a strategy used by many participants, either by putting agricultural produce aside or financial savings to ensure having sufficient food and liquidity during these months. Off-season rice cultivation is undertaken to have a second harvest in January, although this practice that often encroaches into the marshes is illegal, discouraging many. This practice is most prominent in Andreba Gare on the eastern side of the lake and in Andilana Sud, with only a small share of farmers practicing it in Vohimarina. This links to the strategy of agricultural extensification, with farmers increasing their cultivable land up on the hillsides or in the marshes. Planting a variety of crops was often mentioned as a strategy that enabled access to harvests at different times of the year: “We grow lots of different crops, some that can be harvested during the hunger gap, like manioc. This way we have something to do with our time,” said Participant 93, Andilana Sud. Though coping strategies showed no variation across age and income, some patterns emerge when considering gender: Men mentioned crop diversification, off-season cultivation, and agricultural extensification—i.e., all strategies relating to agriculture—as ways to fight the hunger gap significantly more than women (Figure 6).

Reduction in food consumption is the only strategy significantly associated with sites, having been identified by a fifth of participants in Andreba Gare but only by a few in both Vohimarina and Andilana Sud. Borrowing money from friends and family or financial institutions during the hunger gap was also mentioned, as well as the use of microcredits, although not necessarily to combat the impacts of this period. The most mentioned reasons for not using microcredit were fear of being unable to pay them back, as well as having no collateral with which to take out a loan.

Though the above strategies show a large diversity, by far the most employed coping strategy was diversification of sources of income, with farmers having multiple activities when no work is required in their fields: “With it being such a difficult period, I am constantly looking for new opportunities,” said Participant 34, Vohimarina. This diversification takes many forms, with the most common being the selling of goods, mainly agricultural produce, and daily work (e.g., working on other people’s land
or doing occasional jobs). Livestock breeding and fishing are also widely performed. Crafts-making was an important activity in Vohimarina but was hardly mentioned in the two other sites. This was also linked to plant collection, only mentioned in Vohimarina, mainly involving reed collection for crafts. A small number of participants also do brickmaking and mining.

![Activities](chart)

**Figure 6.** Coping strategies between gender as mentioned by study participants from three villages around Lake Alaotra (percentages; n = 123).

When discussing how participants’ experience of the hunger gap has changed over the last ten years, close to a quarter stated that there has been no change and that it was just as difficult ten years ago compared to today; some, however, believed it varies yearly, depending on the rainfall (Figure 7). However, the majority stated that changes have taken place, many negative. Close to a third of participants believe that there is currently less rain and that this rain is arriving later and later in the year. Decreasing amount of agricultural land due to migration and population increase was only mentioned in Andilana Sud.

![Changes](chart)

**Figure 7.** Perceived changes in the hunger gap over the last decade, as mentioned by study participants (percentages; n = 123).

A few participants mentioned the closed fishing season that until recently coincided with the hunger gap, thereby taking away a potential source of income and/or protein. However, some participants believe the hunger gap is more bearable today than previously thanks to off-season cultivations, as well as some mentioning that there are currently more employment opportunities than in the past. Certain differences emerged across gender and sites: Significantly more men identified off-season cultivation as a change than women (p > 0.05), and although participants in Andilana Sud mentioned that arable land was becoming scarcer, this change was not identified in the other two sites.
4. Discussion

From October to March, farmers of the Alaotra region are vulnerable to many climatic events and environmental disruptions that may affect their livelihoods. They are faced with a wide range of problems directly affecting their crops that represent their main source of livelihood, such as having to deal with water scarcity one month and heavy rains and potential flooding the next. The high vulnerability of farmers puts added pressure on the region’s fauna and flora, as livelihood uncertainty and lack of resources push farmers further into the marshes [39].

An issue discussed by participants is the vulnerability of their rice crops to variations in the rainy season, as this is their growing season, and many farmers have noticed changes to the amount and/or temporality of rain in the last decade. Changes in climate patterns, expected to be increasingly felt in Madagascar [14,43], will have drastic effects on farmers’ livelihoods, the flora and fauna, and the country’s economy. The country’s decreasing availability of rice per capita, tied to a growing population and stagnation of agricultural production, is further clearing the way for importation and competition [30]. Nevertheless, rice firmly remains the country’s staple food despite the above-mentioned issues and rice being a water- and labor-intensive crop, as well as its growing season being longer than many other crops [44].

Fishing is an important activity during the hunger gap and coincides with the annual peak in fish stocks, with fish reaching maturity around March. However, with many farmers turning to this activity while there is little work to do in the fields, as well as factors such as habitat loss and destruction of breeding ground, fish stocks continue to decrease despite the annual fishing closure put into effect [25,45]. This closure suffers from a general lack of respect and is not strongly enforced by authorities [34,46,47]. Restrictions regarding the killing of small fish have been implemented by authorities and by certain fishers to encourage reproduction [46]. However, these regulations may lead certain families to no longer be able to afford this commodity [24], particularly during the hunger gap when fish sizes are at their maximum.

The strong difference in nominal wage between sites most months of the year but not during the hunger gap shows that this period breaks down the income disparities that might exist, putting all on a similar level. However, people from communities with overall lower income will have had fewer resources available to take proactive measures to combat the effects of the hunger gap, leaving them in a more precarious situation. This is illustrated by the reactive strategy of decreasing food consumption being a widely-used strategy in the eastern village of Andreba Gare but not in the two other sites. The only other reactive strategy was ‘borrowing,’ and was only expressed by a small number of participants. This may, however, be due to a response bias tied to the stigma attached to borrowing, which could also be the case for other activities such as prostitution or turning to moneylenders. All other identified strategies were proactive, either aimed at increasing agricultural output (off-season cultivation, crop diversification, agricultural extensification) or ensuring sufficient cash availability (income diversification, harvest and/or financial savings).

The variation across gender regarding agricultural strategies indicates than women focus more on impacts affecting the household than their main activity, in this case mostly farming. This links to previous research having shown that women are often more vulnerable to stresses and shocks than men in agrarian environments, as they will have focused more of their resources on the household and their kin than investing in agricultural improvements [24,48]. Men’s stronger sense of insecurity during the hunger gap shows another division of responsibility, as it falls under their duties to guard valuable property such as livestock and prevent stealing.

Relying on off-farm activities as secondary or tertiary sources of income has been found to decrease seasonal vulnerability [3–5], and in the case of this study, income diversification is the most prominently used strategy despite not necessarily being off-farm. Penot et al. [49] expressed that the tendency of farmers in the Alaotra region towards income diversification illustrated their resilience. If many of these secondary activities, e.g., breeding and fishing, are performed in all sites, others are site-specific: Andilana Sud, having the easiest access to large market towns, had significantly more
daily work opportunities than the two others. Craft-making is done significantly more in Vohimarina, where they utilize reeds from the marshes to that effect. Lack of access to markets and a bad state of infrastructure has been shown to increase farmers’ vulnerability due to the increased prices of produce and limited diversity of non-farming activities caused by this remoteness [5,14]. This could explain the lower average income of Andreba Gare’s participants, due to the difficulty of access to the village by the unpaved and badly maintained eastern road, particularly an issue during the rainy season, which coincides with the hunger gap. As a consequence of difficult access, transportation fees increase and thus further add pressure to the already challenging situation.

Many farmers in Andreba Gare do not grow rice, illustrating various levels of resource dependency between the three sites. Farmers in Andreba Gare must use the money they earn from selling other crops to buy this staple food, leaving them with little or no disposable income. Andreba Gare participants who do grow rice have little rice surplus, forcing them to sell higher percentages of their other crops for income, unlike in Vohimarina and Andilana Sud, where selling more of their harvested rice allows them to keep more of their other crops for personal consumption. Differences in rice prices amongst sites show that Andreba Gare, with the lowest income, also has the highest rice price throughout the year. Though prices increase in all sites around 44% during the hunger gap, Andreba Gare’s prices are 14% higher than those in Andilana Sud, likely due to the smaller percentage of rice farmers. Furthermore, the relatively low percentage of participant landownership in Andreba Gare compared to the two other sites could indicate higher vulnerability. Just under a third of Andreba Gare’s landless participants work as day laborers, an activity shown to be most vulnerable to seasonal hunger [5].

Though participants mentioned strategies involving the expansion of agricultural land, such as off-season cultivation and cultivating on less fertile hillsides (see also [39]), they did not mention intensification strategies, such as investing in organic or chemical fertilizer, composting, alternative crop rotation strategies, or agricultural technology. High prices of certain of these products, as is the case for chemical fertilizer, may explain this, with poor farmers often being unable to afford this product [50]. This choice of expansion over intensification has numerous environmental implications. These include increasing deforestation and marshland conversion, both of which negatively affect the services these ecosystems provide, further impacting local populations’ livelihoods and their natural capital asset base [14,37,51–53]. Marsh access can further pose a threat to conservation: In Andreba Gare and Andilana Sud, where access to the marshes is easiest, off-season rice cultivation is more pronounced, and the remaining marsh ecosystems face rapid transformation [34,39]. If conditions for farmers become increasingly difficult, their readiness to respect conservation rules will decrease. Consequently, the higher the pressures on farmers, the more likely they will transform land or engage in illegal activities [34,54].

Though there is no silver bullet to making the hunger gap a thing of the past, many tools and mechanisms have been shown to be effective in the strive for year-round food security and sustainable livelihoods and, if implemented jointly, may help achieving the United Nations’ SDG of global food security and putting an end to hunger. Land reform would be an efficient, although politically unlikely and difficult to implement, way to help reduce the hunger gap: Access of all people to good cultivable land would make them more food secure, as daily laborers are most vulnerable to stresses and shocks. More easily attained, however, is improved access to markets, requiring decent infrastructure and affordable transportation that would allow farmers to increasingly focus on cash crops, as well as allowing knowledge exchange. The promotion of non-farming activities in rural areas could help those more vulnerable have more secure incomes through diversification.

Improved access to finance, which is currently lower in Madagascar than in the rest of Sub-Saharan Africa [55] could help farmers fight the effects of seasonality [56,57]. Microcredit has been put forward as a solution by bringing more stability to financial capital through consumption smoothing. Specific products such as flex loans show promising results in poverty reduction and increasing food security, with studies exhibiting positive impacts of flexible microfinance programs specifically targeted at the
poorest of the poor in agrarian environments [19,56,57]. The small percentage of participants in this study using microcredit shows the potential for expansion of this sector in the Alaotra region and the need to communicate the mechanisms of microcredit to gain the trust of farmers. The majority of participants were afraid of the consequences of taking out loans and being unable to pay them back. Another product offered by one of the largest Micro Finance Institutions (MFIs) in Madagascar and catered for the rural population is the rice Inventory Credit (IC), where rice yields are used as collateral to secure a loan. These loans allow for consumption smoothing by storing rice until the period when it is most needed [58]. Though this product shows promise, peer reviewed research on its impacts is currently limited. Regarding regular microcredit, there is currently no consensus on their effect on poverty alleviation in Africa [59].

Promoting the process of agricultural modernization has been put forward as a key factor in increasing agricultural production in Madagascar [60], as this increase may have a positive effect on income levels and improve food security [61]. Rather than expansion of farmland, mechanization could help decrease production costs and increase smallholders’ income [62]. This could also be achieved using conservation agriculture, composting, improved irrigation, and pest management [63,64]. SAR (Improved Rice System) has shown promising results in Madagascar, being far less labor intensive than SRI (System of Rice Intensification) and allowing better water control [63]. The government’s implementation of its national strategy for the mechanization of the rice sector, aimed at increasing the use of agricultural technologies to improve production levels, will need to be closely monitored. From the 2000s, after two decades of economic liberalization and State disengagement including the privatization of agricultural funding, development projects, focusing on rain-fed farming and land management, such as BVlac and ROR [49,63], as well as government policies aimed at intensifying farmers’ crops through improved access to fertilizer, pesticides and seed varieties [65] were once again implemented. SRI, developed in response to the issue of stagnating rice production, gained wide support since its development in Madagascar in the 1980s. However, although some research shows positive results regarding small-scale farming, the empirical evidence concerning SRI’s objective of increasing yields has been subject of much criticism and debate [64–68].

Despite these development efforts to improve the state of agriculture, the socio-economic and political crisis of 2009 led to a decrease in governmental and international investments into agriculture, leading to a subsequent decrease in agricultural production. (see [63] for a detailed historical background on agricultural practices around Lake Alaotra). Since 2014, the government has once again started investing in policies aimed at increasing agricultural production, inter alia through the implementation of a national strategy for the mechanization of the rice sector, approved in 2015 [66]. Results of these investments on agricultural production are not yet documented. Regarding international development, in recent years, research on conservation agriculture in the Alaotra region has shown promising results to deal with climate variability and crop productivity [69–71] and will likely be increasingly adopted by farmers in the coming years.

Chronic malnutrition remains a major issue in the country [10], and the rates in the Alaotra are reported to be in line with national statistics [72]. Though quantities may be adequate, protein and essential nutrients are often lacking, with families’ having an inaccurate understanding of nutrition and foods [73]. Informing and educating agrarian communities about nutrition, as well as promoting crop diversification would help families in prioritizing protein-rich foods, particularly during the hunger gap when food and cash are scarce. The hunger gap’s effect on schoolchildren needs to be addressed, as certain parents see the negative impact this period has on school results. In Madagascar, almost half of children are affected by chronic malnutrition [12,44], with malnutrition in childhood having been shown to have life-long impacts on brain capacity [74]. Primary school teachers of the Alaotra region reported that many children are malnourished and live in impoverished households [75], and teachers specifically mentioned the hunger gap as being a difficult period, with children being less attentive, less participative, and more tired as compared to the rest of the year. Especially in Andreba Gare, reduced food consumption is a reactive ‘strategy’ to cope with the hunger gap, affecting a fifth of
the survey participants including their children. International research showed that malnourishment causes reduced learning capacity and school success (e.g., [76–78] and results in higher numbers of repeaters and dropout rates [79]. The links between households’ economic situation, malnutrition, and education suggest that the poorest who cannot bridge the hunger gap and thus suffer from (higher) malnutrition will be constrained by life-long consequences in learning and intellectual capacity, further reducing their options and capacities to react to change [80–83].

5. Conclusions

This study highlights the importance of access to various capital stocks in relation to the hunger gap and the degree of impact that the hunger gap has on communities. Farmers currently in vulnerable financial positions will likely be unable to access solutions such as improved agricultural technologies or microcredits, implying that without active governmental intervention, a substantial share of these communities will remain trapped in a downward spiral of poverty. Over the last years, the region has seen fast environmental degradation, affecting local biodiversity. The conservation-development balance is currently in disequilibrium, and with increasing changes taking place in the Alaotra region, it is likely that marsh areas will continue to shrink. It is crucial not to let the impacts of the hunger gap exacerbate and become unendurable for farmers, as those who have so far been unable to adapt to changes will only become more vulnerable to the effects of seasonality and food insecurity, further depleting natural resources out of necessity. Their current coping strategies may not remain effective in sustaining them in an environment of increasing degradation due to overexploitation and climate change. Thus, it is crucial that measures and policies pave the way to support rural resource users in developing capacities enabling them to adapt and protect the natural resources upon which they depend.

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Appendix A. Participant Demographics

Table A1. Participant demographics. Standard Deviations in brackets. *n* = 123.

|                      | Vohimarina | Andreba Gare | Andilana Sud | Total |
|----------------------|------------|--------------|--------------|-------|
| % female             | 65.9       | 42.9         | 51.2         | 53.3  |
| mean age             | 39.4 (12.4)| 40.1 (13.0)  | 44.3 (12.3)  | 41.3  |
| mean years of education | 7.6 (2.5) | 6.3 (3.1)   | 8.5 (2.5)    | 7.5   |
| household size       | 4.8 (2.0)  | 4.8 (2.0)    | 4.6 (1.5)    | 4.7   |
| % land owners        | 85.4       | 61           | 92.68        | 79.7  |
Appendix B. Interview Questions

Fokontany:
Date:
Participant number:

**Introduction**

We are conducting this study as part of the Alaotra Resilient Landscape (AlaReLa) project, based in Ambatondrazaka. We are trying to better understand farmers’ and fishers’ experience of the hunger gap around lake Alaotra. Everything that we discuss is confidential, and your responses will remain anonymous. Do you agree to continue with the interview?

**Personal details**

Sex
How old are you?
Where were you born?

*If not in the Alaotra region, ask when and why they moved to the region.*

Are you married?
What is your main occupation?
What are your secondary or tertiary occupation(s)?
How many years of schooling did you have?
How many people live in your household?
How many children do you have?

*If yes ask how old the children are*
*If yes ask whether the children go to school*

How much do you earn during an average day?

**Physical wealth**

Are you a:
- Land owner

*If yes, ask more details about how much and where*

- Land tenant
- Daily labour
- Other (please specify)

Do you own livestock?

*If yes, ask what kind and how many.*

**Agriculture**

What crops do you grow and where?
What do you do with your crops?

*Ask how much they keep for their own consumption and how much they sell.*

What do you do with the money you earn from selling produce or from your other activities?

**Hunger gap**

What is your understanding and experience of the hunger gap?
What impacts does the hunger gap have for you personally?
What do you do to try to reduce these impacts?
Has the hunger gap changed during the last 10 years?
If yes, ask how, when and why

How does your income vary during the year?
Ask about income and expenses during the hunger gap and the rest of the year

Are you pushed towards new activities during the hunger gap?
If yes, ask what activities and why

What are your eating habits like during the hunger gap compared to the rest of the year?
Ask about type of food, quantity, quality

Finance
Do you or have you ever used microfinancing?
If yes, why and when, and their experience of using microfinancing
If no, ask why

Do you think that microfinancing could help with the hunger gap?

How do you organise your children’s schooling fees during the hunger gap?

Closing question
What do you think could be done by yourself personally, by the community, or by the government, to decrease the impacts of the hunger gap?

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