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**Understanding livelihoods for protected area management:
insights from Northern Madagascar**

24 ABSTRACT

25 Protected areas (PA) are the most common approach to conservation globally; however, their
26 effectiveness is unclear when neighbouring human communities are highly natural resource
27 dependent. While forest-based livelihoods provide important income for rural communities,
28 destructive livelihoods such as charcoal production can also threaten the sustainability of PAs.
29 We aimed to understand drivers of livelihood choices in communities surrounding a proposed
30 PA threatened by charcoal production in northern Madagascar, to inform management strategies
31 that promote forest conservation without negatively impacting local communities. We used semi-
32 structured interviews and focus groups to understand local livelihood dynamics using the
33 Sustainable Livelihoods Framework (SLF). Our findings showed charcoal production to be an
34 important livelihood used to deal with annual food insecurity. Agricultural yields were limited by
35 a lack of assets for clearing land and building protective fences. Households were also hesitant to
36 invest in agriculture due to the perceived risks associated with unpredictable rainfall and cattle
37 grazing. Furthermore, while fishing was an important livelihood for filling income gaps,
38 declining catches due to overexploitation across the study region appeared to be increasing the
39 need for charcoal production. While improvements to agriculture were perceived to be promising
40 strategies for reducing forest-dependence, a landscape approach to conservation in the region
41 will be necessary in order to promote sustainability of all livelihoods and to reduce overall
42 pressures on forest resources.

43

44

45 Key words: charcoal, food security, deforestation, dry forests, fisheries, sustainable livelihoods
46 framework, management effectiveness

47 **1. INTRODUCTION**

48 As biodiversity and forest cover decrease across the globe (Butchart et al. 2010), protected areas
49 (PAs) are becoming increasingly implemented and now cover 15% of land and 7% of the oceans
50 (WDPA 2018). However, their effectiveness in conserving biodiversity is debated (Geldmann et
51 al. 2013), and they are additionally contested on ethical grounds, particularly in developing
52 countries rich in biodiversity (Naughton-Treves et al. 2005) where restrictions on access to
53 natural resources can inflict high socioeconomic impacts on rural communities (Pullin et al.
54 2013; Neudert et al. 2017). The poorest households in rural communities often depend on natural
55 resources as safety nets to help them recover from unexpected shocks or fill gaps during the
56 agricultural off-season, but also for building assets to invest in other livelihoods (Zulu and
57 Richardson 2013; Angelsen et al. 2014; Jones et al. 2016). Given that people lacking alternatives
58 may continue to illegally use resources from within PAs in the absence of effective enforcement
59 (Holmes 2007), it is essential for PA managers to understand the factors driving livelihood
60 choices in surrounding communities if PAs are to be effectively managed without exacerbating
61 poverty.

62 This is particularly true for Madagascar, a global conservation priority harbouring an
63 unparalleled richness of threatened endemic species (Brooks et al. 2006) alongside large rural
64 populations highly dependent on natural resources for subsistence and income (Scales 2014), and
65 which has been rapidly expanding and evolving its protected area system over the last two
66 decades. Prior to 2003 all PA's in Madagascar were managed as strict protected areas (IUCN

67 categories I, II and IV) in which human habitation and all extractive uses of natural resources
68 were forbidden, however the expanded PA system includes new sites managed as multiple-use
69 PAs (IUCN categories III, V and VI) which are zoned to permit the continuation of rural
70 livelihood activities if these are carried out at sustainable levels (Marcus and Kull 1999; Gardner
71 et al. 2013, 2018). Thus, while the management of strict PAs focused on preventing livelihood
72 activities through enforcement (in some cases with ‘compensation’ offered in the form of
73 integrated conservation and development projects), the management of new protected areas is
74 complex because these sites are expected to conserve biodiversity and cultural heritage while
75 simultaneously promoting poverty alleviation and rural development (Gardner et al. 2013).

76 Rural communities in Madagascar typically have diverse livelihood portfolios, which can include
77 a mix of small-scale subsistence agriculture, cash crop cultivation, livestock herding, charcoal
78 production, timber harvesting, collection of non-timber forest products (NTFPs), artisanal
79 mining, collection of marine products, fishing and/or bush meat hunting (Ackermann 2003;
80 Cartier 2009; Golden 2009; Narozanski et al. 2011; Gardner and Davies 2014; Harvey et al.
81 2014; Gardner et al. 2016a). Diversification, and particularly a reliance on forest-based
82 livelihoods such as charcoal production (Casse et al. 2004; Gardner et al. 2016a), is a common
83 strategy for dealing with vulnerability and risk (Hänke and Barkmann 2017). However, the
84 extent of household reliance on forests varies because livelihood choices depend on a complex
85 suite of ecological, economic, political and cultural factors (Scales 2014). Such factors can
86 include: the distance to forest, roads or markets (Urech et al. 2015), household demographics and
87 asset status (Neudert et al. 2015), local taboos (*fady*), informal (*dina*) or formal community
88 regulations (Gardner et al. 2008; Reuter et al. 2018; Ward et al. 2018), ethnic group (Ackermann
89 2003), local social cohesion (Urech et al. 2015), migrant or resident status (Nawrotzki et al.

90 2012), agricultural seasonality and poor yields (Harvey et al. 2014) or regional/national policies
91 and institutions (Scales 2014).

92 Understanding the factors driving livelihood choices is essential for the effective management of
93 Madagascar's PAs because livelihoods such as shifting cultivation (Casse et al. 2004), charcoal
94 production (Gardner et al. 2016a), timber harvesting (Burivalova et al. 2015) and livestock
95 rearing (Waeber et al. 2015) drive deforestation and degradation across the country, including in
96 PAs (Gardner et al. 2018). Charcoal production is of particular concern due to high urban
97 demand coupled with the informality of the sector, making regulation difficult (Minten et al.
98 2013). The production of charcoal from remaining natural forests is an important livelihood for
99 many rural communities (Ackermann 2003; Casse et al. 2004; Gardner et al. 2016a) but has
100 negative impacts on biodiversity (Gardner et al. 2016b); it therefore poses a significant challenge
101 for PAs, which largely occur in areas where local people are heavily natural resource-dependent
102 (Virah-Sawmy et al. 2014). Given that rural populations are predicted to grow rapidly (Harris et
103 al. 2012) and that most remaining forests have been incorporated into the country's expanded PA
104 system (Gardner et al. 2018), understanding how to reconcile conservation with the livelihood
105 needs of local communities will be essential in order to increase PA effectiveness. Ideally, an
106 understanding of local socioecological systems and resource use should be developed prior to PA
107 establishment, in order to plan and mitigate for future changes resulting from management
108 (Urech et al. 2015)..

109 Here, we seek to understand livelihood dynamics within communities surrounding a proposed
110 PA threatened by charcoal production in northern Madagascar, to inform management strategies
111 that promote forest conservation without negatively impacting local communities. This is
112 particularly important as the needs and perceptions of local communities and conservation

113 practitioners may be very different, with different goals surrounding the aim of ‘sustainability’ or
114 ‘success’ in their everyday endeavours (Keller 2008). We aim to determine how current
115 livelihood choices relate to natural resources, how the PA is perceived to affect these choices and
116 how, if at all, constraints in livelihoods affect dependency on forest resources (particularly for
117 charcoal production). We also investigate how livelihoods could be supported to reduce charcoal
118 production, and end by recommending management interventions to promote sustainable
119 development and conservation in the long-term. To answer these questions, we apply the
120 sustainable livelihoods framework (SLF; DFID 1999) to investigate the factors driving
121 livelihood choices across three villages in the region. The SLF acknowledges the complex suite
122 of socioeconomic, political and ecological factors influencing rural livelihoods (Fisher et al.
123 2013) and, therefore, can serve as a useful tool for prioritising actions to reduce livelihood
124 constraints, and identifying important links within the socioecological system for informing
125 policy and management (Ellis 2000).

126

127 **2. METHODS**

128 **2.1 Study Site**

129 The proposed Bobaomby PA is located northwest of Antsiranana in northern Madagascar (Fig
130 1). The landscape consists of fragments of secondary dry deciduous forest and littoral forest
131 (both highly-threatened vegetation types that are under-represented in Madagascar’s PA
132 network, Waeber et al. 2015), within a matrix of anthropogenic wooded savannah of low
133 biodiversity value. The surrounding coastal area consists of Antsiranana Bay to the east and the
134 Nosy Hara Marine Protected Area (MPA) to the west, and comprises mangroves, mudflats and

135 coral reefs. The region experiences a wet and dry season, with the 980 mm of annual rain
136 predominantly falling between January and May. The PA project was initiated in 2018 by
137 multiple promoters including the Malagasy conservation non-governmental organization
138 Madagasikara Voakajy and the University of Antsiranana, in collaboration with the Regional
139 Director of the Ministry of Environment and Sustainable Development (MEDD). The area boasts
140 high herpetofaunal diversity and populations of the endangered crowned lemur (*Eulemur*
141 *coronatus*) (Mitchell et al. 2007; IUCN 2018), however the forests are highly threatened by
142 charcoal production and cattle grazing (Mitchell et al. 2007). Previous surveys in the region
143 found increased levels of charcoal production as rainfall and agricultural productivity has been
144 declining, leading to localized clearing of trees (Mitchell et al. 2007). The PA is proposed as an
145 IUCN category V multiple-use PA in which the sustainable use of natural resources is permitted,
146 and will be co-managed by The University of Antsiranana and local community associations
147 with support from Madagasikara Voakajy. While the area does not yet have protected status,
148 multiple forest fragments are already managed by community forest management associations
149 (COBA) created through joint forest management legislation (Pollini et al. 2014) and some
150 communities also manage their marine environment through local fishers' associations (CLPs).

151 [FIGURE 1]

152 At the time of this study, Bobaomby PA was in the preliminary stage of obtaining temporary
153 protected status, a process requiring the development of a social safeguards plan to identify and
154 mitigate any negative impacts on local communities (Virah-Sawmy et al. 2014). Preliminary
155 socioeconomic surveys carried out as part of this process in January-April 2018 identified 10
156 villages across the PA that, due to their use of forest resources, could be affected by its creation.
157 Of these, we selected three villages for further research, based on their shared use of one of the

158 largest remaining forest fragments (Beantely), and differences in factors that may influence their
159 livelihoods, such as COBA rules, level of isolation and local taboos (Table 1). This comparative
160 analysis across villages allows a thorough assessment of the factors driving livelihood choices in
161 the region and the potential impacts of the proposed PA.

162 [TABLE 1]

163

164 **2.2 Data Collection**

165 We conducted field research over 7 to 10 days in each village during May 2018, using a
166 combination of semi-structured household interviews, key informant interviews, and focus
167 groups. Key informant interviews with local leaders allowed us to obtain an overview of
168 livelihoods, resource use and resource management in each village, while household interviews
169 provided more in-depth information about particular livelihoods. We used purposive sampling
170 for the household interviews, using information from local leaders and preliminary surveys to
171 select interviewees representing different geographical sectors, livelihoods, genders and ages.
172 Interviews were carried out in the local dialect of Malagasy by BIV, KA and a local research
173 assistant familiar with the communities. Interviews were conducted in respondents' homes, at
174 times most convenient to them. Questions focused on individual livelihood choices and the
175 factors driving them, how livelihoods related to the forest, how a PA could affect livelihood
176 choices, and whether and how respondents could envision reducing their forest use. Following
177 household interviews in each village, we used further interviews with leaders and/or households
178 to crosscheck information or clear up uncertainties. Focus groups were conducted in Malagasy
179 near the end of the research in each village by HA and a local research assistant, with additional

180 assistance from BIV and KA. These were conducted at the village's administrative office on
181 days when it is taboo to work, to encourage higher turnout. Focus groups were used to
182 complement information gathered during interviews, and focused on i) how households with
183 different livelihoods perceived a PA affecting them, and ii) potential development interventions
184 or PA investments that could reduce their need for forest resources (particularly charcoal
185 production). We obtained Free, Prior and Informed Consent from all participants, anonymised all
186 responses, and abided by the ethical codes of conduct of the American Anthropological
187 Association and Madagascar Conservation & Development Journal (Wilmé et al. 2016). Ethical
188 approval was also obtained from the University of Kent Ethics Committee.

189

190 **2.3 Data Analysis and the Sustainable Livelihoods Framework**

191 We used the SLF for structuring the analysis of the qualitative data (Ellis 2000). The framework
192 assumes that an individual's livelihood choices are based on their access to human, physical,
193 natural, financial and social assets. Asset availability is influenced by an individual's
194 vulnerability, such as seasonality of income or natural disasters, and by regional and national
195 policies and institutions, including laws, markets or cultural norms. Understanding where and
196 why assets are lacking across populations could contribute to the development of livelihood
197 support programmes (Nawrotzki et al. 2012), making the SLF directly applicable to PA planning.
198 We thematically coded data from interviews and focus groups using the categories of assets,
199 aspects of vulnerability and structures and processes used in the SLF using Nvivo Pro 11
200 software (Fig 2), and coded interviewees for anonymity (e.g. VAI1, VBI1). We then produced a

201 conceptual model of factors leading to the unsustainable use of natural resources to assist in
202 identifying potential intervention points.

203

204 **3. RESULTS**

205 We completed 40 household interviews, 10 key informant interviews and three focus groups
206 across the three study villages. The analysis revealed multiple livelihood constraints contributing
207 to increasing forest dependence.

208

209 **3.1 Livelihood strategies and land-use**

210 Across the three villages, households typically had diverse livelihood portfolios, including some
211 mix of agriculture, livestock rearing, fishing and/or charcoal production (Table SI). The majority
212 of livelihood activities took place in the wooded savannah, locally termed the *fondra*, which also
213 made up the largest proportion of the landscape. The savannah was used for agriculture, which
214 consisted mainly of small-scale subsistence maize and irrigated rice production on flat land, and
215 livestock rearing, which primarily involved raising and/or milking zebu cattle. Cattle were
216 typically kept within fenced paddocks or tethered close to houses during the night, and left to
217 graze freely during the day. Trees and dead wood were also collected within the savannah for
218 cooking, building fences and charcoal production. Households usually cooked with wood
219 collected from the savannah, thus charcoal was typically only produced for sale in Antsiranana.
220 This is with the exception of households in BAIE, where production for sale was prohibited.
221 Fishers typically collected marine products within the mangroves or fished within the bays or

222 along the shoreline, using nets and/or pirogue canoes. Fishing was carried out for both
223 subsistence and trade; however, trade was carried out locally or within Antsiranana and there
224 was no mention of commercial operations

225 The collection of forest products was concentrated in the savannah, as much of the remaining
226 forest is considered taboo, or *fady*; many respondents noted that they never go there. When asked
227 how individuals depended on the forest, the overwhelming response was for harvesting trees for
228 house construction or tools. While the majority of forests were “untouchable”, each forest had
229 portions, named *atiala velona*, where trees for construction could be requested through the local
230 COBA. However, despite the consistent suggestion from informants that the remaining forest
231 was considered taboo, it appeared that the forests were still being used for income either through
232 charcoal production or selling timber in all three communities. In Ambodimadiro (AMB) it was
233 evident that the savannah has been overexploited over the past 10 years, with many respondents
234 commenting on the lack of trees available for any activity, including charcoal production.

235 However, charcoal production was viewed as a major livelihood in the community in both wet
236 and dry seasons, suggesting that the forest was often used for this purpose. When asked whether
237 Beantely was increasing in size VAI14, a cultivator and charcoal producer, stated, “Increasing?!
238 Increasing?! Everybody’s using it for charcoal”. Meanwhile, respondents in AND often
239 mentioned the use of Beantely by members of the nearby village of Cap Diego, which lacks
240 forests or trees in their savannah. Finally, in BAIE, it appears that instead of charcoal production,
241 trees may be illegally cut from the forests for sale as timber. As VCI3 stated regarding
242 individuals breaking forest rules, “...for those who struggle, they will take advantage to cut trees
243 and sell them. Because they don’t get enough help... you know, livelihoods in our area are so
244 hard”.

245 Due to the taboo nature of forest use in the region, it was difficult to discern exactly how
246 dependent individuals were on forest resources. However, conversations with respondents
247 revealed extreme livelihood limitations across all three communities, giving people no choice but
248 to break local taboos and forest management rules. The following sections highlight the factors
249 influencing livelihood options and subsequent resource use using the SLF (Fig 2).

250 [FIGURE 2]

251

252 **3.2 Drivers of livelihood choices**

253 **3.2.1 Seasonality of rain and wind**

254 The seasonality of rain was one of the most important factors driving livelihood choices across
255 all three villages (Fig 3). Cultivation and cattle milking only occurred during the wet season
256 (January-May), while fishing and charcoal production occurred year-round, but became the main
257 livelihoods during the dry season as others became impossible. To maximize the returns from
258 livelihoods during the wet season, it was essential to begin activities immediately upon the start
259 of the rain, including planting crops (in particular rice) and milking cattle.

260 The dry season (June-December) was the time when it was difficult to find income, with few
261 options available beyond fishing or producing charcoal. However fishing was limited between
262 June and October due to strong easterly trade winds, the *varatraza*, and individuals lacking
263 motorized boats were either unable to fish during this time or had greatly reduced catch. It was
264 during this time that many noted having no other livelihood options beyond charcoal production.

265 Households in BAIE were particularly limited during this period, as fishing was the primary
266 livelihood during both seasons and charcoal production for sale was prohibited.

267 [FIGURE 3]

268

269 **3.2.2 Agricultural constraints**

270 Rice was the most important crop for all respondents, but its high water demands made
271 cultivation difficult in such a dry region. Due to the short rainy season, households needed to
272 clear land in the savannah, dig irrigation canals and construct protective fences before the rain
273 commenced. However, these activities were limited by a lack of tools (such as shovels, picks,
274 ploughs) and/or cattle (for ploughing), as well as an overall lack of labour to collect wood for
275 fence construction, a process that could take several weeks or months (Fig SI). Agriculture in
276 BAIE was particularly limited due to local taboos preventing the use of ploughs.

277 The arrival and duration of the rainy season were highly unpredictable, affecting decisions over
278 when to plant rice. Consequently, in AND and BAIE, households were hesitant to invest in such
279 labour-intensive activities until rain started, which limited their production, while in AMB
280 respondents prioritized planting rice but then risked a failed crop and lost labour if rain was not
281 sufficient. Whereas some individuals avoided the risk completely and temporarily migrated to
282 plant rice outside the region of Bobaomby. Due to these limitations, it was difficult for
283 households to produce enough rice to last them the entire year, and they would be obliged to
284 purchase rice for food in the months prior to harvest. Given the rising cost of rice, this left
285 respondents unable to save income or invest it in livelihood improvements. As VBI4, a cattle

286 guard and cultivator, noted, "...I ensure that milk could help me save, but the biggest issue is
287 food [rice]. So we have to use all of our income for surviving."

288

289 **3.2.3 Declining fisheries catch**

290 While the dependence on fishing varied within and between villages, respondents throughout
291 commonly expressed concerns over declining catches over the past 10 years and the unreliable
292 nature of fishing as a livelihood. This is concerning because fishing was an important livelihood
293 for filling income gaps in the dry season in AMB and AND, and was the primary livelihood
294 year-round in BAIE.

295 More people from both within and outside the study communities were fishing now relative to 10
296 years previously. Respondents commonly attributed declining catches to this increase in
297 individuals fishing combined with a lack of materials allowing fishing offshore. This appears to
298 have caused overexploitation of stocks within the bays. Furthermore, a lack of management was
299 evident within both Antsiranana Bay and Nosy Hara MPA. While opening and closing periods
300 and gear restrictions existed (Table 1), enforcement was lacking and rules were not commonly
301 known, understood, respected (AMB, AND) or effective (BAIE): indeed, many respondents
302 expressed concern that people from other communities fished illicitly in their bays. Respondents
303 suggested that more people could be fishing due to increasing market prices, but also due to
304 communities expanding their fishing grounds in response to a widespread trend of declining
305 catches. Respondents in AND noted people from multiple communities across the Bay of
306 Antsiranana fishing within their bay, including fishers from Antsiranana.

307 While declining fishing yields jeopardise income and food security in all communities,
308 respondents nevertheless tended to prefer fishing over investing in agriculture because it involves
309 less risk and can result in quicker income. When asked why he does not invest more in
310 agriculture, VCI12 a fisher, cultivator and cattle owner, stated, “Ah, agriculture is hard because it
311 only works during the rainy season, but fishing is good because you can fish all of the
312 time...even if you don’t get enough, one fish, two fish, it’s okay.”

313

314 **3.3 Charcoal production as a safety net and the proposed PA**

315 Overall, the livelihood choices across all three villages appeared to be driven by the need for
316 cash to purchase food once subsistence supplies ran out: as all livelihoods were limited,
317 respondents tended to regularly switch between activities to meet their needs. Fishing and
318 charcoal production were important livelihoods to make up for shortfalls and generate cash,
319 which was often used to purchase rice. However, decreased fish catches were causing people to
320 turn increasingly to charcoal production. Furthermore, charcoal production appeared to be a
321 more reliable livelihood relative to others. While it is more difficult to do in the wet season,
322 respondents in AMB and AND produced it year-round. Charcoal represents guaranteed income,
323 given the high market price in Antsiranana, and is more consistently available to communities
324 than fishing or farming: therefore, despite being negatively perceived due to its dangerous and
325 difficult nature, charcoal production was seen as an important safety net for many respondents.
326 As VBI3, a community leader, explained, “...when people are hungry, they need to eat, they
327 won’t just stay and die. They will go to the sea, but there is nothing. So they will go to
328 charcoal...”

329 When asked how establishment of the PA could affect livelihoods, most respondents only
330 perceived a PA to affect their access to trees for house construction and did not mention
331 restrictions on charcoal production. However the extent of charcoal production in AMB,
332 combined with respondent comments on the lack of trees for charcoal in the savannah and the
333 decreasing size of Beantely forest, suggest that households may rely on the forest for charcoal
334 production more than they were comfortable revealing. While respondents in AND commonly
335 noted the abundance of trees in their savannah and the increasing size of their forests following
336 the implementation of COBA regulations, the situation in AMB could be used to predict what
337 could occur in AND if charcoal production in the savannah is not sustainably managed in the
338 future. As VBI10, a cultivator and cattle owner stated when asked what would happen in the
339 community if trees in the savannah became overexploited, “I know that they will go [to the forest
340 to produce charcoal]. This forest is not allowed, but since life is so hard, they will not cross their
341 hands and die, they will go.”

342 In BAIE, where there are prohibitions on charcoal production (Table 1), respondents appeared to
343 be much more limited in their options for filling income gaps. Respondents spoke of more people
344 turning to fishing or increasing their fishing efforts following the charcoal prohibition, however,
345 as marine productivity decreases, this appears to be insufficient. While historically households in
346 BAIE rarely cultivated crops, some households are now turning more to agriculture in an attempt
347 to fill gaps despite local taboos restricting the use of ploughs. There was also evidence that
348 people may be selling forest timber, and thus continuing to use the forest as a safety net even
349 without producing charcoal. When noting that individuals do not always respect local forest
350 management rules, COBA leader VCI3, stated,

351 “Imagine now [the price of] rice is increasing every day and the more the price of rice is
352 increasing, the desire of people to cut trees will increase too. Because maybe one tree
353 would buy food before, but now it wouldn’t, so they will add more trees.”

354 Additionally, there was an overall displeasure towards the prohibition on charcoal production,
355 with some individuals expressing the desire and readiness to produce charcoal if their livelihoods
356 do not improve.

357 Overall, it appeared that respondents across all communities did not view charcoal as a preferred
358 livelihood and many relied on it primarily for income once their food reserves had run out;
359 however, some respondents indicated that income from charcoal was also used for daily needs,
360 such as soap, sugar or clothes, and for longer-term investments such as education for their
361 children, purchasing cattle, buying tools or sending money to family elsewhere. Additionally,
362 there was evidence that some individuals in AMB produce charcoal as part of a larger-scale
363 illicit trade influenced by more powerful external actors. As a community leader, VAI17, stated,
364 “It is also too hard, some people are behind this business....people produce 250-600 bags, that’s
365 not for food”: in addition, authorities have been observed allowing producers without permits to
366 pass through checkpoints in exchange for bags of charcoal. Migration of families from southern
367 Madagascar was noted as a common trend in this village, with households often turning to
368 charcoal production on arrival and encouraging the migration of other family members. The
369 greater accessibility (and market integration) of AMB compared to the other villages, combined
370 with a lack of trees for charcoal in the savannah, has led to overexploitation of forest resources
371 near this village.

372 Respondents across all three communities were aware of the environmental consequences of
373 charcoal production in their communities; however, it was clear that it will likely continue to be
374 an important livelihood as long as demand remains high and other livelihoods remain too risky
375 or unproductive. If enforcement of charcoal production in AMB does not improve, charcoal
376 production in the savannah is not managed sustainably in AND, and alternative livelihoods are
377 not supported in BAIE, increased forest exploitation in the region is highly likely. This will
378 negatively affect the long-term sustainability of Bobaomby PA. Due to the difficulties faced in
379 finding food, many respondents perceived agriculture as the livelihood requiring the most
380 support to help reduce pressures on the forests. As VAI3, a community elder, stated, "...If
381 everyone is doing well in agriculture, no one will go to Beantely [the forest]. If more people are
382 planting, Beantely will be free. No one will go and touch it. But the problem nowadays, is
383 agriculture is worth nothing." However, other respondents also stressed the importance of the
384 sustainable management of all aspects of the landscape, including the sea and savannah. When
385 asked what should be done to protect the forests, VBI4, a fisher, cattle guard and cultivator
386 explained,

387 "Well, I think the actors who are planning to manage it, shouldn't focus only on the
388 forest, but they need to protect everything...Because if the sea is not protected too, some
389 people get help from there. They wouldn't just cross their hands and die, but they will go
390 more and more to the savannah for charcoal, and if the savannah disappeared, they would
391 go further [to the forest]. And we know that the savannah is not enough for charcoal, for
392 wood for cooking, for agriculture and for cattle. So I think they really need to focus also
393 on the sea."

394

395 **4. DISCUSSION**

396 This study revealed multiple factors limiting livelihood productivity in communities surrounding
397 the proposed Bobaomby PA, leading to overexploitation of both marine and forest resources and
398 ultimately weakening the resource-bases that livelihoods depend on. While the existing
399 institutions of local taboos and COBA management could contribute to forest protection and
400 provide a foundation for further management through PA establishment, the high vulnerability
401 and constrained livelihoods of local communities mean that forests will likely remain an
402 attractive resource to exploit. Given that local livelihoods rely on all components of the
403 landscape, from the savannah to the mangroves, seas and forests, the PA managers will therefore
404 have to address the sustainability of all livelihood activities if they are to achieve the long-term
405 conservation of forests in the PA. Our research provides a number of insights into how they may
406 do so.

407

408 **4.1 Resource use in an environment of high vulnerability and risk**

409 We found charcoal production to be the most significant livelihood related to forest use, as well
410 as being critically important for cash income to purchase food or other items in times of need.
411 Charcoal production is an important livelihood amongst rural communities across Africa and
412 Madagascar (Ackermann 2003; Minten et al. 2013; Zulu and Richardson 2013; Gardner et al.
413 2016a), offering a source of income during the agricultural off-season (Kalaba et al. 2013; Zulu
414 and Richardson 2013; Ndegwa et al. 2016; Mulenga et al. 2017; Smith et al. 2017), and
415 providing a safety net in case of shocks such as crop failures (Gardner et al. 2016a; Jones et al.
416 2016; Ndegwa et al. 2016; Smith et al. 2017). Declining agricultural productivity has thus led to

417 increased charcoal production in southwestern Madagascar (Casse et al. 2004; Gardner et al.
418 2016a) and in other areas of Africa (Khundi et al. 2011; Mulenga et al. 2017).

419 Many respondents turned to charcoal production due to insufficient agricultural yields, but
420 agriculture is a high risk livelihood because of unpredictable rainfall, risks from cattle grazing,
421 and the high labour investments required. These risks appeared to limit or prevent investments in
422 agriculture, further increasing dependence on the safety net of charcoal production. Fishing was
423 also highly variable in its returns, but is less risky because initial investments are lower, the
424 return on investment is rapidly known, and there is high demand for fisheries products in
425 Antsiranana. However, given the trend of decreased catch over the past decade, the risks
426 associated with fishing are increasing.

427 While charcoal production also carries risks, including health risks, and (for producers lacking
428 permits) the risk of confiscation (Smith et al. 2017), charcoal can be produced year-round and,
429 being one of the most common domestic fuel sources in urban areas, enjoys relatively continuous
430 demand and stable prices (Mwampamba et al. 2013; Zulu and Richardson 2013). Despite being
431 dangerous and labour-intensive, charcoal production requires little to no capital investment or
432 technical know-how, and is therefore a livelihood with few barriers to entry (Arnold et al. 2006;
433 Zulu and Richardson 2013). As such, it is a relatively low risk livelihood compared to those
434 requiring high initial investments (i.e. farming) or those vulnerable to unpredictable or variable
435 returns (including both fishing and farming). As elsewhere in rural Madagascar, the highly
436 unpredictable environment and the subsequent feelings of vulnerability and risk aversion
437 amongst respondents appeared to be a major influence in livelihood decision-making (Neudert et
438 al. 2015; Tucker et al. 2015; Penot et al. 2018).

439 Charcoal production can provide quick income in times of need, but also to buy expensive assets,
440 invest in other livelihoods, or to pay for large expenses (Zulu and Richardson 2013; Jones et al.
441 2016; Smith et al. 2017). We found charcoal production to be attractive as a flexible income
442 source that can be used for a variety of purposes (Smith et al. 2017). Therefore, we expect it will
443 continue being a significant livelihood in the study area even if other livelihoods are supported
444 and significantly improve. This could be a concern both for the success of the proposed PA and
445 the sustainability of local livelihoods, because charcoal production contributes to forest
446 degradation and localized deforestation across the tropics, thus undermining its own resource
447 base (Chidumayo and Gumbo 2013; Zulu and Richardson 2013). In Madagascar, it constitutes a
448 significant threat to biodiversity in and around dry forests (Ackermann 2003; Ramarolanonana et
449 al. 2017), including to the integrity of PAs (Gardner et al. 2016b). In Bobaomby, evidence that
450 charcoal production is threatening the ecological integrity of the study site includes the
451 disappearance of trees in the savannah of AMB, and the decreasing size of Beantely forest which
452 was regularly reported by respondents. While the savannah in AND currently retains sufficient
453 trees for production, the overexploitation of savannah trees and subsequent forest-use may occur
454 there too in the near future, if other livelihoods continue to be limited. It is also probable that,
455 without future change in livelihoods, charcoal production is likely to recur in BAIE.

456 The unsustainable nature of charcoal production threatens both the forests of Bobaomby PA and
457 the future incomes of those who rely on it. Therefore, management should focus on the
458 development of sustainable charcoal production systems in the savannah (for example through
459 plantations of fast growing trees), alongside the enforcement of existing rules. However, the
460 maturation of alternative wood sources will take several years, so strict exclusion from forest use

461 for charcoal production will likely not be a feasible or appropriate PA management strategy at
462 the onset due to the costs this would impose on local communities.

463

464 **4.2 The future of livelihoods in a dry environment**

465 Livelihoods in Madagascar's arid environments are highly limited and, given the increasing
466 unpredictability of rainfall, risky and vulnerable (Ackermann 2003; Harvey et al. 2014; Waeber
467 et al. 2015; Hänke and Barkmann 2017). In the south and west of the country, which also have a
468 short and unpredictable rainy season, agriculture and cattle rearing are also the main livelihoods:
469 however, in these regions the principal crops are maize, manioc and/or peanuts, rather than rice
470 (Harvey et al. 2014; Waeber et al. 2015). While rice cultivation was attempted by many
471 respondents in our study, households in AND and BAIE adapted to the dry environment by only
472 planting rice if rain started, and by prioritizing planting maize which does better in drier
473 conditions. With predictions of increased temperature and decreased rainfall as a result of
474 climate change, agricultural yields (particularly of rice) will likely decline in the region without
475 interventions (Zougmore et al. 2018).

476 As throughout the dry regions of Madagascar, cattle rearing was an important livelihood for all
477 study communities (Casse et al. 2004; Ratovomanana et al. 2013; Waeber et al. 2015; Hänke and
478 Barkmann 2017). However, both the number of people rearing cattle and the total number of
479 cattle reared has been in decline due to decreased rainfall and increased cattle mortality. While
480 respondents often noted cattle rearing as the livelihood with the greatest earning potential,
481 current trends and climate change projections suggest that it will become increasingly difficult in
482 the future (Zougmore et al. 2018). This will not only reduce revenues from milk production, but

483 could also affect the capacity of households to respond to shocks, as cattle serve as a store of
484 wealth that can be sold in times of need. As a result, households may increasingly turn to other
485 livelihoods, such as charcoal production, to fill income gaps (as has been observed amongst
486 herders in Tanzania, Butz et al. 2013).

487

488 **4.3 Fishing as a livelihood strategy**

489 Fishing played an important role in the livelihoods of each community, however it was becoming
490 less reliable due to decreased catches. This reflects trends of declining fisheries production both
491 in northern Madagascar (Browne et al. 2007; Narozanski et al. 2011; Robinson and Sauer 2013)
492 and nationwide (Laroche et al. 1997; Cripps and Gardner 2016;), as a result of overexploitation
493 and the use of destructive methods. While overfishing may be the result of local demographic
494 growth, it is also influenced by limitations in other livelihoods which see people increasingly
495 turn to fishing (Narozanski et al. 2011).

496 Declining catches drive fishers to extend their fishing grounds (Browne et al. 2007), which may
497 explain the increase in fishers from neighbouring communities reported by our respondents.
498 They may also drive fishers to use more destructive methods, such as seine nets, in an attempt to
499 maintain catches, which can ultimately create a poverty trap as the natural capital continues to
500 degrade (Harris 2011). While rules concerning seasonal fisheries closures and gear restrictions
501 exist across the study region, they appear to be either unenforced or insufficient to arrest fisheries
502 declines.

503 Fishing is a lower risk livelihood than agriculture in our study region, a perception also held by
504 communities elsewhere in Madagascar (Tucker et al. 2015). Therefore, we expect that fishing
505 will remain an important livelihood in the region; however, if catches continue to decrease,
506 communities will need to turn elsewhere, including the savannah and forests, to make up for
507 income shortfalls. Decreased viability of fishing has led to increased bushmeat hunting in West
508 Africa (Brashares et al. 2004) and increased charcoal production in Madagascar (Laroche et al.
509 1997; Gardner et al. 2016a). This was already apparent in our study, with charcoal often being
510 used to fill income gaps that fishing could not complete. Overall, the limitations of other
511 livelihoods, compounded by insufficient management of marine resources, has led to
512 overexploitation and the unsustainable nature of fishing as a livelihood. With further declines in
513 catch potential projected under climate change (Cheung et al. 2010), the ability of the ocean to
514 sustain local livelihoods is under threat.

515

516 **4.4 Implications for PA management**

517 While forests are the principal conservation target of the PA, management interventions will
518 need to focus equally on the savannah, coasts and marine environment in order to promote
519 sustainable livelihoods and thus reduce pressures on forest resources in the long term (Fig 4).
520 Local taboos on forest-use may be beneficial to long-term PA management, but are not robust in
521 the face of hunger and destitution; thus, they will only be respected if existing and alternative
522 livelihoods receive support, and the availability of resources within other parts of the landscape
523 is enhanced.

524 Agriculture requires urgent support because agricultural limitations appeared to be the most
525 significant driver of charcoal production. While respondents suggested that the provision of
526 seeds and tools for clearing land within the savannah would be beneficial, the risks associated
527 with agriculture need to be addressed first to encourage greater investment in this livelihood.
528 First, more efficient and less labour-intensive methods and materials (such as barbed wire, as
529 suggested by respondents) are required for building fences to protect crops from cattle,
530 particularly as this would also reduce pressure on wood resources. Risks associated with
531 unpredictable rain also need to be addressed, for example through crop insurance schemes or the
532 dissemination of climate information (Zougmore et al. 2018), and/or the provision of seeds for
533 rice varieties requiring less water (Harvey et al. 2014; this study).. Managers should also
534 stimulate a transition away from rice production to crops that grow better in drier conditions and
535 are perceived as lower risk by cultivators, such as maize, pumpkins or beans (Tucker et al. 2015;
536 this study). However, a shift to cash cropping should be accompanied by investments, such as
537 soil and fertility management, to ensure that cultivation is carried out in permanent fields rather
538 than through shifting cultivation, which has been a major driver of deforestation in other dry
539 regions (e.g. Casse et al. 2004; Scales 2014). Additionally, respondents suggested that water
540 management should be improved by building rainwater capture and small-scale irrigation
541 infrastructure, as well as wells and water points for cattle (Desbureaux and Damania 2018)..
542 While some Malagasy farming communities are adapting their practices to climate change,
543 farmers often lack the technical support to take up new methods, therefore training and
544 disseminating information on techniques and best practices will be essential (Harvey et al. 2014).
545 Given that charcoal will likely remain the principal cooking fuel in urban areas for the
546 foreseeable future (Mwampamba et al. 2013), investments are also required to reduce the

547 impacts of its production. Respondents suggested that plantations of fast-growing trees should be
548 established in the savannah (particularly in AMB), and that existing charcoal improvement
549 projects in the region (such as GTZ's 'green charcoal' program) should be expanded. Plantations
550 should use species with a high growth rate, the ability to grow in dry conditions, and potential for
551 improving soil fertility, as well as the potential for use as fencing materials, firewood, and fodder
552 for cattle (Partey et al. 2018). However, the potential for species to become invasive should also
553 be considered (McConnell et al. 2015). Furthermore, as interventions aim to expand agriculture
554 and plantations in the savannah, the competing requirement for cattle grazing land will need to
555 be considered because conflicts over land could lead to forest encroachment in the long term
556 (Ratovomanana et al. 2013).

557 We recognize that the sensitive nature of forest use and related taboos may have prevented
558 respondents from being completely honest in their answers related to charcoal production and
559 other forest uses. However, we suspect that this only underplays the importance of forest use to
560 local livelihoods. While charcoal production represents the greatest direct threat to the proposed
561 PA, the experience of charcoal prohibitions in BAIE, which stimulated an increase in fishing
562 effort and exacerbated overfishing, should caution managers about potential unintended
563 consequences if more stringent rules on charcoal production are implemented in AMB and/or
564 AND.

565 [FIGURE 4]

566 While the issue of decreased fishing catch is more difficult to address for managers of a
567 terrestrial PA, respondents suggested that strengthening (AND and BAIE) or creating (AMB)
568 institutions for managing marine resources and enforcing gear-based rules would help reduce

569 overexploitation. However, further collaboration with MEDD and Madagascar National Parks is
570 required to improve overall marine management and enforcement of rules within Antsiranana
571 Bay and Nosy Hara MPA. Meanwhile, it will be imperative to decrease fishing pressure locally
572 by providing alternative livelihoods to those who rely on fishing (Newton et al. 2007), while also
573 implementing sexual health and family planning services to reduce pressures in the long-term
574 (Harris et al. 2012; Singleton et al. 2019). Aquaculture, for example of *Holothuria* (sea
575 cucumbers) or algae, could also be considered as an alternative income source (Robinson and
576 Pascal 2009). Such interventions are particularly important for BAIE where the safety net of
577 charcoal production is not legally available.

578 Implementing the above recommendations will be challenging given the inaccessibility of the
579 villages, their relative state of impoverishment, and the difficulties securing funding for new PAs
580 in Madagascar (Virah-Sawmy et al. 2014; Gardner et al., 2018). Nevertheless, this research
581 demonstrates the value of ascertaining and understanding the livelihood needs of local
582 communities so they can be integrated into PA management. While agricultural support has
583 potential to reduce dependence on charcoal production, the interconnectivity between different
584 livelihood activities highlights the importance of a landscape approach to management, in which
585 the livelihood trade-offs faced by all stakeholders are carefully considered (Sayer et al. 2013). It
586 will also be necessary to consider lessons learned from other PAs in Madagascar (e.g.
587 Rabesahala et al. 1995), however the valuable experiences of PA managers are rarely published
588 in the peer-reviewed literature.

589 Finally, it should be cautioned that any PA investments in local communities will alter the
590 dynamics of the socioecological system, and thus require careful management. For example,
591 potential improvements in income arising through investments in livelihoods could be invested

592 in further exploitation of resources (Scales et al. 2018): therefore, development interventions
 593 must be implemented alongside improved enforcement of existing rules (Gardner et al. 2013).
 594 Further, the needs and perceptions of local communities may change over time, and may not
 595 always align with the aims and goals of the PA promoters (Keller 2008). Managers should
 596 therefore adopt an adaptive management approach informed by participatory decisionmaking and
 597 socioeconomic monitoring, to ensure that management is able to rapidly respond to both
 598 emerging threats and the changing needs of resident communities (Gardner et al. 2016a).

599

600

601

		602
Livelihood	Perceived support required	Number of respondents
Agriculture	Water	21
	Tools	19
	Strong fences	12
	Rules on zebu	7
	Seeds	5
	Fertilizer (Soil)	1
	Herbicide	1
Fishing	Tools	17
	Enforcement of rules	6
Farming zebu	Water	6
Farming poultry	Money to invest in chicks	8
	Food	8
	Poultry house	3
	Vaccinations	3
	Water	2
	Training	1

603
604
605 **Table 7.** The different agricultural crops discussed during interviews and attitudes towards planting them

Crop	Attitude	Reasoning
Rice	Positive	Culturally important and is included in every meal; high market price
Maize	Mostly positive, some negative	Grows well in drier conditions and without consistent weeding and could be used to feed poultry, but zebu like to eat it
Cassava	Mostly positive, some negative	Grows well in drier conditions but wild pigs like to eat it
Pumpkins	Positive	Grows well in drier conditions
Squash	Positive	Grows well in drier conditions
Tomatoes	Positive	Grows well in drier conditions
Banana	Positive	Grows well in drier conditions and has high market price
Peanuts	Mostly positive, some negative	Grows well in drier conditions but mixed opinions on whether or not a plough is needed for planting
Cucumber	Positive	Grows well in drier conditions
Sweet potatoes	Positive	Grows well in drier conditions
Other garden vegetables	Mostly negative, some positive	Requires a lot of water but could be planted only during rainy season

606

607 **5. CONCLUSION**

608 The livelihoods of rural communities around Bobaomby are highly limited by the lack of natural,

609 physical, human, financial and social assets, which has led to overexploitation of natural

610 resources and overall feelings of risk and vulnerability. Without support and investments in

611 livelihood-based interventions, the viability of the forests, and thus the PA established to

612 conserve them, will be unlikely in the long term. Given that many PAs in Madagascar and

613 worldwide are established in contexts where local communities depend on natural resources from

614 within the protected area for their subsistence or income (Pringle 2017; Gardner et al. 2018;
615 Horning 2018), this is likely to be a widespread situation. Nevertheless, many PAs around the
616 world continue to be ineffectively managed and fail to achieve desired conservation or social
617 outcomes (Geldmann et al. 2013; Oldekop et al. 2016); highlighting the need for further research
618 to understand how needs of local communities and the objectives of PA managers can be aligned
619 across a range of ecological and socioeconomic contexts.

620 While local-level interventions should be a priority, macro-scale issues such as the demand for
621 charcoal and population growth will also need to be addressed to promote sustainability of both
622 the proposed PA and forest ecosystems across the country (Mulenga et al. 2017). This research
623 has highlighted the value of understanding livelihoods to inform PA management and enable the
624 development of interventions designed to conserve forests while supporting the livelihoods of
625 impoverished local communities. In particular, while conservation efforts in Madagascar have
626 mainly focused on terrestrial landscapes (Harris 2011), our results illustrate the complex
627 interaction between marine and terrestrial resource use in coastal regions, and highlight the need
628 for marine management considerations within coastal terrestrial PA management planning.

629

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837 **LIST OF FIGURES, TABLES & SUPPLEMENTARY MATERIAL**

838 **Fig 1** The study site in northern Madagascar. The inlets show the location of the PA in
839 Madagascar, the delimitation of the proposed PA including the three study villages in the
840 southern end (AMB-Ambodimadiro; AND-Andohazompona; BAIE-Baie de Courier) and the
841 delimitation of Nosy Hara MPA to the west of the proposed PA. The main map shows the
842 component hamlets of AMB and BAIE, the village of AND and the forests, mangroves and bays
843 used by each community

844 **Fig 2** Schematic representation of the factors limiting local livelihoods and leading to
845 overexploitation of marine and savannah resources and, subsequently, encroachment upon forest
846 boundaries, as identified from the Sustainable Livelihoods Framework (adapted from Ellis 2000)

847 **Fig 3** Generalised livelihood activity calendar for communities across the wet and dry seasons

848 **Fig 4** Conceptual model of the forest socioecological system based on interviews and focus
849 groups in three villages surrounding Beantely forest (green), showing direct threats (red),
850 underlying drivers (orange) and potential interventions for minimizing or mitigating threats
851 (yellow)

852 **Table 1** Characteristics of the three study villages, including the hamlets sampled, population,
853 number of households and varying details influencing resource use

854 **Table SI** Details concerning the livelihood activities present across the three study villages

855 **Figure SI** A typical fence for protecting crops from cattle constructed out of trees and bushes
856 collected in the savannah

857 **TABLES**

858 Table 1 Characteristics of the three study villages, including the hamlets sampled, population, number of households and varying
 859 details influencing resource use

	Ambodimadiro (AMB)	Andohazompona (AND)	Baie de Courier (BAIE)
Municipality	Antsahampano	Andranovondronina	Andranovondronina
Hamlets sampled	Ambodimadiro Andilamavo Andranomamy Morafeno	N/A-not divided into hamlets	Andramahimba Madiro Kitamby Ambaro Illomotro Antsatrabe
Population	647	147	187
# households	98	37	42
Distance to Antsiranana (km)	25	30	50
Local bush taxi access	Yes along RN29, during both wet and dry season	Yes along unmaintained road, only during the dry season	No, sectors of Andramahimba, Madiro Kitamby, Ambaro and Illomotro only accessible on unmaintained road via private vehicle during dry season at low tide
Forest restrictions	COBA Active since 2015, restricts charcoal production to areas below a set delimitation within Beantely forest, for sale with permit; permits needed to harvest trees within forest for construction	COBA Active since 2007, restricts charcoal production to savannah using specific tree species, for sale with permit; permits needed to harvest trees within forest for construction	COBA Active since 2007, restricts charcoal production to savannah for personal consumption only (prohibitions in place since 2015); permits needed to harvest trees within forest for construction
Fisheries restrictions	Opening and closing periods for crab, octopus and shrimp and bans on use of small mesh-size nets across Antsiranana	Opening and closing periods for crab, octopus and shrimp and bans on use of small mesh-size nets across	CLP Active since 2010, applies opening and closing periods for crab, octopus and shrimp and bans use of

	Bay, however no local CLP	Antsiranana Bay, however inactive CLP without official status	small mesh-size nets Nosy Hara MPA rules ban fishing close to the islands included within its boundaries
Local taboos related to resource use	<p>Taboo to:</p> <ul style="list-style-type: none"> -Kill animals in the forest, including lemurs and reptiles -Sell tenrecs -Eat wild pig -Work the land on Tuesday or Thursday 	<p>Taboo to:</p> <ul style="list-style-type: none"> -Kill animals in the forest, including lemurs and reptiles -Sell tenrecs -Eat wild pig -Work the land on Tuesday or Thursday 	<p>Taboo to:</p> <ul style="list-style-type: none"> -Kill animals in the forest, including lemurs and reptiles -Sell tenrecs -Eat wild pig -Work the land on Tuesday or Thursday -Sell milk -Work the land with a plough
Resource areas used	<p>Surrounding wooded savannah, Beantely forest and the bay of Cul-de-Sac Gallois and associated mangroves/mudflats.</p> <p>Many restricted to fishing along and within bays, due to eastern location within Antsiranana Bay. Open sea less accessible relative to communities on western shore.</p>	<p>Surrounding wooded savannah, Beantely, Ankarandoha, Analabe and Sacred forests and the bay of Andovobatofofotsy and associated mangroves/mudflats.</p> <p>Many restricted to fishing along and within bays, due to eastern location within Antsiranana Bay. Bays easily accessed by individuals from Antsiranana. Open sea less accessible relative to communities on western shore.</p>	<p>Surrounding wooded savannah, Beantely, Windsor Castle and Analabe forests and multiple bays along west coast, associated mangroves/mudflats and Nosy Hara MPA waters.</p> <p>Less sheltered bays relative to AMB and AND due to western location along Nosy Hara MPA More easily accessed open sea relative to AMB and AND.</p>

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861

862 **Supplementary Online Material**863 **Table SI:** Details of livelihood activities present across the three study villages

	Ambodimadiro (AMB)		Andohazompona (AND)		Baie de Courier (BAIE)	
Main livelihoods	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
	Raising/milking cattle	Charcoal Some fishing	Raising/milking cattle	Charcoal Some fishing	Fishing Raising cattle	Fishing
	Agriculture-permanent and shifting cultivation		Agriculture-permanent and shifting cultivation		Agriculture-permanent and shifting cultivation	
	Some fishing		Some fishing			
	Some charcoal		Some charcoal			
Agriculture	Main irrigated rice maize	Other beans cassava pumpkin sweet potato cucumber tomatoes	Main maize sometimes irrigated rice	Other cassava cucumber pumpkin tomatoes squash peanuts bananas	Main maize sometimes irrigated rice	Other cucumber pumpkin squash tomatoes cassava peanuts
	Use Mostly for consumption, if surplus sold in local area or Antsiranana	Use Mostly for consumption, if surplus sold in local area or Antsiranana	Use Mostly for consumption, if surplus sold in local area or Antsiranana	Use Mostly for consumption, if surplus sold in local area or Antsiranana	Use Mostly for consumption, if surplus sold in local area or Antsiranana	Use Mostly for consumption, if surplus sold in local area or Antsiranana
Livestock rearing	Main cattle	Other chickens ducks	Main cattle	Other chickens ducks	Main cattle	Other chickens ducks goats

	Use Raised for sale/insurance and/or milking for income Milk sold to local collectors	Use Raised for sale in local area or personal consumption	Use Raised for sale/insurance and/or milking for income Milk sold to local collectors	Use Raised for sale in local area or personal consumption	Use Raised for sale/insurance and/or milking for personal consumption only	Use Raised for sale in local area or personal consumption
Fishing	Main fish shrimp <i>patsa</i>	Other crabs	Main fish shrimp <i>patsa</i>	Other sea cucumber octopus	Main fish	Other crab octopus
	Use For sale or personal consumption Sold to local collectors, or personally sold in local area or transported for sale in Antsiranana	Use Sometimes for sale within local area or Antsiranana, dependent on quantity. Mostly for personal consumption.	Use For sale or personal consumption Sold to local collectors, or personally sold in local area or transported for sale in Antsiranana	Use Sometimes for sale within local area or Antsiranana, dependent on quantity. Mostly for personal consumption.	Use For sale or personal consumption Sold to local collectors, or personally sold in local area or transported for sale in Antsiranana	Use Sometimes for sale within local area or Antsiranana, dependent on quantity. Mostly for personal consumption.
Charcoal production	Produced during both wet and dry seasons, mostly for income, but some for personal consumption Sold to collectors or personally transported for sale in Antsiranana		Produced during both wet and dry seasons, mostly for income, but some for personal consumption Sold to collectors or personally transported for sale in Antsiranana		Some produced from trees cleared for agriculture, but only for personal consumption	
Other	Only fishing year-round Charcoal collector Marine product collector		Only fishing year-round Shopkeepers Carpenter Charcoal collector Milk collector		Producer of mats and baskets Seamstress Shopkeeper Marine product collector	