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Human migration to the forest frontier: implications for land use change and conservation management

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Abstract:

Human migration is often considered an important driver of land use change and a threat to protected area integrity, but the reasons for in-migration, the effectiveness of conservation restrictions at stemming migration, and the extent to which migrants disproportionately contribute to land use change has been poorly studied, especially at fine spatial scales. Using a case study in eastern Madagascar (603 household surveys, mapping agricultural land for a sub-set of 167 households, and 49 focus group discussions and key informant interviews), we explore the patterns and drivers of migration within the lifetime of those currently alive. We investigate how this influences forest conversion on the border of established protected areas and sites without a history of conservation restrictions. We show that in-migration is driven, especially in sites with high migration, by access to land. There is a much higher proportion of migrant households at sites without a long history of conservation restrictions than around long-established protected areas, and migrants tend to be more educated and live closer to the forest edge than non-migrants. Our evidence supports the engulfment model (an active forest frontier later becoming a protected area); there is no evidence that protected areas have attracted migrants. Where there is a perceived open forest frontier, people move to the forest but these migrants are no more likely than local people to clear land (i.e. migrants are not 'exceptional resource degraders'). In some parts of the tropics, out-migration from rural areas is resulting in forest regrowth; such a forest transition is unlikely to occur in Madagascar for some time. Those seeking to manage protected areas at the forest-frontier will therefore need to prevent further colonisation; supporting tenure security for existing residents is likely to be an important step.

Introduction

Global commitments to slowing deforestation (UN, 2014; Turnhout *et al.*, 2017) reflect recognition of the importance of forests, especially those in the tropics, as carbon sinks, habitat for biodiversity and for their contribution to regional and local hydrological cycles (Gibson *et al.*, 2011; Achard *et al.*, 2014; Devaraju *et al.*, 2015). Migration is often identified as an important driver of forest change and biodiversity loss in the tropics (Brondizio *et al.*, 2002; Geist & Lambin, 2002; Unruh *et al.*, 2005; de Sherbinin *et al.*, 2007) and as posing a threat to protected areas (Scholte & De Groot, 2010). However there remains a lack of clarity as to whether migrants have impacts disproportionate to their contribution to population growth, and studies to disentangle this (at fine spatial scales, using household level data) are rare (de Sherbinin *et al.*, 2007; Zommers & MacDonald, 2012; Cripps & Gardner, 2016). Understanding household mobility and behaviour at the forest frontier is important for guiding conservation and development policies (Caviglia-Harris *et al.*, 2013).

There has been significant attention in the conservation literature on the extent to which protected areas attract migrants or prevent in-migration. This is important for two reasons. Firstly, increases in human population due to in-migration may result in increased pressures on biodiversity (Scholte & De Groot, 2010), which need to be understood and incorporated into policy responses (Zommers & MacDonald, 2012). Secondly, it can provide insights into the extent to which protected areas pose a net cost (due to restrictions on resource use), or net benefit (improvements in infrastructure, employment, or valued ecosystem services outweigh these costs) to local people (Wittemyer *et al.*, 2008; Joppa *et al.*, 2009; Salerno *et al.*, 2014). Early case studies supported the idea that protected areas caused in-migration leading to increased threats to biodiversity (de Sherbinin & Freudenberger, 1998; Oates, 1999; Scholte,

2003). A major review of population growth rates around protected areas in Africa and Latin America (Wittemyer *et al.*, 2008) found they were almost double background rates (and concluded that migrants were attracted to protected areas by the benefits they offered). However a reanalysis of the same data showed no general pattern of increased population growth near protected areas (Joppa *et al.*, 2009).

Migrants tend not to be a random selection of the population (Borjas, 1987). Migrants responding to pull factors may be 'positively selected', i.e. they tend to be those more able to overcome the barriers to migration (so they may be wealthier or more educated), while those responding to push factors (such as economic problems or environmental pressures) may be poorer and less educated (Lee, 1966; Kanbur & Rapoport, 2005). There have been suggestions that migrants, especially those driven to move to escape conflict (Jacobsen, 1994), but also colonists when compared to indigenous people (Lu et al., 2010), may have a disproportionate influence on natural resources through unsustainable land use practices (Carr, 2009; Etongo *et al.*, 2015). However evidence on the extent to which migrants are 'exceptional resource degraders' is mixed (Codjoe & Bilsborrow, 2012; Cripps & Gardner, 2016; Zommers & MacDonald, 2012).

Many parts of the world are seeing a slowing of forest loss and increasing forest recovery; a phenomenon known as the 'forest transition' (Mather & Needle, 1998). Long recognised in Europe and North America, it is increasingly documented in the tropics (Meyfroidt *et al.*, 2010). Forest transition can arise through a range of mechanisms but urbanisation (which drives up the cost of agricultural labour resulting in land abandonment) has played an important role (Lambin & Meyfroidt, 2010). Understanding the likelihood of such a pattern is important for predicting future forest change scenarios (Aguiar *et al.*, 2016) and developing management responses as

96 a reduction in the supply of potential rural-rural migrants (who make up high proportions of
97 migrants to the forest frontier in many countries; Carr, 2009) would reduce pressure.

98 Madagascar is well known internationally for its incredible biodiversity but also for loss of a
99 high proportion of its natural forest (Harper *et al.*, 2007). There have been suggestions that in-
100 migration at forest frontiers has contributed to deforestation (Ghimire, 1994; Virah-Sawmy,
101 2009) however, there has been little research critically evaluating the extent to which migration
102 poses a threat to Madagascar's remaining forests and the integrity of its protected areas (see
103 Cripps & Gardner, 2016, for an exception from coastal protected areas). We explore the recent
104 patterns of in-migration to small communities in the eastern rainforests of Madagascar. Four of
105 our sites are on the forest frontier and one is approximately 20 km away as the crow flies. Of
106 our forest frontier sites, two border long established protected areas (Zahamena National Park
107 and Mantadia National Park; Table 1), while two surround the Corridor Ankeniheny Zahamena
108 (CAZ) which, although recently gazetted as a new protected area, does not have a history of
109 forest protection. We look at the proportion of migrant households, how this varies across the
110 landscape, the reasons for migration and the characteristics of migrants. We explore whether
111 villages on the border of the two long established protected areas contain more migrants (as
112 predicted if protected areas are a net attractor), or less (as predicted if benefits do not offset
113 opportunity costs). We also explore the extent to which migrants clear land from forest relative
114 to non-migrants (a test of the 'exceptional resource degrader' hypothesis). Finally, we ask
115 whether out-migration is likely to reduce pressures on Madagascar's protected areas in the near
116 future. Our aim is to contribute to debates about linkages between human migration and
117 environmental degradation (much of the existing literature is from Latin America which is at a

different place on the demographic transition to Africa and Madagascar; Bongaarts, 2017), while also informing the challenges of managing Madagascar's protected area network.

Methods

Study area

The eastern rainforests of Madagascar are internationally renowned for their exceptional biodiversity but are under pressure from small-scale agricultural expansion, illegal logging and artisanal mining. A substantial driver of forest loss is small-scale swidden agricultural expansion at the forest frontier (though commentators have noted that conservation narratives overplay the role of peasant farmers and underplay the role of plantations and commercial timber extraction; Scales, 2014). The Corridor Ankeniheny Zahamena is a belt of rainforest linking a number of existing protected areas including Zahamena and Mantadia National Parks. This 370,000 ha forest area was declared a new IUCN category VI protected area in April 2015. The CAZ is managed by Conservation International on behalf of the Malagasy government. Conservation International and their partners have established Community Forest Management agreements in many villages on the periphery of the CAZ, which devolve some rights and responsibilities for forest management to communities and are vehicles through which micro-development schemes are implemented (Brimont & Karsenty, 2015). Madagascar National Parks (a quasi-governmental organisation) manage Zahamena and Mantadia National Parks; established in 1927and 1989 respectively.

New land laws in 2005 and 2006 have recognized the existence of untitled private land in Madagascar (Burnod *et al.*, 2014). Until then, all untitled land was legally considered state land, although in reality, customary rights were recognized *de facto* (Antona *et al.*, 2004). All forested

land in Madagascar is excluded from the new laws (Laws 2005-019 and 2006-031) and remains as state land, as does any land within protected areas (Burnod *et al.*, 2014).

Site selection

Following reconnaissance visits, and pilot surveys, we purposively selected five sites (see Fig. 1 and Table 1). Four are on the forest frontier: two of which have a long history of conservation (Mantadia and Zahamena National Parks); and two of which have limited experience of conservation (Ampahitra and Sahavazina on the boarder of the new CAZ protected area). Although it is not possible to say that these sites differ only in terms of their history of conservation, they were carefully selected to be as similar as possible in terms of other important variables such as access. For example, one established protected area site (Mantadia) and one area with limited experience of conservation (Ampahitra) are situated approximately equidistance away from the major road in the region (national route 2), while the other pair of sites are both similarly (and substantially) remote. One site (Amporoforo) is otherwise similar (e.g. in terms of access) but the nearby forest was lost before the 1950s (Harper *et al.*, 2007).

Data collection

All those involved in data collection were native Malagasy speakers familiar with the local dialect. JPGJ (fluent in conversational Malagasy), MP (basic Malagasy), and KS (no Malagasy) attended a subset of interviews. Questions about land clearance are potentially sensitive. Our team worked hard to build trust by emphasising our independence and spending significant time in the communities (an average of 120 person days per site). Photographs illustrating the fieldwork context are shown in Fig S1.

Defining a migrant

Many definitions of a migrant exist in the literature and selecting an appropriate definition can be challenging as it must be locally appropriate and yet possible to clearly define and consistently apply (Fussell *et al.*, 2014; Thiede *et al.*, 2016). In Malagasy, a migrant (usually called a *mpiavy*: literally 'incomer') is contrasted with *tompon-tany* (literally 'master of the land'). We developed our definition of a migrant household following extensive qualitative work in our pilot site and informal interviews in our study sites. It can be difficult to apply a consistent definition as a person who was not born in an area, but whose ancestors were, might be considered a non-migrant, even if they themselves arrived recently. However for the purpose of our study we define a migrant household as one where the household head was born outside the *fokontany* (the smallest administrative unit in Madagascar) where the household is resident.

We acknowledge that this definition only captures migration within the present generation whereas our qualitative data gives some information on the waves of migration dating back to at least the colonial period. For example, Farizana village in Ampahitra was created by workers brought in by a logging company which closed down in the 1940s. There was later very rapid in-migration during President Ratsiraka's five year plan (*planina dimy taona* which ran from 1975-1980 Rakotondrazafy, 2007) which led to the village splitting; the residents of Farizana Avaratra are descendants of that second wave of immigration.

Quantitative data

To ensure a representative sample of households (including more geographically isolated households), we put intensive effort into developing a complete sampling frame in each study sites (Poudyal *et al.*, 2016). Using the available maps as a starting point, we worked with key informants from the *fokontany* (school teachers, the president of the *fokontany* etc) to sketch a

184 map of all the villages in the area. With the help of key informants such as village elders we
185 mapped the hamlets and isolated houses belonging to each village and then visited each hamlet
186 to record its location with a GPS and confirm the number of houses. Building this representative
187 sampling frame took up to 30% of total field time in each site. We randomly selected 60% of
188 households in each site in Ampahitra and Mantadia and 30% in the other three sites for the
189 household survey. Refusals and dropout rates were very low (less than 4% across all sites). In
190 total we completed the survey with 603 households across our five study sites (see Table 2).

191 The survey (conducted between July 2014 and March 2015) covered socio-economic
192 characteristics of the household including education and wealth indicators. Poverty is a
193 multidimensional concept. We used a range of poverty indicators selected for the rural
194 Malagasy context (Poudyal *et al.*, 2016); household food security, tropical livestock units
195 owned (Chilonda & Otte 2006), whether they own a device for playing music, ownership of
196 irrigated rice fields, house size, house quality, access to lighting (see Table 3). We also asked
197 respondents to list their agricultural plots (including land currently fallow) and how they
198 obtained those plots. The full dataset is archived (Poudyal *et al.*, 2017a).

199 We selected a stratified random sample based on household size and landholdings from our
200 initial survey for a more detailed agricultural survey (see Table 2; NB Mantadia wasn't included
201 in this follow-up work) conducted between August 2014 and May 2015. We visited each field
202 owned by the respondent (564 plots belonging to 167 households), discussed the origin of the
203 field and mapped the field with a GPS. The full dataset is archived (Poudyal *et al.*, 2017b).

204 *Qualitative data collection*

205 We conducted key informant interviews and focus group discussions in each site except
206 Mantadia (see Table 2). This research was part of a wider project investigating land use (see
207 Appendix B for our detailed topic guide). For each focus group we asked key informants
208 (typically village leaders) to bring together about 6-8 people, including men and women, people
209 from different parts of the village and of different ages. In each site we first developed a
210 community timeline (local history, immigration, current conditions and trends in land use, etc).
211 We then held further focus groups to discuss the current land use and livelihood systems,
212 ecosystem services, and institutions governing decisions about natural resources including,
213 where relevant, a focus group with members of the community forest management association.
214 Some topics, especially relating to land tenure, were touched on in several of the focus groups,
215 allowing for a broader representation of views. All discussions were facilitated in Malagasy by
216 two people with one taking free-hand notes. We also recorded discussions using an MP3 player.
217 To complement information obtained from focus group discussion we carried out key informant
218 interviews with local leaders in each site.

219 *Research ethics*

220 The study was approved under the Bangor University Research Ethics Framework. We
221 explained to respondents that participation in the research was voluntary and they could leave
222 at any time. We also made it clear that no identifying information would be shared with others.
223 Participants in the household survey were given a small gift of useful items to a total value of
224 3000 ariary (approximately $1) as a gesture of appreciation. The detailed agricultural surveys
225 took a day so we paid respondents the daily wage rate of 5000 ariary (approximately $1.85).
226 During focus group discussions we provided refreshments.

227 ***Data analysis***

228 All quantitative analyses were conducted in R 3.3.3 (R core development team, 2017), all code
229 and datasets are available at: https://github.com/Ruth-R-Kelly/Migration_Jones_et_al_2017

230 *Characterising poverty*

231 The indicators of poverty were analysed using a principal component analysis (PCA) in the R
232 psych package (Revelle, 2017). Differences in poverty between migrants and non-migrants, and
233 between migrants with different reasons for moving, were examined statistically using a
234 permutation based approach via the function 'factorfit' in the R package 'vegan' (Oksanen *et*
235 *al.*, 2017). Using this technique, values were repeatedly randomly permuted between
236 households within sites to generate a set of null expectations as to the distribution of wealth
237 values expected by chance (n permutations = 999). P-values are calculated by comparing the
238 variance explained in the original dataset by grouping variables (e.g. migrants non-migrants)
239 with that expected by chance (represented by variance explained by those grouping variables
240 applied to the permuted datasets).

241 *Estimating distance of migration*

242 We estimated the Euclidean distance between the centroid of the commune where the head of
243 household was born (using the map BD 500 FTM, scale 1:500000) and the *fokontany* where
244 they are resident (geolocated in the field) using Qgis 2.9 software.

245 *Exploring differences between migrant and non-migrant households on the forest frontier*
246 In order to explore the extent to which migrant status is predicted by education of the household
247 head, household age, distance to the forest, and protected status of the site, we used a binomial

248 Generalised Linear Mixed Model (GLMM) approach (binomial distribution with logit link).
249 We included an interaction between household age and protected area status to account for the
250 fact that patterns of migration may have changed over time differently at protected and non-
251 protected sites. Site was included as a random effect to account for correlations between
252 households within individual sites. We excluded Amporoforo as this site is not at the forest
253 frontier, and four households where we had missing data, therefore n=540. For this and
254 subsequent models, all possible combinations of predictor variables were tested and compared
255 using sample-size corrected Akaike Information Criterion (AICc). As suggested by Burnham
256 & Anderson (2004), model averaging was used to estimate the effect size of variables from
257 models less than 2 delta AICc from the one with the lowest AICc value. Effect sizes of averaged
258 models are given as 'full' model averages; in other words the effect sizes were averaged across
259 all models with zero included in models where they did not occur. This approach results in a
260 conservative estimate of effect sizes for variables found in only a few of the models (Burnham
261 *et al.*, 2002). Model selection was conducted using the R package 'MuMIn' (Barton, 2007).

262 *Exploring the predictors of land clearance*

263 To examine whether the likelihood of having cleared land is predicted by migrant status,
264 household wealth (wealth axis 1 and 2 from the PCA), education of the household head,
265 household age, household size, distance to the forest and the site's protected status, we used a
266 binomial GLMM. Here, the response variable was whether the household 'had cleared land' or
267 'had not land cleared'. We included an interaction between site's protected status and household
268 age (as in previous model) and between site's protected status and migrant status (to account
269 for the fact that migrant land clearance behaviour may differ between established and newly
270 protected areas). Site was included as a random effect. We excluded Amporoforo as this site is

not at the forest frontier and households where we had missing data for at least one variable, therefore n=535.

Exploring the predictors of the area of land cleared

For a subset of households data further information was collected on the amount of land cleared (n = 127), we used a negative binomial GLMM (log link function) to examine whether the total area of land cleared by households is predicted by migrant status, household wealth (wealth axis 1 and 2 from the PCA), education of the household head, household age, household size, distance to the protected area boundary, and protected status of the site. Here, the negative binomial response distribution was chosen as it is appropriate for non-normally distributed continuous data with overdispersion and zero-truncation (Thomas *et al.* 2017), such as that observed in our land clearance area data. We included interactions between site's protected status and migrant status and site's protected status and household age, and site as a random effect as per previous model.

Qualitative data analysis

The facilitators of our focus group discussions and key informant interviews produced a consolidated set of notes (in English) for each discussion based on their free-hand notes combined with additional excerpts transcribed from the MP3 recordings. We used thematic analysis to interrogate the consolidated notes for insights into who migrates and why, whether land use practices of migrants differ from those of non-migrants, and the practicalities of land tenure. Analysis was undertaken using QSR International's NVivo 11 Software.

Results

292 ***Characterising migration***

293 Across the whole sample, 35% of households are headed by a migrant. However, the proportion
294 of migrant households varies markedly between sites (see Fig. 1, Table S1). In the sites adjacent
295 to the CAZ new protected area the proportion of migrants is much higher (Ampahitra: 70%
296 migrants, Sahavazina: 34% migrants) than in sites adjacent to the long established protected
297 areas of Zahamena (15% migrants) and Mantadia (5% migrants). The vast majority of migrants
298 have moved relatively short distances; more than 90% have moved less than 50km (see Fig. 2).
299 Modelling suggests that richer and more educated migrants have moved further (see Table S3).
300 We have no quantitative data from our study sites on the frequency of out-migration but
301 qualitative data suggests that out-migration from these sites (other than temporary periods for
302 work or education) is rare.

303 ***The drivers of migration and migrants' right to settle***

304 The greatest number of people give 'access to land' as the primary reason for their migration,
305 but this varies greatly between sites (see Fig. 1). Access to land is the dominant driver in the
306 sites of Ampahitra and Sahavazina which lack a history of conservation restrictions. Marriage
307 or following family members is also commonly given as a reason for migration (Table S1).

308 The qualitative research gives some valuable perspective on this quantitative data. Some
309 migrants refer to themselves as *mpilaravinahitra* (literally 'looking for green leaves'). This
310 reflects the importance migrants place on moving to make a better life through accessing
311 productive land. It can be difficult to separate reasons for migration; for example someone may
312 marry a person from a forest frontier area and the couple choose to settle in their home area
313 with the hope of accessing land through family links. It is also not unusual for people who move

primarily for the purpose of accessing land to make use of distant family ties and many migrants do have some existing family relationship (however distant) in the community where they settle. They may use the *fatidrà* (blood brotherhood ceremony) to cement these relationships. Those tied by such an alliance cannot refuse land to one another. Migrants often rely on such relationships with non-migrants to access land initially (and sometimes rent, borrow or buy it; Fig. S3).

Our interviews suggest that relatively few people (migrant or non-migrant) have obtained the formal land certificates (issued through the BIF 'Birao Ifoton'ny Fananatany' or local land office). To obtain such a certificate, the elders must agree the ownership of the plot and then the *fokontany* president or commune mayor (the state's legal representatives) are asked to ratify this. The involvement of these local authorities effectively means that migrants have to have been in the area for several years and be seen to be upstanding citizens in order to apply. There is some suggestion that migrants are more likely to rely on this formal process of land certification to formalise their land claims than non-migrants. However BIFs are not present throughout the study site; only those in Amporoforo and some people in Ampahitra felt they had the possibility of accessing a BIF to formalise their tenure.

The characteristics of migrants at the forest frontier

The people living around CAZ are very poor by all measures (see Table 3). For example, the majority of people live in a single roomed thatched house, have insufficient access to light and do not have sufficient food to eat all year round (Table 3). Tropical Livestock Units (a well-accepted measure of household assets in tropical agricultural areas; Chilonda & Otte 2006) are very low with a median value of only 0.05 which is equivalent to only five chickens. However,

there were no systematic differences in wealth between migrants and non-migrants (Fig. 3b), or between migrants with different reasons to migrate (Fig. 3c). There was also no difference between the household age of migrants and non-migrants (meaning that on average the migrant households we interviewed had been established as long as the non-migrant households). However, migrants tend to be more educated than non-migrants and tend to live closer to the forest edge than non-migrants (Fig. 4, Table S3). Migrants are much more common at sites close to the newly established CAZ protected area than the established protected area (Fig. 4, Table S3).

The qualitative data shows that although there are cases of conflict between migrants and non-migrants (especially over access to land), migrants are often well integrated into village life. We heard examples of migrants who became village chiefs (a state administrative role) for example.

What factors predict clearance of land from forest?

Households were less likely to have cleared forest if they live close to established protected areas, live further from the forest, and if they are more recently established. There is a significant interaction between the site's protected status and household age: the positive association of land clearance with household age was stronger in established protected areas. This was quite a marked effect; a household of mean age (11.5 yrs) situated a mean distance from the forest frontier (2 km) has an 10% probability of having cleared land from forest if it is an established protected area compared to 37% if close to an area without a history of protection. Migrant status is not a significant predictor of land clearance (Fig. 5; full model details in Table S3).

Households were likely to have cleared less forest if they live further from the forest edge and are poorer (Fig. S4, Table S3). For example an average household living 1km inside the forest would have cleared on average 27,204 m^2 compared with 10,231 m^2 for a household living at the mean distance away from the forest (ca. 2.4 km). Once again, migration status is not a significant predictor.

The qualitative data shows that accessing forest land to clear is no longer as straightforward as it was in the past (especially during President Ratsiraka's five year plan when the forest was seen as an open resource to be exploited). There was a view among some respondents that all Betsimisarika (the ethnic group found along Madagascar's east coast and dominant in the study area), or even all Malagasy, have the right to land at the forest frontier as it is given by god (*zanahary*). However, the more commonly expressed view is that migrants cannot simply move in and claim land. Local people perceive that land belongs to the people of the area (the *fokonolona*) and there are often additional restrictions due to prior claims by local people (which are supported locally even if not recognised formally by the state).

Some lines of evidence support the fact that although migrants are not necessarily clearing land from forest, they may be farming land (rented or borrowed from non-migrant owners-see Fig. S3) which otherwise would not be farmed (and therefore would be returning to forest). Migrants often rent *tany lava volo* ('land with long hair' ie secondary regrowth that has not been cultivated for a long time) and *tany mahery,* (literally 'hard land'; this isn't cultivated because is supposed to be inhabited by bad spirits: such taboos often have less meaning for migrants).

Discussion

379 Migration researchers suggest that much of what is written about migration is rooted in a false
380 notion that migration is an exception to the norm (Castles, 2011). People have of course always
381 moved, whether to avail themselves of opportunities or avoid undesirable risks and harm (Adger
382 *et al.*, 2015). In-migration into villages in the eastern rainforests of Madagascar is indeed
383 common. Across the sample, more than 30% of households meet our definition of migrants.
384 The majority however have moved only relatively short distances (less than 50km). That most
385 migrants travel only a short distance has been recognised as one of the 'laws' of migration since
386 Ravenstein's seminal work in the 1880s (Lee, 1966). We found no evidence that migrants were
387 richer or poorer (according to our indicators of wealth), however migrants in our sample do
388 tend to be more educated; suggesting a degree of positive selection. This is in contrast to studies
389 in Nigeria (Ekpenyong & Egerson, 2014) and Latin America (Carr, 2009) which suggest that
390 rural-rural migrants who colonize the forest frontier tend to be the poorest of the poor and of
391 usually low education. This may reflect that migration to the forest frontier is a positive
392 livelihood strategy and not a last resort for desperate people with no other options. This matters
393 as evidence from a long–term study in Brazil suggests that the wealth of migrants to the forest
394 frontier influences long-term outcomes in terms of whether they invest in their land or quickly
395 move again with an advancing forest frontier (Caviglia-Harris *et al.*, 2013).

396 ***Why do people migrate into eastern rainforest villages?***

397 The vast majority of migrants gave 'access to land' as their primary reason for migration. This
398 is driven by the high numbers of migrants in Ampahitra, most of whom report having moved
399 to access land. It is interesting to note that in Amporoforo, the one village we studied which is
400 not on the forest frontier, some people are still moving to access land. Therefore migration is

401 not just about clearing land from forest but moving somewhere where land is perceived to be
402 more available (see López-Carr & Burgdorfer, 2013 for similar findings from Latin America).

403 Ranjatson (2011) writing about Manongarivo Reserve in northwestern Madagascar found that
404 early settlers were strongly against the establishment of the protected area and were actively
405 encouraging in-migrants who could clear new land as a way of opposing conservation
406 restrictions. We did not find this to be the case in CAZ and there were many cases where people
407 expressed unwillingness to cede land to migrants. However, we also found cases where
408 migrants were well accepted and their right to settle was acknowledged and legitimized through
409 family connections, often supported by the *fokontany* authorities.

410 ***Do Protected Areas attract migrants?***

411 A much higher proportion of households are migrants where the forest has recent protected
412 status than in sites surrounding established protected area. This is interesting as there has been
413 a debate in the conservation literature about whether protected areas attract in-migration. Some
414 commentators have suggested that investment in development alongside conservation, may
415 delay rural-urban migration and therefore ecosystem recovery (Aide *et al.*, 2013); the rather
416 unpleasant conclusion being that development to offset the opportunity costs of land use
417 restrictions should be avoided to discourage people from settling. Such concerns were first
418 raised in the 1990s (Oates, 1999) and more recent analyses have argued that protected areas do
419 (Wittemyer *et al.*, 2008), or don't (Joppa *et al.*, 2009; Salerno *et al.*, 2014) attract
420 disproportionate levels of in-migration.

421 The migration events explored in our study will have occurred over the past few decades.
422 During this period, both Zahamena and Mantadia have been managed as protected areas and it

423 is clear that in-migration around these protected areas has been low relative to our two other
424 study sites on the forest frontier (which had no protected status until very recently). This is an
425 interesting finding as suggests that conservation has been effective at preventing agricultural
426 expansion (meaning migrants have not settled). This conclusion is supported by a recent remote
427 sensing analysis of forest loss in the region (Hewson *et al.*) showing that these protected areas
428 have had low deforestation from 2000-2015. We interpret these observations as meaning that
429 any benefits provided by the conservation authorities through local development schemes have
430 either been too little to attract in-migration, or any benefits have been targeted to established
431 residents (discouraging opportunistic in-migration). Recent work in both Mantadia (Brimont &
432 Karsenty, 2015; Rakotonarivo *et al.*, 2017) and Zahamena (Rasolofoson *et al.*; Raboanarielina,
433 2012) has highlighted local disappointment with development interventions associated with
434 conservation. There is also evidence of strict enforcement of conservation (we have testimony
435 of arrests for illegal farming in both Zahamena and Mantadia over the last five years). Our
436 interpretation is therefore that these protected areas have not increased in-migration as
437 economic opportunities are not sufficient to overcome the restrictions on agricultural
438 expansion.

439 Scholte and de Groot (2010) present three models of in-migration to protected areas: attraction
440 (where migrants are attracted because of opportunities due to the protected area), engulfment
441 (a protected area is later engulfed by an extraction frontier), or incidental (regions with
442 protected areas may become areas of refuge due to conflict elsewhere). The high level of
443 migration in Ampahitra, on the boundary of the CAZ new protected area, is an example of the
444 engulfment model. Although the CAZ was granted temporary protection in 2006, at the time of
445 our surveys in 2014/2015 there was very little active conservation. The migration is in spite of,

446 not because of, the new protected area status. This finding is similar to that of Zommers &
447 McDonald (2012) who found the high levels of in-migration around a protected area in Uganda
448 were the result of engulfment.

449 ***Are migrants 'exceptional resource degraders'?***

450 Our data on land clearance is self-reported and it is possible that people may be less willing to
451 report clearing land from forest if they live on the boundary of an established protected area
452 (where awareness of conservation rules is relatively high; Razafimanahaka et al., 2012).
453 However, a recent analysis of deforestation rates in the CAZ (Hewson *et al.*) confirms that land
454 clearance in 2005-2010 was much lower in the established protected areas of Zahamena and
455 Mantadia (0.03% annually), than in the rest of the CAZ landscape (1.08% annually). This,
456 combined with the trust built with communities during fieldwork and triangulation from our
457 qualitative work, gives us confidence that we can use our estimates of land clearance.

458 There is a long literature linking migrants to deforestation in the tropics (references in
459 Bilsborrow, 2002) and migrants have been considered 'exceptional resource degraders' (Codjoe
460 & Bilsborrow, 2012; Cripps & Gardner, 2016). The literature provides a range of reasons that
461 migrants may engage in more unstainable land uses. These include high poverty and lack of
462 tenure resulting in high discount rates, and less respect for local institutions managing natural
463 resources (see Codjoe & Bilsborrow, 2012 for references).

464 We found no evidence that migrants were more likely to have cleared land from forest or to
465 have cleared a larger area of land than non-migrants. This may be because migrants' reliance
466 on social relationships means that their awareness of social norms and institutions is not
467 different from those of local people. Of course this finding does not mean that migration does

not contribute to land clearance, anything which increases the population dependent on small-scale farming at the forest frontier will increase demand for land. It is also important to note that this finding refers to the type of migration we were able to study in this research: migration for permanent settlement, often making use of family ties. In recent years there have been a number of 'rushes' (rapid temporary movements of people) into the eastern rainforests of Madagascar by opportunistic artisanal miners looking for sapphires and other gems (Pardieu & Rakotosaona, 2005; Perkins, 2017). Our findings cannot be extrapolated to the impacts of these migrants on forest cover. Previous work (Jenkins *et al.*, 2011) has shown that in-migration to rainforest areas in Madagascar associated with artisanal gold mining has resulted in the erosion of taboos which previously limited the hunting of the critically endangered Indri; such additional potential environmental impacts of migrants are not considered in this study.

Is forest transition likely?

In many parts of the tropics, large scale agri-business expansion and international land-grabbing has become the most significant driver of deforestation (Lambin and Meyfroidt 2011), just as urbanisation trends reduce rates of clearance by smallholder farmers (Meyfroidt *et al.*, 2010). Such large-scale land appropriations are increasing in Madagascar (Burnod *et al.*, 2013), but given the geography of the remaining forest zones (most remaining forest is found at relatively high altitude in inaccessible areas; Vieilledent *et al.*, 2016), the activities of small-scale farmers at the forest frontier remain likely to be the primary driver of deforestation in the foreseeable future. An important question is therefore the extent to which rural depopulation will result in a forest transition. Kull et al (2007) argued that a forest transition was unlikely in the near future in Madagascar because of the rapid rate of population growth and the limited rate of industrialisation (though Elmqvist et al., 2007, found some evidence of a forest transition in

parts of Androy in south eastern Madagascar). Since 2007, when Kull et al were writing, the rural population of Madagascar has continued to grow at between 1.7 and 2.1% per annum (World Bank). Therefore reduction of deforestation and increased forest restoration in rural Madagascar due to out-migration are still not imminent. Large numbers of very poor people, highly dependent on small-scale agriculture, will continue to rely on forest resources for the foreseeable future in Madagascar. Rural-rural migration will be likely to continue wherever people identify opportunities for agricultural expansion.

Can land tenure reform contribute to slowing deforestation?

There is increasing awareness among conservationists of the importance of tenure for conservation outcomes (Robinson *et al.*, 2017). We contribute to this by arguing that in areas where in-migration continues to put pressure on the forest frontier, overcoming this challenge without relying on coercive methods (Peluso, 1993), will require interventions involving improving tenure security for current forest frontier residents.

Protected areas can reduce in-migration by closing the forest frontier to further expansion (as seems to have successfully occurred in eastern Madagascar). However to ensure this does not result in negative impacts on local people, this must be carried out alongside targeted development (Balmford & Whitten, 2003; Poudyal *et al.*, 2016). The challenge is ensuring that such compensation is sufficient, but does not itself attract in-migration. Supporting existing residents to gain tenure over their land at the forest frontier, might make targeting of compensation more straightforward (Duchelle *et al.*, 2014).

There is growing evidence that secure tenure is itself linked to forest cover; with secure land tenure often making deforestation less likely (Robinson *et al.*, 2014; Holland *et al.*, 2017). The

513 mechanisms behind this are complex but it may be that in the absence of secure tenure, people
514 clear land to help cement land claims (Unruh *et al.*, 2005; Oglethorpe *et al.*, 2007), or that
515 farmers with insecure tenure invest only in short term annual crops in a shifting system (Kramer
516 *et al.*, 2009). Another possible mechanism is that lack of tenure security discourages
517 investment; preventing agricultural yields increasing per unit area (Bilsborrow, 2002).

518 Secure tenure does not necessarily mean formal, state recognised tenure; customary systems
519 can remain secure without formal recognition (Simbizi *et al.*, 2014). However, such systems
520 may become overwhelmed by external pressures or claims from migrants meaning that
521 formalisation of locally recognised rights can be an important step in securing tenure (Robinson
522 *et al.*, 2017). The risk is that formalising tenure tends to increase privatisation of common land
523 (often used for grazing and collection of non-timber forest products) which are of particular
524 importance to poorer people. Ensuring that land tenure formalisation includes a process of
525 securing tenure to common lands is therefore important (Wily, 2008).

526 ***Policy implications for Madagascar***

527 Protected Areas in eastern Madagascar have attracted few migrants in the last few decades.
528 However, in-migration rates into other forest frontier villages (such as those around the new
529 CAZ protected area) remain high. We found that migrants are no more likely to clear land *per*
530 *capita* than non-migrants, however it is important to note that by adding to the population they
531 increase demand for land, now and in the future. Policy measures to reduce out-migration from
532 rural areas acting as sources of migrants for the forest frontier (such as the provision of technical
533 assistance and inputs such irrigation improvements or subsidized fertilizers) can, at least in
534 theory, slow in-migration (Bilsborrow, 2002) but given the ongoing increases in rural

535 population growth rates, such interventions will be unlikely to reduce in-migration at the forest
536 frontier in the forseeable future. We argue that improving tenure security for existing residents
537 will be vital to reduce migration to the forest frontier, and protect existing forests without undue
538 costs being placed on existing forest frontier residents.

539 Our study shows that well managed protected areas in Madagascar have successfully reduced
540 the influx of migrants. Malagasy law requires that local people are compensated for costs of
541 conservation incurred but identifying those affected by new protected areas to effectively target
542 such compensation can be very challenging (Poudyal *et al.*, 2016). If established residents were
543 registered and their land rights formally recognised, this may help in future targeting of
544 compensation. Additionally, if existing residents had secure tenure, they may be less likely to
545 see conservation as threatening customarily recognised land rights (Ranjatson, 2011).

546 Legal changes to the land laws in Madagascar in 2005 and 2006 recognised that people who
547 lacked formal title (the vast majority of rural residents) can indeed own their land (Laws 2005-
548 019 and 2006-031) and a relatively low cost system to register land ownership locally was
549 introduced. However, coverage of local land offices able to issue certificates, and the
550 effectiveness of these offices in providing such certificates, is patchy (this study; Burnod et al.,
551 2014; Widman, 2014). There is also some concern about women's land rights being undermined
552 as the lack of requirement for jointly held land to be jointly registered reinforces the primary
553 ownership of land by male household heads (Widman, 2014). Unfortunately, the land laws
554 explicitly exclude farmers from gaining tenure over any of their land which falls under the
555 rather broad definition of forest in Malagasy law (Law 97-017 considers land with woody or
556 shrubby species as forest, which can be interpreted to include tree fallows previously exploited
557 for swidden agriculture). This, and the requirement that land owners do not leave land unused

558 for more than five years, discourages farmers from managing their land in long fallows which
559 can provide ecosystem services (Zwartendijk *et al.*, 2017).

560 We suggest that access to land certification for existing residents at the forest frontier be
561 increased, and that perverse incentives for forest frontier farmers to manage land in short
562 rotations be removed from Malagasy land laws. However increasing land certification may risk
563 disenfranchising the poorest through privatisation of what is currently managed as common
564 land (Wily, 2008) and so much be done carefully.

565 Of course in-migration is not the only demographic pressure on resources at the forest frontier.
566 Madagascar's population is growing at 2.4% (World Bank) and adolescent fertility rates, while
567 falling, remain high (at 115 births per 1000 women age 15-19 they are significantly above the
568 average of least developed countries). Increasing female education is very well understood to
569 have a strong impact on fertility rates (Martin, 1995). Access to education is challenging in
570 much of rural Madagascar; increasing the availability of high quality education (and ensuring
571 access for girls), has potential to play a role in reducing pressure on Madagascar's remaining
572 forests (as well as having other societal benefits). Similarly, access to family planning is limited
573 in many parts of the country especially forest frontier areas; improving this is likely to reduce
574 fertility (Bongaarts, 2017b).

575 ***Conclusions***

576 Migration is the norm: most of us are descendants of people who moved. Our results counter
577 the assumption that migrants to the forest frontier are inherently more likely to contribute to
578 land use change than non-migrants. However, through increasing demand for land, they
579 increase the pressure on remaining forest making rural-rural migration an important issue for

those interested in forest conservation. While rural populations continue to increase (as is the case in many low-income countries), in-migration will continue to pose a threat to remaining forests. Investing in agricultural assistance and subsidizing inputs such as fertilizer and improved seeds in potential source areas may reduce the flow of rural-rural migrants, but is clearly a long process. In the face of a continuing flow of potential migrants, protecting remaining forests in low-income countries while not disadvantaging local people, will likely require improvements in tenure security for existing residents.

Supporting information

Additional supporting information may be found in the online version of this article.

Table S1: The proportion of migrant households by site and protected area status, and their reasons for moving.

Table S2: The distances (km) moved from the household head's place of birth to the place they are currently resident (by site and reason to move).

Table S3: Full model results of model averaged Generalised Linear Mixed Models (GLMMs) for **a)** differences between migrants and non-migrants **b)** distance travelled by migrants, **c)** probability of having cleared land from forest and **d)** amount of land cleared from forest.

Fig. S1: Pictures showing the context of the field work.

Fig. S2: Principal Component Analysis plots showing a) loadings of measures of wealth, b) positions of household at each site in terms of wealth axes.

Fig. S3: The proportion of non-migrant and migrant households with plots obtained in various ways (inherited, cleared from forest, borrowed, bought or rented), at each site.

601 Fig. S4: Predicted amount of land cleared by households based on model averaged

602 Generalised Linear Mixed Models of agricultural data.

603 Appendix B includes the survey instruments used (in English and Malagasy).

604

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805 **Tables**

806 Table 1: Characteristics of study sites.

Sites	Fokontany(s) (Commune) DISTRICT	Protected status	History of conservation
Mantadia	Volove & Vohibazaha (Ambatavola) MORAMANGA	Established Protected Area	Long history of conservation (since 1989) on periphery of Mantadia National Park
Zahamena	Antevibe & Ambodivoangy (Ambodimangavalo) VAVATENINA	Established Protected Area	Long history of conservation (since 1927) on periphery of Zahamena National Park
Ampahitra	Ampahitra (Ambohibary) MORAMANGA	New Protected Area (limited experience of conservation)	Granted temporary protected status in 2006, formally gazetted in 2015.
Sahavazina	Sahavazina (Antenina) TOAMASINA II)	New Protected Area (limited experience of conservation)	Granted temporary protected status in 2006, formally gazetted in 2015.
Amporoforo	Amporoforo (Amporoforo) (TOAMASINA II)	Not applicable (not on forest frontier).	The forest at this site was lost in the 1950s and there is no conservation effort.

807

808 Table 2: Sample sizes for the different surveys under taken

Sites	# of villages	# of HH[1] surveys	# of plots reported on	# of agri. surveys	# of plots measured	# of FGD[2]	# of KII[3]
Mantadia	3	104	448	-	-	0	0
Zahamena	7	152	680	37	259	20	3
Ampahitra	8	203	697	50	204	7	0
Sahavazina	7	95	346	40	231	11	4
Amporoforo	2	49	230	40	255	3	1
Total	27	603	2401	167	949	41	8

809 [1] Household, [2] Focus Group Discussion, [3]Key Informant Interview.

810

811 Table 3: Key socio-economic characteristics of the surveyed households and variables included in our

812 models. Variables included in our wealth index (the PCA; see Fig. 3) are highlighted in italics.

Variable (and sample size if less than 603)	Description of variable	Value of variable
Cleared forest (N=602)	Binary variable indicating whether household has cleared any plots from forest.	71% No
Forest area cleared (N =131)	Continuous variable (ha) showing the area of forest cleared by the household (only available for agricultural survey households).	Median=2.92, Mean=1.60, Std.dev=2.40
Protected area status	The forest frontier sites are classified as 'established' = close to established protected area [Mantadia and Zahamena] or 'new' = close to new CAZ protected area [Sahavazina and Ampahitra].	42.5% households near established protected area
Number of rooms	Total number of rooms (including external kitchens)	Median=1, Mean=1.31, Std. dev=0.47
House quality (N=599)	Type of roof in the primary dwelling (sheet metal, thatch)	95% thatch
Food security	Number of months for which household has enough to eat (continuous variable 0-12)	Median=7, Mean= 6.62, Std.dev=2.76
Tropical Livestock units	Total livestock ownership measured as "Tropical Livestock Unit" (continuous variable 0-14.2)	Median=0.05, Mean= 0.53, Std.dev=0.74
Irrigated rice	Binary variable indicating whether household has access to at least one irrigated rice field	62.6% No
Access to lighting	Type of light (firewood OR candle, petrol, torch OR solar lamp or generator) and whether household have sufficient light (never/rarely OR sometimes OR mostly/always).	82.7% use candle, petrol, torch, 44.9% never or rarely have sufficient light
Music player	Binary variable indicating whether the household has a simple MP3 device for playing music.	76.9% No
Household origin	A household is defined as a migrant where the household head was not born in the *fokontany* where they are resident.	35.4% Migrants
Household size	Number of individuals.	Median=5, Mean=6, Std.dev=2
Household age	The length of time (years) a household has been established (since cohabiting or starting to farm independently).	Median=10, Mean=14.1,Std.dev=9.2
Education level of the household head	Binary variable indicating low or high level of education of the household head. Low (0) = 0 to 5 years of schooling; High (1) = 6 or more years of schooling.	89.5% Low
Distance from the forest	Distance (km) of the household's main home from the nearest protected area boundary (negative values refer to households based within the protected area).	Median=2.08 km, Mean=3.25 km, Std.dev=3.01km

Figures with legends

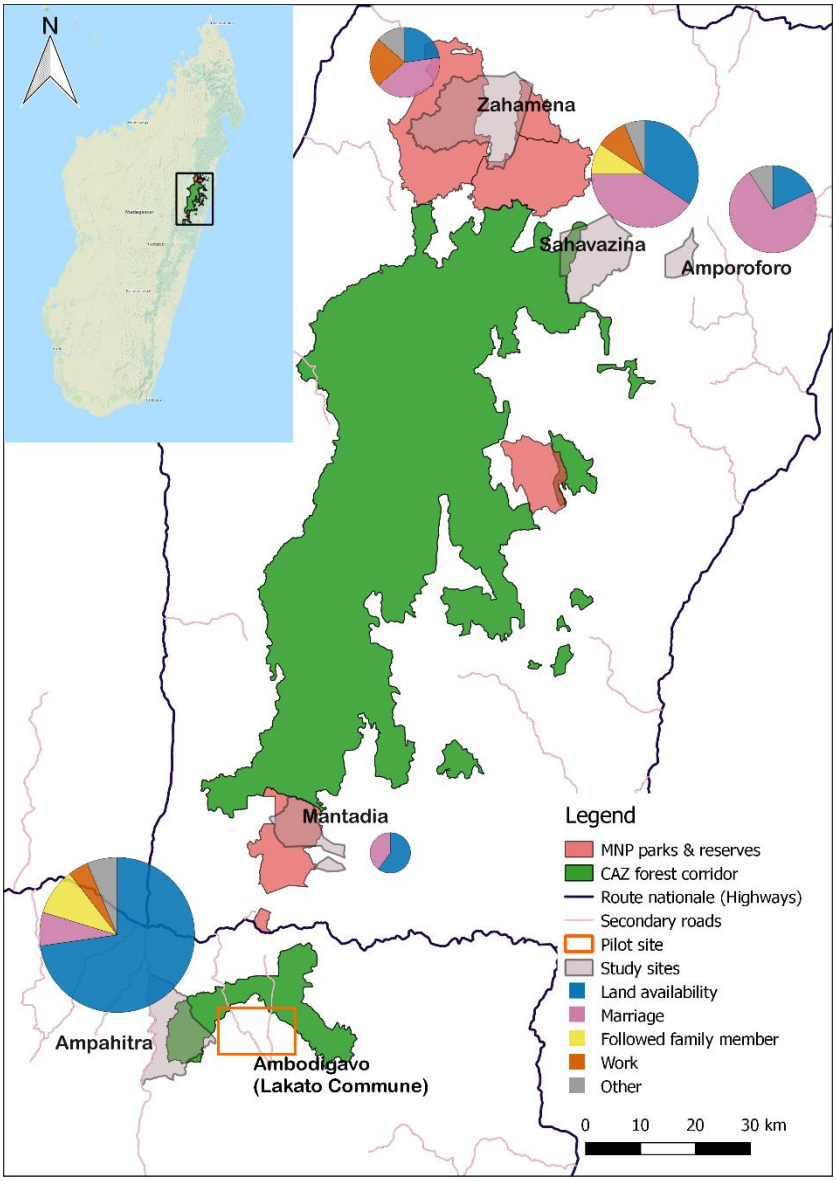


Fig. 1: The location of our study sites and pilot site in the CAZ forest corridor in eastern Madagascar (with associated protected areas). Pie charts indicate the primary reason given by migrants in each site for moving to the area. The size of the pie indicates the proportion of respondents in each sites who are migrants (n=213 migrant households, range 5-70% of population in each site, see Table S1 for details).

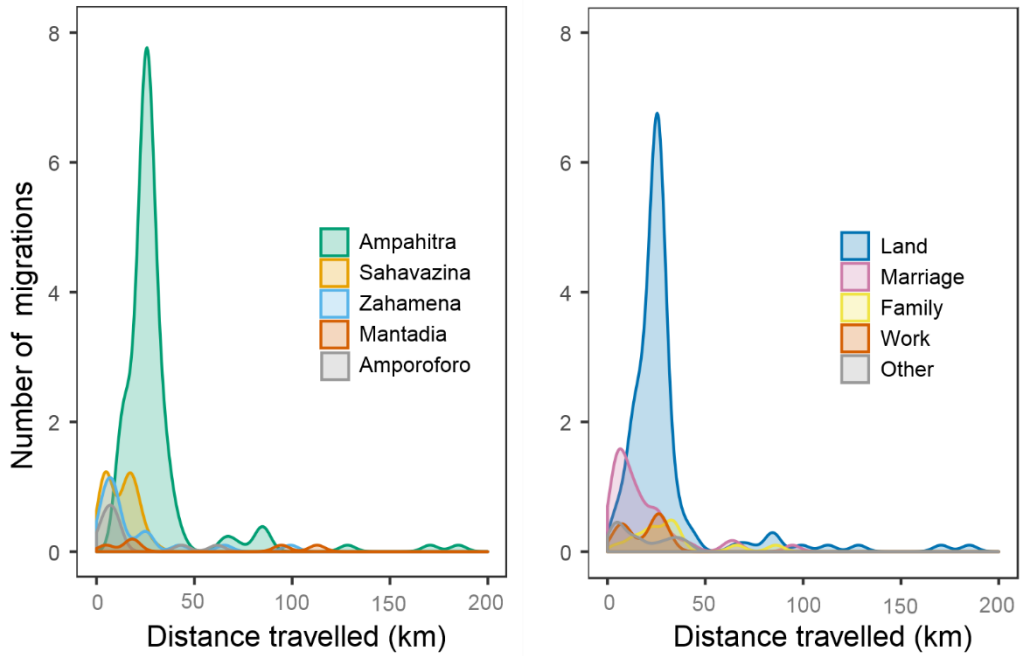
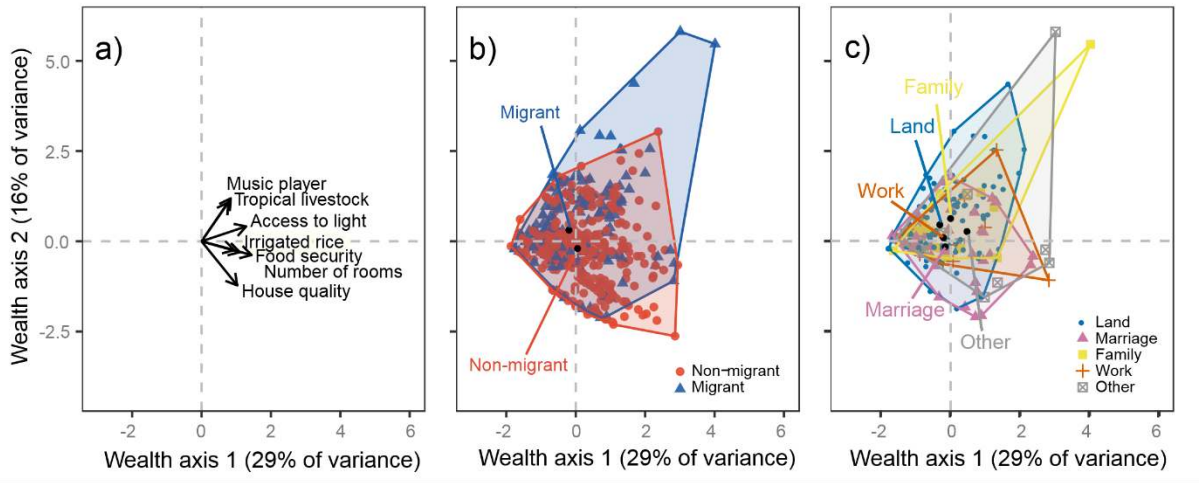


Fig. 2: The distribution of migration distances a) by study site (b) by reason to migrate. Figures show the estimated number of households in each 1 km distance bracket. Migration distance is calculated as the distance from the centre of the commune where the head of household originated to the *fokontany* where they now live. Households which moved more than 200km (n=6) are excluded from the plot; the longest distance travelled was 794 km.

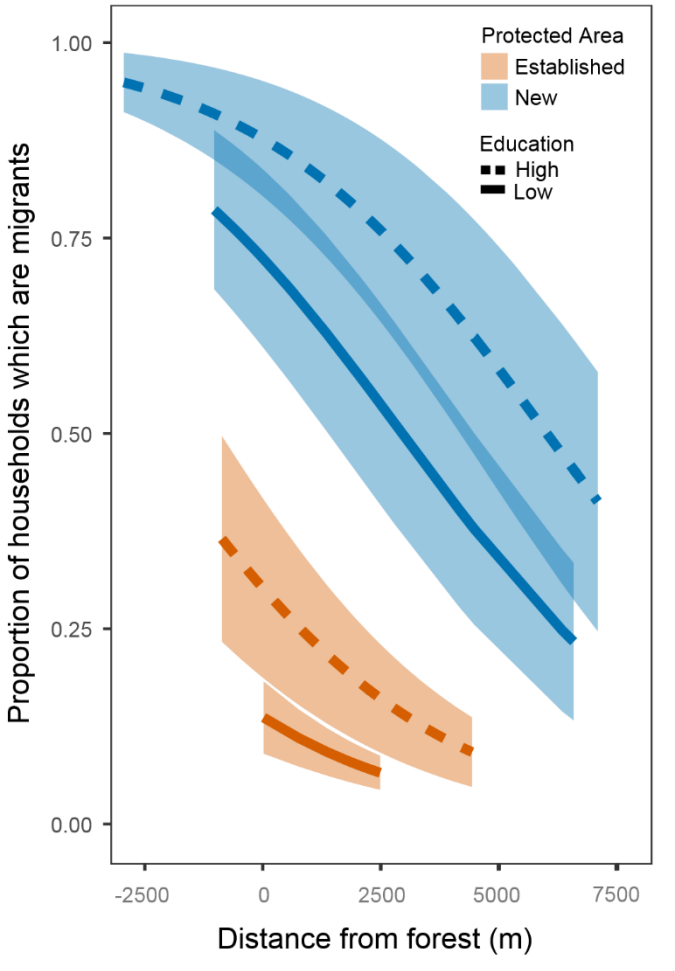


828

829 Fig. 3: Principal Component Analysis showing measures of wealth, and the positions of
830 migrants and non-migrants and migrants with different reasons for moving on wealth axes. a)
831 Wealth axis 1 (29% of variation) can be interpreted as an overall measure of wealth; a higher
832 value indicates higher household wealth. Wealth axis 2 (16%) ranges from low values
833 indicating households with larger, higher quality houses (which may represent old wealth), and
834 high values indicating assets such as Tropical Livestock Units and owning a music player. b)
835 Positions of migrants and non-migrant households on wealth axes. Differences between groups
836 were tested using a permutation based method and migrants/non-migrants were not
837 significantly different (n = 599, variance explained = 3.7, p = 0.153), nor were there significant
838 differences in migrants with different reasons for moving (n=213, variance explained = 4.7, p
839 = 0.152). Factor loadings in plot a) are rescaled by a factor of 2 for clarity.

840

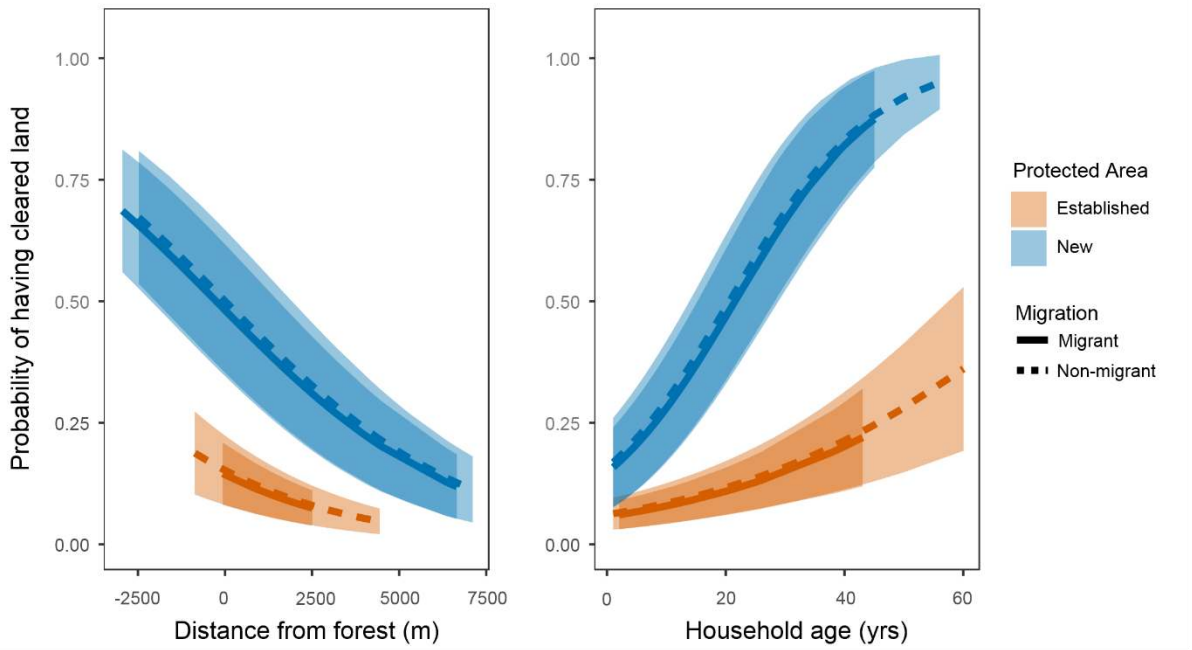
841



842

843 Fig. 4: Predicted proportions of migrant households based on model averaged Generalised
844 Linear Mixed Model results. A higher proportion of households living closer to the forest
845 frontier and on the periphery of the new areas relative to established protected areas are migrant
846 households. Migrants also tend to have a higher level of education than non-migrants.
847 Predictions are estimated for mean household sizes and household age, for which no differences
848 were observed. Shading indicates standard error on predicted proportions.

849



850

851 Fig. 5: Predicted probability of households having cleared land based on model averaged
852 Generalised Linear Mixed Model results. Households living near new protected areas (as
853 opposed to the long-established protected areas), living closer to the forest frontier, and longer
854 established households are more likely to have cleared land from forest. There is no significant
855 difference between migrants and non-migrants. Predictions are estimated for mean household
856 sizes and wealth characteristics, and low levels of education, as no significant differences were
857 observed in these variables. Shading indicates standard error on predicted probabilities.