

## Human migration to the forest frontier

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**Geo: Geography and Environment**

DOI:  
[10.1002/geo2.50](https://doi.org/10.1002/geo2.50)

Published: 01/06/2018

Peer reviewed version

[Cyswllt i'r cyhoeddiad / Link to publication](#)

*Dyfyniad o'r fersiwn a gyhoeddwyd / Citation for published version (APA):*  
Jones, J. P. G., Mandimbiniaina, R., Kelly, R., Ranjatson, P., Rakotojoelina, B., Schreckenber, K., & Poudyal, M. (2018). Human migration to the forest frontier: implications for land use change and conservation management. *Geo: Geography and Environment*, 5(1), Article e00050. <https://doi.org/10.1002/geo2.50>

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

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14  
15 **Acknowledgements:** We thank local leaders and all the people interviewed for participating in  
16 this research. Research permission was granted by the Ministry of Environment, Ecology and  
17 Forests (45/14/MEF/SG/DGP/DCB. SAP/SCB). The work was conducted under Bangor  
18 University research ethics framework. We thank Sarobidy Rakotonarivo, Alexandra  
19 Rasoamanana, Nilsen Andrianantenaina, Ntsiva Andriatsitohaina, Hasina Rakotoarison, Neal  
20 Hockley and Bruno Ramamonjisoa for invaluable help and Simon Willcock for comments.  
21 Thanks also to our colleagues at Conservation International and in the wider p4ges team.

22  
23 **Funding**

24 This work was part of the p4ges project ([www.p4ges.org](http://www.p4ges.org)) funded by the ESPA programme  
25 (NE/K010220/1).

26

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

29 **Abstract:**

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

49

## 50 **Introduction**

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

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

73 2003). A major review of population growth rates around protected areas in Africa and Latin  
74 America (Wittemyer *et al.*, 2008) found they were almost double background rates (and  
75 concluded that migrants were attracted to protected areas by the benefits they offered). However  
76 a reanalysis of the same data showed no general pattern of increased population growth near  
77 protected areas (Joppa *et al.*, 2009).

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

89 Many parts of the world are seeing a slowing of forest loss and increasing forest recovery; a  
90 phenomenon known as the ‘forest transition’ (Mather & Needle, 1998). Long recognised in  
91 Europe and North America, it is increasingly documented in the tropics (Meyfroidt *et al.*, 2010).  
92 Forest transition can arise through a range of mechanisms but urbanisation (which drives up the  
93 cost of agricultural labour resulting in land abandonment) has played an important role (Lambin  
94 & Meyfroidt, 2010). Understanding the likelihood of such a pattern is important for predicting  
95 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

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

## 120 **Methods**

### 121 *Study area*

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

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

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

### 142 ***Site selection***

143 Following reconnaissance visits, and pilot surveys, we purposively selected five sites (see Fig.  
144 1 and Table 1). Four are on the forest frontier: two of which have a long history of conservation  
145 (Mantadia and Zahamena National Parks); and two of which have limited experience of  
146 conservation (Ampahitra and Sahavazina on the boarder of the new CAZ protected area).  
147 Although it is not possible to say that these sites differ only in terms of their history of  
148 conservation, they were carefully selected to be as similar as possible in terms of other  
149 important variables such as access. For example, one established protected area site (Mantadia)  
150 and one area with limited experience of conservation (Ampahitra) are situated approximately  
151 equidistance away from the major road in the region (national route 2), while the other pair of  
152 sites are both similarly (and substantially) remote. One site (Amporofo) is otherwise similar  
153 (e.g. in terms of access) but the nearby forest was lost before the 1950s (Harper *et al.*, 2007).

### 154 ***Data collection***

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

### 161 ***Defining a migrant***

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

172 We acknowledge that this definition only captures migration within the present generation  
173 whereas our qualitative data gives some information on the waves of migration dating back to  
174 at least the colonial period. For example, Farizana village in Ampahitra was created by workers  
175 brought in by a logging company which closed down in the 1940s. There was later very rapid  
176 in-migration during President Ratsiraka’s five year plan (*planina dimy taona* which ran from  
177 1975-1980 Rakotondrazafy, 2007) which led to the village splitting; the residents of Farizana  
178 Avaratra are descendants of that second wave of immigration.

### 179 *Quantitative data*

180 To ensure a representative sample of households (including more geographically isolated  
181 households), we put intensive effort into developing a complete sampling frame in each study  
182 sites (Poudyal *et al.*, 2016). Using the available maps as a starting point, we worked with key  
183 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](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

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

### 273 *Exploring the predictors of the area of land cleared*

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

### 284 *Qualitative data analysis*

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

## 291 **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

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

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

### 330 *The characteristics of migrants at the forest frontier*

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

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

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

#### 348 *What factors predict clearance of land from forest?*

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

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

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

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

## 378 **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 Bilborrow, 2002) and migrants have been considered ‘exceptional resource degraders’ (Codjoe  
460 & Bilborrow, 2012; Cripps & Gardner, 2016). The literature provides a range of reasons that  
461 migrants may engage in more unsustainable 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 & Bilborrow, 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

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

#### 479 *Is forest transition likely?*

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

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

#### 498 *Can land tenure reform contribute to slowing deforestation?*

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

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

511 There is growing evidence that secure tenure is itself linked to forest cover; with secure land  
512 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 foreseeable 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

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

### 587 **Supporting information**

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

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

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

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

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

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

599 Fig. S3: The proportion of non-migrant and migrant households with plots obtained in various  
600 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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- 804

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.
Amporofo	Amporofo (Amporofo) (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 <sup>1</sup> surveys	# of plots reported on	# of agri. surveys	# of plots measured	# of FGD <sup>2</sup>	# of KII <sup>3</sup>
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
Amporofo	2	49	230	40	255	3	1
Total	27	603	2401	167	949	41	8

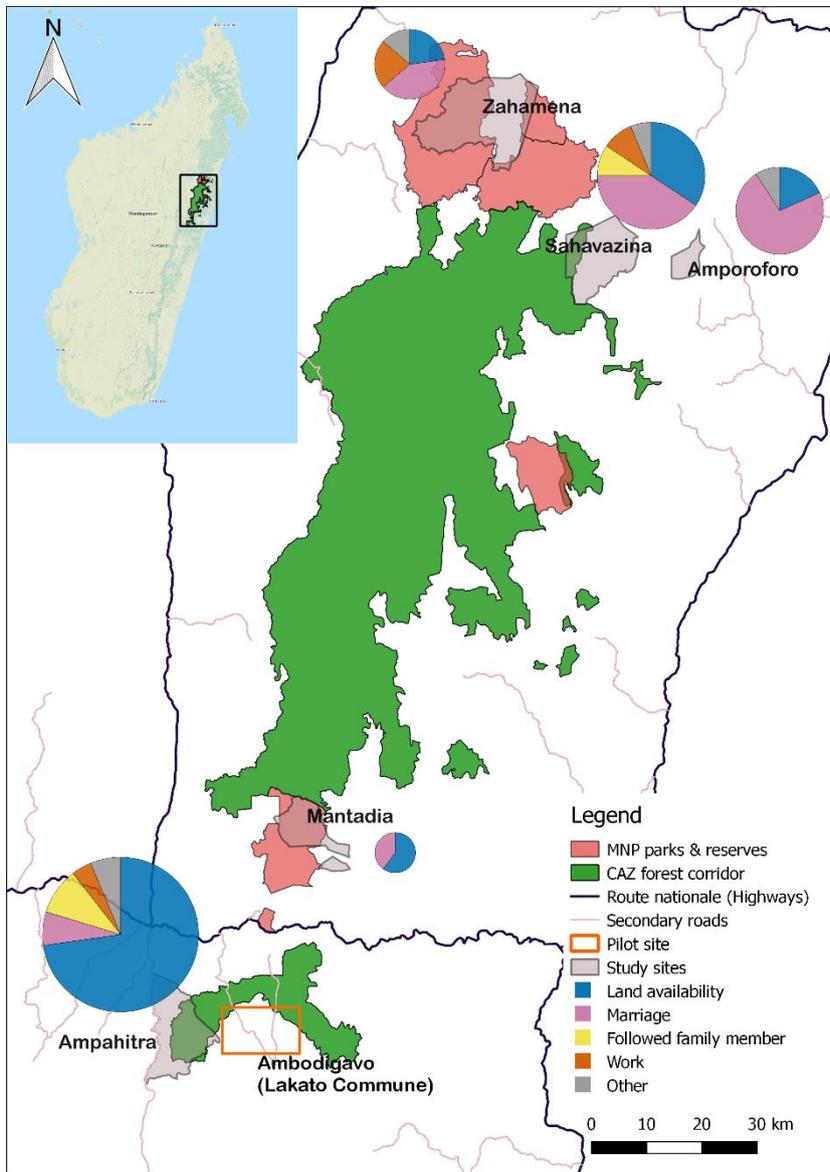
809 <sup>1</sup>Household, <sup>2</sup>Focus Group Discussion, <sup>3</sup>Key Informant Interview.

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
<i>Number of rooms</i>	Total number of rooms (including external kitchens)	Median=1, Mean=1.31, Std. dev=0.47
<i>House quality (N=599)</i>	Type of roof in the primary dwelling (sheet metal, thatch)	95% thatch
<i>Food security</i>	Number of months for which household has enough to eat (continuous variable 0-12)	Median=7, Mean= 6.62, Std.dev=2.76
<i>Tropical Livestock units</i>	Total livestock ownership measured as "Tropical Livestock Unit" (continuous variable 0-14.2)	Median=0.05, Mean= 0.53, Std.dev=0.74
<i>Irrigated rice</i>	Binary variable indicating whether household has access to at least one irrigated rice field	62.6% No
<i>Access to lighting</i>	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
<i>Music player</i>	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 <i>fokontany</i> 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

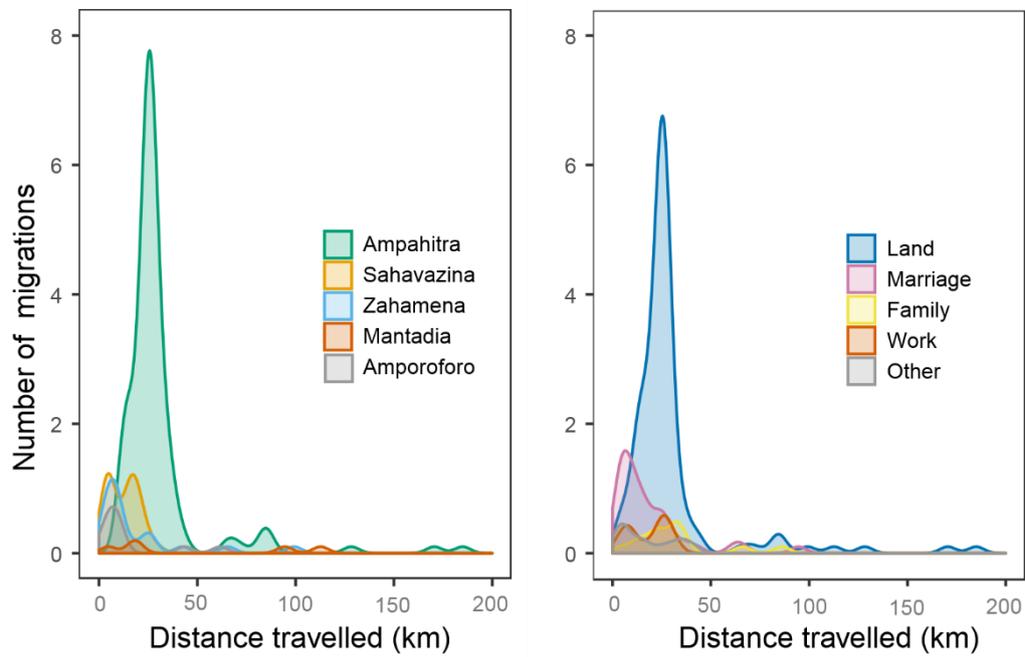
813 **Figures with legends**



814

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

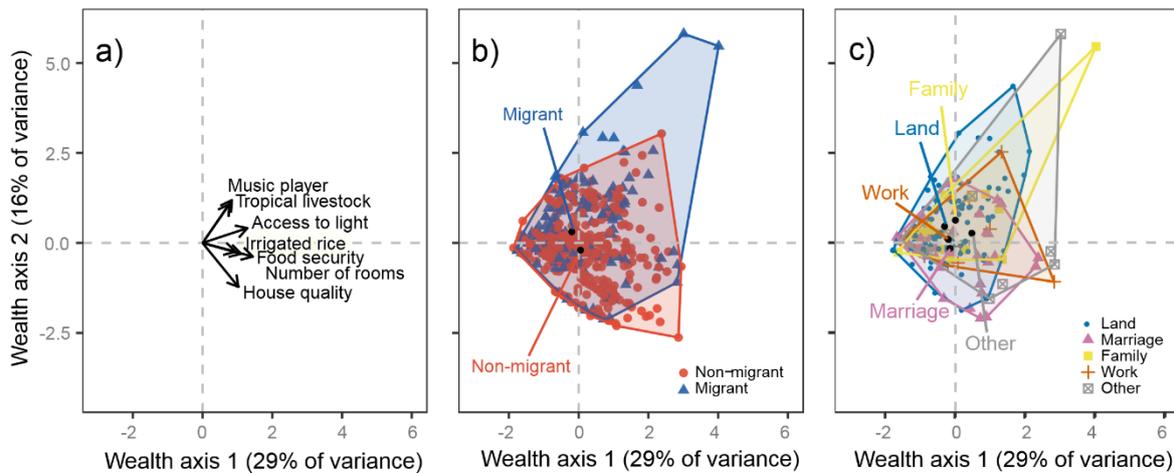
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821

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

827

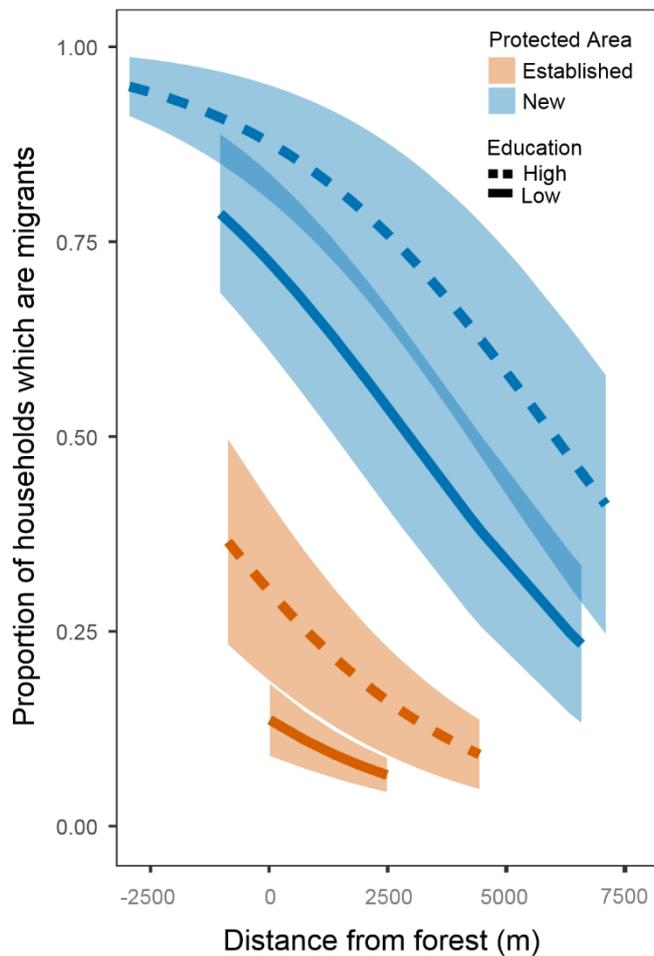


828

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

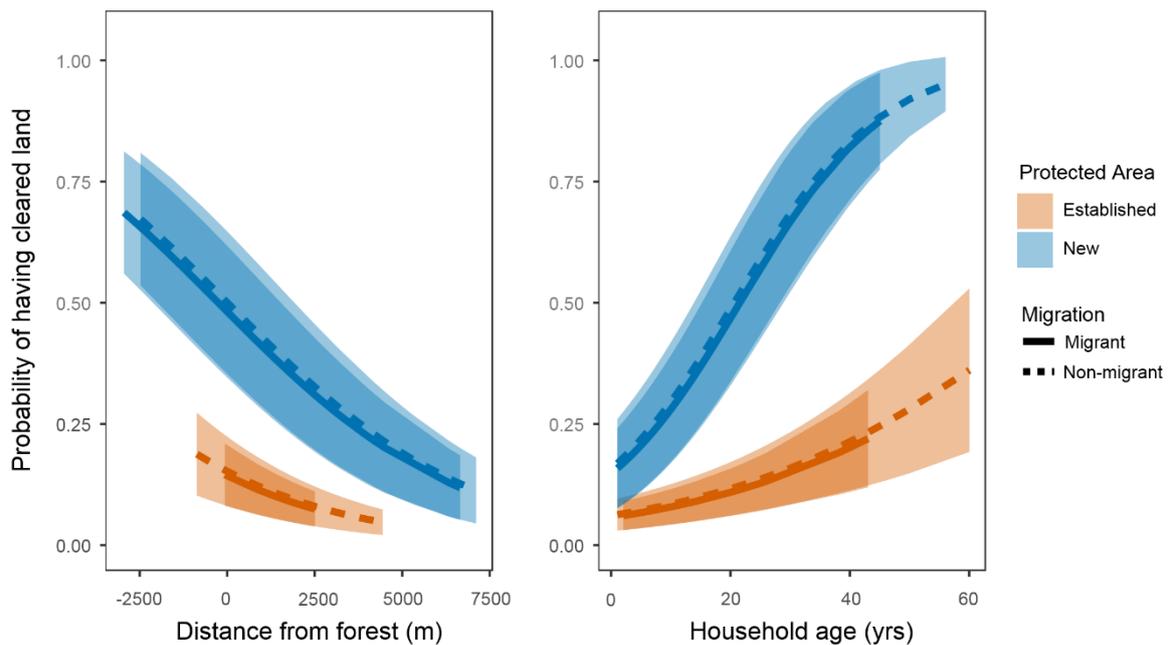
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842

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.