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

Madagascar is well known internationally for its incredible biodiversity but also for loss of a high proportion of its natural forest (Harper *et al.*, 2007). There have been suggestions that in-migration at forest frontiers has contributed to deforestation (Ghimire, 1994; Virah-Sawmy, 2009) however, there has been little research critically evaluating the extent to which migration poses a threat to Madagascar's remaining forests and the integrity of its protected areas (see Cripps & Gardner, 2016, for an exception from coastal protected areas). We explore the recent patterns of in-migration to small communities in the eastern rainforests of Madagascar. Four of our sites are on the forest frontier and one is approximately 20 km away as the crow flies. Of our forest frontier sites, two border long established protected areas (Zahamena National Park and Mantadia National Park; Table 1), while two surround the Corridor Ankeniheny Zahamena (CAZ) which, although recently gazetted as a new protected area, does not have a history of forest protection. We look at the proportion of migrant households, how this varies across the landscape, the reasons for migration and the characteristics of migrants. We explore whether villages on the border of the two long established protected areas contain more migrants (as predicted if protected areas are a net attractor), or less (as predicted if benefits do not offset opportunity costs). We also explore the extent to which migrants clear land from forest relative to non-migrants (a test of the 'exceptional resource degrader' hypothesis). Finally, we ask whether out-migration is likely to reduce pressures on Madagascar's protected areas in the near future. Our aim is to contribute to debates about linkages between human migration and 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 map of all the villages in the area. With the help of key informants such as village elders we mapped the hamlets and isolated houses belonging to each village and then visited each hamlet to record its location with a GPS and confirm the number of houses. Building this representative sampling frame took up to 30% of total field time in each site. We randomly selected 60% of households in each site in Ampahitra and Mantadia and 30% in the other three sites for the household survey. Refusals and dropout rates were very low (less than 4% across all sites). In total we completed the survey with 603 households across our five study sites (see Table 2).

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

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

Qualitative data collection

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

Research ethics

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

Data analysis

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

Characterising poverty

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

Estimating distance of migration

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

Exploring differences between migrant and non-migrant households on the forest frontier

In order to explore the extent to which migrant status is predicted by education of the household head, household age, distance to the forest, and protected status of the site, we used a binomial

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

Exploring the predictors of land clearance

To examine whether the likelihood of having cleared land 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 forest and the site's protected status, we used a binomial GLMM. Here, the response variable was whether the household 'had cleared land' or 'had not land cleared'. We included an interaction between site's protected status and household age (as in previous model) and between site's protected status and migrant status (to account for the fact that migrant land clearance behaviour may differ between established and newly 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

Characterising migration

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

The drivers of migration and migrants' right to settle

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

The qualitative research gives some valuable perspective on this quantitative data. Some migrants refer to themselves as *mpilaravinahitra* (literally 'looking for green leaves'). This reflects the importance migrants place on moving to make a better life through accessing productive land. It can be difficult to separate reasons for migration; for example someone may marry a person from a forest frontier area and the couple choose to settle in their home area 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

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

Why do people migrate into eastern rainforest villages?

The vast majority of migrants gave 'access to land' as their primary reason for migration. This is driven by the high numbers of migrants in Ampahitra, most of whom report having moved to access land. It is interesting to note that in Amporoforo, the one village we studied which is not on the forest frontier, some people are still moving to access land. Therefore migration is not just about clearing land from forest but moving somewhere where land is perceived to be more available (see López-Carr & Burgdorfer, 2013 for similar findings from Latin America).

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

Do Protected Areas attract migrants?

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

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

Scholte and de Groot (2010) present three models of in-migration to protected areas: attraction (where migrants are attracted because of opportunities due to the protected area), engulfment (a protected area is later engulfed by an extraction frontier), or incidental (regions with protected areas may become areas of refuge due to conflict elsewhere). The high level of migration in Ampahitra, on the boundary of the CAZ new protected area, is an example of the engulfment model. Although the CAZ was granted temporary protection in 2006, at the time of our surveys in 2014/2015 there was very little active conservation. The migration is in spite of, not because of, the new protected area status. This finding is similar to that of Zommers & McDonald (2012) who found the high levels of in-migration around a protected area in Uganda were the result of engulfment.

Are migrants 'exceptional resource degraders'?

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

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

We found no evidence that migrants were more likely to have cleared land from forest or to have cleared a larger area of land than non-migrants. This may be because migrants' reliance on social relationships means that their awareness of social norms and institutions is not 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 mechanisms behind this are complex but it may be that in the absence of secure tenure, people clear land to help cement land claims (Unruh *et al.*, 2005; Oglethorpe *et al.*, 2007), or that farmers with insecure tenure invest only in short term annual crops in a shifting system (Kramer *et al.*, 2009). Another possible mechanism is that lack of tenure security discourages investment; preventing agricultural yields increasing per unit area (Bilsborrow, 2002).

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

Policy implications for Madagascar

Protected Areas in eastern Madagascar have attracted few migrants in the last few decades. However, in-migration rates into other forest frontier villages (such as those around the new CAZ protected area) remain high. We found that migrants are no more likely to clear land *per capita* than non-migrants, however it is important to note that by adding to the population they increase demand for land, now and in the future. Policy measures to reduce out-migration from rural areas acting as sources of migrants for the forest frontier (such as the provision of technical assistance and inputs such irrigation improvements or subsidized fertilizers) can, at least in theory, slow in-migration (Bilsborrow, 2002) but given the ongoing increases in rural population growth rates, such interventions will be unlikely to reduce in-migration at the forest frontier in the forseeable future. We argue that improving tenure security for existing residents will be vital to reduce migration to the forest frontier, and protect existing forests without undue costs being placed on existing forest frontier residents.

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

Legal changes to the land laws in Madagascar in 2005 and 2006 recognised that people who lacked formal title (the vast majority of rural residents) can indeed own their land (Laws 2005-019 and 2006-031) and a relatively low cost system to register land ownership locally was introduced. However, coverage of local land offices able to issue certificates, and the effectiveness of these offices in providing such certificates, is patchy (this study; Burnod et al., 2014; Widman, 2014). There is also some concern about women's land rights being undermined as the lack of requirement for jointly held land to be jointly registered reinforces the primary ownership of land by male household heads (Widman, 2014). Unfortunately, the land laws explicitly exclude farmers from gaining tenure over any of their land which falls under the rather broad definition of forest in Malagasy law (Law 97-017 considers land with woody or shrubby species as forest, which can be interpreted to include tree fallows previously exploited for swidden agriculture). This, and the requirement that land owners do not leave land unused for more than five years, discourages farmers from managing their land in long fallows which can provide ecosystem services (Zwartendijk *et al.*, 2017).

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

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

Conclusions

Migration is the norm: most of us are descendants of people who moved. Our results counter the assumption that migrants to the forest frontier are inherently more likely to contribute to land use change than non-migrants. However, through increasing demand for land, they 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.

Fig. S4: Predicted amount of land cleared by households based on model averaged Generalised Linear Mixed Models of agricultural data.

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

Literature cited

Achard F, Beuchle R, Mayaux P et al. (2014) Determination of tropical deforestation rates and related carbon losses from 1990 to 2010. *Global Change Biology*, **20**, 2540–2554.

Adger WN, Arnell NW, Black R, Dercon S, Geddes A, Thomas DSG (2015) Focus on environmental risks and migration: causes and consequences. *Environmental Research Letters*, **10**, 60201.

Aguiar APD, Vieira ICG, Assis TO et al. (2016) Land use change emission scenarios: anticipating a forest transition process in the Brazilian Amazon. *Global Change Biology*, **22**, 1821–1840.

Aide TM, Clark ML, Grau HR et al. (2013) Deforestation and reforestation of Latin America and the Caribbean (2001-2010). *Biotropica*, **45**, 262–271.

Antona M, Bienabe EM, Salles J-M, Pichard G, Aubert S, Ratsimbarison R (2004) Rights transfers in Madagascar biodiversity policies: achievements and significance. *Environment and Development Economics*, **9**, 825–847.

Balmford A, Whitten T (2003) Who should pay for tropical conservation, and how could the costs be met? *Oryx*, **37**, 238–250.

Barton K (2007) MuMIn: Multi-Model Inference. *R package version 2.4-2.*

Bilsborrow RE (2002) Migration, Population Change, and the Rural Environment. *Environmental Change and Security Report*, **8**, 69–94.

Black R, Sessay M (1997) Forced migration, Land-use change and political economy in the forest region of Guinea. *African Affairs*, **96**, 587–605.

Bongaarts J (2017a) Africa's Unique Fertility Transition. *Population and Development Review*, **43**, 39–58.

Bongaarts J (2017b) The effect of contraception on fertility: Is sub-Saharan Africa different? *Demographic Research*, **37**, 129–146.

Borjas G (1987) *Self-Selection and the Earnings of Immigrants*. Cambridge, MA.

Brimont L, Karsenty A (2015) Between incentives and coercion: the thwarted implementation of PES schemes in Madagascar's dense forests. *Ecosystem Services*, **14**, 113–121.

Brondizio ES, McCracken SD, Moran EF, Siqueira AD, Nelson DR, Rodriguez-Pedraza C (2002) The colonist footprint: towards a conceptual framework of land use and deforestation trajectories among small farmers in the Amazonia frontier. In: *Deforestation and land use in the Amazon* (eds Wood C., Porro R). University Press of Florida, Gainesville, USA.

Burnham KP, Anderson DR (2004) Multimodel Inference Understanding AIC and BIC in Model Selection. *Sociological Methods and Research*, **33**, 261–304.

Burnham KP, Anderson DR, Burnham KP (2002) *Model selection and multimodel inference:*

a practical information-theoretic approach. Springer, 488 pp.

Burnod P, Gingembre M, Andrianirina Ratsialonana R (2013) Competition over Authority and Access: International Land Deals in Madagascar. *Development and Change*, **44**, 357–379.

Burnod P, Andrianirina-Ratsialonana R, Ravelomanantsoa Z (2014) Land certification in Madagascar: formalizing (f)or securing? *World Bank Conference on Land and Poverty*, 15.

Carr D (2009) Population and deforestation: why rural migration matters. *Progress in Human Geography*, **33**, 355–378.

Castles S (2011) Migration, Crisis, and the Global Labour Market. *Globalizations*, **8**, 311–324.

Caviglia-Harris JL, Sills EO, Mullan K (2013) Migration and mobility on the Amazon frontier. *Population and Environment*, **34**, 338–369.

Codjoe SNA, Bilsborrow RE (2012) Are migrants exceptional resource degraders? A study of agricultural households in Ghana. *GeoJournal*, **77**, 681–694.

Cripps G, Gardner CJ (2016) Human migration and marine protected areas: Insights from Vezo fishers in Madagascar. *Geoforum*, **74**, 49–62.

Devaraju N, Bala G, Modak A (2015) Effects of large-scale deforestation on precipitation in the monsoon regions: remote versus local effects. *Proceedings of the National Academy of Sciences of the United States of America*, **112**, 3257–62.

Duchelle AE, Cromberg M, Gebara MF et al. (2014) Linking Forest Tenure Reform, Environmental Compliance, and Incentives: Lessons from REDD+ Initiatives in the Brazilian Amazon. *World Development*, **55**, 53–67.

Ekpenyong AS, Egerson D (2014) Rural-Rural Migration in Bayelsa State, Nigeria: A Case Study of Rural-Rural Migrants along Tombia-Amassoma Expressway. *International Journal of Scientific and Research Publications*, **5**, 2250–3153.

Elmqvist T, Pyykonen M, Tengo M, Rakotondrasoa F, Rabakonandrianina E, Radimilahy C (2007) Patterns of Loss and Regeneration of Tropical Dry Forest in Madagascar: The Social Institutional Context (ed Somers M). *PLoS ONE*, **2**, e402.

Etongo D, Djenontin INS, Kanninen M, Fobissie K, Korhonen-Kurki K, Djoudi H (2015) Land tenure, asset heterogeneity and deforestation in Southern Burkina Faso. *Forest Policy and Economics*, **61**, 51–58.

Fussell E, Hunter LM, Gray CL (2014) Measuring the environmental dimensions of human migration: The demographer's toolkit. *Global Environmental Change*, **28**, 182–191.

Geist HJ, Lambin EF (2002) Proximate Causes and Underlying Driving Forces of Tropical Deforestation. *BioScience*, **52**, 143.

Ghimire KB (1994) Parks and People: Livelihood Issues in National Parks Management in Thailand and Madagascar. *Development and Change*, **25**, 195–229.

Gibson L, Lee TM, Koh LP et al. (2011) Primary forests are irreplaceable for sustaining tropical biodiversity. *Nature*, **478**, 378–381.

Harper GJ, Steininger MK, Tucker CJ, Juhn D, Hawkins F (2007) Fifty years of deforestation and forest fragmentation in Madagascar. *Environmental Conservation*, **34**, 325–333.

Hewson J, Razafimanahaka JH, Wright TM et al. Conservation implications of potential land use policies in Eastern Madagascar based on land change modelling. *submitted*.

Holland MB, Jones KW, Naughton-Treves L, Freire J-L, Morales M, Suárez L (2017) Titling land to conserve forests: The case of Cuyabeno Reserve in Ecuador. *Global Environmental Change*, **44**, 27–38.

Jacobsen K (1994) *Impact of refugees on the environment: a review of the evidencee*. Washington DC.

Jenkins RKB, Keane A, Rakotoarivelo AR et al. (2011) Analysis of Patterns of Bushmeat Consumption Reveals Extensive Exploitation of Protected Species in Eastern Madagascar (ed Mappes T). *PLoS ONE*, **6**, e27570.

Joppa LN, Loarie SR, Pimm SL, Burton A, Brashares J (2009) On population growth near protected areas (ed Godley BJ). *PLoS ONE*, **4**, e4279.

Kanbur R, Rapoport H (2005) Migration selectivity and the evolution of spatial inequality. *Journal of Economic Geography*, **5**, 43–57.

Kramer DB, Urquhart G, Schmitt K (2009) Globalization and the connection of remote communities: A review of household effects and their biodiversity implications. *Ecological Economics*, **68**, 2897–2909.

Kull CA, Ibrahim CK, Meredith TC (2007) Tropical Forest Transitions and Globalization:Neo-Liberalism, Migration, Tourism, and International Conservation Agendas. *Society & Natural Resources*, **20**, 723–737.

Lambin EF, Meyfroidt P (2010) Land use transitions: Socio-ecological feedback versus socio-economic change. *Land Use Policy*, **27**, 108–118.

Lee ES (1966) A theory of migration. *Demography*, **3**, 47.

López-Carr D, Burgdorfer J (2013) Deforestation Drivers: Population, Migration, and Tropical Land Use. *Environment*, **55**.

Martin TC (1995) Women's Education and Fertility: Results from 26 Demographic and Health Surveys. *Studies in Family Planning*, **26**, 187.

Mather AS, Needle CL (1998) The forest transition: a theoretical basis. *Area*, **30**, 117–124.

Meyfroidt P, Rudel TK, Lambin EF (2010) Forest transitions, trade, and the global displacement of land use. *Proceedings of the National Academy of Sciences of the United States of America*, **107**, 20917–22.

Oates JF (1999) *Myth and reality in the rain forest: how conservation strategies are failing in West Africa*. University of California Press, 310 pp.

Oglethorpe J, Ericson J, Bilsborrow E, Edmond J (2007) *People on the Move: Reducing the Impacts of Human Migration on Biodiversity*.

Oksanen JF, Guillaume B, Friendly M et al. (2017) vegan: Community Ecology Package. *R package version 2.4-2.*

Pardieu V, Rakotosaona N (2005) Ruby and Sapphire Rush Near Didy, Madagascar. *Gems and Gemology*, **48**, 149–150.

Peluso NL (1993) Coercing conservation? The politics of state resource control. *Global Environmental Change*, **3**, 199–217.

Perkins R (2017) *Old and New Sapphire Rushes in the Bemainty Mining Area, Madagascar*. Paris, 18 pp.

Poudyal M, Ramamonjisoa BS, Hockley N et al. (2016) Can REDD+ social safeguards reach the “right” people? Lessons from Madagascar. *Global Environmental Change,* **37**, 31–42.

Poudyal M, Rakotonarivo OS, Rasoamanana A, Mandimbiniaina R, Spener N, Hockley N, Jones JPG (2017a) Household survey and discrete choice experiment for investigating the opportunity cost of conservation restrictions in eastern Madagascar. *[Data Collection]. Colchester, Essex: UK Data Archive.*

Poudyal M, Rasoamanana A, Andrianantenaina SN et al. (2017b) Household-level agricultural inputs-outputs, off-farm income and wild-harvested products survey in eastern Madagascar - ReShare. *[Data Collection]. Colchester, Essex: UK Data Archive.*

Raboanarielina C (2012) The forgotten resource: Community perspectives on conservation and well - being in Zahamena National Park, Madagascar. *Madagascar Conservation & Development*, **7**, 70–78.

R core development team (2017) R: A language and environment for statistical computing. *Vienna Foundation for Statistical Computing*.

Rakotonarivo OS, Jacobsen JB, Larsen HO et al. (2017) Qualitative and Quantitative Evidence on the True Local Welfare Costs of Forest Conservation in Madagascar: Are Discrete Choice Experiments a Valid ex ante Tool? *World Development*, **94**, 478–491.

Rakotondrazafy HH (2007) *Étude de La Governance Des Aires Proteges de Madagascar: Cas Du Parc National Andasibe Mantadia et Du Lac Alaotra.* University of Antananarivo.

Ranjatson P (2011) *La sécurisation des usages forestiers par les réseaux sociaux et l’économie: Deux exemples aux lisières de la réserve spéciale de Manongarivo et du corridor forestier Ranomafana Andringitra.* University of Antananarivo, 157 pp.

Rasolofoson RA, Nielsen MR, Jones JPG The potential of the Global Person Generated Index (GPGI) for evaluating the perceived impact of conservation interventions on subjective well-being. *World Development*.

Razafimanahaka JH, Jenkins RKB, Andriafidison D, Randrianandrianina F, Rakotomboavonjy V, Keane A, Jones JPG (2012) Novel approach for quantifying illegal bushmeat consumption reveals high consumption of protected species in Madagascar. *Oryx*, **46**, 584–592.

Revelle W (2017) psych: Procedures for Personality and Psychological Research. *R package version 2.4-2.*

Robinson BE, Holland MB, Naughton-Treves L (2014) Does secure land tenure save forests? A meta-analysis of the relationship between land tenure and tropical deforestation. *Global Environmental Change*, **29**, 281–293.

Robinson BE, Masuda YJ, Kelly A et al. (2017) Incorporating Land Tenure Security into Conservation. *Conservation Letters*.

Salerno JD, Borgerhoff Mulder M, Kefauver SC (2014) Human Migration, Protected Areas, and Conservation Outreach in Tanzania. *Conservation Biology*, **28**, 841–850.

Scales I (2014) The future of conservation and development in Madagascar: Time for a new paradigm? *Madagascar Conservation & Development*, **9**, 5.

Scholte P (2003) Immigration: a potential time bomb under the Integration of Conservation and Development. *AMBIO: A Journal of the Human Environment*, **32**, 58–64.

Scholte P, De Groot WT (2010) From Debate to Insight: Three Models of Immigration to Protected Areas. *Conservation Biology*, **24**, 630–632.

de Sherbinin A, Freudenberger M (1998) Migration to protected areas and buffer zones: can we stem the tide? *Parks*, **8**.

de Sherbinin A, Carr D, Cassels S, Jiang L (2007) Population and Environment. *Annual Review of Environment and Resources*, **32**, 345–373.

Simbizi MCD, Bennett RM, Zevenbergen J (2014) Land tenure security: Revisiting and refining the concept for Sub-Saharan Africa's rural poor. *Land Use Policy*, **36**, 231–238.

Thiede B, Gray C, Mueller V (2016) Climate variability and inter-provincial migration in South America, 1970â€“2011. *Global Environmental Change*, **41**, 228–240.

Turnhout E, Gupta A, Weatherley-Singh J et al. (2017) Envisioning REDD+ in a post-Paris era: between evolving expectations and current practice. *Wiley Interdisciplinary Reviews: Climate Change*, **8**, e425.

UN (2014) *New York Declaration on Forests*. New York.

Unruh J, Cligget L, Hay R (2005) Migrant land rights reception and “clearing to claim” in sub-Saharan Africa: A deforestation example from southern Zambia. *Natural Resources Forum*, **29**, 190–198.

Vieilledent G, Gardi O, Grinand C et al. (2016) Bioclimatic envelope models predict a decrease in tropical forest carbon stocks with climate change in Madagascar (ed Lines E). *Journal of Ecology*, **104**, 703–715.

Virah-Sawmy M (2009) Ecosystem management in Madagascar during global change.

Conservation Letters, **2**, 163–170.

Widman M (2014) Land Tenure Insecurity and Formalizing Land Rights in Madagascar: A Gender Perspective on the Certification Program. *Feminist Economics*, **20**, 130–154.

Wily LA (2008) Custom and commonage in Africa rethinking the orthodoxies. *Land Use Policy*, **25**, 43–52.

Wittemyer G, Elsen P, Bean WT, Burton ACO, Brashares JS (2008) Accelerated human population growth at protected area edges. *Science*, **321**.

World Bank Madagascar | Data.

Zommers Z, MacDonald DW (2012) Protected Areas as Frontiers for Human Migration. *Conservation Biology*, **26**, 547–556.

Zwartendijk BW, van Meerveld HJ, Ghimire CP, Bruijnzeel LA, Ravelona M, Jones JPG (2017) Rebuilding soil hydrological functioning after swidden agriculture in eastern Madagascar. *Agriculture, Ecosystems & Environment*, **239**, 101–111.

Tables

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.

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

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

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

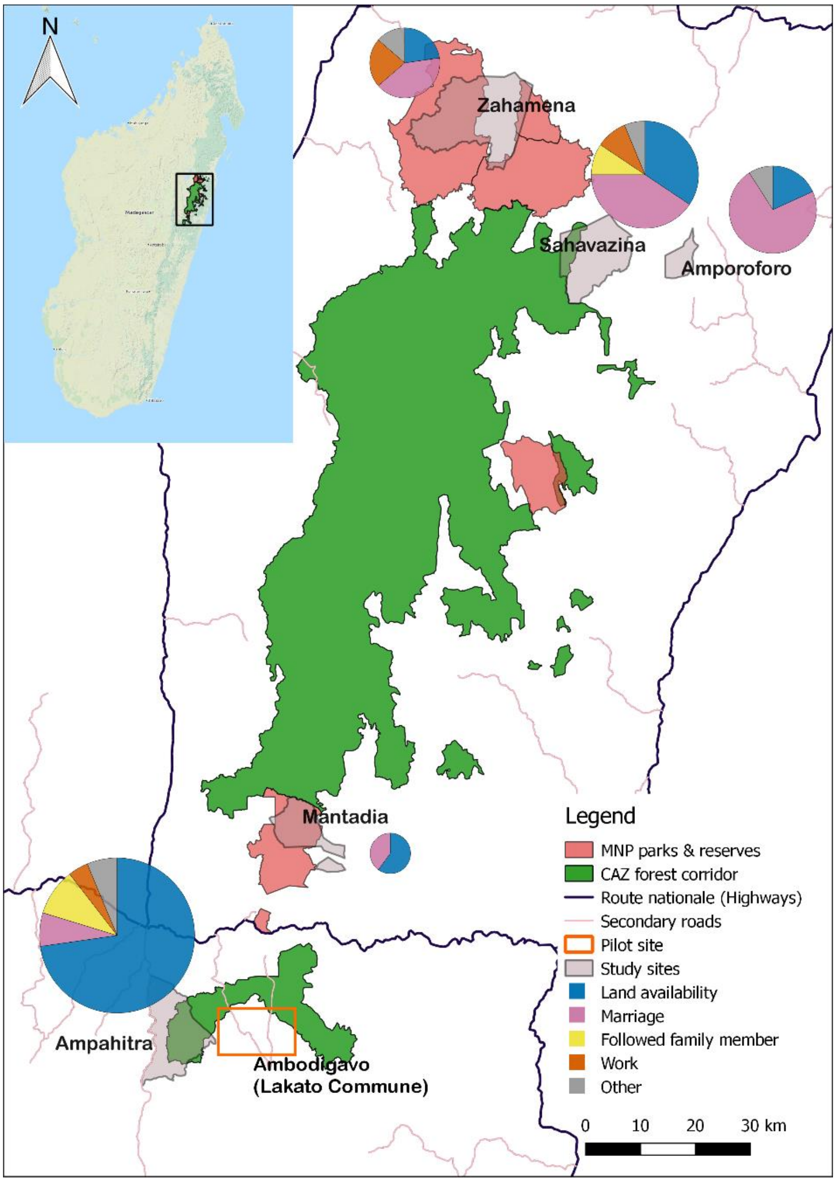

Fig. 1: The location of our study sites and pilot site in the CAZ forest corridor in eastern Madagascar (with associated protected areas). Pie charts indicate the primary reason given by migrants in each site for moving to the area. The size of the pie indicates the proportion of respondents in each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

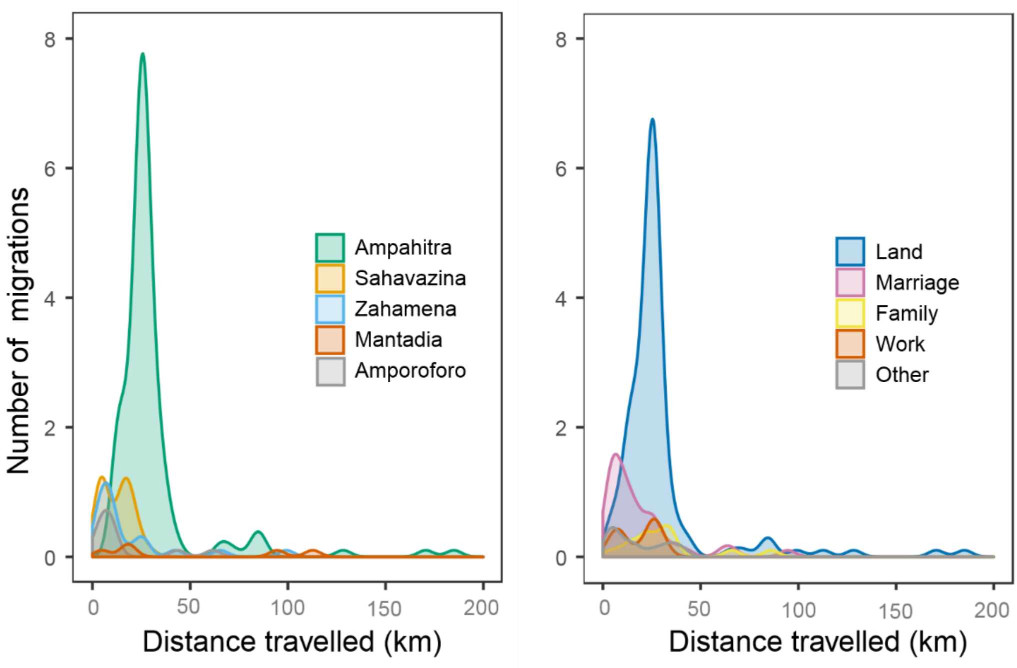

Fig. 2: The distribution of migration distances a) by study site (b) by reason to migrate. Figures show the estimated number of households in each 1 km distance bracket. Migration distance is calculated as the distance from the centre of the commune where the head of household originated to the *fokontany*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

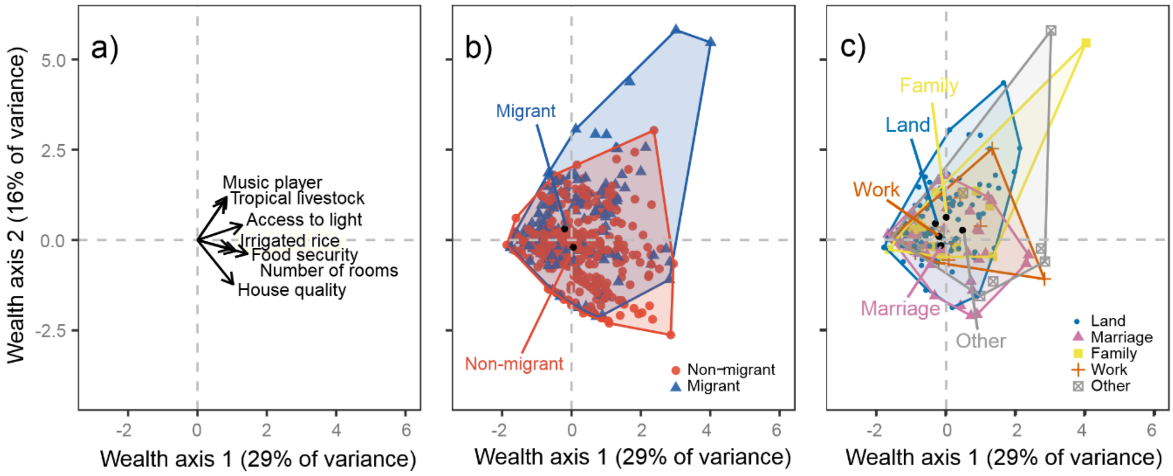

Fig. 3: Principal Component Analysis showing measures of wealth, and the positions of migrants and non-migrants and migrants with different reasons for moving on wealth axes. a) Wealth axis 1 (29% of variation) can be interpreted as an overall measure of wealth; a higher value indicates higher household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

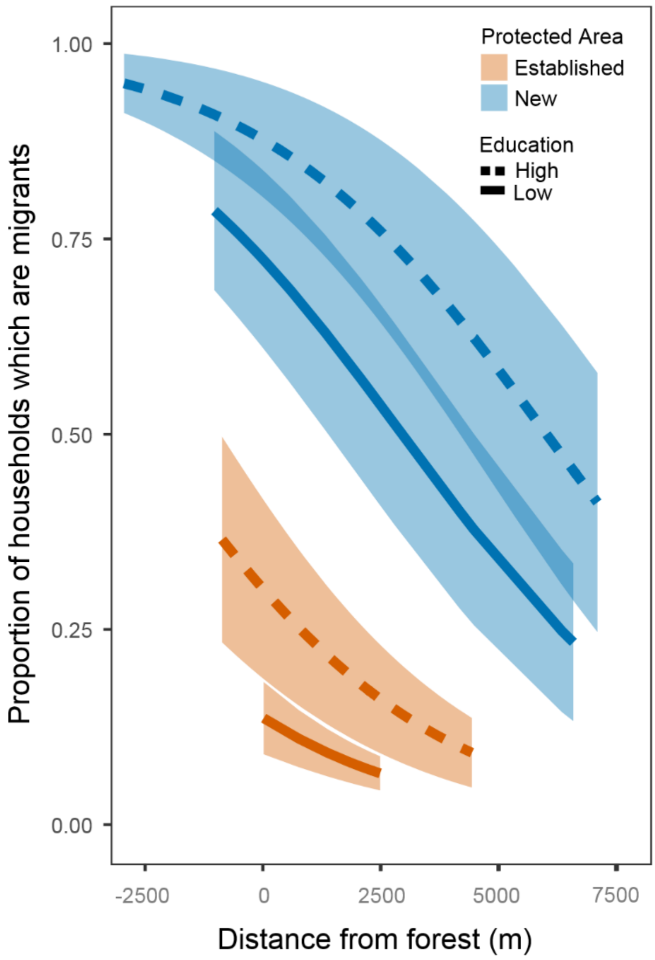

Fig. 4: Predicted proportions of migrant households based on model averaged Generalised Linear Mixed Model results. A higher proportion of households living closer to the forest frontier and on the periphery of the new areas relative to established protected areas are migrant households. Migrants also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

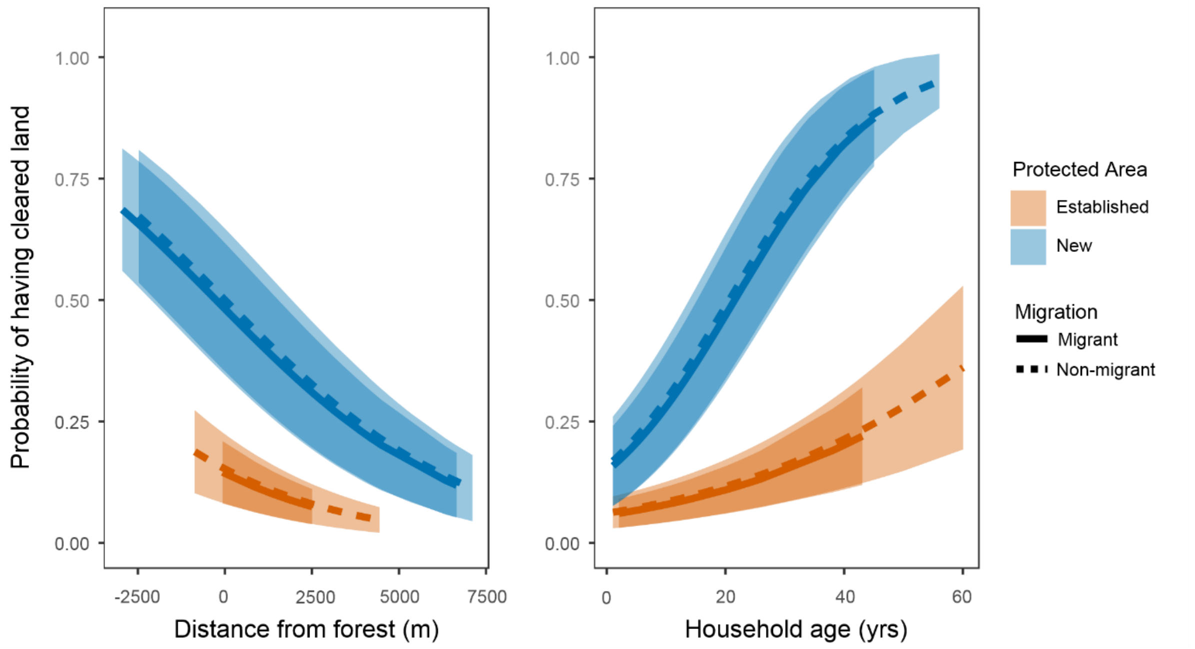

Fig. 5: Predicted probability of households having cleared land based on model averaged Generalised Linear Mixed Model results. Households living near new protected areas (as opposed to the long-established protected areas), living closer to the forest frontier, and longer established households are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