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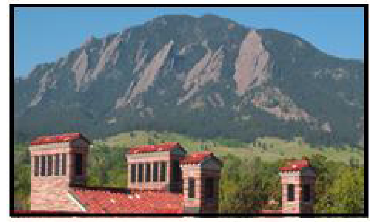

WORKING PAPER

Natural Resources and Rural Livelihoods: Differences between Migrants and Non-Migrants in Madagascar

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Natural Resources and Rural Livelihoods:

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Abstract

This study explores the association between natural resource availability and well-being for migrants' and non-migrants' in rural Madagascar. The aim is to shed light on the ways in which these groups differentially tap into local natural capital. Data from the 2008/2009 Demographic and Health Survey are used in combination with satellite imagery of vegetation coverage to proxy natural resources. Multilevel models yield three key findings. First, higher levels of proximate natural resources are associated with greater financial, human, and social capital for both migrants and non-migrants. Second, migrants have, on average, greater financial, physical, human, and social capital than non-migrants, and urban-to-rural migrants do exceptionally well on all capital asset categories. Third, significant cross-level interactions suggest that the benefits of local natural capital vary between migrants and non-migrants with migrants gaining relatively more from local resources.

Key words: DHS (Demographic and Health Survey), Environment, Madagascar, Urban to Rural Migration, Length of Residency, Multilevel Models, Natural Resources, NDVI, Rural Livelihoods, Sustainable Livelihood Framework, Vegetation.

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1. Introduction

Migration scholars have offered substantial insight into factors that shape migrant well-being, including gender (Abrego 2009), race and ethnicity (Adelman, Tsao, and Tolnay 2006), social networks (Bastia 2007), and employment status (Rabe 2011). Yet, although natural resources play a central role in rural well-being in many regions across the globe, little research has explored the relationship between migrant well-being and natural resource availability (Barbieri and Carr 2005; Massey, Axinn, and Ghimire 2010). This paper begins to fill this gap by asking two innovative questions with regard to rural residents in a less developed setting characterized by dependence on proximate natural resources: (1) *Does well-being differ between migrants and non-migrants?* To gain insight into differential livelihiood strategies and the potential environmental impact of rural migration, we also ask: (2) *Is the well-being, of both migrants and non-migrants, associated with natural resource access in destination regions?* To address the research questions we measure "well-being" as access to, or possession of, financial, physical, human, and social capital, drawing conceptually on the "Sustainable Livelihoods" framework (Carney et al. 1999).

Madagascar is in many regards typical for nations of sub-Saharan Africa. Poverty is a major issue, in part because of socioeconomic and sociopolitical conditions, such as the "lack of local savings, outdated economic and social infrastructure, [and] very unequal and arbitrary application of rules nationwide" (AEO 2007:323). Madagascar's GDP is comparable to those of many East African countries; on average, the private tertiary sector based on the tourist industry contributes most (49.5%), followed by the primary sector, mainly agricultural production (28.3%). A weak industrial secondary sector (16%) is heavily dependent on coffee and spice exports (AEO 2007). In this socioeconomic climate, households struggle daily and draw on strategies such as migration and natural resource extraction to diversify livelihoods.

This article is organized as follows. First, we review the Sustainable Livelihoods framework for conceptual guidance. We then highlight existing literature on migrant/non-migrant differentials in livelihood capital assets – human, financial, physical, and social. A subsequent literature section offers more detailed review of the role of natural capital in rural livelihoods, particularly as we might anticipate that migrants and non-migrants might use proximate natural resources differently. We then discuss our data, methods and present results. Finally, the conclusion offers overarching statements regarding livelihoods, migration, and natural capital as well as policy recommendations.

2. Background

2.1 The Sustainable Livelihoods Framework

Rural households often pursue diverse livelihood strategies including farming, herding, off-farm employment, and the exploitation of natural resources through hunting, fishing, and gathering. The "Sustainable Livelihood" (SL) framework was designed as a conceptual tool to reflect this variety (de Sherbinin et al. 2008). The SL framework, developed and enhanced by a variety of international agencies such as the UK Department for International Development (DFID), CARE, Oxfam, and the United Nations Development Program, has been used to guide programs for poverty alleviation (Carney et al. 1999). The framework's origin can be traced back to the work of Chambers and Conway (1991:6), who explained that a:

> livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living: a livelihood is sustainable which can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation; and which contributes net benefits to other livelihoods at the local and global levels and in the long and short term.

Central to the framework is the understanding that the relative availability of various "capital assets" shapes the livelihood options of rural households in developing countries. These assets include financial, physical, human, social, and natural capital as outlined below (Carney et al. 1999).

- *Financial capital* represents the financial resources available to individuals and households (e.g., savings, supplies of credit, or regular remittances or pensions) that provide opportunity for the pursuit of different livelihood options;
- *Physical capital* represents the basic infrastructure (transport, shelter, water, energy, and communications) and the production equipment and means enabling the pursuit of various livelihood strategies;
- *Human capital* comprises the skills, knowledge, and ability to labor central to various livelihood pursuits;
- *Social capital* includes the social resources, such as networks, group memberships, and trust relationships, upon which individuals and households draw in pursuit of livelihoods;

- *Natural capital* includes access to land, water, and wildlife, from which households engage in agricultural pursuits and/or resource collection for both sustenance and income generation.

Rural households often combine a number of livelihood activities, such as agricultural crop production, wage labor, or forest product collection, to meet subsistence needs. Of course, the household's access to different livelihood capitals and opportunities will shape the potential mix of activities (Ellis 1998; Bryceson 2002).

The SL framework has been successfully used to explore health behaviors (Rugalema 2000), food security (Bank 2005), household diversification strategies (Yaro 2006), and even watershed management (Mahdi, Shivakoti, and Schmidt-Vogt 2009). It is also well suited to examining population-environment interactions (de Sherbinin et al. 2008; Massey, Axinn, and Ghimire 2010), since population dynamics (e.g., migration) are often reciprocally related to livelihood strategies, which are themselves directly or indirectly affected by local environments.[1] For instance, access to natural capital may facilitate improvements in other livelihood assets such as financial capital – for example, as households collect reeds to make baskets that are then sold at markets (Pereira, Shackleton, and Shackleton 2006). We further explore how these capital assets may play different roles in livelihood strategies among migrants and non-migrants, as reviewed next.

2.2 Migrant/Non-Migrant Differentials in Livelihood Assets

[1] Livelihood options and strategies are also clearly shaped by structural, macro-level factors. These include the sociopolitical context, which encompasses laws, policies, institutions, and governance (Mahdi, Shivakoti, and Schmidt-Vogt 2009), cultural factors (status of women, value of children, spiritual connection to the land), economic factors (national and global markets), and global changes affecting the local environment (desertification, flooding, sea level rise) (de Sherbinin et al. 2008). Given our cross-sectional and micro-level approach, the analyses presented here do not incorporate such broad-scale factors.

Early in the development of the Sustainable Livelihoods framework, migration was recognized as an important means of livelihood diversification (Chambers and Conway 1991). In particular, out-migration is a livelihood strategy frequently practiced in response to the insecurity and unpredictability of agricultural activities. Often, farmers leave their village seasonally or permanently to earn additional income elsewhere or to seek new lands for agricultural production and animal husbandry (Kull, Ibrahim, and Meredith 2007; Mahdi, Shivakoti, and Schmidt-Vogt 2009). But the propensity to migrate is not randomly distributed; those who decide to migrate frequently differ from the non-migrant local population in their livelihood asset status and livelihood strategies, as explored below.

2.2.1. Financial Capital

Migration requires capital, so migrants are typically not the poorest of the poor (Brown and Bean 2006). Initially, migration is a risky undertaken and mostly households of the upper middle class, with higher income, are willing and able to send migrants (Taylor et al. 1996). In addition, Mberu (2006) observed that migrants have higher household living standards (a proxy for financial capital) than non-migrants. Even so, other researchers report evidence that severe poverty may also drive out-migration as a last resort (Ezra 2001). Within this study, given high levels of impoverishment in rural Madagascar, we anticipate migrants to possess relatively higher levels of financial capital as compared to rural non-migrants.

2.2.2. Physical Capital

Takenaka and Pren (2010) point out that physical capital such as a home or production assets can either deter migration (owners have greater investment in origin) or facilitate migration (assets can be mortgaged or used to generate income to finance a move). These contrasting tendencies can be explained by different migration theories (Bohra and Massey 2009). According to conventional economic theory, physical capital assets mitigate the costs of migration and thus raise the probability of out-migration (Massey et al. 1998). The new economic theory, on the other hand, argues that households move to self-finance the acquisition of physical assets, so that ownership of these assets (e.g., business, truck, harvesting equipment) reduces the probability of migration (see Massey and Espinosa 1997). Within this study, we anticipate that rural non-migrants, who have longer lived in the areas under study, will have acquired relatively higher levels of physical capital as compared to non-migrants.

2.2.3. Human Capital

The literature on the human capital of migrants and non-migrants is less ambiguous. Migrants tend to be better educated than their non-migrant peers (Lindstrom and Ramirez 2010), a fact that has been well established in the demographic literature for decades (Browning and Feindt 1969). However, the difference does dependent on sociocultural context and thus varies with the country of origin (Takenaka and Pren 2010). Based on this literature, within this study we anticipate migrants to possess higher levels of human capital (education) relatively to rural non-migrants.

2.2.4 Social Capital

Social networks play a critical role in shaping migration. Those who have a spouse, immediate family member, or other relative with migratory experience are significantly more likely to migrate than those without such ties. In addition, living in a community with a higher migration prevalence increases the odds of out-migration (Takenaka and Pren 2010; Bohra and Massey 2009). Migrant networks connect non-migrants in places of origin to current migrants at places of destination and former migrants in home communities, thereby reducing the costs and increasing the expected benefits of migration, and make departure more likely (Massey 1990). At the destination a newly arrived migrant may initially not be as well connected as local residents, but his or her social capital can be expected to increase over time. Indeed, studies have found that embeddedness in social networks and communities has a crucial effect on natural resource use (Curran 2002). For example, migrants with stronger community ties were less likely to use destructive resource extraction techniques in a study of marine ecosystems in Indonesia (Cassels, Curran and Kramer 2005). Within this study, we anticipate rural non-migrants, given their longer time in study areas, to have higher levels of local social capital.

2.3. Natural Capital: Our Analytical Focus

2.3.1. Natural Capital and Livelihood Strategies

Madagascar is renowned for its biological diversity (Dufils 2003). Roughly 80% of the nation's residents live in biologically diverse rural areas and rely heavily on forest resources for subsistence (Ingram, Whittaker, and Dawson 2005). Key natural assets include bushmeat (wildlife for human consumption); timber (as construction material and fuel, and for charcoal production); medicinal plants (for personal use and sale); roots, wild tubers, and honey (as food); and tree bark for tannin extraction (Golden 2009; Casse et al. 2004; Kull, Tassin, and Rangan 2007; Tucker 2007).

However, deforestation is significantly threatening the diversity of available resources. In southern Madagascar's Androy region, it has been estimated that forest cover decreased by 65% between 1950 and 1984, and an additional 7% of forest disappeared between 1984 and 2000 (Elmqvist et al. 2007). These high levels of deforestation are directly connected to rural livelihood strategies that entail fuelwood collection; timber exploitation (either for local consumption or for sale to urban centers); cropland expansion; and expansion of grazing land (pasture) (Casse et al. 2004). Although officially illegal, traditional slash-and-burn techniques (*tavy*) are frequently employed to clear forest and shrubland and to renew pasture (Kull 2002; Styger et al. 2007).

Natural resource extraction also acts as a safety net. As shown in other African settings, in case of harvest failures, natural disasters, or the death of a breadwinner, households may turn to forest product extraction (Casse et al. 2004; Hunter, Twine and Johnson 2011; Hunter, Twine and Patterson 2007; Mahdi, Shivakoti, and Schmidt-Vogt 2009; Paumgarten 2005; Shackleton and Shackleton 2004). Coping strategies in times of crisis may include replacing previously purchased goods with wild equivalents or engaging in temporary sale of natural products and handcrafts to supplement household income (Shackleton and Shackleton 2004; Dovie, Shackleton, and Witkowski 2002). This "safety net" is particularly important for poor and vulnerable households (Hunter, Twine and Patterson 2007; Shackleton and Shackleton 2004).

2.3.2. Natural Capital and Migration

In Madagascar, adverse environmental conditions are a critically important migration trigger. Droughts, invasion by locusts, and cyclones have undermined agriculture-dependent rural livelihoods and provoked large exoduses to more hospitable rural areas, with the prospect of clearing forested areas to create new agro-pastoral land (Durbin, Bernard, and Finn 2003; Elmqvist et al. 2007; Virah-Sawmy 2009). Ethnic groups from the far south have moved northwest and often have migrated again after a short period in the destination area. In these receiving areas, migrants often dominate the population of entire villages (Casse et al. 2004).

The impacts of some of these adverse environmental conditions are likely to become more severe in the near future. For example, droughts are projected to increase for sub-Saharan Africa under the influence of climate change (IPCC 2007). In Madagascar, a decrease in precipitation has been observed since the 1970s, with recurrent drought since 1981 (Casse et al.

2004; Jury 2003). Such rainfall declines have been shown to increase migration in other African regions (Henry, Schoumaker and Beauchemin 2004), and Madagascar may similarly experience intensified livelihood migration and the concomitant increase in environmental pressures in receiving areas (Bilsborrow and DeLargy 1990). Livelihood migration may substantially contribute to deforestation since migrants have been found to be frequently involved in charcoal production for sale to urban areas (QMM 2001; Ingram, Whittaker, and Dawson 2005) or remove forest cover to grow maize (Casse et al. 2004).

Structural conditions also encourage migration and deforestation. For example, the influx of migrants is often exaggerated along territorial boundaries, between communities or on land where ownership by government, clans, lineages, or communities is rather uncertain (Durbin, Bernard, and Fenn 2003). In Madagascar only small areas are covered by formal, state-sanctioned land registers, and much land is under relatively unclear traditional customary tenure arrangements (Kull, Ibrahim, and Meredith 2007). Clearing land is seen as a way to gain formal ownership (Elmqvist et al. 2007). In all, although migration may yield environmental change, we expect to see a positive association between access to natural resources and well-being since natural capital is widely used in rural livelihood strategies within Madagascar and can be translated into other forms of capital (Shackleton and Shackleton 2004).

Making use of the background literature review above, we return to our two research questions. In line with the migrant selectivity literature we aim first to understand distinctions across migrant categories within rural Madagascar, asking, (1) *Does well-being differ between migrants and non-migrants?* We then examine how any such variation is associated with the availability of proximate natural capital to gain insight into differential livelihood strategies and the potential environmental impact of rural migration, asking, (2) *Is the well-being, of both migrants and non-migrants, associated with natural resource access in destination regions?*

3. Methods

3.1. Data

We use the 2008-2009 Demographic and Health Survey (DHS) for Madagascar. The DHS, a standardized survey administered in 84 countries, collects a wide variety of sociodemographic and health information and has been described as one of "the largest, coordinated social science research efforts in history" (Morgan and Hagewen 2006). The DHS's analytical foci are fertility, family planning, and maternal and child health, and therefore its sample predominantly includes women and men of reproductive age. This targeted sample, in combination with the lack of consistent residence history data, has minimized the use of the DHS for migration research (an exception is Islam and Azad's [2008] work using data from Bangladesh). However, the Madagascar DHS data, collected by Madagascar's Institut National de la Statistique (INSTAT), are an exception and are well suited for our research purposes since they include some residence history information and are also geo-referenced, allowing spatial information on vegetation cover to be appended to the social data.

Given our focus on natural capital within rural livelihoods, we limit our analysis to DHS respondents within Madagascar's rural areas (about 70% of the total population). The DHS uses a stratified two-stage cluster sampling design in which the primary sampling unit (PSU) in stage 1 and the households in stage 2 are randomly selected. The DHS then administers its two main survey instruments: a household schedule and an individual questionnaire. The household schedule provides a list of household members from which individuals eligible for the individual interview are selected (DHS 1996). Eligible individuals comprise all women of reproductive age in the household. The DHS also collects information about men of reproductive age from every other sampled household, resulting in a somewhat smaller sample for men. We combined these two samples to investigate overall patterns of migrant/non-migrant differences in capital asset status, with a focus on natural capital.

3.2. Measures

3.2.1. Dependent Variables

We created a number of measures to reflect financial, physical, human, social, and natural capital. In Table 1, we report frequencies and group-mean comparisons (t-test) between migrants and non-migrants separately for rural and urban areas. This allows for an overall appraisal of the uniqueness and similarities between migrants and non-migrant sub-populations across geographical regions in Madagascar.

(Table 1 about here)

Financial capital. The DHS does not collect information on household consumption or income. However, it provides a wealth index that categorizes people as poorest=1, poorer=2, middle=3, richer=4, and richest=5.[2] In many less developed countries (LDCs) monetary income is difficult to measure, since many individuals are self-employed, involved in seasonal and/or other temporary labor arrangements, and/or involved in home production for which the financial cost of goods sold or produced is less relevant. Household wealth, in contrast, represents a more

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[2] The wealth index is a weighted measure that is based on items reflecting economic status. It includes variables such as quality of housing structure, quality of toilet facility, availability of electricity, vehicle and assets ownership (e.g., radio, television, and telephone), whether there is a domestic servant, and whether the household owns agricultural land (Rutstein and Johnson 2004). The wealth index is sometimes considered problematic in distinguishing within geographical regions (rural/urban). However, investigating the distribution of the wealth index revealed sufficient variation for our rural sample.

permanent measure of economic status and has been used by other studies as a proxy for income or consumption/expenditure measures (Gwatkin et al. 2007).

Physical capital. In the Sustainable Livelihoods framework, physical capital includes (1) productive assets that can be used as tools, and (2) communal assets, such as access to roads or local infrastructure (de Sherbinin et al. 2008). Unfortunately, the DHS does not collect data on communal assets, and thus we restrict our physical capital measure to productive assets. On the basis of face validity and statistical evidence from an exploratory factor analysis, we use four items to create a physical capital scale.[3] Motorcycles, as well as cars and trucks, allow access to distant resources that can then be sold (Quiroz-Carranza and Orellana 2010); telephones assist in selling or buying goods, and/or in other entrepreneurial endeavors; refrigerators allow small businesses to store and sell perishable materials (e.g., food items, medicine).

Human capital. Educational attainment is a common measure of human capital (Saenz and Morales 2006) given its importance in securing employment. Education also helps negotiation through the sociocultural environment and offers skills to manage scarce resources. We measure educational attainment in the form of a categorical variable ranging from no education=0 to higher education=5.[4] In addition to formal education, reading newspapers, listening to radio, or watching television provides individuals with valuable information about weather, shifts in markets, and new ideas or innovative production techniques. Thus, we include frequency measures for these factors in the human capital scale. The standardized scale shows an alpha reliability of .640.

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[3] The possession of a car/truck, motorcycle, refrigerator, and telephone was used to construct this scale. All four items were coded 1 if available to the household. We included these four variables, together with nine additional items reflecting economic status (e.g., possession of television, radio, and electricity), in an exploratory factor analysis. Using the rotated factor matrix with a threshold of .40 shows that the four physical capital items load separately on the second factor. The standardized scale shows a Cronbach's alpha reliability of .626.

[4] Madagascar's school enrollment rate for children age 11-14 is below the sub-Saharan average and one of the lowest rates in the world (AEO 2007).

Social capital. Social capital has been defined by Brown and Bean (2006:358) as "the repertoire of resources such as information, material assistance, and social support that flow through ties to kin, to community, and to institutions." Social capital is enhanced as the number and intensity of social ties between a focal individual and other persons increase (Hagan 1998). To measure social capital we used a variable for association membership (1=member), based on the assumption that organizational members likely have larger social networks on which to draw during difficult times.[5] Organization membership has been used by other authors as a proxy for social capital (Mutenje et al. 2010). Unfortunately, this measure is only available for the female sample. We recognize that relying on a single, dichotomous measure is not ideal and thus our findings regarding social capital should be evaluated with caution.

3.2.2. Independent Variables

Migration variables. Our main variable of interest is individual migration status. We follow the demographic approach of examining migration as an individual behavior, recognizing its social embeddedness in a household-level decision-making process (Stark 1991). The DHS survey collects basic information on the area of current residency (rural/urban), number of years spent at the current place of residence, and type of residence (rural/urban) before the most recent migration.[6] Using this information, we constructed three migration measures following Islam and Azad (2008). First, a simple dummy variable "migrant" reflects whether a person has migrated to the current place of residency (coded 1) or has lived there since birth (coded 0).[7] We then used information about location characteristics of the area of origin and destination (rural/urban) to create a set of dummy variables for different migration streams. Since we restricted our sample

[5] The question (item s831) in the French questionnaire was worded "Est-ce que vous êtes un membre d'une association quelconque?" with answer options yes and no.

[6] The DHS defines cities and towns as urban and the countryside as rural.

[7] Within rural areas 28% of the respondents were classified as migrants while for urban areas migrants accounted for 45% of the surveyed population.

to rural areas, only urban-to-rural and rural-to-rural migration streams are examined. We expect to see substantial differences in access to livelihood assets between these two migration streams, since migrants with long periods of residence in urban origins bring with them, to their rural destinations, the experiences, behaviors, and attitudes acquired while living and working in urban areas (White and Lindstrom 2006). On the one hand, these skills, knowledge, and experiences can provide urban-rural migrants with a competitive advantage in entrepreneurial endeavors, resulting in higher levels of financial and physical capital. On the other hand, the cultural and status difference between former city dwellers and the local population might inhibit the development of social capital. However, only a quarter (27%) of all migrants originated in urban areas. Three-quarters (73%) have moved from a rural location to another rural location, a demographic phenomenon identified in some portions of Africa and South America (Henry, Schoumaker and Beauchemin 2004, Barbieri and Carr 2005).

The third migration variable, "length of residency" (LOR), reflects time spent at the current destination.[8] This variable was intended to capture the effect of adaptation and assimilation on migrants' attitudes, behavior, and well-being over time (Adeola 2009; Wang and Lo 2005; St-Hilaire 2002). Based on standard assimilation theories we expect an improvement in well-being over time (Wang and Lo 2005). On average migrants in our sample have lived 8.5 years at their current residence.

Normalized Difference Vegetation Index (NDVI). We derived measures of natural resource availability from the normalized difference vegetation index (NDVI), calculated from daily satellite-based observations. NDVI is a relative measure of biomass and is often used to show impacts of environmental change on vegetative health and abundance (Roerink et al. 2003;

[8] LOR was created using a multiplicative term "count x migrant," where "count" is a continuous variable that has values from 1 to 50 for the years since the most recent move, and was 0 for all non-movers. Interacting this variable with the dummy variable "migrant" results in a term that measures the effect of time since the last move for migrants only.

Wang, Rich, and Price 2003; Zhou et al. 2003). Vegetation indices such as NDVI exploit vegetation's reflectance of near-infrared light and absorption of red light. In healthy plant tissue, chlorophyll absorbs red light and mesophyll tissues scatter near-infrared light; the NDVI is the difference between the values in the red and near-infrared bands divided by the sum of these same values (Tucker 1979). NDVI values thus range from -1 to +1, with actively growing green vegetation exhibiting strong positive values. Low NDVI values (approximately 0.1 and below) indicate water and barren or developed land covers; moderately positive values (0.2 to 0.3) may correspond to shrublands and grasslands. In general, vegetation biomass and productivity are positively correlated with NDVI (Foody et al. 2001; Mutanga and Skidmore 2004; Wang et al. 2004). These characteristics make NDVI a particularly good measure for the environmental scarcity we expect to see in Madagascar because of deforestation; and, indeed, NDVI has been used for research in Madagascar to measure changes in forest cover in relation to the social institutional context (Elmqvist et al. 2007). As noted above, we expect to see a positive association between access to natural resources and well-being given the widespread use of natural resources within rural livelihoods in this setting, and since natural capital can be translated into other forms of capital (Shackleton and Shackleton 2004).

The NDVI was calculated from data collected by the MODIS/Terra sensor, averaged over 16-day intervals to reduce the effects of cloud cover, corrected to reduce atmospheric effects, masked to indicate pixel reliability (e.g., where water or clouds make the image unreadable), and processed and validated for geometric accuracy. We obtained images from the MODIS/Terra Vegetation Indices dataset (16-Day L3 Global 500m SIN Grid, MOD13A1), provided by the Land Processes Distributed Active Archive Center (LP DAAC) of the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center (LPDAAC 2011).

Madagascar is influenced alternately by dry trade-wind conditions in winter (May-September) and monsoon-driven tropical storms in summer (December-March) (Jury 2003). Fuelwood collection is intensified during the low agricultural season, from mid-August to the end of October and again from February to March (Randriamanarivo 1997, cited in Casse et al. 2004). Thus, we analyzed NDVI data for August 2008 (winter) and February 2009 (summer) to capture the effect of vegetation during times of higher forest resource dependency for both seasons.

The DHS data do not provide geographic location of individual households which would allow construction of a more precise measure of household specific natural resource access; instead the location is recorded at the center of a geographical cluster, a small settlement such as a rural village (Montana and Spencer 2004). For each of the 445 cluster points, we created buffer zones to calculate mean NDVI at a range of distances surrounding each point. Geospatial Modelling Environment (GME) software version 0.5.3 Beta, developed by Hawthorne L. Beyer (Spatial Ecology LLC), was used to calculate the NDVI means for the buffer zones.

We generated a variety of buffers, circling each sample point at intervals from 2 to 20 kilometers. We then investigated the influence of buffer zone radius size on the estimates by repeatedly running a fully adjusted multivariate model predicting financial capital including a different buffer zone radius at each time (see Appendix Table 1). Although we observed a slight increase in the effect size for larger buffer radii, we based our decision for the final buffer size primarily on theoretical considerations. For instance, the literature on natural resource extraction finds that individuals typically walk about 4 km from their settlement to collect firewood (Quiroz-Carranza and Orellana 2010). In addition, DHS uses a “Geo-Scrambling” method for confidentiality reasons, which randomly adds a position error between 0 and 5 kilometers to the coordinates of each sampling point (DHS 2011). Thus, we chose to use a 10-kilometer buffer (6.21 miles) for the subsequent analyses to account for both the position error and the average walking distance (5 km + 4 km = 9 km). Figure 1 shows NDVI measures and the location of the different cluster points in Madagascar for both seasons.

(Figure 1 about here)

3.2.3. Control Variables

As noted above, the DHS was designed to explore fertility behavior and maternal health issues and restricts its universe to individuals of reproductive age (DHS 2008). Thus, the included control variable for age ranges from 15 to 49 for females and from 15 to 59 for males. A dichotomous predictor differentiates between males (coded 1) and females (coded 0) in our sample. Since men are interviewed in only about half of all households they contribute a third (34%) of the cases.

A dummy variable for marital status is also used, with categories 1=married and 0=other (including divorced, single, widowed). A dummy for religiosity was coded 1 if an individual claimed any religious affiliation. In addition, a set of dummy variables reflect a person's occupation status. The various occupations were grouped into 5 distinct categories (1=Professionals [including supervisor, administrators, business directors]; 2=Service worker [includes working in shops and markets]; 3=Skilled manual worker [agriculture, forestry, fishing, transportation, and industry]; 4=Unskilled worker) with not working as reference category. Further, we include variables for household size, and number of young children as controls in our models.

Finally, it might be argued that NDVI measures development, modernization, or industrialization, rather than access to natural resources. To control for this alternative explanation, we used a number of variables as proxies for development, such as the quality of cooking fuel; the quality of floor, wall, and roof material of the housing unit; access to piped water; quality of toilet facility; access to electricity; and possession of a radio and television. These nine items were used to construct a standardized "development scale" (Cronbach's alpha reliability of 0.76), which was then aggregated at the cluster level.

3.3. Estimation Strategy

The data provided by the Demographic and Health Survey for Madagascar shows a distinct hierarchical structure. In our rural sample, 19,033 individuals (level-1) are nested within 11,260 households (level-2), while these households are nested within 445 geographical clusters (level-3). The hierarchical data structure suggests the use of a multilevel modeling approach (Subramanian et al. 2009, Gelman and Hill 2007), and the three aggregation levels would suggest a three-level model. However, the group size at the household-level poses challenges to this approach since each higher order group should contain at least 5 units to guarantee unbiased estimates (Clarke 2008, Maas and Hox 2005). In our sample, only one individual was interviewed in over half of the households (53%). This large number of households with single representation defies the separation of the individual-level (level-1) variance component from the household-level (level-2) variance component, which frequently prevents convergence of the models (Clarke and Wheaton 2007). The predominant approach to reduce observation sparseness is to use cluster analysis with the goal of combining level-2 groups to larger aggregates based on sociodemographic similarity or/and geographic proximity (Beland et al. 2002, Cutrona et al. 2000, Buka et al. 2003). In this way, clustering reduces the number of level-2 groups and increases the average group size. We follow this approach conceptually; but rather than creating artificial clusters, we make use of the pre-existing DHS clusters households within "ultimate area units" (UAU). We make use of this measure as our level-2 identifier, resulting in 445 cluster-level groups with an average group size of 43 individuals -- ideal conditions for a multilevel analysis (Maas and Hox 2005, Clarke and Wheaton 2007).

Using UAU clusters as the second level is important for two reasons: First, one of our main predictors, NDVI, operates at this aggregation level. Second, the Intraclass Correlation Coefficient (ICC) statistic indicates that a substantial amount of variation (≥20%) in our outcome variables lies between clusters.[9] In case of ICC values above 20%, ordinary least squares regression yields biased estimates and multilevel modeling becomes the preferred method (Clarke and Wheaton 2007).

In our two-level models, we allow both the intercept and the slope to vary across the 445 geographical clusters to capture heterogeneity across units. This adjusts for clustering, different sample sizes for level-1 and level-2 units, heteroscedastic error terms, and varying numbers of cases within level-2 units. The model can be described by a list of equations.

(1) Level 1: $$Y_{ij} = \beta_{0j} + \beta_{1j} X_{1ij} + \beta_{2j} X_{2ij} + \ldots + \beta_{zj} X_{zij} + r_{ij}$$

Level 2: $$\beta_{0j} = \gamma_{00} + \gamma_{01} * W_j + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11} * W_j + u_{1j}$$

The level-1 component of the model is similar to a standard OLS multivariate regression model with β_0 as the intercept, β_{1-z} the regression coefficients for individual-level variables X_{1-z} (age, marital status, etc.), and r_{ij} the traditional individual-level error term. However, the *j*

[9] For financial capital 54%, for physical capital 20%, for human capital 45%, and for social capital 24% of the variation occurs at the cluster level. To calculate the ICC for social capital we use a threshold approach, which treats the level-1 variation as having a variance of a standard logistic distribution amounting to a value of 3.29 (Snijders and Bosker 1999).

subscript indicates that a different level-1 model is estimated for each of the *j* level-2 units (clusters). Each geographical cluster may have a different average level of financial, physical, human, or social capital (β_{0j}) and a different effect of migration on these capitals (β_{1j}). Thus, the intercept β_{0j} and the slope β_{1j} of migration (X_{1ij}) were allowed to vary across level-2 units (geographical clusters).

The level-2 component of the model indicates how each of the level-1 parameters is a function of level-2 predictors and variability. β_{0j} is the level-1 intercept in level-2 unit *j*; γ_{00} is the mean value of the level-1 dependent variable, controlling for NDVI as level-2 predictor; γ_{01} is the effect (slope) of the level-2 predictor; and u_{0j} is the error, or unmodeled variability, for unit *j*. The interpretation of the second equation is similar, but here the level-2 effect on the slope of X_{1ij} (migration) is modeled. β_{1j} is the level-1 slope in level-2 unit *j*; γ_{10} is the mean value of the level-1 slope, controlling for the level-2 predictor W (NDVI); γ_{11} is the effect of the level-2 predictor W (NDVI); and u_{1j} is the error for unit *j* (Luke, 2004).

Instead of using a system of equations to specify the multilevel model, the level-2 parts of the model can be substituted into the level-1 equation. This single prediction equation of the multilevel model (not shown) is used by MLwiN 2.24 software (Rasbash et al. 2009), which we employed to fit the models. We ran MLwiN in STATA 11 (StataCorp LP, College Station, Texas) by using the macro *runmlwin* (Leckie and Charlton 2011).

We used simple additive multilevel models to explore our first research question, whether migrants differ from non-migrants in well-being, by predicting levels of financial, physical, human, and social capital. These models are random intercept models in which the constant is allowed to vary across geographical units. To address the second research question we included the measure of greenness (NDVI) in all models. However, the NDVI measure was not included in this analysis for its own sake; rather, we were interested in whether the difference between migrants and non-migrants in livelihood assets varies with the greenness of a particular area. For this purpose we employed random-slope, random-intercept models that allowed for cross-level interactions between the three migration variables and the greenness scale (Migrant x NDVI, LOR x NDVI, Rural-to-Rural x NDVI, Urban-to-Rural x NDVI). In addition to the variation of the constant, these models allowed the slope (effect size) of the migration measures to vary across geographical units. To provide a meaningful interpretation of the coefficients involved in the cross-level interaction, we specified a different parameterization by grand mean centering of NDVI.

4. Results

4.1. Sample Overview and Summary Statistics

Madagascar is one of the world's poorest countries (UN 2003), with a per capita gross domestic product (GDP) of $918 in 2007 (Heston, Summers, and Alton 2009). This overall poverty is reflected quantitatively in our data. In rural Madagascar 82% of households use non-durable material such as earth/sand/dung or bamboo mats as floor material; 69% of homes have walls made of palm branches or dirt; and 57% have no toilet facility. The vast majority of respondents obtain water from rivers, springs, and wells, with fewer than 1% having access to piped water within the homestead.

Since our main concern was to explore the asset difference between migrants and non-migrants, the first step in our analysis was to use ordinary group-mean comparison (t-tests) (see Table 1). In both rural and urban areas migrants exhibit significantly higher access to all capital assets, lending credence to the notion of the resilient migrant (Seror, Chen, and Gunderson 2005). As examples, migrants score significantly higher on the wealth index than their non-migrant counterparts, and also higher on all physical capital items, including refrigerators, motorcycles, trucks, and telephones. A similar picture is revealed for human capital, with migrants having above-average educational levels, reading newspapers more frequently, listening more to radio, and watching more TV. Female migrants appear better connected through association membership, perhaps because migration is often facilitated by an extended social network and embedded in a web of friendship and employment affiliations that might help to build social networks at the destination (Curran 2002; White and Lindstrom 2006). Interestingly, migrants tend to live in areas with slightly lower natural capital in the form of vegetation coverage, which might be the consequence of resource extraction (Durbin, Bernard, and Fenn 2003; Virah-Sawmy 2009).[10]

4.2. Additive models

We constructed separate models for each of the four livelihood asset scales. The model building procedure includes running a null-model (Model 1), followed by a stepwise addition of the migration variables (Model 2), the level-1 control variables (Model 3), and finally NDVI and "development" as level-2 predictors (Model 4).[11] Because of space limitations, we show the model-building process for financial capital only.

(Table 2 about here)

The Bayesian Information Criteria (BIC) statistic shows that the full model results in the best model fit. Including the control variables only slightly changes the effect size of the

[10] The advantageous position of migrants is not a unique phenomenon of rural areas, rather similar relationships are observed for the urban sample, though the differences are less pronounced and not presented (beyond the bivarate tables) within this manuscript.

[11] Given the values for the variance inflation factor (VIF) statistic, we were able to confirm that multicollinearity is of no concern, even if NDVI and "development" are included at the same time.

migration measure without impacting the significance level. Table 3 presents the results for all four livelihood asset categories and responds to our first research question: (1) *Does well-being differ between migrants and non-migrants?* In general, the results of the multivariate analysis mirror the bivariate relations to some extend and confirm that migrants score significantly higher on financial and physical capital, net of controls.

(Table 3 about here)

A measure for length of residency adds nuance to the migrant/non-migrant distinction. In line with research on the impact of length of residency (LOR) on adaptation and assimilation, we find a positive association between LOR and human and social capital (Wang and Lo 2005). Individuals with longer residency in their rural community have more human capital, as measured by higher levels of education and more frequent access to media, and report more frequently to be members of associations, suggesting an increase in social capital.

Comparing different migration streams offers additional insight. Migrants from urban origins score higher on all livelihood capital scales, except for social capital. For example, on the standardized human capital scale (range -0.8 to 3.4), migrants from urban areas score on average 0.206 points higher than non-migrants, which is significant at the 0.1% level. Migrants from rural areas, on the other hand, do not differ significantly from non-migrants, except in financial capital. One explanation for this marked difference may be that migrants from urban origins possess innovative knowledge and may be more entrepreneurial, which helps them to profit from economic and social relations developed on arrival (Durbin, Bernard, and Fenn 2003). Also, urban migrants may bring with them financial capital and physical capital items, as well as perhaps higher levels of education.

The crux of our analysis, focusing on the role of natural resources in rural livelihoods, is our second research question: (2) *Is the well-being, of both migrants and non-migrants, associated with natural resource access in destination regions?* To answer this question we included a measure of "greenness," the normalized difference in vegetation index (NDVI). The models suggest that access to natural resources plays an important role in rural Madagascar as a vital livelihood strategy during challenging times (Casse et al. 2004; Mahdi, Shivakoti, and Schmidt-Vogt 2009). Higher levels of proximate natural resources are associated with higher levels of financial, human and social capital.[12] Regarding social capital we can speculate that within more remote, "green" areas, associations function as a traditional form of insurance systems in the absence of formal institutions. For example, Dercon et al. (2006) find that in traditional communities of Ethiopia and Tanzania indigenous associations are highly important because of their risk-sharing function. These associations' main focus is to pay for funerals, but they also provide insurance against harvest failure, illness, fire, destruction of one's house, and death of cattle, and they sometimes provide members with short-term loans. Regarding financial capital, households in areas of dense vegetation cover may garner income/wealth by selling natural resources and/or products made from them (e.g., selling of marula beer or palm brushes; Shackleton and Shackleton 2004). As for human capital, it appears that individuals in our study site are able to use "forest resources in order to finance education" and thus, transform natural capital to human capital (de Sherbinin et al. 2008:40). An interesting observation is that the

[12] To investigate the influence of extreme values we re-estimated the financial capital model by omitting cases with values on the NDVI (August 2008) variable in the 1% and 99% percentiles. The effect size of NDVI slightly decreases from b=.297 (z=2.49) to b=.273 (z=2.14) but remains significant. Thus, our findings are not influenced by outliers on our natural capital measure.

positive association between natural capital and financial, human, and social capital is substantially stronger during the summer (February 2009). In most cases the effect size doubles comparing the coefficients of NDVI for the winter to the summer season. This result confirms findings by Timko, Waeber, and Kozak (2010) regarding the importance of seasonality for natural resource extraction.

4.3. Cross-level interactions

To investigate how the association between natural capital and well-being differs across migrants and non-migrants, we included cross-level interactions between the migration measures and NDVI in all models. For financial, physical, and social capital, these interactions were not significant. Thus, the difference between migrants and non-migrants with regard to these livelihood assets does not vary with the greenness of the particular area. However, there were significant cross-level interactions for the models predicting human capital.

(Table 4 about here)

Table 4 shows that the human-capital difference between migrants and non-migrants is small for average green (NDVI=.47) locations as of August 2008. However, the interaction term indicates that this difference increases dramatically when NDVI increases by one unit (e.g., from 0=barren land to 1=dense vegetation cover). A graphic visualization helps to describe this relationship (see Figure 2).

(Figure 2 about here)

Figure 2 (a) illustrates that both migrants and non-migrants benefit from better access to natural resources. However, the "greener" the area, the larger the difference between migrants and non-migrants becomes. We can evaluate this phenomenon from two perspectives. A purely descriptive explanation would suggest that highly educated migrants selectively move to these biodiverse areas to apply innovative knowledge of techniques for natural resource extraction they have learned in urban centers (Durbin, Bernard, and Finn 2003). A more causal explanation might propose that migrants are more likely to use gains from natural resource extraction to finance education (c.f. de Sherbinin et al. 2008). Unfortunately, the data used here do not allow disentangling these explanations.

Further, Table 4 shows a significant interaction between length of residency (LOR) and vegetation cover. This relationship is visualized in Figure 2 (b). In areas with low vegetation coverage, the effect of length of residency is positive: long-term residents show higher levels of human capital than recently arrived migrants. However, in areas of dense vegetation coverage the relationship becomes inverse, supporting St-Hilaire's (2002) theory of downward assimilation: long-term residents seem to have lower levels of human capital, and more closely resemble non-migrant locals. This phenomenon might be explained by a diffusion of ideas, attitudes, and behaviors (Montgomery and Casterline 1993). It is likely that in less green, developed areas with an established industrial sector, residents learn from their surroundings that formal schooling pays off in terms of better job opportunities and higher wages (de Brauw and Rozelle 2008). In contrast, as people reside longer in greener areas, formal education becomes progressively less important as residents specialize in natural resource extraction and adopt livelihood practices based on knowledge of the local ecology (Pichon 1997; Godoy, Groff, and O'Neill 1998; Arnold 1994; Ohmagari and Berkes 1997). The coefficients for both the interaction with education and that with length of residency remain significant ($p<.05$) and slightly increase in their effect size when greenness measures are used for February 2009 (summer), again suggesting an impact of seasonality on the observed associations.

An additional cross-level interaction emerges for different migration streams, which was found to be significant only during the summer season (February 2009). As the vegetation coverage of an area increases, the human-capital difference between urban-to-rural (U-to-R) migrants and non-migrants becomes increasingly pronounced.

(Figure 3 about here)

For U-to-R migrants, an increase in vegetation cover in the area of residency results in progressively higher levels of human capital compared to non-migrants. Figure 3 demonstrates that the widening gap between migrants and non-migrants in human capital (compare Figure 2[a]) can be completely attributed to the influence of the small group of U-to-R migrants. The larger group of R-to-R migrants does not contribute much (Figure 3[a]) to the interaction and thus does not differ significantly from local non-movers in the ability to utilize natural resources.

5. Conclusions and Policy Recommendations

Our findings suggest that access to natural capital is associated with individual financial, human, and social capital. Thus, neglecting natural capital in livelihoods analyses may yield model misspecification. Moreover, we find that the relationship between natural and human capital is not static but rather contingent on a person's residential status. Future studies might test whether the relationship between natural capital and the other livelihood capitals varies with other major sociodemographic characteristics, such as religion, marital status, or occupational status. Also, it might be helpful to replicate this study for regions within other developing nations.

A number of limitations deserve mention. A major constraint of this study is its cross-sectional nature. The core measures would be more meaningful in a time-dependent longitudinal study (cf., Henry, Schoumaker, and Beauchemin 2004) since livelihood strategies may shift over time (Mahdi, Shivakoti, and Schmidt-Vogt 2009). Similarly, a variable reflecting long-term change in vegetation cover could provide some additional insight into households' adaptive capacity in times of global environmental change. In regard to spatial influences, Entwisle (2007) emphasizes that time-dependent lagged effects may be stronger than contemporaneous effects. A longitudinal data set would allow modeling the risk for migration (see for example Riosmena 2009), and the separation between temporary and permanent moves instead of focusing solely on the difference between migrants and non-migrants. Furthermore, the currently used measures of migration streams do not account for variations in the distance traveled which might influence the adaptation and assimilation process at the area of destination.

In addition, the availability of variables in the DHS constrains the construction of the livelihood asset scales: the physical capital scale does not include communal assets such as access to roads or local infrastructure, and the social capital measure does not include social networks or relationships of trust. Among our outcome variables, social capital shows the greatest conceptual and measurement weakness and we encourage future research to investigate the social capital, natural capital, migration relationship by using a more comprehensive data set allowing for construction of a more robust social capital measure.

Finally, the livelihood capital measures are conceptually related and might influence each other. For example, human capital is likely to be a function of financial capital, since wealthier individuals can afford higher education. Higher educational attainments in turn provide better job opportunities with higher income that might be used to obtain physical assets. Possession of physical assets (especially production assets and tools) might then reduce the required labor input, freeing time that can be used for educational purposes. [13]

However, the analyses clearly show the importance of natural resources as a livelihood asset in rural Madagascar, regardless of migrant status. Therefore, policies should be designed to protect the natural resource base while affording sustainable use. Well-defined property rights could be an important starting point to maintain the current forest cover and prevent the depletion of the natural resource base (Elmqvist et al. 2007). Kull, Ibrahim, and Meredith (2007:229) point out that "tree planting is an officially recognized means of claiming vacant, communal land." Thus, designing a program that provides saplings at low cost and encourages tree planting might help to deal with unclear property rights and enhance resource availability for disadvantaged rural communities.

A number of forest protection policies are already in the implementation stage and deserve mention. A laudable conservation effort is the commitment of the Malagasy government in the 2003 Durban Vision to tripling the amount of protected area in Madagascar to 10% by creating a 6.0 million hectare network of terrestrial and marine reserves (Duffy 2006; Kull, Tassin, and Rangan 2007). Also, the legalization of private natural reserves, or aires protégées (Kull, Tassin, and Rangan 2007), is likely to improve the management and protection of forest areas and may provide employment from tourism for many people (Naughton-Treves, Holland, and Brandon 2005).

[13] To investigate whether a potential overlap affects the observed cross-level interactions, we included the financial and physical capital measures as predictors in the interaction models (not shown, available on request). Interestingly, when financial capital is included separately, the migrant x NDVI interaction (for February 2009 only) drops below significance, while all other interactions stay significant. However, if both financial and physical capital measures are included simultaneously, all interactions remain significant which confirms the robustness of the reported relationships.

At the same time, it is important to design conservation policies in a way that allows rural people to use the natural resources to ensure a diversity of livelihood options. One long-standing example combining conservation efforts with support of rural livelihoods is so-called integrated conservation and development projects (ICDPs). Although not without critics, ICDPs aim to establish core protected areas in which uses are restricted and in the surrounding areas (buffer zones) to promote sustainable socioeconomic development and income generation, including ecotourism, agroforestry, and sustainable harvest of biological resources (Naughton-Treves, Holland, and Brandon 2005).

Another option for forest protection is outlined by Styger et al. (2007), who recommend intensifying and diversifying agriculture by improving soil fertility through optimized organic and inorganic inputs. Clearly, however, local cultural attitudes are key – for example, Tucker (2007) describes a case where a well-intended program that encouraged the replacement of maize, which requires slash-and-burn cultivation, with manioc was not accepted by rural Malagasy.

Our findings suggest that urban-to-rural migrants benefit disproportionately from access to natural resources and are able to transform these benefits into human capital. Qualitative studies would enhance our understanding of *how* urban-to-rural migrants make use of such resources, since the potential for unsustainable resource extraction is high. Indeed, Ingram, Whittaker, and Dawson (2005:792) argue that "local practices seem to have a lesser impact on tree communities than the practices of itinerant people." In rural Madagascar, migrants may in fact be disproportionately responsible for deforestation and thereby disruptive of traditional, more sustainable, production systems (Durbin et al. 2003). If migration is fostering unsustainable natural resource extraction, a wholly different set of policies and programs may be required to sustain rural livelihoods.

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Table 1: Summary statistics and two-sample mean comparison (t-test) between migrants and non-migrants residing in rural and urban areas of Madagascar in 2008

	Rural areas							Urban areas				
					Migrant					Migrant		
Outcomes	**N**	**Mean**	**Min**	**Max**	**No**	**Yes**	**p**[1]	**N**	**Mean**	**No**	**Yes**	**p**[1]
Financial capital												
Wealth index	19033	2.61	1	5	2.46	2.99	***	6928	4.66	4.58	4.77	***
Physical capital												
Physical capital index[2]	19032	0.00	-0.11	9.68	-0.04	0.09	***					
Refrigerator	19031	0.01	0	1	0.01	0.02	***	6925	0.17	0.16	0.19	**
Motorcycle/scooter	19025	0.01	0	1	0.01	0.02	***	6922	0.08	0.06	0.09	***
Car/truck	19025	0.01	0	1	0.01	0.02	***	6924	0.10	0.08	0.12	***
Telephone	19029	0.01	0	1	0.00	0.02	***	6919	0.11	0.10	0.12	*
Human capital												
Human capital index[2]	19033	0.00	-0.84	3.42	-0.07	0.17	***					
Reading newspaper	18983	0.22	0	3	0.18	0.30	***	6919	1.05	1.01	1.11	***
Listening to radio	19011	1.37	0	3	1.28	1.59	***	6923	2.23	2.21	2.26	
Watching television	19016	0.18	0	3	0.14	0.28	***	6920	1.93	1.88	1.98	**
Education (category	19033	1.25	0	5	1.15	1.49	***	6928	2.64	2.61	2.69	*
Social capital												
Association member	12592	0.10	0	1	0.09	0.12	***	4766	0.20	0.19	0.22	
Predictors												
Migration												
Migrant	18872	0.28	0	1	0	1	NA	6844	0.45	0	1	NA
Rural-to-Rural	18828	0.20	0	1	0	0.73	NA	6819	0	0	0	NA
Rural-to-Urban	18828	0.00	0	0	0	0	NA	6819	0.16	0	0.37	NA
Urban-to-Rural	18828	0.08	0	1	0	0.27	NA	6819	0	0	0	NA
Urban-to-Urban	18828	0.00	0	0	0	0	NA	6819	0.28	0	0.63	NA
Length of residence	18872	2.36	0	49	0	8.51	NA	6844	3.55	0	7.98	NA
Natural capital												

NDVI (August 2008)	18751	0.47	0.20	0.83	0.47	0.45	***	6771	0.40	0.40	0.40	
NDVI (February 2009)	18751	0.61	0.31	0.84	0.61	0.60	***	6771	0.55	0.55	0.56	***
Controls												
Age	19033	29.81	15	59	29.36	31.10	***	6928	29.38	28.78	30.16	***
Male	19033	0.34	0	1	0.37	0.25	***	6928	0.31	0.32	0.30	*
Married	19033	0.70	0	1	0.65	0.81	***	6928	0.63	0.60	0.67	***
Religious	19030	0.70	0	1	0.66	0.79	***	6925	0.95	0.94	0.96	***
Occupation												
Not working	19031	0.10	0	1	0.10	0.09		6923	0.31	0.32	0.29	**
Professional/Supervisor	19031	0.02	0	1	0.01	0.05	***	6923	0.10	0.09	0.12	***
Service worker	19031	0.05	0	1	0.04	0.09	***	6923	0.22	0.21	0.24	***
Skilled manual worker	19031	0.81	0	1	0.84	0.75	***	6923	0.27	0.29	0.24	***
Unskilled worker	19031	0.02	0	1	0.01	0.03	***	6923	0.10	0.09	0.11	**
Household size	19033	5.86	1	22	6.00	5.45	***	6928	5.47	5.67	5.17	***
No. children (< 5years)	19033	1.12	0	7	1.14	1.07	***	6928	0.73	0.74	0.73	
Rural	19033	1.00	1	1	1	1		6928	0	0	0	
Development index[2]	19033	0.00	-0.56	1.89	-0.04	0.12	***					

[1] Significance calculated based t-test for group mean comparison; [2] The standardized physical capital index, human capital index, and development index were constructed for the rural sample only as the focus of our analysis.

*≤.05; **≤.01; ***≤.001

Source: Demographic and Health Survey for Madagascar 2008/2009

Table 2: Unstandardized coefficients showing the model building process for random intercept models predicting financial capital for migrants in rural areas of Madagascar

	Model 1			Model 2			Model 3			Model 4		
	b		z	b		z	b		z	b		z
Intercept	2.579	***	56.21	2.530	***	55.66	2.497	***	50.41	2.366	***	35.22
Migrant				0.140	***	6.43	0.116	***	5.39	0.110	***	5.08
Length of residency				0.030		1.85	0.023		1.41	0.029		1.82
Age							-0.002	*	-2.47	-0.002	**	-2.65
Male							0.088	***	6.54	0.089	***	6.58
Married							0.080	***	5.08	0.077	***	4.85
Religious							0.362	***	20.33	0.364	***	20.71
Professional/Supervisor[1]							0.608	***	12.86	0.597	***	12.56
Service worker[1]							0.210	***	5.83	0.207	***	5.73
Skilled manual worker[1]							-0.309	***	-12.75	-0.283	***	-11.64
Unskilled worker[1]							-0.091		-1.72	-0.111	*	-2.09
Household size							0.029	***	10.15	0.028	***	9.76
No. children (<5years)							-0.157	***	-21.27	-0.156	***	-21.03
NDVI (August 2008)										0.297	*	2.49
Development index										1.584	***	36.10
Variance components												
Between clusters	0.918	***	14.61	0.892	***	14.72	0.638	***	14.52	0.143	***	13.22
Within clusters	0.780	***	96.41	0.775	***	95.79	0.710	***	95.97	0.711	***	95.26
ICC[2]	0.54			0.54			0.47			0.17		
BIC[3]	51,062			50,519			48,855			47,544		
N	19,033			18,872			18,867			18,587		

[1] Reference category for occupation: Not working; [2] ICC=Intra-class Correlation Coefficient; [3] Bayesian Information Criteria (lower numbers indicate better model fit);

*p≤.05; **p≤.01; ***p≤.001

Source: Demographic and Health Survey for Madagascar 2008/2009

Table 3: Unstandardized regression coefficients for random intercept models predicting financial, physical, human, and social capital in rural areas of Madagascar using NDVI at two time points

	Financial capital			Physical capital			Human capital			Social capital[1]		
	b		z	b		z	b		z	b		z
NDVI for August 2008 (winter)												
Migrant	0.110	***	5.08	0.050	**	3.22	0.014		1.17	-0.023		-0.24
Length of Residency	0.029		1.82	-0.003		-0.30	0.038	***	4.28	0.159	*	2.24
NDVI	0.297	*	2.49	-0.105		-1.64	0.119	*	2.29	1.297	***	3.69
N	18587			18586			18587			12296		
R-to-R migrant[2]	0.082	***	4.89	0.005		0.43	-0.003		-0.30	0.112		1.43
U-to-R migrant[2]	0.291	***	11.27	0.161	***	8.70	0.206	***	14.43	0.178		1.63
NDVI	0.307	*	2.55	-0.097		-1.52	0.127	*	2.43	1.273	***	3.63
N	18543			18542			18543			12264		
NDVI for February 2009 (summer)												
Migrant	0.110	***	5.09	0.050	**	3.22	0.014		1.18	-0.025		-0.25
Length of Residency	0.029		1.81	-0.003		-0.29	0.038	***	4.27	0.157	*	2.23
NDVI	0.834	***	5.11	-0.121		-1.34	0.323	***	4.53	2.157	***	4.22
N	18587			18586			18587			12296		
R-to-R migrant[2]	0.082	***	4.87	0.005		0.45	-0.003		-0.34	0.107		1.37
U-to-R migrant[2]	0.292	***	11.32	0.161	***	8.70	0.206	***	14.49	0.179		1.64
NDVI	0.862	***	5.24	-0.099		-1.10	0.349	***	4.87	2.151	***	4.21
N	18543			18542			18543			12264		

All models control for age, marital status, occupation, religion, number of children age<5years, household size, gender, and development; [1] Logistic multilevel models were used to estimate social capital. This measure is only available for females; [2] R-to-R = rural-to-rural migration, U-to-R = urban-to-rural migration. The reference group for this set of dummy variables was non-migrants; *p≤.05; **p≤.01; ***p≤.001

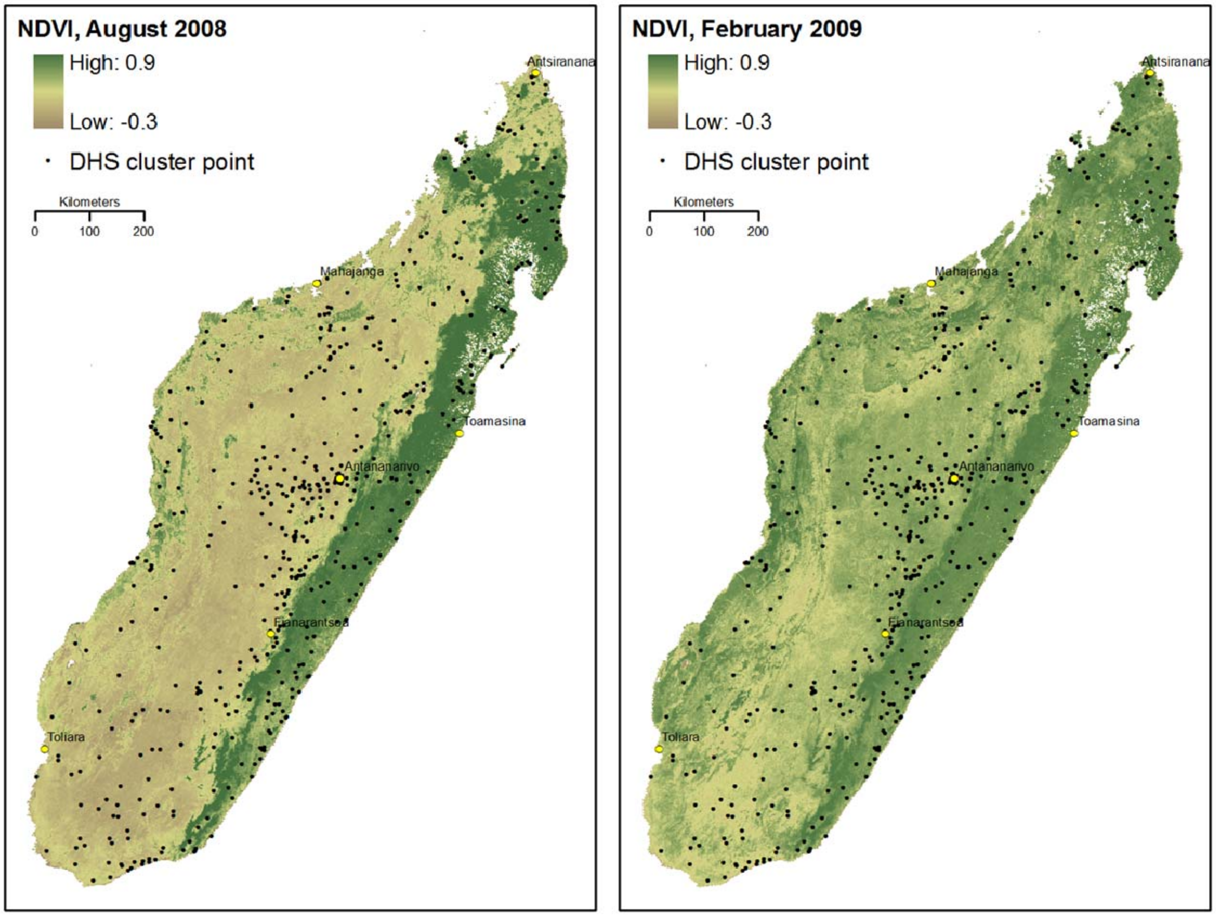
Source: Demographic and Health Survey for Madagascar 2008/2009

Table 4: Unstandardized coefficients for random slope random intercept models, predicting human capital using cross-level interactions between migration variables and NDVI at two time points

	Human capital					
	August 2008[3]			February 2009[3]		
	b		**z**	**b**		**z**
Migrant	0.023		1.55	0.022		1.48
Length of residency	0.030	**	2.62	0.032	**	2.79
NDVI[1]	0.107	*	1.97	0.310	***	4.12
x Migrant	0.227	*	2.42	0.276	*	2.08
x Length of residency	-0.212	**	-2.84	-0.272	*	-2.53
Variance component						
Migrant[5]	0.030	***	4.94	0.029	***	4.94
Length of residency[5]	0.016	***	4.89	0.016	***	4.87
Between clusters[6]	0.026	***	11.45	0.025	***	11.36
Within clusters[6]	0.215	***	93.51	0.215	***	93.51
N	18587			18587		
BIC[4]	25415			25402		
R-to-R migrant[2]	-0.002		-0.16	-0.003		-0.23
U-to-R migrant[2]	0.205	***	10.81	0.207	***	10.94
NDVI[1]	0.104		1.90	0.313	***	4.15
x R-to-R migrant	0.046		0.67	0.049		0.49
x U-to-R migrant	0.195		1.60	0.362	*	2.23
Variance component						
R-to-R migrant[5]	0.015	***	4.44	0.015	***	4.44
U-to-R migrant[5]	0.038	***	4.62	0.037	***	4.58
Between clusters[6]	0.026	***	11.53	0.025	***	11.43
Within clusters[6]	0.212	***	93.45	0.212	***	93.46
N	18543			18543		
BIC[4]	25178			25160		

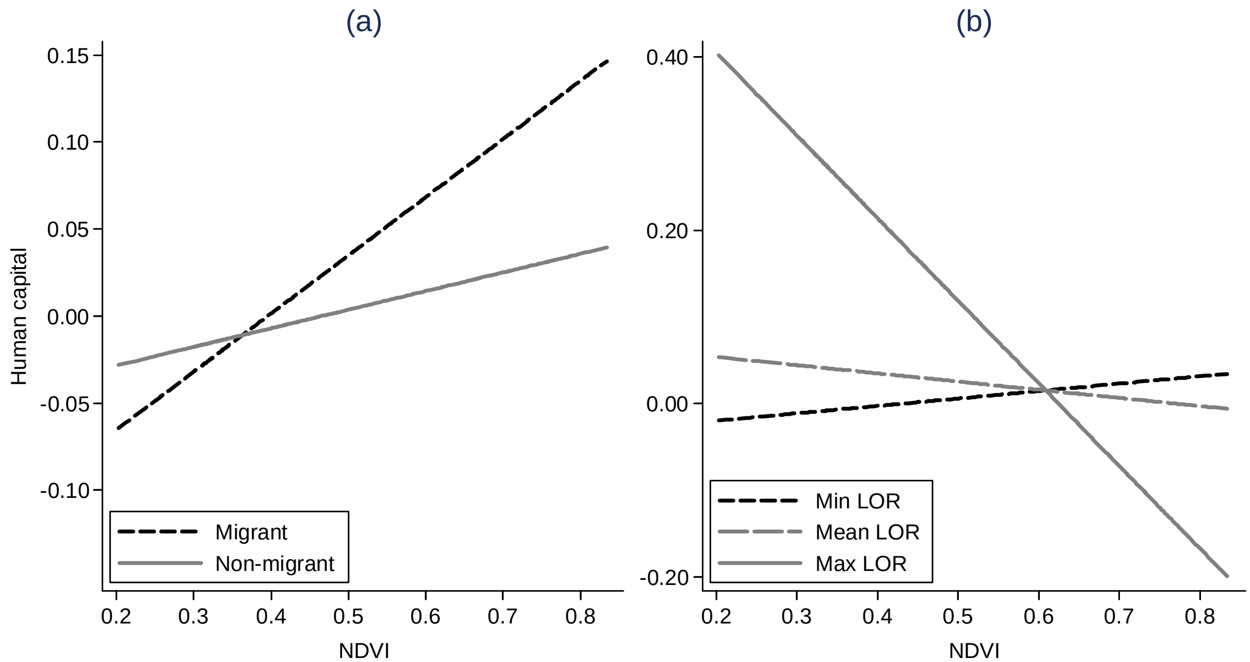
All models control for age, marital status, occupation, religion, number of children age<5years, household size, gender, and development; [1] NDVI was grand mean centered to facilitate the interpretation of the regression coefficients; [2] R-to-R = rural-to-rural migration, U-to-R = urban-to-rural migration. The reference group for this set of dummy variables was non-migrants; [3] the NDVI measures, but not the socio-demographic data, were obtained for two different time points, August 2008 (winter) and February 2009 (summer); [4] Bayesian Information Criteria (lower numbers indicate better model fit); [5] random slope; [6] random intercept;
*p≤.05; **p≤.01; ***p≤.001
Source: Demographic and Health Survey for Madagascar 2008/2009

Figure 1: Map of Madagascar colored according to greenness (NDVI) during winter (August 2008) and summer (February 2009)



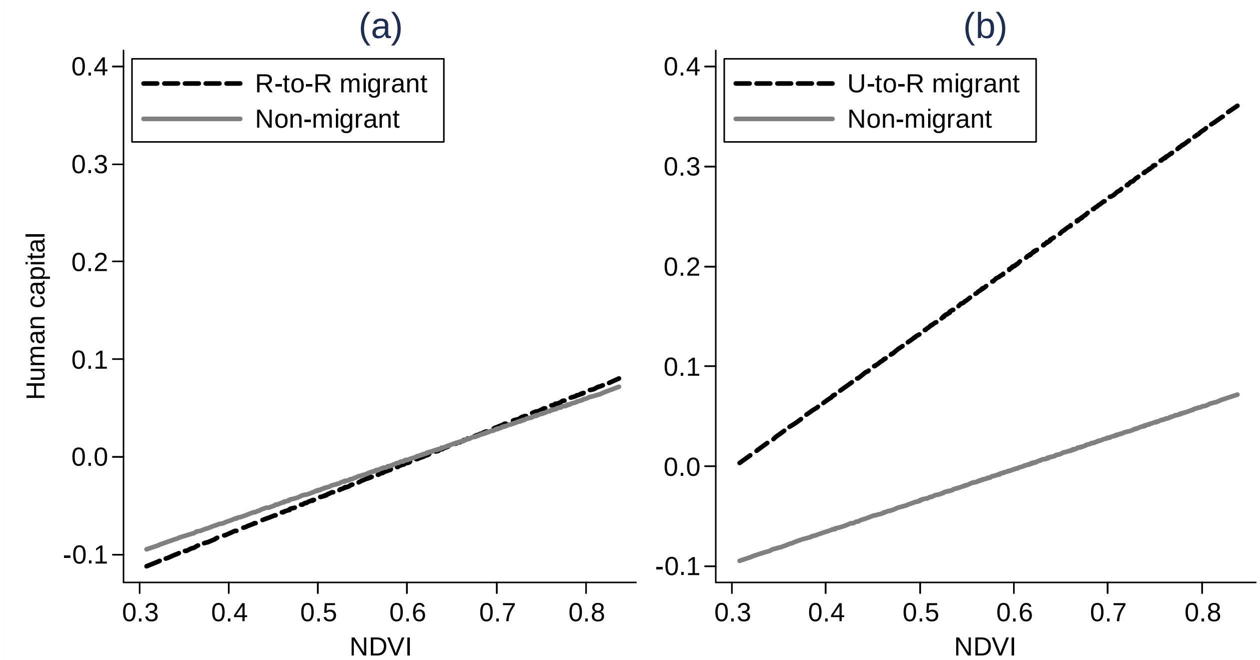
Note: Cluster-points for which the mean NDVI values were calculated are shown as dots.

Figure 2: Interaction between NDVI and (a) migration and (b) length of residency for August 2008



Note: Length of residency (LOR) min=0 years; mean=8.5 years; max=49 years

Figure 3: Interaction between NDVI and rural-to-rural migration (a) as well as NDVI and urban-to-rural migration (b) for August 2008



Appendix Table 1: Unstandardized regression coefficients for NDVI (August 2008) predicting financial capital

Buffer radius	b		z
2 km	0.258	*	2.19
5 km	0.290	*	2.41
10 km	0.297	*	2.49
15 km	0.326	**	2.73
20 km	0.340	**	2.82

Each line represents a fully adjusted multivariate model. These models use the same set of predictors and controls as Model 4, Table 2.

*p≤.05; **p≤.01; ***p≤.001

Source: Demographic and Health Survey for Madagascar 2008/2009