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Rural Outmigration, Natural Capital, and Livelihoods in South Africa

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Demographers have long explored the socioeconomic dimensions of migration processes. Yet the contemporary era of climate change has brought increasing scholarly attention to migration's environmental dimensions which may be of particular importance in regions where daily livelihoods are tied to the local natural environment. In settings where natural resources provide sustenance and fodder for income generation through, for example, brewing beer or weaving baskets (Shackleton et al. 2008), shifts in natural resource availability may result in livelihood adaptations, including either temporary or permanent migration (Bilsborrow 2002).

This study was designed to contribute to the rapidly emerging empirical research linking migration, environmental conditions and environmental change. Rural South Africa has not received substantial research attention within this topic although, in many regions households remain heavily dependent on natural resources (e.g. Shackleton and Shackleton 2004, 2011) while also regularly engaging in labor migration as a livelihood strategy (Collinson et al. 2006a). We tap into the strength of household-level demographic surveillance data to answer two research questions: First, is availability of natural resources and a change in this availability associated with temporary and/or permanent out-migration from rural areas in South Africa? Second, does the association between out-migration and natural capital vary across the study site? Results consistently demonstrate a positive association between local natural capital and household migration propensity, but only for temporary migration. We argue a focus on migration's environmental aspects is especially timely in the contemporary era of climate change (IPCC 2007) and that natural capital availability and variability represents a critical piece of the empirical migration puzzle, especially regarding cyclical livelihood migration.

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Natural Resources and Rural Livelihoods

Proximate natural resources are central to rural household economies in many regions of the developing world – in rural South Africa, for example, gathered reeds are used for market-bound mats or rugs and edible herbs are collected for evening meals. Indeed, a large body of evidence reveals that the use and sale of natural resources can move some households out of poverty, while acting as a safety net for those most deeply impoverished (Shackleton and Shackleton 2004, 2011). In South Africa, for example, case studies in two rural villages demonstrated that 70% of households made use of non-timber forest products, such as fuelwood, wild fruit, and edible herbs during times of shortage and crisis (Paumgarten and Shackleton 2011). Even in rural South African villages with readily available electricity, over 90% of households use fuelwood as a primary energy source due to the cost of electricity and appliances (Twine et al. 2003). This trend has been observed in the general region of our study in Bushbuckridge, Mpumalanga Province (Madubansi and Shackleton 2007) as well as specifically in our study site where natural resources act as buffers against household shocks such as a breadwinner's death (Hunter, Twine and Johnson 2011; Hunter, Twine and Patterson 2007; Kaschula 2008).

High levels of natural resource use among residents of small urban areas and peri-urban regions has also recently been documented (Davenport, Gambiza, and Shackleton 2011; Shackleton et al. 2010), with resources from nearby common lands contributing between 14-20% of livelihood income (Davenport, Gambiza and Shackleton 2011).

The Environmental Dimensions of Migration

Like natural resource use, migration is a livelihood diversification strategy regularly employed by households across the globe. With a particular focus on rural regions, we couch the connection between natural capital and migration decision-making within the Sustainable Livelihoods Framework which outlines various capital assets that shape livelihood options including human (e.g., labor), financial (e.g., savings), physical (e.g., automobiles), social (e.g., networks), and natural (e.g., wild foods) capital.

Of course environmental factors are rarely migration's sole “push”, but instead they combine with the social, economic and political context to shape migration decision-making (Black et al 2011). Isolating environmental factors from the myriad other forces shaping household migration is, therefore, a formidable empirical challenge. Still, the past several years have seen a spate of new migration-environment scholarship including at least 3 dedicated special issues of academic journals – *International Migration* (Afifi and Warner 2010), *Population & Environment* (Adamo and Izazola 2010) and *Global Environmental Change* (Black, Arnell and Dercon, 2011), as well as several book-length collections of conceptual and empirical advances (McAdam 2010; Piguet, Pecoud and de Guchteneire 2011). Another recent collection, through the EACH-FOR project, has offered important contributions through application of comparable methodologies across a range of migration “hotspots” (Warner 2011).

Several central findings are emerging from the growing body of empirical scholarship. First, some research suggests that natural capital shortages, or variability, can act as a migration push factor, thereby engaging households' human capital in a quest for alternative livelihood strategies (e.g. Grote and Warner 2010; McAdam 2010). The "push" of drought, for example, is felt in Burkina Faso where residents of drier regions are more likely to engage in both temporary and permanent migrations to other rural areas, as compared to residents of high-precipitation regions. In addition, short-term rainfall deficits increase long-term migration to rural areas but have the opposite effect on short-term moves to distant destinations (Henry et al. 2004). The 1983-1985 drought in Mali revealed similar patterns -- a dramatic increase in short-term cyclical migration as well as increases in the migration of women and children (Findley 1994). As another example, rural Mexican households in regions with strong migration histories are particularly likely to emigrate to the U.S. in the face of drought (Hunter, Murray and Riosmena 2012).

U.S.-based research also provides insight on these forms of migration-environment linkages (e.g., Deane and Gutmann 2003). Using an historical perspective and set in the Great Plains, climate effects on migration were observed, working through agricultural impacts, especially during the 1930s-40s (Gutmann et al. 2005). Indeed, settlement abandonment in the face of environmental pressures has a long history (McLeman 2010, 2011).

Yet precipitation shortages aren't the only migration environmental "push." Lower natural capital in the form of smaller fish catches intensifies livelihood vulnerability in East Africa, resulting in the migration of fisherfolk (Njock and Westlund 2010). Access to land has also been demonstrated to impact migration patterns. Fragmentation of land holdings in Syria, for example, appears to shape human capital decisions since land shortages often "push" males to migrate to urban areas and neighboring countries (Abdelali-Marini et al. 2003). A similar dynamic has been identified in rural Thailand; VanWey (2003) finds that households with smaller landholdings diversify their livelihoods through migration in order to supplement rural income. And in rural Benin, insecure land tenure plays a central role in continued internal migration among households already pushed from degraded origins (Doevenspeck 2011).

Even so, migration is costly and another key finding of the emerging literature is that in some settings, relatively higher levels of capital can fuel migration by providing resources for additional livelihood diversification – the "environmental capital" hypothesis (Gray 2009). For example, studies in villages of the Kayes area, Mali, observed that relatively more advantaged households were willing to invest a sizable amount of resources to send migrants given the prospect of increasing wealth through remittances and thus, reinforce their social status (Azam and Gubert 2006). In rural Ecuador, as well, land appears to provide capital that can facilitate migration (Gray 2010). And land as a form of natural capital can buffer adverse climatic impacts -- in Ethiopia, the drought's migration "push" is less for households with greater availability of land (Gray and Mueller 2012b).

A third central finding suggests a different association – one in which natural capital is associated with a decline in migration – but the mechanism can work in distinct ways. In rural Bangladesh, for example, disasters can actually reduce mobility through heightened resource constraints (Gray and Mueller 2012a). Further, crop failure and flooding are more likely to propel migration among women who have less secure access to land in this setting.

Substantial methodological innovation also characterizes this field. Examples include recent use of Agent-Based Modeling to bring together knowledge of sociodemographic correlates of migration to simulate migrant streams as far forward as to 2045 (Kniveton, Smith and Black 2012). Migration-environment researchers have also been quick to integrate multilevel analytical methods given the relevance to the questions at-hand (e.g., Ezra and Kiros 2001; Gray 2010; Nawrotzki, Hunter and Dickinson 2012).

In all, the study presented here is grounded in prior research on livelihoods and migration-environment connections. In addition, although prior work in Africa has primarily focused on migration as related to precipitation, we make use of more direct measures of availability and variability of natural resources used by rural households.

Research Setting

The Agincourt Health and Demographic Surveillance Site (Agincourt HDSS) is located in the far northeast of South Africa (Figure 1).[1] Since 1992, the Agincourt HDSS has conducted an annual census, today encompassing 24 villages including approximately 84,000 residents and 14,000 households (an expansion from 21 villages during our study year). Importantly, each village and household is geo-coded, allowing for the analysis of social phenomena within a spatially heterogeneous context.

During the Apartheid era, the study site was part of a Bantustan or black South African “homeland” and, as a result, is characterized by high population densities, high levels of poverty and a backlog in development and availability of services. The high human densities are primarily a result of racially-based Apartheid land allocation policies combined with the 1980s large influx of refugees from Mozambique. The former Mozambican refugees are from the same ethnic group as most other residents (Shangaan) and many have become naturalized South African residents. They are referred to within the current analyses as of “Mozambican background.” Local employment is scarce and residents often migrate seeking work outside the area (additional detail below). Social security grants are also an important income source, with child support, foster care and pension grants available through the national government. As to public health, HIV/AIDS is a formidable force shaping livelihood strategies. In 2009, the Mpumalanga provincial HIV prevalence amongst 15-49 year antenatal women was 34.7% (95% CI: 32.5% – 36.9%) (South Africa Department of Health 2010).

Livelihoods and natural resource dependence

Household livelihoods in the Agincourt HDSS site incorporate a wide range of formal and informal cash sources supplemented by land-based activities such as cultivating home gardens, rearing livestock, and gathering natural resources (Dovie, Witkowski and Shackleton 2003). Households reside in well-defined villages, each of which has an area of surrounding communal land used by the residents for resource harvesting, crop cultivation and livestock grazing. Harvested resources include fuelwood, wild foods, medicinal plants,

[1]The Agincourt HDSS is operated by the Rural Public Health and Health Transitions Research Unit of the South African Medical Research Council and University of the Witwatersrand.

plant fiber and construction material. These make important contributions to household economies both for domestic use and income generation (Shackleton and Shackleton 2004, 2011). In a review of 6 studies in 14 rural South African villages, Shackleton and Shackleton (2004) found that wild edible herbs, wild fruit, and fuelwood were used by the majority of households in all cases. Average consumption was substantial: 58.2 kg/year for wild herbs, 104.2 kg/year for wild fruit and 14.2 kg/day for fuelwood.

Migration trends

Prior to South Africa's democratic transition, the political economy of migration was dominated by 1) the mining industry, 2) rapid industrialization following the mineral discoveries of the late nineteenth century, and 3) the apartheid-driven "homeland" system. In rural regions, residents were forced into "homelands" based on ethnic homogeneity. Availability of land was further restricted by a process of "villagization" (Collinson et al. 2006a). Ultimately, these forces yielded a transition from an agrarian to a cash-based rural economy, although these areas remain poor and are characterized by continual labor migrations. Further, these migrations have resulted in large numbers of complex households with local and distant members. Indeed, in Agincourt, approximately 60% of adult males and 40% of adult females in the region are labor migrants. Yet, many rural to urban migrants are temporary and remain connected to their rural homes (Collinson et al. 2006b), and indeed the most prevalent type of move is circular oscillating migration in which a migrant does not permanently leave the rural home but shuttles between home and workplace with different degrees of regularity. Around 20% of the rural population make this kind of move each year (Collinson et al. 2006b). In settings such as Agincourt, migration is a livelihood diversification strategy most often undertaken as a family or household decision, as opposed to an individual one (Taylor 1999, Carney et al. 1999, Chambers and Conway 1991).

Data

We investigate the association between availability of natural capital and the probability of outmigration in 2007. This year was chosen because of data availability and a trend of increase in natural resource availability during 2005-2007. Importantly, the household is our unit of analysis given that this tends to be the decision-making unit with regard to migration and livelihood strategies (Collinson et al. 2006b). Within the Agincourt HDSS, a household is defined as "a group of people living on the same property who eat from the same pot of food" (Madhavan, Schatz and Clark, 2009:39).

Dependent Variable: Household Adult Outmigration

We model the number of adult outmigrations (age 15+) from Agincourt households during the 12 months prior to data collection. We examine both temporary and permanent adult migration, classification of which makes use of a *de jure* household definition.[2]

[2]In contrast to a *de facto* definition of a household, which only considers the population of residents who permanently reside at a location (excludes temporary migrants), a *de jure* definition considers person belonging to a household, permanently or occasionally residing at a location (includes temporary migrants).

Temporary migration is discerned from census questions on residence status over the prior 1-year period; Temporarily absent household members are noted as absent but included on the household roster at census-taking. Permanent migration is discerned through details regarding the migration event, at an individual level, giving the move's date and other key variables such as destination (Agincourt HDSS 2011; Collinson, Tollman and Kahn 2007). More generally, permanent migration is defined as a person leaving a household with a "permanent intention" (Collinson 2010: 6). This includes individuals who leave the indexed household and establish or join a household elsewhere. In contrast, a temporary (or circular) migrant is a household member who was away at least six months in the past year, but "retained a significant link to their base household and remains a household member while away" (Collinson 2010: 6). This discriminates between cyclical labor migration (temporary) and migration for marriage out of the area (permanent).

Central Independent Variables, Natural Capital Availability

Using the Normalized Difference Vegetation Index (NDVI), several *greenness* metrics were derived to quantify spatially varying natural resource availability for households in the 21 villages in the Agincourt study area during 2007. NDVI is calculated based on spectral reflectance measurements in the red and near infrared (NIR) spectral ranges of remotely sensed imagery and is calculated as NDVI = (NIR-red) / (NIR+red). NDVI has been widely used to monitor plant growth (vigor), density of vegetation cover and biomass production (e.g., Foody et al. 2001, Wang et al. 2004). The NDVI is insensitive to differences in species composition of vegetation, but quite sensitive to differences in vegetation structure and greenness; in the study area NDVI does not show a saturation point for greater values meaning that all actual differences in greenness can be measured meaningfully through this method. NDVI, therefore, acts as a proxy for vegetation amount and vegetation quality -- important characteristics of natural capital -- and represents an effective measure of natural resources that potentially affect livelihood strategies (e.g. firewood, wild fruits, fencing materials). The effects of human settlements on surrounding vegetation structure is also well-documented (Fisher et al. 2011), and NDVI values around villages reflects these spatial patterns, making it an ideal measure to assess changes in natural capital over large areas.

Using MODIS satellite imagery (250 meter resolution) NDVI values were calculated for each year by taking the annual mean of 16-day composites. To create an initial greenness grid, we took the mean of these annual means at each pixel. Including the two years prior takes into account resource availability variation leading up to the year of potential outmigration. From the greenness grid, we excluded areas within village boundaries as these are not communal lands and therefore not used for natural resource collection.

Next, informed by the distance residents typically travel to access natural resources (Fisher et al. 2011; Giannecchini, Twine and Vogel 2007), we created 2,000 meter buffers around each village (but excluding the area within that village and within neighboring villages, see Figure 2).

Finally, using the greenness pixel values within these buffers we generated two measures of interest: 1) the sum of temporally averaged NDVI values within the village buffer (NDVI_sum). That is, for each pixel the mean greenness value across the years 2005, 2006 and 2007 was calculated and then the total for all greenness pixel values within the communal area buffer of a particular village was derived. This measure reflects the average availability of natural resources within each village-level collection (buffer) zone. Second, we calculated a slope measure to capture changes in the availability of natural resources across the three years (NDVI_slope). To do so, for each pixel location, we fit a linear regression line through the NDVI values of the three years and calculated its slope. We then calculated the mean of all slope values found for pixels within the communal area of one village. A byproduct of this calculation is the intercept of the regression line (NDVI_intcpt). We make use of this metric to account for differences in initial conditions when calculating NDVI_slope.

Figure 3(a) reveals a gradient in greenness values increasing from east to west as the western side of the study site is characterized by rolling hills, higher elevations and more precipitation. We observe relatively consistent NDVI values in the study site's western portion while significant spatial variation in greenness can be found across the region's central and eastern regions.

Household-level Independent Control Variables:[3] In order to better understand the effect of natural resource availability on migration, we include a number of control variables. Household head's age is included, as well as household gender composition (proportion male). Approximately 39% of all households were female headed and the head's average age was nearly 52 years, and less than half (44%) of the members of a typical household were males of working age (15-64 years). Another important measure of human capital is adult members' educational attainment (Saenz and Morales 2006), generally associated with a higher probability of out-migration (Lindstrom and Ramirez 2010). On average, household members have approximately 7 years of education and 29% of working-age adult household members indicate being employed.

Mozambican background may also shape migration propensity given networks within their homelands. In 2007, approximately 27% of Agincourt households were headed by an individual of Mozambican background.

The dependency proportion is included to reflect both age structure and potential household productivity (Madhavan et al. 2009). On average, households have 10% dependent members.[4] Also included is the number of prime age deaths (age 15 to 49, Hunter et al. 2011) within a household in the past 3 years as an indicator of household mortality experience – a particularly important household shock given the high local level of HIV/AIDS. About 9% of households had experienced a prime-age adult death in the past three years.

[3] *Within the Agincourt HDSS, different modules are fielded annually so that some information is collected only every second, third, or fourth year. As such we use some data collected prior to our study year as proxies -- educational data collected in 2006 were used in the 2007 models, as was labor status information from 2004.*

[4] We use household size in the denominator to avoid losing observations. Any construction of a proportion that uses a quantity smaller than the total household size runs the risk of dropping cases for which the denominator becomes zero. In our case, the households at the extreme end would be omitted.

Finally, in many rural settings, income is often received in monetary and non-monetary forms, while the amount and composition of income is subject to seasonal fluctuation (Montgomery et al. 2000). Thus, we used a household's physical asset status as a more stable measure for a household's socio-economic status (SES) constructed as an additive scale with items from five major asset categories: modern assets, livestock assets as well as information about power supply, water and sanitation, and dwelling structure (Agincourt HDSS 2009; Mberu 2006).[5]

Methods

Our data show a clear hierarchical structure with households nested within 21 villages. Therefore we employ multilevel models, making use of both household-level and village-level characteristics to estimate migration. This approach allows both the intercept and slope for selected variables (see details below) to vary across villages. Advantages include adjustment for clustering and different sample sizes in level-1 (household) and level-2 (village) units. The models also adjust for heteroscedastic error terms and varying numbers of cases within level-2 units (Luke 2004).

We use Poisson models since our outcome variable is the count of temporary or permanent outmigrants in a household (e.g. Bohara and Krieg 1996; Boyle and Flowerdew 1993; Congdon 1993; Leyk et al. 2012). We first estimate a model that contains only socio-demographic controls:

$$\begin{aligned} \eta_{ij} &= log_e(\mu_{ij}/\varphi) \\ \eta_{ij} &= \beta_0 + \beta_1(X_{1ij}) + \beta_{2-z}(X_{2ij-zij}) + v_{0j} + u_{0ij} \end{aligned} \quad \text{Equation 1}$$

The Poisson model uses a natural logarithmic link which guarantees that the set of independent variables linearly produces η_{ij} (Hoffmann 2004). The symbol μ_{ij} in the link function represents the expected counts of migrants (temporary migrants: Model 1 to 4; permanent migrants: Model 5 to 8) for a household *i* located in village *j*. The parameter β_0 constitutes the intercept (mean log migrant rate), while β_{1-9} are the regression coefficients of the control variables $X_{1ij-9ij}$. This specification constitutes a two-level random intercept model and includes a village-level random effects term (ν_{0j}). This variance component is assumed to be normally distributed with a mean of zero and a variance $\sigma^2_{\nu 0}$, quantifying the between-village variation in mean migration counts.

In the present analysis we are more interested in migration rates as opposed to actual counts, since households vary in number of adult members. As such, we use an additional parameter (ϕ), known as an offset, which is set to be equal to the log (base e) of the individuals at risk for migration (i.e., household number of adult members (termed “household size”).

Finally, the Poisson distribution assumes that the variance is equal to the mean (var/mean = 1) (Gelman and Hill 2007). This holds true for temporary migration but permanent

[5]Initially we included a set of dummy variables for marital status of the household head with categories including divorced (12%), widowed (18%), missing (17%) and married (53%) as reference group. However, in our regression analysis only households in the missing category showed a significantly different migration behavior. Due to the limited information value of this measure, and for the sake of parsimony, it was excluded.

migration shows a substantial amount of overdispersion (var/mean > 1). In multilevel Poisson models, overdispersion can be directly modeled through the inclusion of random effects (e.g. Gelman and Hill 2007; Huang and Abdel-Aty 2010; Link and Sauer 2002; Liu and Dey 2006). We therefore add an additional random effect (u_{0ij}) referred to as the dispersion parameter.

Once the base model is correctly specified the foundation is laid for the inclusion of our main predictors, the Normalized Difference Vegetation Index (NDVI) measures (Z_{10j}), which serve as proxy for availability of natural resources by village (see Equation 2). The effect of either the absolute natural resource availability (NDVI_sum: Models 1, 3, 5, and 7) or the change in access to natural resources (NDVI_slope: Models 2, 4, 6, and 8) is reflected by the regression coefficient β_{10}. For example, a positive coefficient for NDVI_sum would suggest that an increase in access to natural resources is associated with an increase in the number of migrants a family is likely to send.

$$\eta_{ij}=\beta_0+\beta_1\left(X_{1ij}\right)+\beta_{2-9}\left(X_{2ij-9ij}\right)+\beta_{10}\left(Z_{10j}\right)+v_{0j}+u_{0ij} \quad \text{Equation 2}$$

In these models, NDVI reflects mean (or change in) vegetation cover for the 21 included villages and, as such, the estimated coefficients and standard errors are adjusted for this clustering. In a final step we investigate whether the impact of NDVI on household level migration rate is conditional on socio-demographic characteristics through cross-level interactions (e.g. age of head × NDVI) (Models 9 to 13). Here, the slopes of level-1 variables (e.g. age of head) are allowed to vary across level-2 units (e.g., Subramanian et al. 2009, Dedrick et al. 2009). To guard against issues of collinearity, we reparameterize NDVI by grand-mean centering in order that a value of zero on the centered scale for the X-axis represents the mean NDVI value. The specification of the interaction models can be formally described as follows (Equation 3):

$$\eta_{ij}=\beta_0+\beta_1\left(X_{1ij}\right)+\beta_{2-9}\left(X_{2ij-9ij}\right)+\beta_{10}\left(Z_{10j}\right)+\beta_{11}\left(X_{1ij}{}^{*}Z_{10j}\right)+v_{1j}\left(X_{1ij}\right)+v_{0j}+u_{0ij} \quad \text{Equation 3}$$

The parameter β_{11} shows the effect of the cross-level interaction between, for example, age of household head (X_{1ij}) and NDVI_sum (Z_{10j}). The added variance component ν_{1j} allows the slope for age of household head to vary across villages. All residual errors at the village-level (ν_{1j}, ν_{0j}) are assumed to be independent of the individual-level within-group variation captured by the dispersion parameter (u_{0ij}). The models were fit using MLwiN 2.24 software (Rasbash et al. 2009) in STATA 11 (StataCorp LP, College Station, Texas) using the macro *runmlwin* (Leckie and Charlton 2011).[6]

[6]MLwiN uses quasi-probability methods to fit discrete response multilevel models (Rasbash et al. 2008). These procedures use a linearization method, based on a Taylor series expansion, which transforms a discrete response model to a continuous response model. The transformation to a linear model requires an approximation to be used. In our models we use a 1st order marginal quasi-probability (MQL) method for the linear approximation. After applying the linearization the model is then estimated using iterative generalized least squares (IGLS) (see Goldstein 2003 for further details).

Results

Descriptive Results

As discussed above, temporary migration is a well-established livelihood strategy in South Africa. Approximately 62 percent of households in the study area had at least one household member absent in 2007 due to temporary migration, while this number was substantially lower for permanent migration at 6 percent.

As an instructive first step in examining migration-environment associations, group mean comparisons (t-test) examine distinctions between migrant and non-migrant households (Table 1). The bivariate analysis reveals systematic differences between temporary migrant vs. non-migrant households and NDVI. Households with temporary migrants are more likely to be located in areas characterized by relatively higher levels of natural capital (NDVI_sum). In addition, temporary migrant households tend to reside in villages typified by a stronger increase in vegetation cover between 2005-2007 (NDVI_slope). Even so, no such differences are detected for permanent migrant households as compared to those without migrants.

Migrant households also differ systematically from non-migrant households on a number of socio-demographic characteristics. Households more likely to send temporary migrants include those with male heads, overall higher levels of education, more workers and male members, lower dependency ratios, and higher SES. In addition, a statistically significant difference emerged as related to household mortality experience. Households sending a temporary migrant were slightly less likely (9% vs. 10%, $p<.05$) to have experienced mortality in the three years prior compared to non-migrant households. In contrast, permanent migrant households are characterized by older household heads who are more likely of Mozambican background, have a smaller proportion of dependent members, and have less members employed.

Multivariate Results

Table 2 presents the results for additive multilevel models predicting both temporary (Panel A) and permanent (Panel B) migration.[7]

Contrasting NDVI and the spatial distribution of migration, there is substantial visual overlap between higher levels of greenness and higher temporary migration rates at the village level (Figure 3 [b]). However, no such pattern can be visually detected for permanent migration (Figure 3 [c]). Indeed, as a key finding, a significant positive association exists within the multivariate models between the village level measure of natural resources and temporary out-migration but not for permanent out-migration. Including socio-demographic control variables resulted in a size reduction for the NDVI coefficient, although the natural resource measure retained a significant and substantial association within the full model of temporary migration. More precisely, the coefficient for the NDVI_sum measure suggests

[7]Note that Poisson model transformation involves a log link. Thus, the coefficients in the regression tables must be exponentiated to obtain the expected counts and should be interpreted in multiplicative terms (Hoffmann 2004). All models were checked for the presence of multicollinearity using the variance inflation factor (VIF) statistic.

that an increase in greenness by one unit (about 24%) increases the expected rate of migrants within a household by 6.2% (exp[.060] = 1.062), net of controls. This finding is in line with the environmental capital hypothesis, which suggests that availability of natural resources can facilitate income diversification, including migration (Gray 2009).

The NDVI_slope measure adds further nuance. As the steepness of the slope increases by one unit (28%) the expected rate of temporary migrants per household increases by 8.1% (exp[.078] = 1.081). In the unadjusted model (Model 2), the intercept of the NDVI slope has an independent positive effect, suggesting that a greener area in 2005 is associated with higher levels of out-migration in 2007 regardless of the change in greenness. However, the intercept effect becomes insignificant in the full model. In sum, both the absolute level of natural resource availability and an increase in these resources over time appears to propel temporary outmigration from the Agincourt study site as a whole.

Importantly, availability of natural resources is neither the only nor the strongest factor associated with a household's decision to send a member elsewhere. Our models suggest that socio-demographic factors play a key role in facilitating or deterring a move. Temporary migration propensity is greater in households with older household heads, likely due to the greater probability of adult children (Juelich 2011). Further, in line with much migration research (e.g. Lindstrom and Ramirez 2010; Takenaka and Pren 2010), we find education positively associated with temporary out-migration.

Household composition is also clearly associated with migration – likely both as a cause and effect. Households with larger numbers of out-migrants have higher employment rates and relatively higher numbers of men. Migration propensity, however, is dampened by high dependency ratios, most likely because households with a large proportion of very old or very young members lack the human capital to send a migrant (Juelich 2011).

Finally, the socio-economic status of a household, as reflected by the asset index (SES), positively predicts temporary out-migration, although our cross-sectional data does not allow disentangling causality in this association.

Robustness tests

Before proceeding, we undertook two tests to investigate the robustness of the observed NDVI effects. Our estimates appear robust as evidenced by both estimations with repeated split samples, and through jackknife procedures to identify particularly influential villages.

Cross-Level Interactions

A full screening of cross-level interactions revealed five significant interactions for temporary migration but none for permanent migration (Table 3). Statistically significant cross-level interactions exist between temporary migration, NDVI_sum and household head age, Mozambican background, as well as household education. In addition, the effect of NDVI_slope on temporary out-migration varies by number of household members employed and the level of education.

The cross-level interactions are intriguing. The interactions with the measure of absolute greenness (NDVI_sum) suggest that relatively advantaged households may be better positioned to utilize available natural resources as a form of capital to finance a move (Gray 2009). Of course, given the cross-sectional nature of our data, the opposite could also be true. Migrant households may be relatively advantaged due to remittances, with that advantage allowing for greater use of natural capital.

The cross-level interactions also reveal that higher levels of resource availability increase the probability of migration especially from households with older heads (Model 9). Each additional 10 years of age increases NDVI's effect size on the expected rate of migration by 1 percent. This effect might be explained by an increase in human capital, in form of knowledge and experience of how to utilize natural resources, that is gained over the life-course. For example, indigenous knowledge is likely to increase with age and experience, and the elderly are frequently the keepers of traditional knowledge regarding the use of wild fruits and plants (c.f. Briggs 2005; Mahanta and Tiwari 2005; Pardo-de-Santayana et al. 2007).

In addition, a distinction emerges based on Mozambican background. The positive association between NDVI and out-migration is 7 percent stronger for those lacking Mozambican background as compared to those with such origin. Similarly, Model 11 demonstrates that natural resources are used differently depending on a household's education level. For households with the lowest level of education, the greenness of a particular area does not impact the number of migrants per household. However, for moderately educated households a positive association between NDVI and temporary out-migration emerges, which becomes strongest for highly educated households. Specifically, each one-year increase in education (ranging from 1 to 13 years) increases the effect of NDVI on the expected rate of migration per household by 1 percent. A visual depiction of the interaction effects is provided in Figure 4.

A somewhat different picture emerges for NDVI_slope, the measure of change in natural resource availability across the three year period (2005-2007). In regions where natural capital available increased during 2005-2007, the increase appears to act more as a “push” for less advantaged households, as compared to those better-off (Models 12 and 13). For example, low-educated households are 13% more likely than higher-educated households to engage in temporary outmigration associated with increasing proximate natural capital. In this way, resource availability may offer capital necessary to support outmigration from those households lacking other forms of capital.

Discussion, Limitations, Conclusion

Our central conclusion is that availability and variability of natural capital matters in understanding temporary outmigration from rural South African households, even net of household socio-economic characteristics. Village-level availability of natural resources consistently demonstrates a statistically significant positive association with temporary outmigration – supporting an “environmental capital” hypothesis suggesting natural capital may provide households a form of economic security from which migration may be supported.

Another key contribution of this work is the distinction between temporary and permanent migration – leading to our second central conclusion: natural capital does not exhibit an association with permanent outmigration. Such a lack of association is interesting and perhaps related to a larger portion of permanent outmigration being driven by marriage and family formation, as opposed explicitly to ongoing livelihood strategies. On the other hand, Agincourt's temporary migration streams tend to be cyclical in nature and, therefore, represent household livelihood strategies. Our results suggest these strategies have important associations with local natural capital. Such association has also been noted in Burkina Faso (Henry, Schoumaker and Beauchemin 2004), as well as for rural Bangladesh (Gray and Mueller 2012a).

A third key conclusion is that the association between natural capital and temporary outmigration varies across different types of households. Distinctions are particularly notable across human capital categories and, in this way, offer insight into the mechanisms of differentiation. Higher levels of proximate natural capital are associated with greater probability of outmigration particularly among households with higher levels of human capital (i.e. education, non-Mozambican background). As such, natural capital, as a livelihood asset, may fuel further diversification by those households most likely to be able to take advantage of proximate assets. This finding is in line with work from rural Ecuador (Gray 2009). Relatively higher levels of human capital through education may facilitate the intensification of agricultural production and enable households to more efficiently extract natural resources (Douangngeune, Hayami and Godo 2005; Escobal and Aldana 2003; Godoy, Groff and O'Neill 1998), which in turn allows them to free human capital and send a member elsewhere (Aggarwal, Netanyahu and Romano 2001).

In contrast, net of the overall availability of local natural capital, higher levels of responsiveness to trends in resource availability were observed for less educated households and those headed by an individual of Mozambican background. This intriguing association likely reveals the closer dependence on natural capital felt by disadvantaged households with the ebbs and flows of resource availability fueling or constraining migration potential. Among the most vulnerable households, natural resources may act as a safety net for those most deeply impoverished (Shackleton and Shackleton 2011) – but not sufficient to fuel migration. Indeed, in our study setting, households of Mozambican background – which tend to be socio-economically disadvantaged within this setting (Hargreaves et al. 2004) -- were less likely to exhibit an association between natural capital and outmigration, although they tend to exhibit higher levels of natural resource use generally (Twine personal comm.).

Substantively this study adds to the understanding of natural resources as a form of capital. Indeed, a large body of evidence reveals that the use and sale of natural resources can move some households out of poverty. Ellis (2003:5) explains that seasonality and risk “predispose poor people to high degrees of vulnerability. Both of them can be substantially ameliorated by migration.” On the one hand, natural capital may be used to diversify livelihoods, for instance through extraction of non-timber forest resources to produce and trade reed-based crafts (Pereira, Shackleton, and Shackleton 2006). On the other hand, availability of natural resources in itself may constitute a prerequisite for further livelihood diversification (here migration) that reduces the vulnerability of rural populations. Staying with this dichotomy, former studies have emphasized migration as a particular adaptation strategy in the face of environmental strain (McLeman and Hunter 2010; Nunan 2010) while we find that greater availability of natural resource might also increase migration (c.f. Gray 2009). Interestingly, in the long run, the strategy of temporary migration may lower natural resource dependence through the provision of remittances and household purchase of resource substitutes (Qin 2010).

Limitations

Three limitations deserve mention. First, our analyses are cross-sectional due to the currently available data. Even so, migration and environmental change are both dynamic processes and may be best approached by means of a time-dependent longitudinal design (c.f., Henry et al. 2004). We expect that a time-dependent lagged effect, measuring change over longer time periods, may be stronger than the more contemporaneous effects observed in our study (Entwisle 2007).

Second, additional regional, community, household and environmental variables remain to be investigated. The availability of other nearby livelihood activities, the impact of social networks (Fussell and Massey 2004), access to natural resources (in addition to availability as measured here), and measures for land degradation and road networks (Gray 2009) are all possible variables of interest for future modeling efforts. The assumption that greater access to proximate natural capital translates into greater use or reliance on such capital at the household level is currently being investigated in a complementary longitudinal study in our study site. In addition, a variety of recently published commentary notes important factors such as gender dimensions (Hunter and David 2011; Massey, Axinn and Ghimire 2010), characteristics shaping immobility (Findlay 2011), and aspects of urban “pull” factors (Adamo 2010; Parnell and Walawege 2011) including uneven spatial variation in economic development (Seto 2011). These remain to be included in future efforts.

Third, integration with spatial modeling approaches is warranted. The multilevel models used here account for the data's hierarchical structure. However, employing approaches accounting for spatial variation in associations of interest within the study site could also be useful (c.f. Leyk et al. 2012). Next steps will include using spatial methods to detect regional hot-spots of migration and evaluate the unique associations with availability of natural resources for those areas.

Despite these limitations, the study presented here offers an important contribution to the burgeoning literature on the link between migration and the environment and environmental processes. The results provide important evidence with regard to the link between migration and natural resource availability, particularly timely in the contemporary era of climate change (IPCC 2007). In rural South Africa, natural capital represents a critical piece of the empirical migration puzzle, especially regarding cyclical livelihood migration. Based on these findings, we are confident that future research will continue to enhance understanding of rural South African migration patterns, especially their environmental dimensions.

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References

Abdelali-Marini M, Goldey P, Jones GE, Bailey E. Towards a feminization of agricultural labour in northwest Syria. The Journal of Peasant Studies. 2003; 30(2):71–94.

Adamo S. Environmental migration and cities in the context of global environmental change. Current Opinion in Environmental Sustainability. 2010; 2(3):161–165.

Adamo S, Izazola H. Human Migration and the Environment. Special issue of Population and Environment. 2010; 32(2-3):105–284.

Afifi X, Warner K. Environmentally induced migration in the context of social vulnerability. Special issue of International Migration. 2011; 49(S1):e1–e242.

Aggarwal R, Netanyahu S, Romano C. Availability of natural resources and the fertility decision of women: the case of South Africa. Environment and Development Economics. 2001; 6:209–236.

Agincourt HDSS. Core Data Dictionary. University of the Witwatersrand; Johannesburg, South Africa: 2009. from http://www.agincourt.co.za/DataSection/DataDocumentation.htm [September 20, 2011]

Agincourt HDSS. Agincourt Health and Population Unit: Data Definitions. University of the Witwatersrand; Johannesburg, South Africa: 2011. from http://www.agincourt.co.za/DataSection/DataDocumentation.htm [September 19, 2011]

Azam JP, Gubert F. Migrants' remittances and the household in Africa: A review of evidence. Journal of African Economies. 2006; 15:426–462.

Bilsborrow RE. Migration, Population Change and the Rural Environment. ECSP Report. Woodrow Wilson International Center for Scholars, Environmental Change and Security Project. 2002; (8): 69–94.

Black R, Adger WN, Arnell NW, Dercon S, Geddes A, Thomas DS. The effect of environmental change on human migration. Global Environmental Change. 2011; 21:S3–S11.

Black R, Arnell N, Dercon S. Migration and Global Environmental Change – Review of Drivers of Migration. Special issue of Global Environmental Change. 2011; 21(1):S1–S130.

Bohara AK, Krieg RG. A zero-inflated poisson model of migration frequency. International Regional Review. 1996; 19(3):211–222.

Boyle PJ, Flowerdew R. Modelling sparse interaction matrices: interward migration in Hereford and Worcester, and the underdispersion problem. Environment and Planning. 1993; 25:1201–1209.

Briggs J. The use of indigenous knowledge in development: problems and challenges. Progress in Development Studies. 2005; 5(2):99–114.

Carney, D.; Drinkwater, M.; Rusinow, T.; Neefjes, K.; Wanmali, S.; Singh, N. Livelihoods Approaches Compared. A Brief Comparison of the Livelihoods Approaches of the Livelihoods Approaches of the UK Department for International Development (DFID), CARE, Oxfam and the United Nations Development Programme (UNDP). Department For International Development; London UK.: 1999.

Chambers, R.; Conway, GR. Sustainable rural livelihoods: Practical concepts for the 21st century. Institute for Development Studies; Brighton: 1991.

Collinson, M. [August 2012] Striving against adversity: the dynamics of migration, health and poverty in rural South Africa.. Global Health Action, North America. 2010. Available at: <http://www.globalhealthaction.net/index.php/gha/article/view/5080/5671>.

Collinson, MA.; Tollman, SM.; Kahn, K.; Clark, SJ.; Garenne, M. Highly prevalent circular migration: households, mobility and economic status in rural South Africa.. In: Tienda, M.; Findley, SE.;

Tollman, SM.; Preston-Whyte, E., editors. Africans on the Move: Migration in Comparative Perspective. Wits University Press; Johannesburg, South Africa: 2006a.

Collinson MA, Wolff B, Tollman SM, Kahn K. Trends in internal labour migration from rural Limpopo Province: Male risk behaviour, and implications for the spread of HIV/AIDS in rural South Africa. Journal of Ethnic and Migration Studies. 2006b; 32(4):633–648. [PubMed: 20396611]

Collinson M, Tollman S, Kahn K. Migration, settlement change and health in post- apartheid South Africa: Triangulating health and demographic surveillance with national census data. Scandinavian Journal of Public Health. Aug.2007 69:77–84. [PubMed: 17676507]

Congdon P. Approaches to modelling overdispersion in the analysis of migration. Environment and Planning. 1993; 25:1481–1510.

Davenport NA, Gambiza J, Shackleton CM. Use and users of municipal commonage around three small towns in the Eastern Cape, South Africa. Journal of Environmental Management. 2011; 92(6):1449–1460. [PubMed: 21251751]

Deane GD, Gutmann MP. Blowin' Down the Road: Investigating Bilateral Causality Between Dust Storms and Population Change in the Great Plains. Population Research and Policy Review. 2003; 22:297–331.

Dedrick RF, Ferron JM, Hess MR, Hogarty KY, Kromrey JD, Lang TR, Niles JD, Lee RS. Multilevel Modeling: A Review of Methodological Issues and Applications. Review of Educational Research. 2009; 79(1):69–102.

Doevenspeck M. The Thin Line Between Choice and Flight: Environment and Migration in Rural Benin. International Migration. 2011; 49:e50–e68.

Douangngeune B, Hayami Y, Godo Y. Education and natural resources in economic development: Thailand compared with Japan and Korea. Journal of Asian Economics. 2005; 16:179–204.

Dovie DBK, Witkowski ETF, Shackleton CM. Direct use value of smallholder crop production in a semi-arid South African village. Agricultural Systems. 2003; 76:337–357.

Ellis, F. Paper Commissioned by the Department for International Development (DFID). University of East Anglia; Norwich, Norfolk, UK: 2003. A livelihoods approach to migration and poverty reduction.; p. 1-22.CNTR 03 4890

Entwisle B. Putting people into place. Demography. 2007; 44(4):687–703. [PubMed: 18232206]

Escobal J, Aldana U. Are nontimber forest products the antidote to rainforest degradation? Brazil nut extraction in Madre De Dios, Peru. World Development. 2003; 31(11):1873–1887.

Ezra M, Kiros G-E. Rural out-migration in the drought prone areas of Ethiopia: A multilevel analysis. International Migration Review. 2001; 35(3):749–771. [PubMed: 19186413]

Findlay AM. Migrant destinations in an era of environmental change. Global Environmental Change. 2011; 21:S50–S58.

Findley S. Does drought increase migration? A study of migration from rural Mali during the 1983-1985 drought. International Migration Review. 1994; 28(3):749–771.

Fisher JT, Witkowski ETF, Erasmus BFN, Van Aardt JAN, Asner G, Wessels K, et al. Human-modified landscapes: patterns of fine-scale woody vegetation structure in communal savanna rangelands. Environmental Conservation. 2011; 39(1):72–82.

Foody GM, Cutler ME, McMorrow J, Pelz D, Tangki H, Boyd DS, Douglas I. Mapping the biomass of Bornean tropical rain forest from remotely sensed data. Global Ecology and Biogeography. 2001; 10(4):379–387.

Fussell E, Massey DS. The limits to cumulative causation: International migration from Mexican urban areas. Demography. 2004; 41(1):151–171. [PubMed: 15074129]

Gelman, A.; Hill, J. Data analysis using regression and multilevel/hierarchical models. Cambridge University Press; New York: 2007.

Giannecchini M, Twine W, Vogel C. Land-cover change and human environment interactions in a rural cultural landscape in South Africa. The Geographical Journal. 2007; 173:26–42.

Godoy R, Groff S, O'Neill K. The role of education in neotropical deforestation: Household evidence from Amerindians in Honduras. Human Ecology. 1998; 26(4):649–675.

Goldstein, H. Multilevel statistical models. Arnold; London: 2003.

Gray CL. Environment, Land, and Rural Out-migration in the Southern Ecuadorian Andes. World Development. 2009; 37(2):457–468.

Gray CL. Gender, natural capital, and migration in the southern Ecuadorian Andes. Environment and Planning. 2010; 42:678–696.

Gray CL, Bilsborrow RE, Bremner JL, Lu F. Indigenous land use in the Ecuadorian Amazon: A cross-cultural and multilevel analysis. Human Ecology. 2008; 36(1):97–109.

Gray, CL.; Mueller, V. Natural Disasters and Population Mobility in Rural Bangladesh.. Proceedings of the National Academy of Sciences. 2012a. (early edition) Available online (downloaded July 2012) http://www.pnas.org/content/early/2012/03/28/1115944109.full.pdf

Gray CL, Mueller V. Drought and Population Mobility in Rural Ethiopia. World Development. 2012b; 40(1):134–145. [PubMed: 22523447]

Grote U, Warner K. Environmental Change and Forced Migration: Evidence from Sub- Saharan Africa. International Journal of Global Warming. 2010; 2(1):17–47.

Gutmann MP, Deane GD, Lauster N, Peri A. Two Population-Environment Regimes in the Great Plains of the United States, 1930-1990. Population and Environment. 2005; 27(2):191–225.

Hargreaves JR, Collinson MA, Kahn K, Clark SJ, Tollman SM. Childhood mortality among former Mozambican refugees and their hosts in rural South Africa. International Journal of Epidemiology. 2004; 33(6):1271–1278. [PubMed: 15319405]

Henry S, Schoumaker B, Beauchemin C. The impact of rainfall on the first outmigration: A multilevel event-history analysis in Burkina Faso. Population and Environment. 2004; 25(5):423–460.

Henry S, Piché V, Ouédraogo D, Lambin EF. Descriptive analysis of the individual migratory pathways according to environmental typologies. Population and Environment. 2004; 25(5):397–421.

Hoffmann, JP. Generalized linear models: An applied approach. Pearson Education, Inc.; Boston, MA: 2004.

Huang H, Abdel-Aty M. Multilevel data and Bayesian analysis in traffic safety. Accident Analysis and Prevention. 2010; 42(6):1556–1565. [PubMed: 20728603]

Hunter, LM.; David, E. Climate Change and Migration: Considering Gender Dimensions.. In: Piguet, Etienne; Guchteneire, Paul de; Pecoud, Antoine, editors. Invited chapter in Climate Change and Migration. UNESCO Publishing and Cambridge University Press; Cambridge UK.: 2011.

Hunter, LM.; Murray, S.; Riosmena, F. CU Population Center Working Paper. University of Colorado Boulder; 2012. Rainfall Variation and U.S. Migration from Rural Mexico..

Hunter LM, Twine W, Johnson A. Adult Mortality and Natural Resource Use in Rural South Africa: Evidence From the Agincourt Health and Demographic Surveillance Site. Society & Natural Resources. 2011; 24(3):256–275. [PubMed: 21866207]

Hunter LM, Twine W, Patterson L. Locusts Are Now Our Beef': Adult Mortality and Household Dietary Use of Local Environmental Resources. Scandinavian Journal of Public Health. 2007; 25(Suppl. 69):165–174. [PubMed: 17676519]

IPCC, Intergovernmental Panel on Climate Change. Climate Change 2007: The physical science basis. Summary for policymakers. IPCC Secretariat; Geneva, Switzerland: 2007. URL: http://ipcc-wg1.ucar.edu/wg1/docs/WG1AR4_SPM_PlenaryApproved.pdf

Juelich S. Drought Triggered Temporary Migration in an East Indian Village. International Migration. 2011; 49:e189–e199.

Kaschula SA. Wild foods and household food security responses to AIDS: evidence from South Africa. Population and Environment. 2008; 29(3-5):162–185.

Kniveton DR, Smith CD, Black R. Emerging migration flows in a changing climate in dryland Africa. Nature Climate Change. 2012; 2:444–447.

Leckie, G.; Charlton, C. runmlwin: Stata module for fitting multilevel models in the MLwiN software package. Center for Multilevel Modelling, University of Bristol; Bristol, UK: 2011.

Leyk S, Maclaurin GJ, Hunter LM, Nawrotzki R, Twine W, Collinson M, Erasmus B. Spatially and temporally varying associations between temporary outmigration and natural resource availability in resource-dependent rural communities in South Africa: A modeling framework. Applied Geography. 2012; 34:559–568. [PubMed: 23008525]

Lindstrom DP, Ramirez A. Pioneers and followers: Migrant selectivity and the development of U.S. migration streams in Latin America. The Annals of the American Academy of Political and Social Sciences. 2010; 630:53–77.

Link WA, Sauer JR. A hierarchical analysis of population change with application to Cerulean Warblers. Ecology. 2002; 83(10):2832–2840.

Liu J, Dey DK. Hierarchical overdispersed Poisson model with macrolevel autocorrelation. Statistical Methodology. 2006; 4:354–370.

Luke, DA. Sage university papers series: Qunatitative applications in the social sciences 143. Sage Publications, Inc.; Thousand Oaks, CA: 2004. Multilevel modeling..

Madhavan S, Schatz E, Clark B. Effect of HIV/AIDS-related mortality on household dependency ratios in rural South Africa, 2000-2005. Population Studies. 2009; 63(1):37–51. [PubMed: 19184720]

Madubansi M, Shackleton CM. Changes in fuelwood use and selection following electrification in the Bushbuckridge lowveld, South Africa. Journal of Environmental Management. 2007; 83(4):416–426. [PubMed: 16930808]

Mahanta D, Tiwari SC. Natural due-yielding plants and indigenous knowledge on dye preparation in Arunachal Pradesh, northeast India. Current Science. 2005; 88(9):1474–1480.

Massey DS, Axinn WG, Ghimire DJ. Environmental change and out-migration: evidence from Nepal. Population and Environment. 2010; 32(2-3):109–136. [PubMed: 21350676]

Mberu BU. Internal migration and household living conditions in Ethiopia. Demographic Research. 2006; 14:509–539.

McAdam, J. Climate Change and Displacement: Multidisciplinary Perspectives. Hart Publishing; Oxford UK.: 2010.

McLeman RA. Settlement abandonment in the context of global environmental change. Global Environmental Change. 2011; 21:S108–S120.

McLeman RA. Impacts of population change on vulnerability and the capacity to adapt to climate change and variability: a typology based on lessons from “a hard country”. Population and Environment. 2010; 31(5):286–316.

McLeman RA, Hunter LM. Migration in the context of vulnerability and adaptation to climate change: insights from analogues. Wiley Interdisciplinary Reviews-Climate Change. 2010; 1(3):450–461. [PubMed: 22022342]

Montgomery MR, Gragnolati M, Burke KA, Paredes E. Measuring living standards with proxy variables. Demography. 2000; 37(2):155–174. [PubMed: 10836174]

Nawrotzki R, Hunter LM, Dickinson T. Natural Resources and Rural Livelihoods: Differences between Migrants and Non-Migrants in Madagascar. Demographic Research. 2012; 26(24):661–700.

Njock JC, Westlund L. Migration, Resource Management and Global Change: Experiences from Fishing Communities in West and Central Africa. Marine Policy. 2010; 34(4):752–760.

Nunan F. Mobility and fisherfolk livelihoods on Lake Victoria: Implications for vulnerability and risk. Geoforum. 2010; 41(5):776–785.

Pardo-de-Santayana M, Tardio J, Blanco E, Carvalho AM, Lastra JJ, San Miguel E, Morales R. Traditional knowledge of wild edible plants used in the northwest of the Iberian Peninsula (Spain and Portugal): a comparative study. Journal of Ethnobiology and Ethnomedicine. 2007; 3(27):1–11. [PubMed: 17201916]

Parnell S, Walawege R. Sub-Saharan African urbanisation and global environmental change. Global Environmental Change. 2011; 21(1):S12–S20.

Paumgarten, Fiona; Shackleton, CM. The role of non-timber forest products in household coping strategies in South Africa: the influence of household wealth and gender. Population and Environment. 2011; 33:108–13.

Pereira T, Shackleton CM, Shackleton S. Trade in reed-based craft products in rural villages in the Eastern Cape, South Africa. Development Southern Africa. 2006; 23(4):477–495.

Piguet, E.; Pécoud, A.; de Guchteneire, P., editors. Migration and Climate Change. Cambridge University Press; Cambridge UK.: 2011.

Qin H. Rural-to-Urban Labor Migration, Household Livelihoods, and the Rural Environment in Chongqing Municipality, Southwest China. Human Ecology. 2010; 38(5):675–690.

Rasbash, J.; Charlton, C.; Browne, WJ.; Healy, M.; Cameron, B. MLwiN Version 2.1. Center for Multilevel Modelling, University of Bristol; Bristol, UK: 2009.

Rasbash, J.; Steele, F.; Browne, W.; Goldstein, H. A user's guide to MLwiN version 2. 10. Centre for Multilevel Modeling, University of Bristol; Bristol, U.K.: 2008.

Saenz, R.; Morales, MC. Demography of race and ethnicity.. In: Poston, DL.; Micklin, M., editors. Handbook of population. Springer; New York: 2006. p. 169-208.

Seto K. Exploring the dynamics of migration to mega-delta cities in Asia and Africa: Contemporary drivers and future scenarios. Global Environmental Change. 2011; 21(Supplement 1):S94–S107.

Shackleton SE, Campbell B, Lotz-Sisitka H, Shackleton C. Links between the local trade in natural products, livelihoods and poverty alleviation in a Semi-arid region of South Africa. World Development. 2008; 36:505–526.

Shackleton CM, Paumgarten F, Mthembu T, Ernst L, Pasquini M, Pichop G. Production of and trade in African indigenous vegetables in the urban and peri-urban areas of Durban, South Africa. Development Southern Africa. 2010; 27:291–308.

Shackleton C, Shackleton S. The importance of non-timber forest products in rural livelihood security and as safety nets: a review of evidence from South Africa. South African Journal of Science. 2004; 100:658–664.

Shackleton, C.; Shackleton, S. Exploring the role of wild natural resources in poverty alleviation.. In: Hebinck, Paul; Shackleton, Charlie, editors. Reforming land and resource use in South Africa: impact on livelihoods. Routledge; UK: 2011. p. 209Chapter 9

South Africa Department of Health. National Antenatal Sentinel HIV and Syphilis Prevalence Survey in South Africa, 2009. Pretoria, South Africa: 2010.

Subramanian SV, Jones K, Kaddour A, Krieger N. Revisiting Robinson: The perils of individualistic and ecologic fallacy. International Journal of Epidemiology. 2009; 38(2):342–360. [PubMed: 19179348]

Takenaka A, Pren KA. Determinants of emigration: Comparing migrant's selectivity from Peru and Mexico. The Annals of the American Academy of Political and Social Science. 2010; 630:178–193.

Taylor JE. The new economics of labour migration and the role of remittances in the migration process. International Migration. 1999; 37(1):63–88. [PubMed: 12322077]

Twine W, Moshe D, Netshiluvhi T, Siphugu M. Consumption and direct-use values of savanna bio-resources used by rural households in Mametja, a semi-arid area of Limpopo province, South Africa. South African Journal of Science. 2003; 99:467–473.

VanWey L. Land ownership as a determinant of temporary migration in Nang Rong, Thailand. European Journal of Population. 2003; 19(2):121–145.

Warner K. Environmental change and migration: methodological considerations from ground-breaking global survey. Population & Environment. 2011; 33(1):3–27.

Wang J, Rich PM, Price KP, Kettle WD. Relations between NDVI and tree productivity in the central Great Plains. International Journal of Remote Sensing. 2004; 25(16):3127–3138.

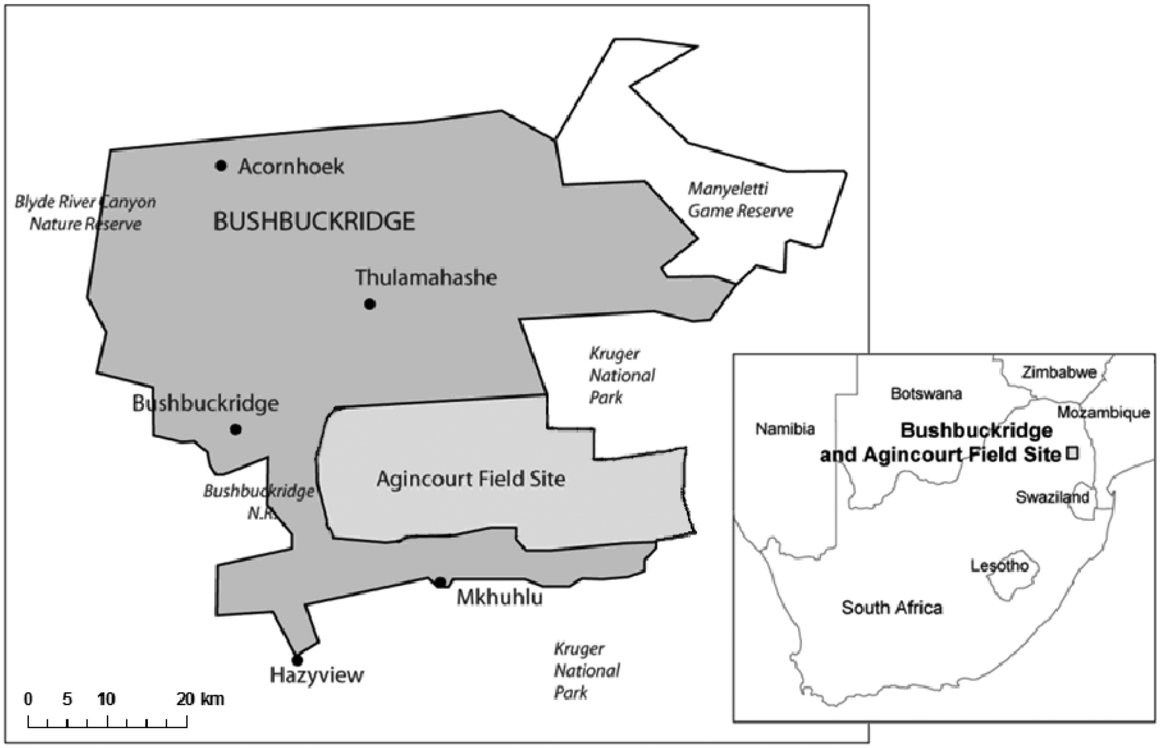
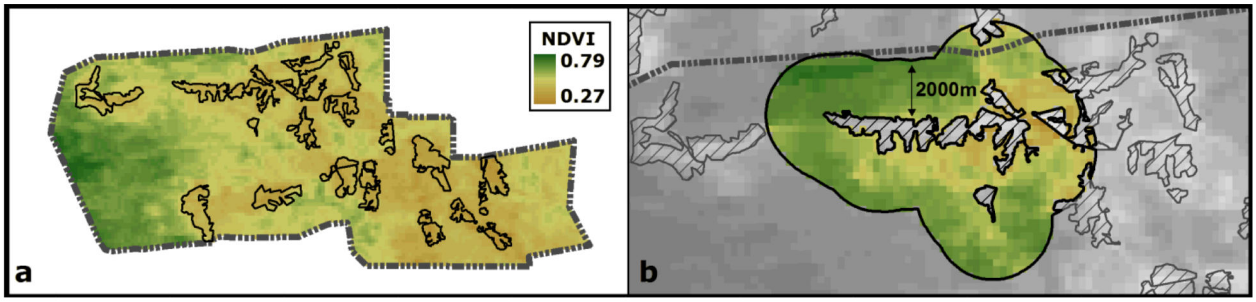


Figure 1.
Study Area, Agincourt Health and Demographic Surveillance Site, Mpumalanga Province, South Africa



Note: Each village was assigned a value reflecting the sum of the greenness values of the area surrounding the village with a radius of 2 km. Each greenness pixel value represents the average of annual greenness estimates across the years 2005, 2006 and 2007.

Figure 2.

Mean relative greenness for the Agincourt HDSS for 2007 (a) and conceptual diagram for the calculation of available greenness for one village (b).

Note: Each village was assigned a value reflecting the sum of the greenness values of the area surrounding the village with a radius of 2 km. Each greenness pixel value represents the average of annual greenness estimates across the years 2005, 2006 and 2007.

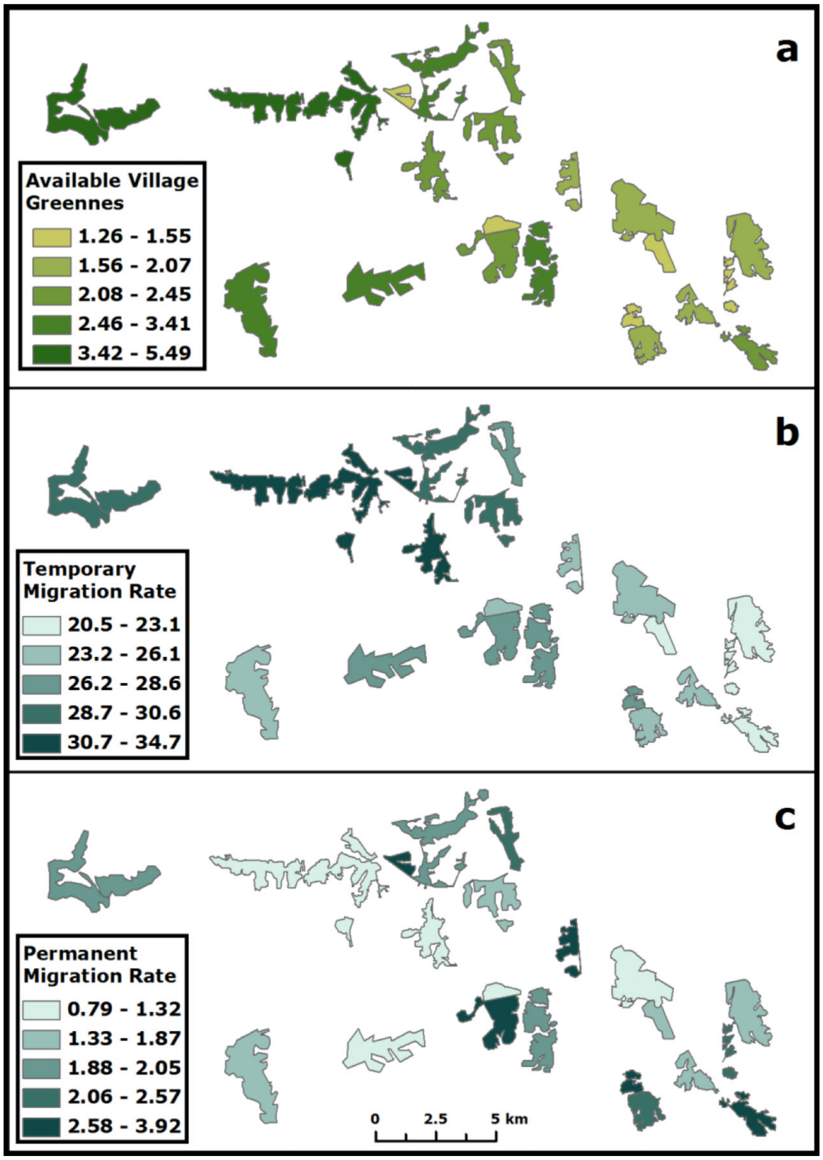
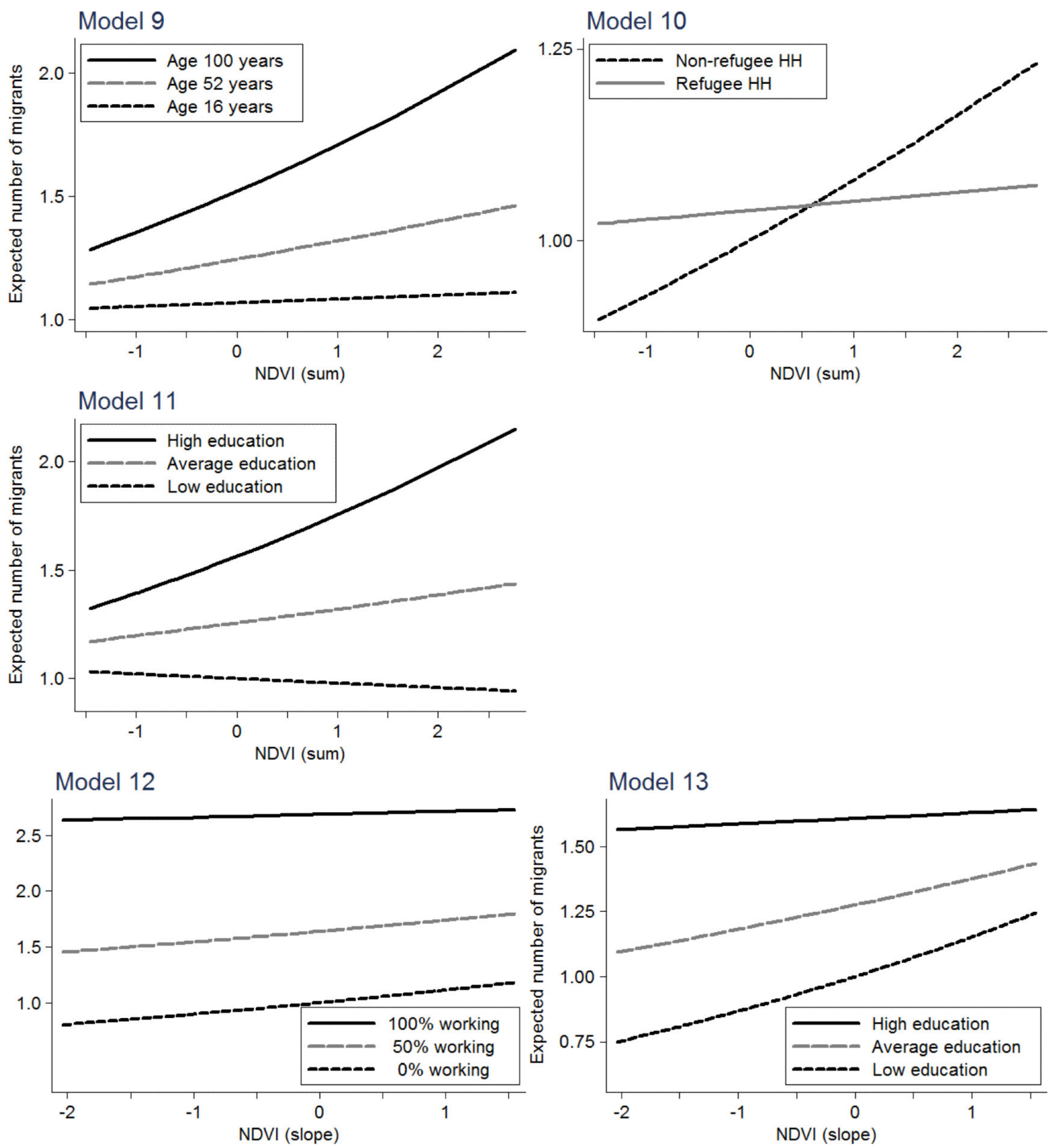


Figure 3.

Variation in mean greenness, reflecting a west-east gradient of decreasing values (a), temporary migration rates (b), and permanent migration rate (c) in percent across villages of the Agincourt study site for 2007.



Note: All NDVI measures were grand mean centered to facilitate the interpretation of the regression coefficients. A value of zero on the centered scale for the X-axis represents the mean NDVI value.

Figure 4.

Interactions between NDVI measures and household-level socio-demographic characteristics, predicting temporary out-migration for the year 2007

Note: All NDVI measures were grand mean centered to facilitate the interpretation of the regression coefficients. A value of zero on the centered scale for the X-axis represents the mean NDVI value.

Table 1

Summary statistics and group mean comparison (t-test) for selected variables for the Agincourt study site 2007

	All HH				Temporary migrant HH			Permanent migrant HH		
	Mean	(S.D.)	Min	Max	Yes	No	sig.[1]	Yes	No	sig.[1]
Outcomes										
Temporary migrants per HH	1.19	(1.36)	0	12	62.9%	37.1%		6.4%	93.6%	
Permanent migrants per HH	0.08	(0.38)	0	10						
Predictors										
NDVI_sum	2.72	(1.17)	1.26	5.49	2.77	2.65	***	2.68	2.73	
NDVI_intcpt	3.96	(0.43)	3.34	4.93	3.96	3.96		3.96	3.96	
NDVI_slope	4.40	(0.95)	2.37	5.95	4.43	4.35	***	4.39	4.40	
Controls										
Age of HH head	52.27	(15.09)	15	100	52.28	52.25		53.57	52.18	*
Female HH head	0.39	(0.49)	0	1	0.36	0.45	***	0.40	0.39	
Mozambican background	0.27	(0.45)	0	1	0.27	0.28		0.31	0.27	*
Masculinity proportion	0.44	(0.25)	0	1	0.48	0.39	***	0.43	0.44	
Dependence proportion	0.10	(0.21)	0	1	0.06	0.16	***	0.08	0.10	*
Working proportion	0.29	(0.27)	0	1	0.32	0.24	***	0.25	0.29	***
Education proportion	6.64	(3.26)	0	13	7.16	5.76	***	6.74	6.64	
SES	2.43	(0.44)	0	3.97	2.49	2.33	***	2.43	2.43	
Prime age death (last 3 years)	0.09	(0.29)	0	1	0.09	0.10	*	0.12	0.09	
N	9,625				6,056	3,569		617	9,008	

HH=Households; [1]Ordinary t-test was performed to evaluate group mean differences;

**p≤.01

Source: Agincourt Health and Demographic Surveillance Site (Agincourt HDSS) for the year 2007

* p≤.05

*** p≤.001

Table 2

Random intercept models predicting the number of temporary and permanent out-migrants at the household level as associated with village level NDVI for the Agincourt study site in 2007

Panel A: Temporary migration								
	Model 1		**Model 2**		**Model 3**		**Model 4**	
	b	**sig.**	**b**	**sig.**	**b**	**sig.**	**b**	**sig.**
Predictors								
NDVI_sum	0.082	**			0.060	*		
NDVI_intcpt			0.180	*			0.111	
NDVI_slope			0.107	**			0.078	**
Controls								
Age of HH head					0.004	***	0.004	***
Female HH head					0.010		0.009	
Mozambican background					0.052		0.053	*
Masculinity proportion					0.457	***	0.457	***
Dependence proportion					−0.672	***	−0.671	***
Working proportion					0.982	***	0.980	***
Education proportion					0.037	***	0.037	***
SES					0.069	**	0.071	**
Prime age death					0.013		0.013	
Intercept	−1.474	***	−2.444	***	−2.547	***	−3.183	***
Variance components								
Between villages	0.012	**	0.011	**	0.011	**	0.011	**
Dispersion parameter	0.000		0.000		0.000		0.000	
N	9625		9625		9367		9367	

Panel B: Permanent migration								
	Model 5		**Model 6**		**Model 7**		**Model 8**	
	b	**sig.**	**b sig.**		**b**	**sig.**	**b**	**sig.**
Predictors								
NDVI_sum	−0.079				−0.044			
NDVI_intcpt			−0.101				−0.018	
NDVI_slope			−0.026				0.006	
Controls								
Age of HH head					0.000		0.000	
Female HH head					−0.083		−0.081	
Mozambican background					0.027		0.045	
Masculinity proportion					−0.341		−0.341	
Dependence proportion					−0.601		−0.595	

Panel B: Permanent migration								
	Model 5		**Model 6**		**Model 7**		**Model 8**	
	b	**sig.**	**b**	**sig.**	**b**	**sig.**	**b**	**sig.**
Working proportion					−0.343		−0.339	
Education proportion					−0.019		−0.020	
SES					−0.288	*	−0.291	*
Prime age death					0.134		0.133	
Intercept	−3.702	***	−3.385	***	−2.694	***	−2.745	**
Variance components								
Between villages	0.036		0.045		0.037		0.041	
Dispersion parameter	4.634	***	4.458	***	4.337	***	4.235	***
N	9625		9625		9367		9367	

Coefficients represent logged rates of events; Log transformed household size was used as offset in all models, resulting in a parameter estimate (for log(exposure)) constrains to 1;

Source: Agincourt Health and Demographic Surveillance Site (Agincourt HDSS) for the year 2007

* $p \leq .05$

** $p \leq .01$

*** $p \leq .001$

Table 3

Random intercept random slope models allowing for cross level interactions between village level NDVI measures and socio-demographic characteristics predicting temporary out-migration from the Agincourt study site for 2007

	Model 9		Model 10		Model 11	
	b	**sig.**	**b**	**sig.**	**b**	**sig.**
Age of HH head	0.004	***	0.004	***	0.004	***
Mozambican background	0.052		0.038		0.046	
Education proportion	0.037	***	0.036	***	0.034	***
NDVI_sum	−0.005		0.075	**	−0.021	
x Age of HH head	0.001	*				
x Mozambican bkgrnd			−0.064	*		
x Education proportion					0.010	**

	Model 12		Model 13	
	b	**sig.**	**b**	**sig.**
Working proportion	0.989	***	0.977	***
Education proportion	0.037	***	0.037	***
NDVI_intcpt	0.110		0.100	
NDVI_slope	0.108	***	0.142	***
x Working proportion	−0.098	*		
x Education proportion			−0.010	*

All models control for age of head, Moz. background, working proportion, dependence proportion, masculinity proportion, prime age deaths, and SES; Coefficients represent logged rates of events; Log transformed household size was used as offset in all models;

Source: Agincourt Health and Demographic Surveillance Site (Agincourt HDSS) for the year 2007.

* p≤.05

** p≤.01

*** p≤.001