The Environmental Dimensions of Rural Outmigration in South Africa:

Will Climate Change Constrain Livelihood Options?

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Early Draft ~ Extended Abstract

Submitted for presentation consideration for

2012 Population Association of America Meeting

Acknowledgements: Supported by NIH 1R03 HD061428, "Environmental Variability, Migration, and Rural Livelihoods." The work has also benefited from the NICHD-funded University of Colorado Population Center (grant R21 HD51146) for research, administrative, and computing support. The content is solely the responsibility of the authors and does not necessarily represent the official views of the CUPC, NIH, or NICHD.

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Demographers have long explored the socioeconomic dimensions of migration processes. Yet the contemporary era of environmental change has brought increasing scholarly attention to migration's environmental dimensions as well. Such environmental diemsions may be of particular importance in regions where daily livelihoods are tied to the very local environment, where gathered natural resources provide sustenance as well as fodder for income generation through, for example, brewing beer or weaving baskets and brooms. Here, shifts in the availability of proximate natural resources likely result in livelihood adaptations -- migration representing one such adaptation.

Of course, isolating environmental factors from the myriad other forces shaping household migration is a formidable empirical challenge. Within this project, we tap into demographic surveillance data in combination with remotely sensed imagery to shed improved light on this association. An enhanced understanding of migration's environmental aspects is important since the Intergovernmental Panel on Climate Change asserts climate changes are "unequivocal" (IPCC 2007:4) and many changes will impact already-vulnerable regions (Thomas and Twyman 2006), such as rural South Africa, our study site, with expected shifts in precipitation and temperature (Schultze et al. 2001).

Background

In rural regions of the world's less developed nations, environmental change has immediate and direct impacts on the health and well-being of millions of households since natural resources are often essential in meeting basic living requirements (Koziell and Saunders 2001). Important land-based activities include arable farming, livestock husbandry, and consumption and trade in natural resources (e.g., fuel wood, wild herbs). Natural resources also act as "buffers" against household shocks such as job loss and/or mortality (Hunter, Twine, and Johnson 2011; Hunter, Twine and Patterson 2007). Given this high level of resource dependence, vegetation cover change holds tremendous potential to impact health and livelihoods. As related to outmigration, a decline in livelihood options can act as a “push” factor (Bates and Rudel 2004).

“Rural Livelihoods” as a Conceptual Framework: The “Rural Livelihoods” framework has been successfully used in a wide variety of analytical endeavors including exploration of health behaviors (Rugalema 2000), food security (Bank 2005) and household diversification strategies (Yaro 2006). The framework reviews various “capital assets” that shape livelihood options, including human capital (e.g., labor), financial capital (e.g., savings), physical capital (e.g., automobiles), social capital (e.g., networks), and natural capital (e.g., wild foods). Of course, the assets’ relative availability is shaped by individual and household actions as well as broader socioeconomic-political structures and processes. The assets’ relative availability shapes livelihood strategies which may include human capital use (e.g., labor migration (Collinson et al. 2006a, 2006b)) or natural capital use (e.g., making reed-based craft products for market (Pereira, Shackleton, and Shackleton 2006)). Yet both the relative availability of capital assets and the structures/processes that transform asset availability are shaped by the vulnerability context (e.g., shocks and stresses). Some occur at the household level (e.g., job loss), although they may characterize broader economic trends (e.g., tourism industry decline).

Migration, Livelihoods and Natural Capital: Focusing on Environmental Change: The majority of existing research on migration-environment focuses on land availability and/or land use decisions, and is situated in Asia and South America (e.g., Ayuwat 1993). Results suggest when faced with lack of livelihood options, often due to cumulative processes of environmental degradation (Zweifler, Gold and Thomas 1994), households may strategically diversify with some household members migrating to seek opportunity elsewhere (Bilsborrow 2002). In this way, changes in the availability of proximate natural capital shape household decisions about use of available human capital. On the association between migration and land availability, several studies find land shortage to be a factor in outmigration decisions from rural areas (Abbott 1976; Abdelali-Marini et al. 2003; Keely 1973). As an example, Bates and Rudel (2004) explore migration in the Ecuadorian Amazon finding that young migrants engage in temporary labor migration to distant places as means of amassing capital to purchase land. In Thailand, VanWey (2003) finds that households with smaller landholdings diversify livelihoods through migration to supplement rural income. That said, households with larger landholdings also diversify through migration but mostly to overcome the absence of accessible credit. Fragmentation of land holdings in Syria also appears to shape human capital decisions since land shortages "push" males to migrate to urban areas and nearby countries (Abdelali-Marini et al. 2003).

U.S.-based research also provides insight on migration-environment linkages (e.g., Deane and Gutmann 2003). Using an historical perspective and set in the Great Plains, Gutmann et al. (2005) use pooled time series models to explore population dynamics and environmental characteristics, 1930-1990. Climate effects on migration were observed, working through agricultural impacts, especially during the 1930s-40s. These findings are of particular relevance to our study since the early 1900s were characterized by relatively greater vulnerability to environmental extremes given lower levels of technological adaptation that might reduce the impact of environmental disasters (i.e. drought) on crop failures – much like contemporary rural South Africa with its dry climate and environmental vulnerability due to resource dependence (Gutmann et al. 2005).

Three additional studies deserve mention. One, undertaken in Ethiopia, evaluates historical experience gained from drought-induced migration. Meze-Hausken (2000) finds that families with more survival strategies tended to resist distress migration longer (Meze-Hausken 2000:382). In Burkina Faso, work by Henry and colleagues (Henry, Schoumaker and Beauchemin 2004; Henry et al. 2004) reveals that 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. Findley (1994) explored the migratory implications of a drought in Mali in the late 1980s finding that the severe drought of 1983-1985 was associated with a dramatic increase in migration of women and children, and also an increase in short-term cyclical migration.

In all, the study presented here is grounded in prior research on livelihoods and migration-environment connections. However, 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 households in impoverished rural regions.

Research Setting

The Wits/MRC Agincourt Health and Demographic Surveillance Site is located in the far northeast of South Africa (Figure 1). The AHDSS encompasses 21 villages, each with 500-1,000 households. The total population is approximately 70,000 in 12,000 households. A main advantage of this data set is that each household is geo-coded, allowing for the analysis of social phenomena in a spatial heterogenous context.

(Figure 1 about here)

During the Apartheid era, the study site was part of a Bantustan or black South African "homeland" and, as a result, it is characterized by high population densities, high levels of poverty and a backlog in development and access to services. The high human densities are primarily a result of racially-based Apartheid land allocation policies and the large influx of refugees from Mozambique in the 1980s. The former Mozambican refugees are from the same ethnic group as most other residents (Shangaan) and many have become naturalized residents. Local employment is scarce and residents often migrate seeking work outside the area (details below). Social security grants are also an important income source. As to public health, HIV/AIDS is a formidable force shaping livelihood strategies with health indicators for Limpopo Province suggest that the impact of HIV/AIDS is only beginning to be felt. In the province in the year 2000, 21.5% of deaths were attributed to HIV/AIDS. It is projected that by 2010, this will rise to nearly 65 percent (Day and Gray 2003).

Livelihoods and natural resource dependence: Household livelihoods in the AHDSS are quite diverse, incorporating 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 2002; Shackleton et al. 2000). Natural resources such as fuelwood, wild foods, medicinal plants, plant fiber and construction material are widely used, typically harvested from communal rangelands surrounding the villages, and make important contributions to household economies both for domestic use and income generation (Shackleton and Shackleton 2000). In this study, the availability of these resources is measured by a vegetation index as well as a more specific indicator of tree canopy cover.

As noted above, the high reliance on natural resources, such as wild foods and fuelwood, by households in the study site is certainly not unique in the South African context, nor across rural sub-Saharan Africa more generally. A study undertaken across South Africa estimated the total annual direct use value of natural resources consumed by households ranges from R2213/$340 (Shackleton and Shackleton 2000) to R3435/ $528 (Dovie et al. 2002). This is comparable with data from other studies in South Africa (Letsela et al. 2002; Twine et al 2003; Shackleton 2004 Shackleton and Shackleton 2004) and Zimbabwe (Campbell et al. 1997). In a review of 6 studies in 14 rural South African villages, Shackleton and Shackleton (2004) found that wild herbs/spinaches, wild fruit, and fuelwood were used by the majority of households in all cases. Average amounts consumed were substantial 58.2 kg/year for wild spinaches, 104.2 kg/year for wild fruit and 14.2 kg/day for fuelwood.

Clearly important, natural resources also play a vital role as a “safety net” against destitution particularly in times of crisis (Letsela et al. 2002: 352; Shackleton, Shackleton, and Cousins 2001; Shackleton and Shackleton 2004). For example, 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 Limpopo region generally (Madubansi and Shackleton 2007) as well as specifically within the AHDSS where natural resources act as buffers against shocks such as a breadwinner’s death (Hunter, Twine and Patterson 2007).

<u>Migration trends</u>: 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. During the apartheid era,

black South Africans' settlement patterns and livelihood strategies were restructured to provide necessary labor, while forcing unemployed family members to remain in densely settled, rural areas. Laws controlled migration and resulted in an enforced impermanence in the black population's urbanization. Urban areas were characterized by a gross inadequacy of planning and the diversion of settlement into sprawling peri-urban areas. In rural regions, residents were forced into "homelands" based on ethnic homogeneity. Access to land was further restricted by a process of "villagization" (Collinson et al. 2007). Ultimately, these forces yielded a transition from an agrarian to a cash-based rural economy, although a poor, rural economy characterized by continual labor migrations. Further, the migrations created large numbers of complex households with both rural and urban components. Post-apartheid, urbanization has occurred more rapidly but retains the feature that many rural to urban migrants are temporary and remain connected to their rural homes (Collinson et al. 2007). The proposed study's migration focus offers another example of the utility of linking environmental context to demographic surveillance. The surveillance of the entire population results in in- and outmigration data that are highly accurate, while temporary migration can be tracked when an individual returns to the surveillance household (Collinson et al. 2007).

As in sub-Saharan Africa more generally, migration is a significant livelihood strategy in the Agincourt field site; Approximately 60% of adult males and 40% of adult females in the region are labor migrants. 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. 2006). This can be discriminated from permanent migration that occurs for different reasons, namely, family formation or dissolution or for households moving to preferable locations. A typology of moves incorporating temporary and permanent categories shows very different age and sex patterns, trends over time, reasons for migration and consequences for the household (Collinson 2006).

Data

The goal of this study is to investigate the impact of access to natural resources on the likelihood of outmigration during two years with relatively different weather regimes. Our unit of analysis is the household with 9,914 households available for two study years 2002 and 2007. The first time period was characterized by relatively high but slightly decreasing greenness values (between 0.53 – 0.47 in average); the latter time period showed similar mean greenness but higher variation across the years with an increasing trend from 2005 to 2007 (between 0.43 – 0.54). Thus in average the mean greenness values where very similar in both time periods but were based on different "histories" of resource availability. As a result the spatial distributions in 2002 and 2007 differed considerably.

As suggested by the Sustainable Livelihoods Framework, in settings such as rural South Africa, migration is a diversification strategy most often undertaken as a family or household decision, as opposed to an individual one (Carney et al. 1999, Chambers and Conway 1991). Within the AHDSS, a household is defined as "a group of people living on the same property who eat from the same pot of food" (Madhavan et al. 2009:39).

Dependent Variable: Household Experience of Adult Outmigration: We model the probability of an Agincourt household experiencing an adult (age 15+) outmigration during the 12 months prior to data collection in each of two census years (2002 and 2007). We focus on adult outmigration given our interest in household livelihood strategies.

We examine both temporary and permanent migration, classification of which makes use of a *de jure* household definition. 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 migrations are discerned through details regarding the migration event, at an individual level, giving the move's date and other key variables such as destination (Collinson, Tollman and Kahn 2007). More generally, permanent migration is defined as a person entering or leaving a household with a permanent intention, whereas temporary (or circular) migration is defined as a person leaving a household with a temporary intention and spending at least six months of a year away from home, although still linked to the rural household. This discriminates between livelihood migration and migration for marriage or a family moving out of the area, a difference that is easily operationalized in the field and has analytic advantages. Labor migration is a form of temporary migration and implies strong ties between a work setting, usually urban, and a rural home. If out-migration is associated with natural resource availability/variability, it is important to know whether the outmigration was temporary, which enables remittances, or permanent out-migration thereby reducing rural population (Collinson, Kok and Garenne 2006; Posel 2006).

Within 2007 (our relatively drier year), households had a maximum of ten members permanently out-migrating and up to twelve members migrating on a temporary basis, and slightly lower numbers (eight and eleven respectively) for the year 2002 which experienced higher levels of precipitation (see Table 1).

(Table 1 about here)

Generation of Key Independent Variables: Natural Resource Availability: Using the Normalized Difference Vegetation Index (NDVI), a *greenness* metric was derived to quantify natural resource availability for residents of the Agincourt study area. NDVI has been widely used to monitor plant growth (vigor), density of vegetation cover and biomass production (Foody et al. 2001, Wang et al. 2004). It is therefore an effective measure of the availability of natural resources used in livelihood strategies (e.g. firewood, seeds, wild foods, fencing materials, etc.). NDVI values for each year were calculated by taking the annual mean of 16 day composites from MODIS satellite imagery (250 meter resolution). From these annual means, we took the mean of the year of analysis, and the two years prior, to create greenness grids for 2002 and 2007. Including the two years prior takes into account variation in natural resource availability leading up to outmigration years of 2002 and 2007. From the two greenness grids, we excluded areas within village boundaries as these are not communal lands and therefore do not afford equal access to wild natural resources. Further, the resolution of MODIS imagery does not allow for analysis at the household level within village boundaries.

The next step was to create 2000 meter buffers around each village (but excluding the area within that village and within neighboring villages). The size of these buffers was based on the distance that residents typically travel to access natural resources (WITS 2011). Finally, the sum of NDVI values within this buffered area was calculated for each village. The sum was taken as a surrogate for the amount of natural resources available to residents of each village.

Household-level Explanatory Variables: Migration, as a social process, is obviously shaped by myriad socio-demographic factors. Thus, in order to isolate the effect of access to natural resources on migration we included a number of control variables. First, the age of the household head was used, ranging from 15 to 100 years with a mean around fifty. We expect that older household heads are more established, have a larger social network, and have better access to livelihood assets, thus might be better positioned to send a labor migrant. Household gender composition may also shape migration strategies I that, particularly for temporary migration, prior research suggests men have generally better employment prospects than women (Donato 1993, Kok et al. 2003). This gender aspect might be reflected in a larger number of female heads among migrant households and more generally in the proportion of males in a certain household. In our data set, 37% (41%)[1] of the households are female headed. In addition, the masculinity proportion was calculated as the number of working age adult males (age 15-64) divided by the number of adult household members.

Refugee status may also shape migration propensity, given refugees' existing networks within their homelands. During the 1990s AHDSS experienced a high influx of refugees from neighboring Mozambique (Madhavan et al. 2009) as a result of the Mozambique civil war that lasted from 1983 to 1992 (Hargreaves et al. 2004). Within our study years, approximately 27% (27%) of the households in AHDSS consist of refugees.

In addition, we included a set of dummy variables reflecting the marital status of the household head. In the year 2002 around 38% (42%) of household heads were married and a sizable fraction of 12% (6%) were widowed. However, 46% (49%) of all household heads did not provide information regarding

[1] In the variable description the frequencies given in parenthesis refer to the numbers for the year 2007.

marital status, presumably since this western categorization is not always applicable to the local context. Even though it might be reasonable to assume that a household with a married couple is more stable and able to send a migrant, compared to a household with a widowed head, studies frequently do not find significant associations between marital status and migration (c.f. Riosmena 2009).

Educational attainment is one of the most important measures of human capital (Saenz and Morales 2006) and has been generally associated with a higher likelihood of out-migration (Lindstrom and Ramirez 2010). We calculated a household education proportion by dividing the years of education of all adult household by the household size (Booysen 2006). On average, individuals have 6 (7) years of education. Another important measure for human capital, frequently used in migration studies is employment status (Massey et al. 2010). Thus, we calculated a household level employment proportion dividing the number of individuals currently working by the total number of household members. Only 29% (29%) of the adult household members indicated being employed. In addition, we use the dependency proportion to reflect both age structure and productivity of a household (Madhavan et al. 2009). The dependency ratio is conventionally constructed as the balance of those likely to be economically productive, in the denominator, against those who depend on them financially, in the numerator (Verdugo 2006). Since we limit our analysis to adults (age $\geq$ 15) only the elderly (age >64) are counted in the numerator. In addition, we used the household size in the denominator to avoid losing cases.[2] On average, households had 8% (10%) dependent members. The dependency proportion is sensitive to the death of household members which may also impact migratory behavior. For example, a study of rural Tanzanian households showed that the mobility of household members increased before and after a death (Urassa et al. 2001, Booysen 2006). Newcomers may join the household to replace the member who passed away, while in other cases a death may encourage a number of other household members to leave to reduce the pressure on scarce food resources.

[2] 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. For example, in the case of the traditional definition of the dependency ratio (Verdugo 2006) households that consist entirely of dependent individuals, either very young or very old, would receive a missing value since the denominator of economically productive individuals would be zero.

Finally, in settings such as Agincourt, 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 wealth. Following Mberu's (2006) we included an asset index (variable SES), which was constructed as an additive scale combining modern assets, livestock assets as well as information about power supply, water and sanitation, and dwelling structure (for details see SES Index module in AHDSS 2009).

Methods: Estimation strategy

Our data show a distinct hierarchical structure with households nested within 21 villages. An exploratory investigation suggests substantial spatial variation in our dependent and independent variables across geographical units. As such, the hierarchical structure and spatial dependence suggest the use of multilevel models is most appropriate and we use hierarchical models allowing both the intercept and the slope to vary across villages. This statistical approach has many advantages since it 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 formally described by a list of equations.

(1) Level 1:

$$\eta_{ij} = \log_e \mu$$

$$\eta_{ij} = \beta_{0j} + \beta_{1j} X_{1ij} + \beta_{2j} X_{2ij} + \ldots + \beta_{zj} X_{zij} + r_{ij}$$

Level 2:

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

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

Our outcome variable is a count of the number of temporary or permanent out-migrants from a particular household. A number of studies have suggested using Poisson models for migrant count variables (e.g. Bohara and Krieg 1996, Boyle and Flowerdew 1993, Congdon 1993). We follow this approach after thoroughly evaluation of the distribution of the residuals using different forms of generalized linear models (GLM).[3] The Poisson model uses a natural logarithm link which guarantees that the set of independent variables linearly produces η_{ij} (Hoffman 2004). The symbol μ in the link function represents the expected value, or what is sometimes called the conditional mean of Y_{ij}. The other components of the model's level-1 are similar to a standard OLS multivariate regression model with β_0 as the intercept, $\beta_{1\text{-}z}$ the regression coefficients for individual-level variables $X_{1\text{-}z}$ (age, marital status, etc.), and r_{ij} the traditional individual-level error term. However, the *j* subscript indicates that a different level-1 model is estimated for each of the *j* level-2 units (villages). Each village may have a different average number of out-migrants (β_{0j}) and a different effect of for example household education on the number of out-migrants (β_{1j}). Thus, we allow the intercept β_{0j} and the slope of selected variables (e.g. β_{1j}) to vary across level-2 units (villages).

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 W_j (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 at the village level (unit *j*). The interpretation of the second equation is similar, but here the level-2 effect on the slope of X_{1ij} (e.g. household education) 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_j (NDVI); γ_{11} is the effect of the level-2 predictor W_j (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 STATA 11 (StataCorp LP, College Station, Texas) in its *xtmepoisson* procedure, which we employed to fit the models. In addition, we included a term for unstructured covariance to account for the relationship between the random slopes and random intercepts.

[3] We recognize the assumption of independence between the events (Long 1997) might be violated since the likelihood of out-migration is impacted by the migration experience within the household as suggested by cumulative causation theory (Fussell and Massey 2004).

We proceeded as following in our modeling strategy. First we estimated additive random intercept models that adjust for variation across villages. These models illustrate the isolated impact of village level NDVI on out-migration controlling for a host of socio-demographic predictors. In a second step, we explore whether the effect of socio-demographic factors on out-migration is dependent on the access to natural resources (NDVI). To this end, we included cross level interactions between the village level NDVI and household level socio-demographic factors. The models that include the cross level interactions allow the slope of the household level predictors to vary across villages and thus, constitute random slope random intercept models.

Results

Group mean comparison: In order to obtain a first impression of possible associations that might emerge from the data, we use ordinary group mean comparisons (t-test) to investigate whether the mean of the predictor and control variables between households with at least one migrant are significantly different from non-migrant households. Table 1 shows that households with a permanent out-migrant do not differ from households without a migrant with regard to natural resources access (NDVI). However, households with temporary migrants were significantly more likely to be located in greener areas (NDVI=2.65 vs. NDVI=2.82). This difference was observed for both study years, 2002 and 2007. However, this bivariate approach is limited in its informative value and significant differences between migrant and non-migrant households on numerous socio-demographic predictors warrant the use of multivariate regression models. As such, we ran models for both temporary and permanent out-migration. However, as preliminarily suggested from the bivariate comparison, no significant multivariate results were obtained using NDVI to predict permanent out-migration. Thus, we present and discuss only models predicting temporary out-migration in the remainder of this article.

(Table 2 about here)

Additive models: The consecutive steps of model building are displayed in Table 2. We include first NDVI as our main predictor of interest in tandem with a control for household size.[4] We then add all socio-demographic controls that pertain to the household head, followed by the complete model, which includes controls for the other household socioeconomic characteristics. As the Bayesian Information Criterion (BIC) shows the model fit is superior for the fully adjusted models (Model 3 and 6).

As our main finding, we observe a strong positive association between the village level measure of natural resources and temporary out-migration. Including socio-demographic control variables resulted in a decrease of the size of the coefficient but NDVI showed still a significant strong impact in the full model. For the year 2002, an increase in greenness by one unit (about 25% greener area) would equate with an increase the expected number of migrants within a household by 9% (exp(.087)=1.09). For the year 2007, the size of the coefficient for NDVI was similar with a slight reduction in the expected number of migrants by 2%. Thus, we did not observe major differences in the impact of access to natural resources on out-migration under different resource conditions (recall that 2002 had relatively more rainfall).

The socio-demographic predictors behaved largely similar across the two study years. Larger households send more members in search of work elsewhere. Also, the number of temporary migrants is greater in households with older household heads. In line with Lindstrom and Ramirez (2010), we find that education as a measure of human capital is positive associated with out-migration, presumably since education provides enhanced job opportunities in the non-agriculture sector outside our rural study site. Also the strong positive coefficient for working proportion shows that those households who report larger numbers of out-migrants have also higher employment rates, which supports the assumption that temporary migration constitutes largely labor migration. However, sending a migrant to work elsewhere appears to be only an option for households with a low dependency proportion. For example, an increase

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[4] Note that the transformation in Poisson models involves a log link. Thus, the coefficients in the regression tables need to be exponentiated in order to obtain the expected counts and should be interpreted in multiplicative terms (Hoffmann 2004).

in the proportion of elderly individuals (age >64) in a household leads to a significant decrease in the number of temporary migrants.

Our findings also provide some information regarding the household gender composition in predicting elevated numbers of temporary out-migrants. An increase in the proportion of males in a household increases the number of temporary migrants. As outlined above this observation might be attributed to the fact that in many settings, men generally have greater outside employment prospects than women (Donato 1993, Kok et al. 2003). Finally, the socio-economic status of a household as reflected in the asset index positively predicts temporary out-migration. Unfortunately, the causal order of this relationship cannot be determined in a cross-sectional analysis – on the one hand, sending temporary migrants might increase the wealth of a household through remittances. On the other hand, it is possible that only relatively well-situated households have the means to send a migrant.

Interaction models: As a final step, we explore whether the effect of NDVI on the number of out-migrants differs by socio-demographic characteristics. We found significant cross-level interactions between NDVI and the gender of the household head as well as for NDVI and household education.

(Table 3 about here)

Table 3 demonstrates that for both socio-demographic predictors, the interaction coefficients are positive. This indicates that the strength of the effect of the predictors for female head and household education on temporary out-migration increases with better access to natural resources as reflected by the greenness of a particular village. This association is graphically represented, for 2002, in Figure 2. Panel (a) demonstrates that a small, but significant, difference in the steepness of the slope exists between female and male headed households. In numerical terms we can say that the effect of access to natural resources in predicting outmigration is by .049 log count units (5%) stronger for female compared to male headed households.

(Figure 2 about here)

Panel (b) demonstrates the change in NDVI predicting outmigration for differentially educated households. For households with the lowest level of education, a change in greenness of the 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 even stronger for relatively highly educated households. Specifically, each one-year increase in education (ranging from 1 to 12 years) increases the effect of NDVI in predicting temporary out-migration by 2 percent. An initial explanation might be approached in line with the reasoning regarding the impact of SES on out-migration. Households that are able to access financial capital through remittances might self-select to live in natural resource richer areas. The interaction between NDVI and household education remains significant for both years 2002 (relatively greener) and 2007. However, the coefficient for the interaction between NDVI and female head achieves significance only for 2002.

Conclusion – *to be further developed.*

The world's climate is changing and rural households with daily dependence on local natural resources will clearly be impacted. Prior research demonstrates the significance of migration as a rural livelihood strategy, as households seek to diversify assets. Yet much scholarly work remains to be done to shed light on the migratory implications of contemporary climate change.

Here, we tap into the potential presented through demographic surveillance data, to explore at two time points, the migration-environment association from a natural-resource dependent region of rural South Africa. We find natural resource availability particularly influential with regard to household temporary migration strategies, in years with both high and low rainfall. In this way, our multi-level models suggest migration is a consistent livleihood strategy, tending to be positively associated with the availability of natural capital. Our work also explores nuance within this association through interactions which reveal natural resource availability may fuel migration especially within more educated households, perhaps suggesting that natural capital, as a livelihood asset, fuels further diversification. As for implications, in the wake of shifting environmental conditions, lack of predictability of natural capital portends unpredictable and uncertain future livelihood options, particulalry with regard to temporary labor migration.

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

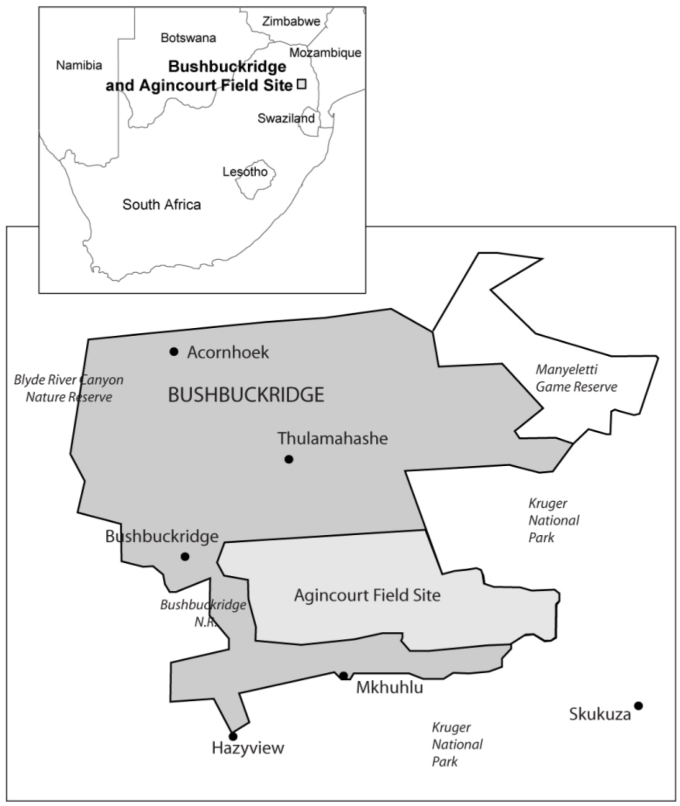

Table 1: Summary statistics and group mean comparison (t-test) for selected variables for years 2002 and 2007

Panel A: Year 2002

						Permanent out-migrant[1]			Temporary migrant[1]		
Variable	N	Mean	Std. Dev.	Min	Max	No	Yes	p	No	Yes	p
Outcome											
No. of permanent out-migrants	9914	0.11	0.42	0	8						
No. of temporary migrants	9914	0.98	1.17	0	11						
Predictors											
NDVI (village)	9914	2.75	1.14	1.27	5.43	2.74	2.77		2.65	2.82	***
Controls											
Age of household head	9672	48.95	14.78	15	100	48.70	51.64	***	48.61	49.20	
Female head	9672	0.37	0.48	0	1	0.36	0.41	*	0.42	0.33	***
Refugee household	9668	0.27	0.45	0	1	0.27	0.26		0.28	0.27	
Married	9914	0.38	0.49	0	1	0.39	0.30	***	0.33	0.42	***
Divorced	9914	0.04	0.20	0	1	0.04	0.05		0.05	0.04	**
Widowed	9914	0.12	0.32	0	1	0.12	0.11		0.11	0.12	
Missing	9914	0.46	0.50	0	1	0.45	0.54	***	0.51	0.42	***
Household education	9914	6.15	3.21	0	12	6.15	6.08		5.56	6.58	***
Working proportion	9914	0.29	0.27	0	1	0.29	0.26	***	0.26	0.32	***
Dependency proportion	9914	0.08	0.17	0	1	0.08	0.07		0.11	0.05	***
Masculinity proportion	9914	0.43	0.24	0	1	0.44	0.42	*	0.40	0.46	***
Death per household last 3 years	9914	0.12	0.36	0	3	0.11	0.18	***	0.11	0.12	
SES	9909	2.14	0.49	0.88	3.76	2.14	2.21	***	2.05	2.21	***

[1] Ordinary t-test was performed to evaluate group mean differences

Source: Agincourt Health and Socio-Demographic Surveillance System (HSDSS) years 2002 and 2007

Panel B: Year 2007

Variable	N	Mean	Std. Dev.	Min	Max	Permanent out-migrant[1] No	Permanent out-migrant[1] Yes	p	Temporary migrant[1] No	Temporary migrant[1] Yes	p
Outcome											
No. of permanent out-migrants	9914	0.08	0.37	0	10						
No. of temporary migrants	9914	1.18	1.35	0	12						
Predictors											
NDVI (village)	9914	2.72	1.17	1.26	5.49	2.72	2.68		2.64	2.77	***
Controls											
Age of household head	9812	51.77	15.26	15	100	51.70	52.83		51.77	51.77	
Female head	9812	0.41	0.49	0	1	0.41	0.41		0.47	0.37	***
Refugee household	9806	0.27	0.45	0	1	0.27	0.31	*	0.28	0.27	
Married	9914	0.42	0.49	0	1	0.43	0.37	**	0.35	0.47	***
Divorced	9914	0.03	0.17	0	1	0.03	0.09	***	0.03	0.03	
Widowed	9914	0.06	0.24	0	1	0.06	0.06		0.06	0.06	
Missing	9914	0.49	0.50	0	1	0.49	0.48		0.56	0.44	***
Household education	9914	6.67	3.35	0	15	6.67	6.74		5.80	7.19	***
Working proportion	9914	0.29	0.27	0	1	0.29	0.25	***	0.24	0.32	***
Dependency proportion	9914	0.10	0.21	0	1	0.10	0.08	*	0.15	0.06	***
Masculinity proportion	9914	0.44	0.26	0	1	0.44	0.43		0.39	0.47	***
Death per household last 3 years	9914	0.20	0.47	0	4	0.20	0.28	***	0.22	0.19	*
SES	9639	2.43	0.44	0	3.97	2.43	2.42		2.33	2.49	***

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

Source: Agincourt Health and Socio-Demographic Surveillance System (HSDSS) years 2002 and 2007

Table 2: Additive random intercept models predicting the number of temporary migrants at the household level in relation to a change in village level NDVI for years 2002 and 2007
Panel A: Year 2002

	Model 1			**Model 2**			**Model 3**		
	b		**z**	**b**		**z**	**b**		**z**
NDVI (village)	0.118	***	3.99	0.105	***	3.33	0.087	**	2.79
No. household members	0.194	***	62.72	0.199	***	58.70	0.186	***	48.95
Age of head				-0.003	***	-4.35	0.004	***	4.04
Female head				-0.090	**	-3.18	-0.043		-1.44
Refugee				-0.121	***	-4.39	0.071	*	2.25
Divorced (ref: married)				-0.074		-1.31	-0.027		-0.47
Widowed ref: married)				-0.057		-1.70	-0.024		-0.72
Missing (ref: married)				0.021		0.74	0.075	*	2.52
Household education							0.041	***	9.03
Working proportion							0.681	***	15.64
Dependency proportion							-0.838	***	-7.47
Masculinity proportion							0.320	***	5.76
Deaths in last 3 years							-0.028		-1.00
SES							0.076	**	2.80
Intercept	-1.261	***	-15.52	-1.011	***	-10.78	-2.088	***	-18.69
Variance component									
Village	0.016	***	-10.29	0.018	***	-9.89	0.017	***	-9.86
N	9914			9668			9665		
BIC	24064.5			23489.7			22934.6		

Coefficients represent expected log-numbers of events.

Source: Agincourt Health and Socio-Demographic Surveillance System (HSDSS) years 2002 and 2007

Panel B: Year 2007

	Model 4			Model 5			Model 6		
	b		**z**	**b**		**z**	**b**		**z**
NDVI (village)	0.105	***	3.77	0.085	**	3.24	0.070	**	2.63
No. household members	0.204	***	71.70	0.213	***	68.72	0.205	***	57.95
Age of head				-0.005	***	-6.60	0.003	**	3.03
Female head				-0.105	***	-3.79	-0.006		-0.18
Refugee				-0.156	***	-6.21	0.003		0.11
Divorced (ref: married)				-0.065		-1.10	-0.019		-0.32
Widowed ref: married)				-0.031		-0.75	0.019		0.46
Missing (ref: married)				0.075	**	2.66	0.088	**	2.96
Household education							0.037	***	9.41
Working proportion							0.796	***	19.43
Dependency proportion							-0.685	***	-7.05
Masculinity proportion							0.379	***	7.66
Death in last 3 years							-0.050	*	-2.50
SES							0.103	***	3.90
Intercept	-1.111	***	-14.73	-0.802	***	-10.09	-2.070	***	-19.26
Variance component									
Village	0.015	***	-11.14	0.013	***	-11.27	0.013	***	-11.36
N	9914			9806			9545		
BIC	25864.8			25570.4			24083.4		

Coefficients represent expected log-numbers of events.

Source: Agincourt Health and Socio-Demographic Surveillance System (HSDSS) years 2002 and 2007

Table 3: Random intercept random slope models allowing for cross level interactions between village level NDVI and socio-demographic variables predicting an increase in the number of temporary migration for years 2002 and 2007

Panel A: year 2002	**Model 7**			**Model 8**		
	b		**z**	**b**		**z**
Female head	-0.187	**	-2.97	-0.044		-1.46
Household education	0.041	***	9.00	-0.003		-0.18
NDVI (village)	0.070	*	2.12	-0.006		-0.12
x Female head	0.049	**	2.59			
x Household education				0.015	*	2.31
Variance component						
Predictor (slope)	0.000	**	-2.96	0.000	***	-10.09
Village (intercept)	0.019	***	-9.18	0.037	***	-7.05
N	9665			9665		
BIC	22955.0			22944.8		
Panel B: year 2007	**Model 9**			**Model 10**		
	b		**z**	**b**		**z**
Female head	-0.034		-0.60	-0.007		-0.22
Household education	0.037	***	9.42	0.001		0.07
NDVI (village)	0.066	*	2.37	-0.030		-0.68
x Female head	0.010		0.60			
x Household education				0.013	***	3.36
Variance component						
Predictor (slope)	0.000		-1.43	0.000	***	-7.51
Village (intercept)	0.014	***	-10.52	0.026	***	-7.54
N	9545			9545		
BIC	24110.4			24089.0		

Coefficients represent expected log-numbers of events; All models control for number of household members, age of head, refugee, marital status, working proportion, dependency proportion, masculinity proportion, deaths within the last 3 years, SES

Source: Agincourt Health and Socio-Demographic Surveillance System (HSDSS) years 2002 and 2007

Figure 2: Interactions between village level NDVI and female head (a) as well as NDVI and education proportion (b) in predicting temporary out-migration for the year 2002