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Soil Quality and Human Migration in Kenya and Uganda

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Abstract

Soil degradation is widely considered to be a key factor undermining agricultural livelihoods in the developing world and contributing to rural out-migration. To date, however, few quantitative studies have examined the effects of soil characteristics on human migration or other social outcomes for potentially vulnerable households. This study takes advantage of a unique longitudinal survey dataset from Kenya and Uganda containing information on household-level soil properties to investigate the effects of soil quality on population mobility. Random effects multinomial logit models are used to test for effects of soil quality on both temporary and permanent migration while accounting for a variety of potential confounders. The analysis reveals that soil quality significantly reduces migration in Kenya, particularly for temporary labor migration, but marginally increases migration in Uganda. These findings are consistent with several previous studies in showing that adverse environmental conditions tend to increase migration but not universally, contrary to common assumptions about environmentally-induced migration.

Keywords

soil quality; migration; environmental migrant; population mobility

1. Introduction

Soil degradation, including soil erosion and nutrient depletion, is widely considered to be an important factor undermining the livelihoods of smallholder agriculturalists in the developing world (Stocking et al., 2003). Smallholders often lack the capital to maintain soil resources, but without external inputs the productivity of soils under continuous cultivation inevitably declines, potentially exacerbating rural poverty and creating a poverty trap (Barrett, 2008). Drawing on field measures of soil erosion and nutrient balance, soil scientists have long argued that the scope of this problem is severe (Stoorvogel and Smaling, 1990; Sanchez, 2002), particularly in the East African highlands where rural population densities are high, poverty is endemic, and access to modern agricultural inputs is poor (Pender et al., 2006).

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More recently, however, a collection of social scientists have challenged this interpretation on the basis of smallholder experiences and the limitations of soil studies (Scoones and Toulmin, 1998; Mortimore and Harris, 2005), arguing instead that "soil fertility is a major constraint to production for some people in some places at some times" (Scoones, 1997, p162). Perpetuating this debate is the absence of any large-scale program to monitor soil degradation (Richter, 2007), though an effort to systematically map soil types across Africa is now underway (Sanchez et al., 2009). Also lacking are studies to assess the consequences of soil degradation for social and economic outcomes beyond agricultural production, particularly at the household scale. Together these lacunae leave unclear the extent to which soil degradation undermines the well-being of smallholder households in vulnerable regions such as the East African highlands.

Among potential social outcomes of soil degradation, human migration is of particular interest. A parallel debate has considered the extent to which a variety of forms of environmental change contribute to rural out-migration and population mobility. This issue rose to prominence with a widely-cited study by Myers (1997), who claimed that 25 million people were displaced by soil degradation and other forms of environmental change as of 1995. This specific claim has since largely been dismissed (Kniveton et al., 2008), but accumulating evidence of global environmental change has reinforced the salience of this issue (Laczko and Aghazarm, 2009; Warner, 2010). Only recently, however, have quantitative studies begun to address these claims by linking survey data on migration to high-resolution environmental datasets, with results that only partly support the assumption that environmental change is an important driver of migration (Henry et al., 2004; Massey et al., 2010). Very few of these studies have investigated the effects of soil quality on migration (Laurian et al., 1998; Gray, 2010), and none have used data from soil samples.

This study addresses both of these debates by evaluating the effects of soil quality on internal migration from grain-producing households in highland Kenya and Uganda. These two countries have featured prominently in the debate over the consequences of soil degradation and a large proportion of their populations are poor smallholders dependent on vulnerable soil resources (Ehui and Pender, 2005). The study takes advantage of a unique longitudinal survey dataset collected by the REPEAT project that includes data on both migration and soil properties for 1200 households (Matsumotoa et al., 2006). These data are used to build a household-level measure of soil quality and individual-level measures of temporary and permanent out-migration for labor and other reasons. Random effects multinomial logit models are then used to test the effects of soil quality on migration while controlling for a variety of individual and household characteristics. The results indicate that, consistent with common assumptions, out-migration declined with soil quality in Kenya, particularly for households with small farms. However, reflecting important differences between these two countries, migration in Uganda marginally increased with soil quality, consistent instead with the existence of a poverty trap.

2. Literature Review

2.1 Soils as Natural Capital

For agricultural households, soils can be thought of as a form of natural capital that supports rural livelihoods and complements reserves of human, social and physical capitals (Ellis, 2000). Physical, chemical and biological properties of soils all contribute to their suitability for agriculture or soil quality, and these properties vary over space and time at scales that are highly salient to household decision-making (Tittonell et al., 2005; Govaerts et al., 2006). Soil quality can also serve as a key form of household wealth and is an important contributor to land value (Gardner and Barrows, 1985). Just as for other forms of capital, households can also act to both improve and degrade soil quality. Inorganic or organic inputs can be applied to maintain or improve the quality of soils under cultivation, but unchecked erosion or continuous cultivation without inputs (e.g., soil mining) will eventually undermine the quality of even highly-productive agricultural soils (Kapkiyai et al., 1999; Richter et al., 2007).

In many agricultural regions of the developing world, declining soil quality or soil degradation is believed to be severe and widespread (Sanchez, 2002), though these claims are not without controversy (Mortimore and Harris, 2005). A common scenario, recognized by both sides of this debate, is that farmers are aware of soil quality decline but lack the capital to invest in soil amendments. Positive feedbacks can exacerbate this process in that falling agricultural yields can undermine the household's ability to invest in inputs, leading to further declines in soil quality (Shepherd and Soule, 1998). Some studies have also found biophysical thresholds in soil quality below which it is not profitable to invest in soil amendments (Antle and Stoorvogel, 2006; Marenya and Barrett, 2009). Together these processes could theoretically lead to the formation of poverty traps from which poor households with low soil quality could not escape (Barrett, 2008), though as of yet little empirical evidence exists for this outcome. Additionally, it is important to note that the operation of these processes is likely to differ significantly from site to site given important heterogeneity in underlying biophysical, social and economic conditions (Blaikie, 1985; Blaikie and Brookfield, 1987).

2.2 Soils and Migration

One option for households with low soil quality is to send temporary or permanent out-migrants, a decision which can generate additional income, reduce consumption in the origin household, and diversify household livelihood strategies against the risk of agricultural failure (Stark and Bloom, 1985). This process, in which poor environmental quality leads to out-migration, is consistent with a simple push-pull model of migration (Petersen, 1958) and with the expectations of the majority of the literature on environmentally-induced migration (Myers, 1997; Laczko and Aghazarm, 2009).

Multiple qualitative and quantitative studies have also documented a positive relationship between soil quality decline and rural out-migration. Among qualitative and small-scale studies, Zweifler et al. (1994) observed that migration, soil degradation and land scarcity jointly increased over a period of decades in a rural highland community in the Dominican Republic. Additionally, Warren et al. (2001) documented a positive correlation between soil erosion and male out-migration for a rural community in southwest Niger. Finally, Carr (2008) found that community members in two of three regions in rural Guatemala reported soil degradation as an important underlying cause of out-migration. Among quantitative studies, Laurian et al. (1998) showed that men's out-migration declined with self-reported high soil quality in the Ecuadorian Amazon but women's migration was not affected. Henry et al. (2003), using census data from Burkina Faso and a global map of soil degradation, found that out-migration increased with soil degradation. Finally, Massey et al. (2010) used longitudinal survey data from lowland Nepal to show that migration increased with perceived declines in agricultural productivity, particularly for low-caste individuals. The latter finding is consistent with the common view that poor and marginal populations will be more severely affected by adverse environmental conditions (Wisner et al. 2004).

The studies suggest that the most common relationship will be for out-migration to be higher where soil quality is poor. Nonetheless, both migration theory and a subset of previous studies indicate that the opposite effect is also possible, i.e. that out-migration might be higher where soil quality is high. The key theoretical issue is that the demands of migration, such as access to migrant networks and the cost of housing, can be high relative to household resources and thus create barriers for entry that exclude poor households from particular migration streams (White and Lindstrom, 2006). In extreme cases, a poverty trap might prevent agricultural households from both purchasing agricultural inputs *and* sending out-migrants. Consistent with the view are studies showing that international migrants often originate from land-rich households (Vanwey, 2005; Gray, 2009). Among studies of environmentally-induced migration, Henry et al. (2004) also found that international migration of men from Burkina Faso *decreased* with drought, and Halliday (2006) found that international migration from El Salvador *decreased* following an earthquake. Particularly relevant to this study, Gray (2010) found that international migration of women from Ecuador *decreased* with perceived soil erosion. These studies indicate that positive effects of soil quality on migration are possible, though this has not yet been demonstrated for the case of internal migration.

3. Data Collection and Study Area

3.1 Data collection

The survey and soils data were collected as part of the REPEAT project (Research on Poverty, Environment, and Agricultural Technology) based at the National Policy Institute for Graduate Studies in Tokyo, Japan (GRIPS) (Matsumoto et al., 2006)1. In both Kenya and Uganda, longitudinal interviews were conducted with approximately 900 households. In both cases, households were sampled from the respondents to a previous household survey, conducted by the International Livestock Research Institute in Kenya and by the International Food Policy Research Institute in Uganda. The first REPEAT survey in Kenya was conducted in 2004, and 899 households were interviewed from five highland provinces (Nyanza, Western, Rift Valley, Central and Eastern) and 99 rural sublocations2 (Yamano et al., 2005). An immediate follow-up survey was conducted in late 2004 with the same households, but data from both 2004 rounds are combined here and refered to collectively as the first round. A subsequent follow-up survey was conducted in 2007, and 777 households were successfully interviewed following the exclusion of 71 households from Eastern province for logistical reasons. In Uganda, the first round REPEAT survey was conducted in 2003, and 940 households were interviewed in 94 rural local councils in the Eastern, Central and Western regions (Yamano et al., 2004). The Northern region was excluded due to security issues. In 2005 a second round was conducted and 895 households were successfully re-interviewed. Rates of attrition were thus low and regression analyses of this process indicate that it was not significantly influenced by soil quality.

At the time of the first-round surveys (but not the second-round surveys), soil samples were collected from grain-producing households either from the largest plot maize or another grain-producing plot if maize was not grown. Samples were collected to a depth of 20 cm from five positions in the plot and mixed. Samples were then analyzed at the World Agroforestry Center using diffuse reflectance spectroscopy, a method which is particularly appropriate for large sample sizes (Matsumoto and Yamano, 2009). In this method, soil reflectance across near-infrared wavelengths is measured using a portable spectrometer. These values are then transformed into measures of soil chemical and physical properties using multivariate adaptive regression splines fit to samples which had also undergone traditional laboratory analysis. These models have R^2 values of 0.70–0.90 indicating a good fit (Shepherd and Walsh, 2002). The following soil properties were derived for each sample: percent carbon, percent nitrogen, extractable calcium, extractable potassium, extractable phosphorus, percent clay and pH. Following the exclusion of non-grain producing

[1]Additional information about the REPEAT project, including how to access the data, can be found here: http://www3.grips.ac.jp/~globalcoe/e/

[2]Kenyan sublocations and Ugandan local councils are both small administrative units containing one or more rural villages. For simplicity they are refered to jointly as “locations”.

households and the loss of a small number of soil samples, these data are available for 682 households in Kenya and 561 households in Uganda.

3.2 Study area

As described above and displayed in Figure 1, the study locations span the majority of the area of Uganda as well as the adjacent Kenyan highlands, the country's most populated region and agricultural center. This binational study area is notable for its high suitability for agriculture and dense rural populations relative to other parts of Sub-Saharan Africa (Pender et al., 2006). This study locations range from 1000–2700 meters above sea level and the climate ranges from semi-arid and subtropical to moist and temperate. The suitability of the soils for agriculture is moderate to high, and soil types include Oxisols, Ultisols, Inceptisols, and, in a few areas, Vertisols and Andisols (USDA, 2005). Smallholder agriculture is the primary land use and farm sizes are relatively small (5.6 acres on average in the study sample). Nutrient balance studies suggest that soil degradation is severe in many locations (Stoorvogel and Smaling, 1990; Nkonya et al., 2005), but farmers tend to perceive the problem as moderate (Kiome and Stocking, 1995; Adams and Watson, 2003) and some areas have notably escaped predictions of population-induced soil degradation (Tiffen et al., 1994; Carswell, 2002). Maize, beans and bananas are the primary subsistence crops, supplemented by income from cattle and milk production, cash crops such as coffee, and off-farm employment.

Temporary and permanent forms of migration are also important livelihood strategies in both Kenya and Uganda (Black et al., 2006). Both countries continue to be predominantly rural, and rural-rural migration is common, particularly in association with lifecourse transitions such as marriage (Black et al., 2006; Oucho, 2007). Both countries are also rapidly urbanizing, focused on the capital cities of Nairobi and Kampala, providing many opportunities for both temporary and permanent urban-bound migrants, who are disproportionately male and well-educated (Hoddinott, 1994; Agesa, 2001). Many temporary urban migrants repeatedly return to the same destination and source of employment, leaving their families in their place of origin (Bigsten, 1996; Matsumoto et al., 2006). Rates of international migration are low relative to internal migration (Black et al., 2006). Armed conflict in northern Uganda has also contributed to involuntary displacement (Vinck and Pham, 2009), but the affected areas were excluded from the REPEAT study.

Despite these commonalities, there are also important differences in the characteristics and contexts of the study households between Kenya and Uganda (Ehui and Pender 2005; Pender et al., 2006). In Kenya, especially in the central highlands near Nairobi, there is good access to urban markets and agricultural inputs, and many households have successfully diversified their livelihood strategies and intensified their agricultural and animal production, resulting in significantly higher standards of living. In contrast, in most of rural Uganda access to urban markets and agricultural inputs remains poor and standards of living are significantly lower. Uganda is also considerably more diverse both in terms of ethnicity and land tenure institutions. Nearly all agricultural land in Kenya is under private tenure, but in Uganda there are at least four distinct tenure systems (customary, *mailo*, freehold and leasehold), reflecting the historical experiences of different regions and varying packages of rights for owners versus users (Nkonya et al. 2008).

These differences are reflected in results from the first-round REPEAT surveys (Yamano et al., 2004; Matsumoto et al. 2006; Yamano et al., 2006; author's calculations). The consumption-based poverty rate was twice as high in Uganda (30%) as in Kenya (15%), and Ugandan homes were more often made of unimproved materials (mud walls, thatch roofs and earth floors). Ugandan adults on average also had fewer years of education (8.2) than Kenyans (5.7), and Ugandan households were more dependent on crop production, which represented 59% of their incomes. In contrast, Kenyan livelihoods were considerably more diversified, with non-farm employment, livestock, and migrant remittances providing 38%, 21% and 7% of household income respectively. Among Kenyan households, 80% used chemical fertilizers and 63% applied manure, whereas only 7% and 16% of Ugandan households used these inputs. Similarly, 68% of Kenyan cattle were from improved breeds, versus only 22% of Ugandan cattle.

Regarding ethnic and tenure diversity, seven ethnicities were represented among the Kenyan households and nearly half of households were Kikuyu, whereas the Ugandan households included members of 28 ethnicities with no dominant group. In Kenya, almost all agricultural plots were privately held (with 13% rented-in), whereas Ugandan plots were variously held under customary (46%) or freehold tenure (41%), will a smaller proportion under *mailo* tenure (13%). Consistent with evidence that all three Ugandan forms of tenure often serve as de facto individualized tenure (Nkonya et al. 2008), a majority of plot owners across all three types (64–81%) reported being able to sell their plots.

4. Analysis

The analysis of the effects of soil quality on migration proceeded in three steps as described below. First, the soils data were used to build a household-level measure of soil quality. Second, the survey data were used to build four individual-level measures of migration, which were linked in an individual-level dataset containing potential predictors of migration. Third, random effects multinomial logit models were used to examine the influences of soil quality and other factors on migration. Finally, I conclude with a discussion of the strengths and weaknesses of this approach.

4.1 Soil quality

To build a measure of soil quality, principal components analysis was used to construct an index of the seven measured soil properties. This is a common approach to reducing data dimensionality, and creates an index that maximizes the proportion of variance explained in the underlying data (Sena et al., 2002). Raw values of the seven soil measures are presented in Table 1. Consistent with previous studies, these values indicate the soils of the study area are relatively fertile overall but with considerable variability, particularly in Kenya. The values of five measures, those for carbon, nitrogen, calcium, potassium and phosphorus, were strongly right-skewed and thus were transformed by ln(x+1) prior to the analysis to reduce the influence of outlying values. To remove any influence of the scale of measurement, all seven measures were then standardized into z-scores prior to conducting the analysis. The results of the analysis indicate that the first principal component explained 50% of the variance and the variable loadings for this component are consistent with a measure of soil quality. The loading increases with the levels of carbon, nitrogen, calcium, potassium and phosphorus and decreases with the level of clay (Table 1). The value of the first principal component was rescaled to range from 0–10, and this value is referred to below as the soil quality index.

The soil quality index is also highly correlated with two other potential measures of soil productivity: the first principal component of the soil spectrometer readings across all wavelengths ($r = 0.92$), and a measure of soil organic matter which was measured using traditional laboratory techniques for the Uganda samples ($r = 0.82$). Both of these alternative measures have been linked to improved crop yields in previous analyses of the REPEAT data (Matsumoto et al., 2008; Yamano, 2008). These results suggest the highly-correlated soil quality index constructed here is also an appropriate measure, with the additional benefits of being available for both countries and being a transparent function of key soil

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properties. Robustness checks incorporating these alternative measures or equivalent indices derived separately for each country replicate the key features of the results presented below.

The soil quality index has a skewed and multimodal distribution that likely reflects nonlinear soil processes and the clustering of soil properties around discrete soil types (Figure 2). To simplify the interpretation of this measure, it is collapsed for the primary regression specification into a simple dichotomous indicator for index values greater than the global median (2.79). This indicator is referred to as high soil quality. To capture any limitations of this approach three alternative specifications are also tested: a linear specification using the raw soil quality index, a four-category indicator for the quartile of the soil quality distribution, and an equivalent dichotomous measure for soil carbon only, referred to as high soil carbon. Soil carbon is a key measure of soil quality that is particularly resistant to change over time (Kapkiya et al., 1999; Richter et al., 2007), and this measure is included to address the possibility that other measured soil properties might be responsive in the short-term to land management decisions and thus endogenous to household livelihood strategies (see section 4.4).

4.2 Migration

To characterize the diversity of population mobility in the study locations, four migration outcomes were constructed by drawing on a question about migration asked in both rounds of the survey and on the longitudinal aspect of the data. In the household roster, the survey recorded the number of months that each member had lived at home in the previous 12 months, and, for those who were absent, coded the motivation for their absence. Using the first-round survey, household members who had lived in the household for 1–11 months in the previous year were defined to be temporary migrants. These were further classified into those who had departed for employment-related reasons (labor migrants) and for other reasons (non-labor migrants) to create a multinomial outcome. Non-labor migration was most commonly for schooling, marriage or to live with other family members. Then, drawing on the longitudinal aspect of the data, individuals who were resident for one or more months at baseline but were resident for zero months at follow-up were defined to be permanent migrants, and again classified as labor or non-labor migrants based on the motivation for their absence. Individuals can be both temporary and permanent migrants if they were temporarily absent in the first round and fully absent in the second round. However only one motivation was recorded for each move, thus both temporary and permanent moves were classified as either labor-related or non-labor-related but not both. The destination of moves was not recorded, thus this definition likely includes some moves that would be excluded by a restrictive definition of migration (see section 4.4).

To analyze these outcomes, an individual-level dataset containing the migration measures was linked to the household-level measure of soil quality and several control variables, all measured in the first-round survey (Table 2). At the individual level, control variables include gender, age, relationship to the household head, marital status and years of education. At the household level these include household size, gender of the head, agricultural land area, and the value of livestock. As the latter two variables are censored at zero and right-skewed, these values were transformed by ln(x+1) prior to inclusion, and in both cases a squared term was added to allow for nonlinear effects. Examination of Table 2 reveals that, consistent with the description above, asset values and levels of education are higher in Kenya. However, both farm and household sizes are larger in Uganda, and overall soil quality is similar.

Together these controls account for the majority of important small-scale influences on migration that have been identified by previous studies (White and Lindstrom 2005). Preliminary analyses also explored the inclusion of measures of migrant networks at the level of the household and location (i.e., sublocation/local council), which were derived from reports of departures prior to the first-round REPEAT survey. Ultimately these were excluded because (1) household-level networks might reflect the effects of past soil quality, (2) location-level networks were not well measured for small and singleton clusters, (3) inclusion of these predictors did not substantially alter the effects of soil quality described below.

Preliminary regression models of the four outcomes revealed that rates of migration were very low for household heads, their spouses, and individuals under age 18 and over age 49, and they were thus excluded from the analysis as not at risk of migration. This finding and analytical approach are both consistent with previous studies (e.g., Hoddinott 1994; Gray 2009). Households without soils data were also excluded. The results can thus be interpreted as applying to individuals who are at risk for migration in grain-producing households. Following these exclusions, the dataset contains 1343 individuals from 518 households in Kenya and 778 individuals from 307 households in Uganda. Due to attrition and sample exclusions for the second-round surveys, the sample size for permanent migration is smaller, and includes 1013 individuals from Kenya and 654 individuals from Uganda.

Table 3 displays propensities of migration for the four migration streams stratified by country and by the dichotomous measure of soil quality. Chi-squared tests were used to compare migration propensities across soil quality categories, and adjusted for clustering at the level of the location. The results reveal that rates of temporary migration are much higher in Kenya, consistent with reports in the literature (Black et al., 2006). Additionally, approximately one half of temporary migration and one third of permanent migration are motivated by the search for employment. Comparisons between households with high and low soil quality reveal that temporary migration and labor-motivated temporary migration in particular were significantly lower from Kenyan households with high soil quality. Thus in Kenyan households with low soil quality 29% of all individuals were temporary migrants, versus 18% in households with high soil quality ($p < 0.001$). Permanent labor migration was also marginally lower from households with high soil quality in Kenya ($p = 0.07$). In contrast, permanent non-labor migration was marginally higher from households with high soil quality in Uganda ($p = 0.06$). These results suggest that soil quality influences migration in the study area, but the results do not account for any other individual, household or contextual characteristics that might be correlated with soil quality. These additional factors are accounted for using multivariate regression models as described below.

4.3 Regression models

Random effects multinomial logit models (Skrondal and Rabe-Hesketh 2004) were estimated to investigate the influences of soil quality on migration while accounting for other factors. This model is appropriate for categorical outcomes and, as described below, accounts for clustering and contextual effects at the level of the household, location and region. For this model, the outcome is coded 0 for no migration, 1 for labor migration, and 2 for non-labor migration. The model is estimated separately for temporary and permanent migration in both Kenya and Uganda, i.e. four versions of the model. The model has one equation for each form of migration (labor and non-labor), with the following form:

$$\log\left(\frac{\pi_{mij}}{1-\pi_{nij}}\right)=\beta_{m0}+\beta_{mk}X_{mijk}+\alpha_{mr}+e_{mj}$$

where π_{mij} is the odds of migration for individual i in household j for migration stream m (labor or non-labor migration), π_{nij} is the odds of no migration, β_{m0} is a stream-specific constant, β_{mk} is a vector of parameters for the effects of the independent variables (k), X_{mijk}

is a vector of the independent variables including soil quality, e_{mj} is a household-level random effect, and α_{mr} is a fixed effect for the region, defined as provinces in Kenya and administrative regions in Uganda. All models are also adjusted for clustering at the level of the location (Angeles et al. 2005). For presentation, coefficients are exponentiated (e^{β}) to create odds ratios, which can be interpreted as the multiplicative effect of a one unit increase in the predictor on the odds of migration. Predicted probabilities of migration can also be derived from this equation.

This model corrects for clustering and contextual effects at three levels: the household, the location and the region. The inclusion of household-level random effects accounts for any unobserved characteristics at the household level under the assumption that they are not correlated with the observed characteristics. The adjustment for clustering at the location level additionally corrects for any location-level correlation arising from the clustered sampling strategy. Finally, the inclusion of fixed effects at the regional level accounts for all large-scale contextual factors as long as the effects are linear. This collection of approaches thus accounts for household-level migration strategies, the clustered sampling strategy, and large-scale contextual influences on migration.

A supplementary set of models was also estimated to tested for interactions between soil quality and the other predictors, allowing the effects of soil quality to vary between population subgroups. This analysis provides insights into which groups are most vulnerable soil quality-induced migration, but should be considered exploratory given the large number of interaction terms that were separately tested for significance.

4.4 Strengths and Weaknesses of the Approach

The methodological approach described above has several notable strengths. First, the data are derived from a large, binational household survey with a longitudinal component, a type of data that is rarely available for analyses of agriculture and migration in the developing world. Second, the data are even more exceptional for including the results of household-level soil analyses, allowing the construction of multiple measures of biophysical soil quality that do not rely on self-reporting. Third, specific survey questions on migration and the longitudinal nature of the data permit the disaggregation of four different kinds of migration, better capturing the diversity of rural population mobility than many previous studies. Fourth, the use of random effects regression allows controls for variety of potential confounders as well as corrections for contextual effects at the household, location and regional scales.

However the methodological approach also has at least two weaknesses that should be noted, one specific and one general. The specific issue is that, as mentioned above, data on the distance and destination of moves was not collected, thus it is likely that some moves were to nearby destinations and would not be considered migration under a restrictive definition. This is more likely to be the case for moves made for non-labor-related reasons, such as marriage, relative to labor-related moves which are commonly made to distant destinations (Hoddinott, 1994; Agesa, 2001). The more general issue is that the analysis does not attempt to model potential feedbacks between migration and soil quality, i.e. the possibility that soil quality is endogenous to migration. This problem could arise if past migration influenced soil quality via a loss of access to agricultural labor or the investment of migrant remittances in soil amendments (Crowley and Carter, 2000; Warren et al., 2001). To address this problem, as described above, I have included a measure of soil carbon in an alternative specification of the regression model. Soil carbon is a long-term measure of soil quality that only changes slowly under agricultural management (Kapkiya et al., 1999; Richter et al., 2007), limiting the possibility that it could be endogenous to past migration.

5. Results

5.1 Kenya

The results for Kenya are presented in Table 4. First the results for the control factors and then the results for soil quality are discussed below. Overall the results of the control variables are consistent with previous studies from East Africa (Hoddinott, 1994; Bigsten, 1996; Agesa, 2001). At the individual level, women and married individuals were more likely to become non-labor migrants for both temporary and permanent moves, reflecting the role of women as the most frequent family-related movers and the ties of married individuals to multiple households. Migration was also strongly stratified by age with most moves peaking at ages 25–29, with the exception of permanent labor migration where rates were highest for ages 35–49. The effects of age were strongest for temporary labor migration, reflecting an important lifecourse dimension to this move, and weakest for temporary non-labor migration, consistent with moves to visit and assist other family members. Educated individuals were also more likely to move, particularly for temporary labor migration. Children of the head, with strong ties to the household, were more likely to make labor-related moves and less likely to make other types of moves.

Household-level control factors were not as consistently important but also had significant effects. Non-labor migration increased with household size, likely reflecting moves to live with other family members, but labor migration was not affected. Female headship did not influence migration. The nonlinear effects of land area and livestock value were jointly significant for permanent labor migration but not other migration streams. Permanent labor migration decreased with land area but at a decreasing rate. Consistent with the complex nonlinear effects of wealth seen in previous studies (e.g., VanWey, 2005), permanent labor migration is low for households with no livestock, increases to a maximum at $75 of livestock value (the 18th percentile for Kenya) and then declines slowly. Thus land appears to act as an amenity, retaining migrants, as does livestock above a minimum value that is necessary to migrate, likely due to migration costs.

Consistent with the descriptive results in Table 3, soil quality had negative effects on migration that were most important for temporary labor migration. In the primary specification with the dichotomous indicator for high soil quality, the odds of temporary labor migration were 67% lower for households with high soil quality ($p < 0.001$) and the odds of permanent labor migration were 42% lower ($p = 0.041$). High soil quality was also associated with marginally lower odds of temporary non-labor migration ($p = 0.098$), and had a negative but non-significant effect on permanent labor migration. The negative effect on temporary labor migration was also evident in the three alternative specifications: temporary labor migration decreased with the linear quality index, was lower for the highest two quartiles of soil quality, and was also significantly lower for households with high soil carbon. Thus there is a clear negative effect of soil quality on temporary labor migration and some evidence for negative effects on other migration streams.

5.2 Uganda

The results for Uganda are presented in Table 5. Overall the results are not as strong as those for Kenya, reflecting the smaller sample size, but an interesting story emerges nonetheless regarding soil quality as described below. Among the control factors, gender did not have significant effects but age was again important. Temporary labor migration and permanent non-labor migration peaked at ages 25–29, permanent labor migration peaked at ages 30–34, and temporary non-labor migration was not affected, similar to the pattern for Kenya. Non-labor temporary migration was again higher for married individuals, though relationship to the head was unimportant. Permanent non-labor migration also unexpectedly decreased with education, potentially reflecting lower family-related mobility for individuals with access to skilled employment.

At the household level, temporary non-labor migration and permanent labor migration both unexpectedly decreased with household size, which may reflect lower per capita resources in these households that are available to invest in migration. The nonlinear effects of land area and livestock value were jointly significant only for temporary labor migration, with a similar pattern to that of permanent labor migration in Kenya. Temporary labor migration decreased at a decreasing rate with land area, and increased rapidly with livestock value to a maximum at \$20 (at the 20^{th} percentile for Kenya) and then declined.

In contrast to Kenya but consistent with the descriptive results, soil quality had marginally positive effects on migration, specifcally for permanent non-labor migration. In the primary specification, the odds of permanent non-labor migration were 91% higher from households with high soil quality (p = 0.081). This effect was also evident in the linear, categorical and carbon-only specifications.

5.3 Interaction models

A supplementary set of exploratory models also tested for interactions between soil quality and the other predictors in all four models. Consistent with expectations, the interaction between soil quality and land area emerged as the most important interaction, and was jointly significant for the case of permanent labor migration in Kenya (p = 0.019). Given the large number of interaction coefficients that were tested for significance as part of this exploratory analysis, these results should not be considered as definitive but instead as a point of departure for future studies. To present the results of the interaction between soil quality and land area, predicted probabilities of permanent labor migration were derived for households with high and low soil quality using mean values of the other predictors from the Kenyan sample (Figure 3). This reveals that permanent labor migration is low for households with high soil quality and low for land-rich households with low soil quality, but very high for land-poor households with low soil quality.

6. Discussion

Taken together, the results provide strong evidence that soil quality is associated with reduced migration in Kenya, particularly for temporary labor migration, and weak evidence that soil quality is associated with increased migration in Uganda, most clearly for permanent non-labor migration. The pattern in Kenya suggests that households respond to low soil quality, and consequently reduced agricultural yields, by sending temporary migrants as a way to generate additional household income. Temporary migration is a common strategy in Kenya (Table 3) that likely has low barriers to entry, potentially explaining how even households with poor soil quality can afford to participate. In contrast in Uganda, the pattern is less clear but the results suggest that low soil quality reduces households' ability to send permanent non-labor migrants for reasons such as marriage and schooling. Due to costs such as housing, school fees and bridewealth, these forms of mobility may have relatively high barriers to entry, perhaps explaining why households with poor soil quality might be excluded.

The divergent results reflect the quite different economic contexts of these two countries and reinforce Blaikie and Brookfield's (1987) claim that land degradation is always contextual. In Kenya, temporary migration is a common livelihood strategy and there are substantial opportunities for agricultural intensification and diversification (section 3.2). In this context, households with low soil quality can afford to send migrants, with the knowledge that they will be able to profitable invest the wages on their farms. Households with small farms appear to be most affected, consistent with expectations that poor households would be more vulnerable to environmentally-induced migration (Wisner et al., 2004). In Uganda, in contrast, households have access to fewer resources and fewer opportunities for both temporary migration and agricultural intensification. In this context, it appears that soil quality enables costly permanent migrations as a form of capital. This result is consistent with the existence of a poverty trap which restricts participation in both migration and agricultural intensification for Ugandan households (Barrett 2008), though confirmation of this process will require additional empirical research.

7. Conclusions

The findings of this study have important implications for theories of environmentally-induced migration, for research methods in this field, and for development policy in Kenya and Uganda. Regarding theories of environmentally-induced migration, the results contribute to a growing number of empirical studies indicating that while adverse environmental conditions typically increase migration (section 2.2), local and temporary moves are often most affected, and effects can also occur in the opposite direction. Thus Henry et al. (2004) found that migration could decrease with drought, Halliday (2006) found that migration could decease following a natural disaster, and Massey et al. (2010) found that local moves were most affected by environmental conditions. Similarly, this study finds that temporary moves were most affected in Kenya, and that migration marginally increased with soil quality in Uganda. Together these studies highlight the contextually contingent nature of migration-environment relationships, and suggest that skepticism is warranted for broad narratives that predict large-scale and long-distance displacements due to soil degradation or other forms of local environmental change (e.g., Myers, 1997).

Regarding research methods in this field, this study adds to a small number of previous studies which have combined household surveys, environmental data sources and multivariate analyses to examine environmental influences on human migration (Henry et al., 2004; Gray, 2009). This approach addresses the need for a robust, generalizable methodology in this field, where sophisticated empirical applications have lagged significantly behind the high level of interest by academics and policy-makers (Kniveton et al., 2008). Regarding soil quality specifically, empirical research would clearly benefit from additional household surveys that collect matched soil samples, as implemented in the REPEAT project and facilitated by spectroscopic methods of soil analysis (Yamano et al. 2004; Yamano et al. 2005). Future efforts should additionally consider collecting subjective reports of soil quality, enabling comparisons between the two data sources (Mairura et al., 2008), as well as repeating soil sampling in the same locations. The latter approach would enable a variety of analyses of how soil quality, livelihood strategies, and household well-being interact over time, including potential feedbacks between soil degradation and migration.

Finally, this study also has important implications for development policy in Kenya and Uganda. In Kenya, land-poor households with low soil quality appear to be particularly dependent on labor and temporary migration. This result suggests that expanding opportunities for labor migration, such as through the construction of rural infrastructure (Pender et al., 2006), will likely benefit vulnerable households without leading to rural depopulation. In Uganda, access to chemical fertilizers is very poor (Yamano et al., 2004), and potentially contributes to rural households being caught in a poverty trap. Policies that increase access to chemical fertilizers and other agricultural inputs via targeted subsidies, removal of trade barriers or improvements in infrastructure are needed to increase agricultural productivity and reduce rural poverty (Matsumoto and Yamano, 2009).

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References

Adams W, Watson E. Soil erosion, indigenous irrigation and environmental sustainability, Marakwet, Kenya. Land Degradation and Development. 2003; 14(1):109–122.

Agesa R. Migration and the urban to rural earnings difference: A sample selection approach. Economic Development and Cultural Change. 2001; 49(4):847–865.

Angeles G, Guilkey D, Mroz T. The impact of community-level variables on individual-level outcomes: Theoretical results and applications. Sociological Methods and Research. 2005; 34(1): 76–121.

Antle J, Stoorvogel J. Multiple equilibria, soil conservation investments, and the resilience of agricultural systems. Environment and Development Economics. 2006; 11(4):477–492.

Barrett, C. Poverty traps and resource dynamics in smallholder agrarian systems. In: Dellink, R.; Ruijs, A., editors. Economics of Poverty, Environment and Natural-Resource Use. Springer; 2008. p. 17-40.

Bigsten A. The circular migration of smallholders in Kenya. Journal of African Economies. 1996; 5(1):1–20. [PubMed: 12320851]

Black, R.; Crush, J.; Peberdy, S. Migration and development in Africa: An overview. Idasa Publishing; 2006.

Blaikie, P. The Political Economy of Soil Erosion in Developing Countries. Longman; 1985.

Blaikie, P.; Brookfield, H. Land Degradation and Society. Methuen; 1987.

Carr D. Migration to the Maya Biosphere Reserve, Guatemala: Why place matters. Human Organization. 2008; 67(1):37–48. [PubMed: 19657470]

Carswell G. Farmers and fallowing: Agricultural change in Kigezi District, Uganda. Geographical Journal. 2002; 168(2):130–140.

Crowley E, Carter S. Agrarian change and the changing relationships between toil and soil in Maragoli, Western Kenya (1900–1994). Human Ecology. 2000; 28(3):383–414.

Ehui S, Pender J. Resource degradation, low agricultural productivity, and poverty in sub-Saharan Africa: Pathways out of the spiral. Agricultural Economics. 2005; 32(S1):225–242.

Ellis, F. Rural Livelihoods and Diversity in Developing Countries. Oxford University Press; 2000.

Gardner K, Barrows R. The impact of soil conservation investments on land prices. American Journal of Agricultural Economics. 1985; 67(5):943–947.

Govaerts B, Sayre K, Deckers J. A minimum data set for soil quality assessment of wheat and maize cropping in the highlands of Mexico. Soil and Tillage Research. 2006; 87(2):163–174.

Gray C. Environment, land and rural out-migration in the southern Ecuadorian Andes. World Development. 2009; 37(2):457–468.

Gray C. Gender and rural out-migration in the southern Ecuadorian Andes. Environment and Planning A. 2010; 42(3):678–696.

Halliday T. Migration, risk, and liquidity constraints in El Salvador. Economic Development and Cultural Change. 2006; 54 (4):893–925.

Henry S, Boyle P, Lambin E. Modelling inter-provincial migration in Burkina Faso, West Africa: The role of socio-demographic and environmental factors. Applied Geography. 2003; 23(2–3):115–136.

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

Hoddinott J. A model of migration and remittances applied to western Kenya. Oxford Economic Papers. 1994; 46(3):459–476.

Kapkiyai J, Karanja N, Qureshi J, Smithson P, Woomer P. Soil organic matter and nutrient dynamics in a Kenyan nitisol under long-term fertilizer and organic input management. Soil Biology and Biochemistry. 1999; 31(13):1773–1782.

Kiome R, Stocking M. Rationality of farmer perception of soil erosion: The effectiveness of soil conservation in semi-arid Kenya. Global Environmental Change. 1995; 5(4):281–295.

Kniveton, D.; Schmidt-Verkerk, K.; Smith, C.; Black, R. Migration Research Series No. 33. International Organization for Migration; 2008. Climate change and migration: Improving methodologies to estimate flows.

Laczko, F.; Aghazarm, C. Migration, Environment and Climate Change: Assessing the Evidence. International Organization for Migration; 2009.

Laurian L, Bilsborrow R, Murphy L. Migration decisions among settler families in the Ecuadorian Amazon: The second generation. Research in Rural Sociology and Development. 1998; 7:169–195. [PubMed: 12294796]

Mairura F, Mugendi D, Mwanje J, Ramisch J, Mbugua P, Chianu J. Scientific evaluation of smallholder land use knowledge in Central Kenya. Land Degradation and Development. 2008; 19(1):77–90.

Marenya P, Barrett C. Soil quality and fertilizer use rates among smallholder farmers in western Kenya. Agricultural Economics. 2009; 40(5):561–572.

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

Matsumoto T, Kijima Y, Yamano T. The role of local nonfarm activities and migration in reducing poverty: evidence from Ethiopia, Kenya, and Uganda. Agricultural Economics. 2006; 35(S3):449–458.

Matsumoto, T.; Yamano, T. Soil fertility, fertilizer, and the maize green revolution in East Africa. World Bank Policy Research; 2009. Working Paper 5158. http://ssrn.com/abstract=1527368

Matsumoto, T.; Yamano, T.; Nyoro, J. Intensification of maize production in Kenya and Uganda. Centre for the Study of African Economies Conference; Oxford: 2008 March 16–18. http://www.csae.ox.ac.uk/conferences/2008-EDiA/papers/256-Matsumoto.pdf

Mortimore M, Harris F. Do small farmers' achievements contradict the nutrient depletion scenarios for Africa? Land Use Policy. 2005; 22(1):43–56.

Myers N. Environmental refugees. Population and Environment. 1997; 19(2):167–182.

Nkonya E, Kaizzi C, Pender J. Determinants of nutrient balances in a maize farming system in eastern Uganda. Agricultural Systems. 2005; 85(2):155–182.

Nkonya, E.; Pender, J.; Kaizzi, K.; Kato, E.; Mugarura, S.; Ssali, H.; Muwonge, J. Linkages between Land Management, Land Degradation, and Poverty in Sub-Saharan Africa: The Case of Uganda. International Food Policy Research Institute; 2008.

Pender, J.; Place, F.; Ehui, S. Strategies for Sustainable Land Management in the East African Highlands. International Food Policy Research Institute; 2006.

Petersen W. A general typology of migration. American Sociological Review. 1958; 23(3):256–266.

Richter D. Humanity's transformation of Earth's soil: Pedology's new frontier. Soil Science. 2007; 172(12):957–967.

Richter D, Hofmockel M, Callaham M, Powlson D, Smith P. Long-term soil experiments: Keys to managing Earth's rapidly changing ecosystems. Soil Science Society of America Journal. 2007; 71(2):266–279.

Sanchez P. Soil fertility and hunger in Africa. Science. 2002; 295(5562):2019–2020. [PubMed: 11896257]

Sanchez P, Ahamed S, Carré F, Hartemink A, Hempel J, Huising J, Lagacherie P, McBratney A, McKenzie N, Mendonça-Santos M, Minasny B, Montanarella L, Okoth P, Palm C, Sachs J, Shepherd K, Vågen T, Vanlauwe B, Walsh M, Winowiecki L, Zhang G. Digital soil map of the world. Science. 2009; 325(5941):680–681. [PubMed: 19661405]

Scoones I. The dynamics of soil fertility change: Historical perspectives on environmental transformation from Zimbabwe. The Geographical Journal. 1997; 163(2):161–169.

Scoones I, Toulmin C. Soil nutrient balances: What use for policy? Agriculture, Ecosystems and Environment. 1998; 71(1–3):255–267.

Sena M, Frighetto R, Valarini O, Tokeshi H, Poppi R. Discrimination of management effects on soil parameters by using principal component analysis: A multivariate analysis case study. Soil and Tillage Research. 2002; 67(2):171–181.

Shepherd K, Soule M. Soil fertility management in west Kenya: dynamic simulation of productivity, profitability and sustainability at different resource endowment levels. Agriculture, Ecosystems and Environment. 1998; 71(1–3):131–145.

Shepherd K, Walsh M. Development of reflectance spectral libraries for characterization of soil properties. Soil Science Society of American Journal. 2002; 66(3):988–98.

Skrondal, A.; Rabe-Hesketh, S. Generalized Latent Variable Modeling: Multilevel, Longitudinal, and Structural Equation Models. CRC Press; 2004.

Stocking M. Tropical soils and food security: The next 50 years. Science. 2003; 302(5649):1356–1359. [PubMed: 14631030]

Stoorvogel, J.; Smaling, E. Report 28 DLO Winand starring Center for integrated land, soil and water research (CSCDLO). Wageningen; Netherlands: 1990. Assessment of soil nutrient depletion in Sub-Saharan Africa 1983–2000.

Stark O, Bloom D. The new economics of labor migration. American Economic Review. 1985; 75(2): 173–178.

Tiffen, M.; Mortimore, M.; Gichuki, F. More people, less erosion: Environmental recovery in Kenya. John Wiley and Sons; 1994.

Tittonell P, Vanlauwe B, Leffelaar P, Rowe E, Giller K. Exploring diversity in soil fertility management of smallholder farms in western Kenya: I. Heterogeneity at region and farm scale. Agriculture, Ecosystems and Environment. 2005; 110(3–4):149–165.

USDA. Global Soil Regions Map. 2005. http://soils.usda.gov/use/worldsoils/mapindex/order.html

VanWey L. Land ownership as a determinant of international and internal migration in Mexico and internal migration in Thailand. International Migration Review. 2005; 39(1):141–172.

Vinck P, Pham P. Peacebuilding and displacement in Northern Uganda: A cross-sectional study of intentions to move and attitudes towards former combatants. Refugee Survey Quarterly. 2009; 28(1):59–77.

Warner K. Global environmental change and migration: Governance challenges. Global Environmental Change. 2010; 20(3):402–413.

Warren A, Batterbury S, Osbahr H. Soil erosion in the West African Sahel: A review and an application of a ‘local political ecology’ approach in South West Niger. Global Environmental Change. 2001; 11(1):79–95.

White, M.; Lindstrom, D. Internal migration. In: Poston, D.; Micklin, M., editors. Handbook of Population. New York: Kluwer Academic Publishers; 2005.

Wisner, B.; Blaikie, P.; Cannon, T.; Davis, I. At Risk: Natural Hazards, People’s Vulnerability and Disasters. Routledge; 2003.

Yamano, T. Dairy-banana integration and organic fertilizer use in Uganda. GRIPS Policy Information Center; 2008. Discussion Paper 08-03. http://www3.grips.ac.jp/~pinc/data/08-03.pdf

Yamano, T.; Otsuka, K.; Place, F.; Kijima, Y.; Nyoro, J. The 2004 REPEAT survey in Kenya (First Wave), Results. GRIPS Development Database No. 1. 2005. http://www3.grips.ac.jp/~globalcoe/e/index.html

Yamano, T.; Sserunkuuma, D.; Otsuka, K.; Omiat, G.; Ainembabazi, J.; Shimamura, Y. The 2003 REPEAT survey in Uganda: Results. Foundation for Advanced Studies on International Development Development Database 2004-09-01. 2004. http://www3.grips.ac.jp/~globalcoe/e/index.html

Zweifler M, Gold M, Thomas R. Land use evolution in hill regions of the Dominican Republic. The Professional Geographer. 1994; 46(1):39–53.

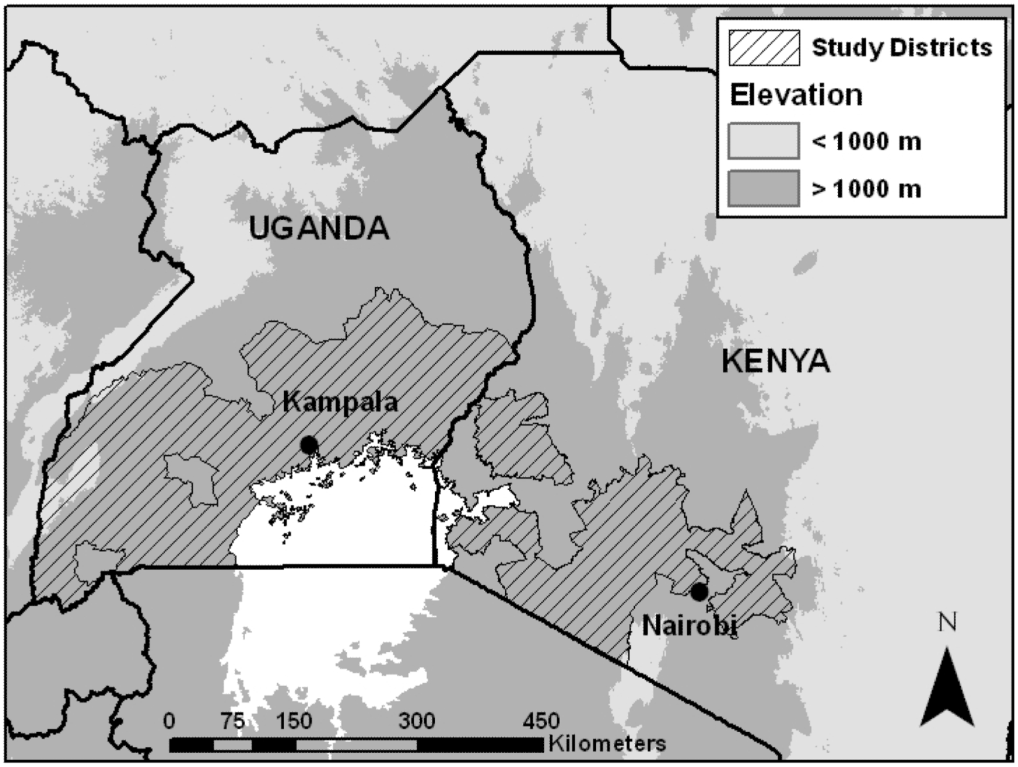

Figure 1.
Map of the study area.

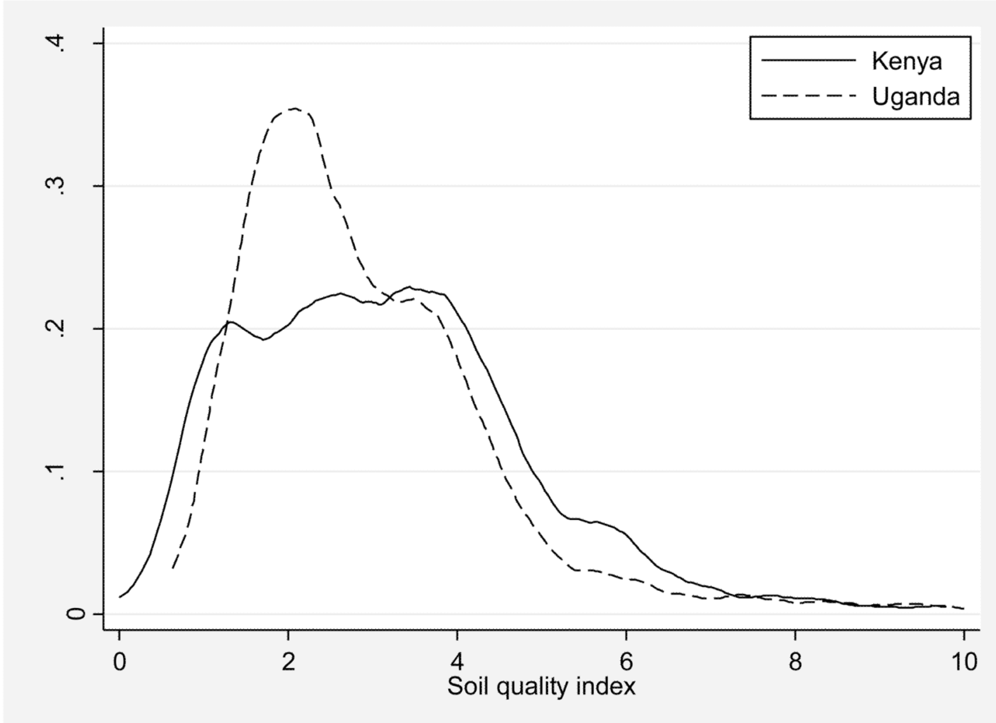

Figure 2.
Kernel density of the soil quality index in Kenya and Uganda.

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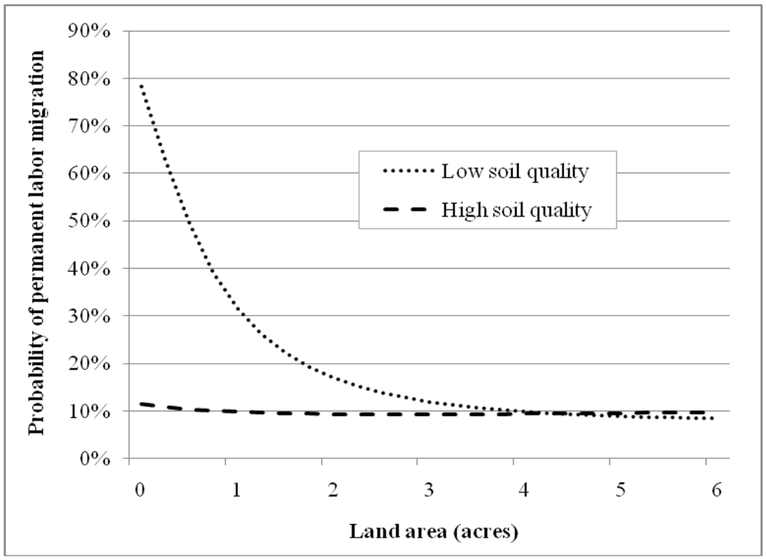

Figure 3.
Predicted probabilities of permanent labor migration in Kenya by land area and soil quality.

Table 1

Results of the principal components analysis of soil quality.

Soil property	Mean values (and standard deviations) Full sample	Kenya	Uganda	PCA loading
Carbon (%)[a]	2.41 (1.49)	2.43 (1.50)	2.38 (1.49)	0.50
Nitrogen (%)[a]	0.22 (0.14)	0.22 (0.13)	0.23 (0.14)	0.47
Extractable calcium (cmolc/kg)[a]	7.50 (6.05)	7.76 (6.08)	7.18 (6.01)	0.33
Extractable potassium (cmolc/kg)[a]	0.84 (1.33)	0.99 (1.76)	0.66 (0.33)	0.42
Extractable phosphorus (cmolc/kg)[a]	13.5 (10.5)	14.7 (11.9)	12.1 (8.2)	0.32
Clay (%)[b]	28.1 (4.0)	28.6 (4.2)	27.6 (3.8)	−0.38
pH[b]	6.39 (0.61)	6.19 (0.61)	6.63 (0.51)	−0.01
$N_{households}$	1,243	682	561	1,243

[a]Transformed by ln(x+1) and standardized to z-scores prior to analysis.

[b]Standardized to z-scores prior to analysis

Table 2

Mean values of the regression predictors for individuals at risk of migration.

Predictor	Full sample	Kenya	Uganda
Individual controls			
Female (0/1)	0.48	0.48	0.47
Age 18–19 (0/1)[a]	0.23	0.20	0.28
Age 20–24 (0/1)	0.40	0.41	0.39
Age 25–29 (0/1)	0.19	0.21	0.15
Age 30–24 (0/1)	0.08	0.10	0.07
Age 35–49 (0/1)	0.10	0.09	0.12
Child of head (0/1)	0.72	0.77	0.63
Married (0/1)	0.22	0.20	0.26
Years of education	8.86	9.58	7.61
Household controls			
Household size (#)	9.86	8.34	12.49
Female head (0/1)	0.21	0.24	0.15
Land area (acres)	7.07	5.16	10.37
Livestock value (US$)	584	607	543
Soil quality			
High soil quality (0/1)	0.49	0.50	0.48
Soil quality score	3.05	3.04	3.07
Soil quality Q1 (0/1)	0.27	0.30	0.22
Soil quality Q2 (0/1)[a]	0.24	0.20	0.29
Soil quality Q3 (0/1)	0.22	0.21	0.25
Soil quality Q4 (0/1)	0.27	0.29	0.24
High soil carbon (0/1)	0.50	0.49	0.51
$N_{individuals}$	2121	1343	778

[a]Reference category.

Table 3

Propensities of temporary and permanent migration by migration stream, country and soil quality.

Country	Migration stream	Full sample	Low soil quality	High soil quality	Low vs. High	Sample size	Number of moves
		Propensities of migration					
Kenya	Temporary, all	52%	59%	45%	***	1343	692
	Temporary, labor	24%	29%	18%	***		317
	Temporary, non-labor	28%	29%	27%			375
	Permanent, all	37%	40%	35%		1013	371
	Permanent, labor	12%	15%	11%	+		126
	Permanent, non-labor	24%	24%	24%			245
Uganda	Temporary, all	11%	10%	11%		778	82
	Temporary, labor	4%	4%	5%			32
	Temporary, non-labor	6%	6%	7%			50
	Permanent, all	28%	25%	32%		654	186
	Permanent, labor	7%	7%	7%			46
	Permanent, non-labor	21%	18%	25%	+		140

+ $p < 0.10$,

* $p < 0.05$,

** $p < 0.01$,

*** $p < 0.001$

Table 4

Odds ratios and significance tests from the multinomial logistic regression models of temporary and permanent migration in Kenya.

	Temporary		Permanent	
Predictor	**Labor**	**Non-labor**	**Labor**	**Non-labor**
Individual controls				
Female	1.21	2.09 ***	0.70 +	2.12 ***
Age 20–24	3.15 ***	1.42 *	2.34 *	2.09 **
Age 25–29	7.28 ***	1.56 +	3.43 **	3.55 ***
Age 30–34	4.95 ***	1.19	3.73 **	2.39 *
Age 35–49	4.32 ***	1.39	4.32 *	1.55
Child of head	1.73 *	0.50 **	1.38	0.62 +
Married	1.49	2.09 **	0.50 +	2.11 *
Years of education	1.11 ***	1.06 *	1.07 +	0.99
Household controls				
Household size	1.04	1.09 **	1.05	1.11 **
Female head	0.95	1.19	0.92	1.12
Ln(land area+1)	0.48	0.74	0.21 **	1.00
Ln(land area+1)^2	1.24 +	1.06	1.45 **	0.97
Ln(livestock value+1)	1.34	0.99	2.21 *	1.11
Ln(livestock value+1) ^{2}	0.96	1.01	0.91 *	0.98
Soil quality				
High soil quality	0.33 ***	0.65 +	0.58 *	0.67
Fixed and random effects				
Regional fixed effects (χ^2)	11.32 *	10.46 *	4.72	6.54 +
HH random effects (e_{mj})	2.27 ***		2.89 ***	
$\mathbf{N}_{\text{invidiuals}}$	1337		1010	
Alternative specification 1				
Soil quality score	0.82 *	0.95	0.94	0.96
Alternative specification 2				
Soil quality Q1	0.68	0.74	0.94	1.38
Soil quality Q3	0.29 ***	0.64 +	0.51 +	0.69
Soil quality Q4	0.33 ***	0.59 +	0.62	0.72
Joint test (χ^2)	16.49 ***	3.67	4.37	1.90
Alternative specification 3				
High soil carbon	0.57 *	0.71	0.66	0.82

Reference categories are age 18–19 and soil quality Q2.

$^+$ $p < 0.10$,

* $p < 0.05$,

** $p < 0.01$,

*** $p < 0.001$

Table 5

Odds ratios and significance tests from the multinomial logistic regression models of temporary and permanent migration in Uganda.

	Temporary		Permanent	
Predictor	**Labor**	**Non-labor**	**Labor**	**Non-labor**
Individual controls				
Female	0.53	1.43	0.50	0.97
Age 20–24	2.34	0.88	3.80*	2.45*
Age 25–29	6.80**	1.32	4.69*	3.64**
Age 30–34	5.67*	1.18	9.63**	1.36
Age 35–49	2.28	0.85	1.82	0.55
Child of head	0.80	1.17	1.32	0.64
Married	0.99	6.47***	1.20	1.48
Years of education	1.05	0.98	1.06	0.92*
Household controls				
Household size	1.05	0.76***	0.90**	0.97
Female head	1.84	1.35	0.62	0.43+
Ln(land area+1)	0.25+	1.77	1.39	1.21
Ln(land area+1)^2	1.38**	0.88	0.94	0.88
Ln(livestock value+1)	1.92+	1.03	0.66	0.94
Ln(livestock value+1)^2	0.90**	0.99	1.04	1.01
Soil quality				
High soil quality	1.48	1.32	1.60	1.91+
Fixed and random effects				
Regional fixed effects (χ^2)	8.45*	6.17*	4.35	0.08
HH random effects (e_{mj})	2.97***		5.26***	
N$_{\text{invidiuals}}$	654			
Alternative specification 1				
Soil quality score	1.34*	0.99	1.15	1.25*
Alternative specification 2				
Soil quality Q1	1.11	1.40	1.43	1.36
Soil quality Q3	0.95	2.16	2.01	1.91
Soil quality Q4	2.25	0.93	1.76	2.51*
Joint test (χ^2)	2.73	2.30	2.10	4.22
Alternative specification 3				
High soil carbon	1.30	0.89	1.60	2.00+

Reference categories are age 18–19 and soil quality Q2.

+ $p < 0.10$,

*$p < 0.05$,

**$p < 0.01$,

***$p < 0.001$