Migration and Climate Change in Rural Africa

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Summary

We analyse whether migration is an adaptation that households employ to cope with climate in Ghana and Nigeria. If migration is part of the present adaptation portfolio of households in developing countries, it is reasonable to expect that it will also be an adaptation to future climate change. It is important to stress that we are interested in long-term climatic conditions rather than in short-term weather fluctuations. The data to test these predictions are drawn from two different household surveys: the Nigeria General Household Survey and the Ghana Living Standard Survey. We find a hill-shaped relationship between temperature in the dry season and the propensity to migrate in households that operate farms. We also find a significant hill-shaped relationship between precipitations in the wet seasons and the propensity to migrate in farm households. Climate has instead no significant impact on the propensity to migrate in non-farm households. Climate change scenarios generated by General Circulation model reveal that, ceteris paribus, migration may decline in Ghana and in Nigeria.

Keywords: Climate Change Impacts, Migration, Development Economics
JEL Classification: O15, Q54, R23

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Migration and climate change in rural Africa *

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February 11, 2015

Abstract

We analyse whether migration is an adaptation that households employ to cope with climate in Ghana and Nigeria. If migration is part of the present adaptation portfolio of households in developing countries, it is reasonable to expect that it will also be an adaptation to future climate change. It is important to stress that we are interested in long-term climatic conditions rather than in short-term weather fluctuations. The data to test these predictions are drawn from two different household surveys: the Nigeria General Household Survey and the Ghana Living Standard Survey. We find a hill-shaped relationship between temperature in the dry season and the propensity to migrate in households that operate farms. We also find a significant hill-shaped relationship between precipitations in the wet seasons and the propensity to migrate in farm households. Climate has instead no significant impact on the propensity to migrate in non-farm households. Climate change scenarios generated by General Circulation model reveal that, ceteris paribus, migration may decline in Ghana and in Nigeria.

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1 Introduction

The scientific evidence that climate is changing produced a lively interest among scholars regarding the economic effects of climate change.

In this paper we study how climate affects migration decisions of households in Ghana and Nigeria. If migration is part of the present adaptation portfolio of households to different climatic conditions, it is reasonable to expect that it will also be an adaptation to climate change. Thus, with this paper we also provide estimates of the expected impact of future climate change on migration in Ghana and Nigeria.

It is important to stress that we are interested in climate — the average of weather conditions over a long period of time — rather than in short-term weather fluctuations, which represent single realizations of climate. Our approach thus accounts for the long-run adaptation response to climate. The existing literature has instead mainly focused on the relationship between weather variability as well as weather extreme shocks, such as flood or drought, and migration. Overall this literature finds moderate evidence that out-migration is a response to agricultural productivity losses due to harmful weather events.

For example, Feng et al. (2010) find that weather shocks that reduce crop yields in Mexico increase emigration to the United States. However, Auffhammer and Vincent (2012) demonstrate that this effect vanishes if one appropriately accounts for time effects. Gray and Mueller (2012a) study the effects of flooding on individual mobility. The authors report that, despite the expectations of a positive influence, flood fails to increase mobility in Bangladesh. Lower available resources and increased labour need after the shock may explain such finding. Bohra-Mishra et al. (2014) report that weather fluctuations more than sudden climatic disasters influence household permanent migration in Indonesia. Dillon et al. (2011) find that in Nigeria the likelihood of migration increases with greater temperature variability, which proxies for ex-ante unanticipated shocks. Moreover, male migration is positively influenced by hot ex-post shocks. Mueller, Gray and Kosec (2014) find that heat stress rather than high rainfall, flooding or moisture, are responsible for migration in Pakistan.

In Brazil, Mueller and Osgood (2009) find mixed results. They report that climate shocks, expressed as the deviation from the mean precipitation, encourage migration if the shock occurred one to four years prior the year of migration. On the contrary, shocks that realized in the far past, namely more than five years before, discourage emigration. The authors reconcile these mixed findings arguing that the sample of migrants is composed by households which have been pushed to migrate due to the shocks as well as by households which have been attracted by urban employment opportunities. Different studies relate exposure to drought and migration. Gray and Mueller (2012b) find that drought increases men's labor migration in Ethiopia. Henry et al. (2004) for Burkina Faso report increased migration as a consequence of scarce precipitations.

Barrios et al. (2006) from a macro-perspective analyse the link between average annual rainfall and urbanization rate in Sub-Saharan countries. The paper finds that a decrease in precipitation is a strong determinant of migration to urban areas. Marchiori et al. (2012) estimate that temperature and rainfall anomalies produced the displacement of 5 million people between 1960 and 2000 in Sub-Saharan Africa. Beine and Parsons (2015) on the contrary, find that neither natural disasters nor deviations and volatilities of temperatures and rainfall from their mean have a statistically significant effect on emigration in a panel of 137 origin countries. Having accounted for other determinants of emigration, including GDP, what the paper finds is that there is no direct effect of weather on emigration, by the effect of weather fully absorbed in the other (economic) controls.

The analysis of migration response to weather variation and shocks is a very interesting area of research but the estimated elasticities should not be used to estimate the response to slowly changing climate patterns. Short-term responses may either overestimate or underestimate the long-run response. In the short-run households may react by implementing adaptations that are viable only in the short-term. For example farmers may implement non-sustainable management activities. In this case the short-run response is flatter than the long-run response. Alternatively, in the short-run households do not have the time to invest into adaptations that would alleviate the impact of a persistent change in weather. In this case the short-run response is steeper than the long-run response. By looking at the long-run relationship between climate and migration our goal is to provide a more accurate characterization of how climate change may alter long-run migration decisions.

To our knowledge, only few papers have studied how climate affects migration. Munshi (2003) reports that low rainfall in rural Mexico is associated with larger emigration to the United States. Gray (2009) for Ecuador introduces in an individual migration regression a time-invariant value of community mean annual precipitation. While both internal and international migration are found to decrease with community precipitation, the authors report that negative environmental conditions do not necessarily increase migration.

In this article we follow the spirit of the Ricardian studies of climate change impacts on agriculture (Mendelsohn et al., 1994). Ricardian models assume that the long term productivity of land is reflected in agricultural land prices. By regressing land values per hectare on climate and on other control variables it is possible to estimate how climate affects the long-run productivity of agricultural land. The present sensitivity of land values to climate can be used to estimate the sensitivity of agriculture to future climate change, keeping all else fixed, in a comparative statics exercise. In this article we regress long-run migration patterns of households on climatic conditions and on other control variables. The advantage of this method is that it fully accounts for adaptation to the present climate. The set of adaptation options is large. In a rural setting, as in Ghana and Nigeria, households have adapted agriculture to local climatic conditions by selecting crops, the mix of crop and animal farming, irrigation, planting and harvesting dates. Household have also choosen the optimal mix of farm and non-farm activities to maximize their welfare. Migration is one of the many possible adaptations to local climatic conditions. The method thus identifies the relationship between climate and migration by exploiting the cross-section variation of climate and of long run migration decisions.

What is the expected shape of the relationship between climate and migration? It is reasonable to assume that with less favorable climatic conditions the incentive to migrate increases. However, migration is an expensive investment and it may be too costly for some households.

High temperatures and extreme precipitation patterns reduce agricultural productivity for many reasons. The relationship between crop productivity and average temperature and rainfall is typically hill-shaped. Farmers adapt to different climatic conditions by choosing the optimal crop mix, the growing season and the optimal mix of crops and animal activities, but at high temperature and at extremely low or high precipitation levels, the overall profitability of agriculture declines (Mendelsohn et al., 1994; Porter et al., 2014). For example, higher temperatures in the tropics reduce the size of the agro-climatic zones suitable for perennial crops (Porter et al., 2014). The migration of a family member can therefore compensate for a decrease in farming income.

Migration is even more attractive if adaptation possibilities are limited because of credit or information constraints (Nhemachena and Hassan, 2007). Poor farmers may lack means to pursue structural adjustments. Moreover, low levels of education can limit the possibility to adapt through technology or input switches as farmers may not be able to identify the most efficient inputs mix and the most appropriate technology to face changes in the external environment (Baez et al., 2008). It is therefore possible that farmers chose to diversify income sources, engaging some members in activities external to the family business.

Climate change at the low latitudes may thus well increase the incentive to migrate. However, it is important to note that migration is an investment requiring the availability of capital. Climate change may increase the incentive to migrate but, with incomplete and imperfect markets, households may not be able to migrate because they may see a reduction in the very capital required to enable a move. A worsening in the climate could be associated with a lower chances of migration. Gray (2009) labels this hypothesis as the environmental-capital hypothesis, whereby increased productivity due to better conditions provides the capital to finance costly migration.

Thus, given these different channels, working in opposite direction, the relationship between climate and migration decisions deserves an empirical analysis.

In this paper we narrow our focus on Ghana and Nigeria. The data are drawn from two different household surveys: the Nigeria General Household Survey, conducted between 2010 and 2011, and the Ghana Living Standard Survey, conducted between 2005 and 2006. Both surveys gather individual as well as household information. We chose these countries as a place for the analysis, because the sub-Saharan Africa (SSA) region is among the most vulnerable region to the impacts of climate change. Moreover, both Ghana and Nigeria display a great geographic variability in terms of temperatures and precipitation between the North and the South. Nigeria and Ghana are also countries in which for many households agriculture is still the most important economic activity. As agriculture is more climate sensitive to climate than other sectors, migration decisions are more influenced by climatic factors than in developed economies.

Migration not necessarily requires that the entire household moves. The household can retain the local activities and send one or more family members in another location, to look for alternative revenue sources. In this respect we heavily draw on the predictions of the New Economics of Labour Migration, introduced by Stark and Bloom (1985), which emphasizes the role played by the family in migration decisions. The contributing insight of the authors is that the decision to migrate may take place within the family, rather than being an individual choice. Migration of some individuals responds to an overall family strategy, designed to adapt to a variety of conditions, including climate. For example, a farm household may send some members to urban centres to be employed in non-farm activities or to a different rural locations as a form of income diversification, ensured through the transfer of remittances on a regular basis. Climate may also affect migration in households that are engaged in climate insensitive activities as a result of general equilibrium effects at village or regional level.

Our results reveal that the relationship between the probability that at least one member of the household is a migrant and temperature in the dry season is hill-shaped. A hill-shaped relationship results as well between precipitation in the wet season and migration. The highest propensity to migrate is at 23 °C during the dry season and at 125 mm/month of precipitation during the wet season. This relationship holds only for households that are engaged in farming activities. The empirical findings reveal that migration decisions of non-farming households are not affected by climate, presumably because their productivity is not strongly linked, directly or indirectly, to temperature and precipitation levels. Our findings are robust to a series of alternative model specifications.

Households located in districts with mild temperatures/precipitations have a positive chance to become migrant families if temperatures/precipitations increase. On the contrary, in districts with already high temperature/precipitations, the reverse occurs. Mild temperatures/precipitations benefit agricultural productivity and make migration more likely. On the contrary, for higher levels of temperatures/precipitations, households may be caught in a poverty trap from which they cannot escape, due to low productivity.

We also calculate non-marginal changes of migration using a uniform +2°C temperature increase and a +25% precipitation change and by using geographically and seasonally differentiated climate change scenarios generated by the last generation of General Circulation Models using the Representative Concentration Pathways 4.5 and 8.5. The large majority of the scenarios used suggests that climate change may discourage migration in Ghana and Nigeria.

A crucial assumption that we share with the Ricardian literature and with all cross-section studies is that the error component is not correlated with the regressors. Omitted variables that are correlated with climate variables would cause estimates of climate coefficients to be biased. Although we cannot rule this possibility completely out, two strategies have been pursued. First, fixed effects at geographical level are added in all regressions. These fixed effects should absorb a large array of geographical characteristics and they should be a sufficient control to identify a causal effect in a cross-section analysis. Second a set of robustness tests are conducted, adding controls for soil quality and other geographic variables at district level.

The rest of the paper is structured as follows. Section 2 illustrates the method used to estimate the relationship between climate and migration. Section 3 describes our data set and section 4 presents the empirical findings. Section 5 computes local, regional and national marginal and non-marginal impacts of climate on migration. A concluding section provides a summary and a discussion of results.

2 Methodology

The present paper draws on the insights of the New Economics of Labor Migration (NELM), introduced by Stark and Bloom (1985). The contributing insight of the authors is that the decision to migrate may take place within a family or a household context, rather than being a purely individual decision. Rather than a sole response to individual returns, the migration choice is designed within an overall family strategy, eventually finalized to compensate for the adverse effects produced by climate change. Drawing from the NELM models of migration, we estimate the following probit model, where the units of observations are the households:

$$y_j^* = \gamma C_i + \beta X_j + u_j \tag{1}$$

where $y^*$is the household's unobservable propensity to migrate, C is a set of location specific seasonal climate variables in local administrative unit i, namely precipitations and temperatures. Temperatures and precipitations enter with a linear and a squared terms, separately for the wet and the dry seasons. X controls for all the household characteristics that affect household production activities.

For each household we count the total number of members who live away and send remittances back home on a regular basis at the time the survey was administered. We define a migration household a family where at least one member is a migrant. In this article we capture the so called extensive margin of climate change on migration, as we assess how the variation in temperature and rainfall influences the number of migrating households, rather than the number of family members migrating (the intensive margin).

A household member is someone who is connected to the household by blood or marriage. The survey does not record the reason for not living within the household and some members may be away momentarily or because they formed a new household. To circumvent this limitation, we consider only households that receive remittances. In this way we better identify household members who move for productive reasons and we exclude those moving for education or marriage. Unfortunately, the survey does not record when migration occurred emigration, but we believe that this is not a problem for this analysis. Climate change occurs slowly and therefore it is not requested to link single episodes of migration with climate variables. What matters in this type of analysis is the cross-section, geographical variation in long-term migration decisions and long-run averages of temperature and of rainfall. Finally, we don't know the individual characteristics of the migrating members. We only know if they live within or outside the country of origin. TSome households report having both internal and international migrants (with remittances). We define as an international migration a household where at least one member is abroad, irrespectively of the number of internal movers. On the contrary, an internal migration household has only members that moved within their own country.

Climate influences farm households directly but it also influences non-farm households indirectly via local market effects. Migration decision of farm households is directly influenced by climate, as agriculture is directly related to climate. Migration in non-farm households could be indirectly affected, through linkages between agricultural income, demand for non agricultural goods and demand for non-agricultural labor. Given that the channels are different in the two samples, all estimations are conducted for farm and non-farm households separately.

Among the household characteristics that enter specification (1), we include an indicator of household welfare. Welfare certainly affects migration decisions but the sign of the relationship is ambiguous,, being correlated with the household income generation potential and the ability to secure against risk. On the one hand, wealthier households can invest more in local adaptation and therefore should have a lower propensity to migrate. On the other hand, poorer families may have greater incentive to migrate but they may also lack the resources to finance migration, and therefore might not be able to migrate. The welfare variable is computed applying the principal component technique (Filmer and Pritchett, 2001).[1] The advantage of this index is that it aggregates into a single measure a range of different variables, which individually may not be sufficient to differentiate the welfare characteristics of the household. In this study, the components that enter the index are related to the ownership of specific assets (e.g.: fridge, television .) or the characteristics of the housing structure. Given that the components that enter the formula are not solely influenced by the productivity of the household activities, this index measures the general welfare of the family.

The asset index could be endogenous to the migration decision, as the assets that enter the index may be purchased through migrant remittances. To limit the potential endogeneity, the index is computed using the dwelling characteristics and the ownership of durables as they were five years before the surveys used in this study were conducted.

The other explanatory variables for migration include age, gender and the educational attainment of the household head, the number of dependents, the urban or non-urban location of the family, the ownership of livestock and a control to distinguish between Nigeria and Ghana.

The vector of explanatory variables should contain only variables that are exogenous to climate (Dell et al., 2014). The presence of controls that are themselves an outcome of climate would produce an over-controlling problem. For this reason we first present results of a specification where only climate variables are included. We then add the other demographic controls discussed above to assess the effect of climate on migration over and above its effect through the demographic controls.

3 The data

The data for this analysis are drawn from two different household surveys: the Nigeria General Household Survey, conducted between 2010 and 2011, and the Ghana Living Standard Survey,

[1]The choice of the asset index to control for wealth in the migration equation is done in line with McKenzie (2005), Rozelle et al. (1999) and Taylor et al. (2003).

conducted between 2005 and 2006. Both surveys gather individual as well as household information.

The surveys provide an agriculture module, which allows us to distinguish between farm and non-farm households. We define a farm household any family which reports a farm or a plot operated by a household member.

Migration is a widely spread phenomenon both in Ghana and in Nigeria, with 43 and 23 per cent of households in Ghana and Nigeria, respectively, reporting at least one family member living away from the family (Table 1). The majority of households are classified as internal migration families, as they do not report any member living abroad. In Nigeria it is documented that a considerable part of the moves are represented by rural-urban migration (Black et al., 2006). In Europe and North America Nigerians represent the largest group of foreigners amongst Africans, although they correspond to a limited proportion of Nigeria's vast population. In Ghana internal migration is primarily from north to south, with in-migrants representing a large share of the population in the Greater Accra, Volta and Western regions. This internal flows are fueled by infertile soils and underdeveloped local services in the North (Black et al., 2006). The majority of migrant families reports only one member who lives away and sends remittances back home, but there are families who can quote more the one mover (Table 2).

As far as agriculture is concerned, farming and livestock raising are by far the most important activities of households in both countries. As indicated in Table 3, nearly 48.5 and 44.1 per cent of the households report a farm or a plot operated by a household member or are engaged in raising animals in Ghana and Nigeria, respectively. Both in Nigeria and Ghana, as in many developing countries, the majority of rural agricultural households operates with small land holdings, which tend to produce few commodities at subsistence level. They barely have access to irrigation, improved seeds or fertilizer (Chamberlin, 2007; Liverpool-Tasie et al. 2011). These features are confirmed by the data, as indicated in Table 4. Less than one percent of households in Ghana and 4 percent in Nigeria has access to irrigation devices, and 0.2 and 1.5 percent owns a tractor, in Ghana and Nigeria respectively. The percentage of farming households reaches 73.9 and 72.6 per cent in northern Ghana and in northern Nigeria, respectively. The northern areas in both countries are also those where poverty is more widespread (Omonona, 2009; World Bank, 2011). The north-south divide is also confirmed by the surveys. The asset index that measures the welfare of the households display higher scores in the south compared to the north (Table 5). The difference in the average index between the southern and the northern households is larger in Nigeria than in Ghana, being 1.03 units the difference in Nigeria and 0.78 unit in Ghana.

In Ghana, migration occurs more likely among the farm households (Table 6). 48.3 percent of farm households reports a member away, whereas among the non-farm households, the percentage of migrant families declines to 38.8 per cent. In Nigeria, on the contrary, farm households are marginally less likely to be migrant families than non-farm households.

Gridded climatologies of 1961-1990 monthly mean temperature and precipitations have been obtained from the CRU CL v2.0 data set developed by the Climatic Research Unit at the University of East Anglia (New et al., 2003). Gridded climate data has been down-scaled at each region's centroid by averaging the four closest grid points, with weights inversely proportional to distance.

Both Ghana and Nigeria have a tropical climate, characterised by two major seasons: the dry and the wet season. Temperatures do not vary significantly in the different periods, in particular in Nigeria. Mean temperatures are 27.6 and 26.1 degrees in the dry and wet seasons, respectively, in Ghana and 27.2 and 26 in Nigeria. On the contrary, rainfall displays a larger seasonality. Mean precipitations are equal to 53.9 mm/month in the dry season and equal to 145 mm/month in the wet season in Ghana and 48.1 mm/month and 220.2 mm/month in Nigeria (Table 7). The different intensity of rainfall between the wet and the dry seasons is a common tread of all geographic areas (Figure 1).[2] However, while precipitations in the dry season are uniformly low, there is a large variation in the level of precipitations during the wet season. During the wet season precipitations can exceed 200 mm/month in the southern part of the countries. In particular in Nigeria, the southern belt can reach 400 mm/month of rainfall, level of precipitations typical of areas affected by monsoons.

Climate change scenarios are from the CMIP5 (Climate Modeling Intercomparison Project 5) database and have been extensively reviewed by the IPCC Fifth Assessment Report (IPCC 2013). In the CMIP5 exercise GCMs have used the so-called Representative Greenhouse Gases (GHG) concentration pathways (RCPs) to describe the evolution over time of forcing gases (van Vuuren et al. 2011). For this study we consider the RCP4.5 and the RCP8.5 among the four available. In the RCP4.5 total radiative forcing is equal to $4.5w/m^2$ in 2100 and the global mean temperature in 2081-2100 likely increases by 1.1°C to 2.6°C with respect to the 1986-2005 period (IPCC 2013). In the RCP8.5 scenario, radiative forcing is equal to $8.5w/m^2$ in 2100 and the global mean temperature in 2081-2100 likely increases by 2.6° C to 4.8°C (IPCC 2013). The RCP 8.5 scenario is highly pessimistic and describes a world in which emissions of GHGs are above the business-as-usual trend. Global emissions peak around 2050 in the RCP 4.5 scenario, thus assuming a high (but not extreme) policy effort to reduce GHG emissions.

We use eight GCMs and we consider the climate in two periods: 2031-2060 and 2071-2100. Temperature change is obtained by subtracting from the future monthly climatologies (i.e. the 30-

[2]Ghana, is subdivided into Regions and Districts, while Nigeria is subdivided into States and Local Government Areas (LGAs).

year averages) the 1986-2005 climatologies generated by the same model. The temperature change in each month is then added to the CRU monthly temperature climatologies. By using the change of temperature instead of the level we avoid model bias in the replication of the observed climate. For precipitation changes we proceed analogously but we consider percentage changes rather than changes in levels, as it is common practice in the literature.

It is important to note that future climate change scenarios are fundamentally uncertain. We lack information to attribute probabilities to each scenario and thus it is not possible to determine the most likely future outcome. Thus, the average of all climate change scenarios should not be interpreted as the expected climate scenario. However, due to space concerns, we present in the article only three representative impact scenarios, for both RCPs, in 2071-2100. The scenarios for the other models and for 2031-2060 are presented in the Appendix.

Soil data used in the robustness tests is from the FAO HWSD data set.[3] A full description of the soil characteristics used in the analysis is provided in the Appendix.

4 Empirical Evidence

In this section we present the estimates of equation (1). We control for a series of household and geographic characteristics. First, we describe the demographic characteristics of the household using the age, the gender and the educational attainment of the household head, as well as the number of dependents. Second, we control for the geographic location of the household. We include a dummy for whether the household is urban or not. We also add regional and county fixed effects. Third, we introduce a dummy variable that captures whether the household owns livestock or not. Fourth, we include a measure of household welfare. Finally, we add regional and country fixed effects. The choice of the control variables is in line with other NELM models of migration. To account for possible correlation within geographical areas, standard errors are clustered at local level.

Table 8 presents the empirical findings, for farm and non-farm households separately. In specifications (1) and (3) we introduce only climate variables. Specifications (2) and (4) add also the control variables described above. Both the linear and the quadratic coefficients of temperature during the dry season are significant in the farm household specifications. We find a hill-shaped relationship between temperature in the dry season and the propensity to migrate. We also find a significant hill-shaped relationship between precipitations in the wet seasons and the propensity to

[3]FAO/IIASA/ISRIC/ISS-CAS/JRC. 2008. Harmonized World Soil Database (version 1.0). Rome, Italy and Laxenburg, Austria.: FAO and IIASA.

migrate. These effects do not feature in the non-farm households. None of the climate coefficients are statistically significant in the non-farm specification.

As far as the other controls are concerned , the table shows that wealthier households display a greater likelihood to migrate, as indicated by the positive and statistically significant coefficient of the welfare index. This indicates that poorer families may not find the resources to emigrate. The number of dependents does not influence the propensity to migrate. Location has a remarkable effect on the likelihood of migration but only among non-farm household. Among farm operating household, living in a urban setting makes migration more likely. Migration is not significantly influenced by the gender and the age of the head.

High skills are not a critical asset for migration for farm-operating households, whereas they represent a critical asset for non-farm ones. Families with a secondary and a tertiary educated heads are significantly more likely to migrate compared to families with basic and no education. Nigerian families display lower propensity to migrate compared to Ghanaian families. Among farm operated families, those owning livestock are more likely to migrate than those who don't own any. Livestocks represent an asset for households that augments family wealth.

The coefficients of the climate variables are robust to the inclusion of the demographic controls, both in terms of size and in terms of magnitude. A hill-shaped relationship indicates that farm households located in districts with mild temperatures/precipitations have a positive chance to become migrant families if temperatures/precipitations increase. In districts with already high temperature/precipitations, the reverse occurs. In a rural, underdeveloped setting the relationship between agricultural productivity and climate is usually hill-shaped (Kurukulasuriya et al. 2006). A possible interpretation of our findings is that at the optimal climatic conditions for farming, families are able to find the resources to emigrate. On the contrary, at high temperatures/precipitations, households may be caught in a poverty trap from which they cannot escape. An interesting extension to this analysis would test the link between climate and productivity. [4]

The existing empirical studies find a moderate evidence that households respond to weather adversities by migrating. However, there is also some evidence that better weather and environmental conditions increase migration by allowing households to escape from a poverty trap (Barrett, 2008; Gray, 2009; Gray and Bilsborrow, 2013). Weather adversities in Gray and Mueller (2012a) do not influence mobility, likely because the shocks decrease available resources for migration.

To give strength to these results, a set of robustness checks are conducted for the farm house-

[4]Unfortunately it is not possible to compute a reliable measure of agriculture productivity using the available data sets. The two surveys collect different information on agricultural inputs and therefore the productivity is not comparable between the two datasets.

holds, adding controls or selecting different forms of migration and different forms of farming.

The existing literature on migration has identified that the networks formed by friends and relatives with previous migration experience is as an important determinant of migration. The networks diffuse information regarding opportunities related to labor and credit markets at destination and alleviate the risks of migration (Palloni et al., 2001; Massey and Espinosa,1997; Winters et al. 2001; McKenzie and Rapoport, 2011; Munshi, 2003). These factors contribute to increase the likelihood of migration. Table 9 adds a network variable, computed as the total number of migrants moving from the same local area of household j.[5] The coefficient of the network is positive but it is not statistically significant. We are aware that this is a poor proxy for the network, as stronger ties than just being a migrant from the same origin area should be embedded in the variable. For example a stronger link should develop from persons of the same area of origin migrated to the same local destination. Unfortunately detailed information on the destinations of migrants is not Available, neither in the Census nor in the survey. The hill-shaped relationship described above is robust to the inclusion of the network variable.

A cross sectional analysis of migration decisions can produce biased coefficients due to omitted variables (Schlenker et al., 2005; Deschenes and Greenstone, 2007; Dell et al., 2014). In other words, the empirical estimates can be driven by the presence of time invariant confounders that cannot be disentangled from the climate variables. To address this issue, all regressions are estimated controlling for geographical fixed effects. After controlling for these fixed effects, we expect temperature and precipitations in each local areas to be the main determinant of migration. However, the geographical boundaries of these controls are quite large (regions in Ghana and states in Nigeria). We introduce additional geographical controls at local level to avoid the possibility that other factors that vary within the regions and the statesmay bias the estimates. Average elevation, the standard deviation of elevation and distance from big cities are controlled for. Elevation affects climate directly but also affects economic productivity and mobility through other channels. Distance from large cities may be correlated with climate as remote areas may have an hostile climate.[6] None of the coefficients of the geographical variables turned statistically significant (Table 10). The coefficient of the precipitation variable in the wet season and its squared are robust to the inclusion of these geographical controls. On the contrary, the coefficients of temperature in the dry season

[5]The data to compute the network variable are taken from the 2000 Census for Ghana and from the LSMS for Nigeria. Individual weights are used.

[6]The distance is calculated from the centroid of the district in which the household lives. We use three population thresholds to define cities: greater than 100,000 (100k in Table 10), between 100,000 and 500,000 (100k-500k in Table 10) and greater than 500,000 (¿500k in Table 10).

becomes not statistically significant.

We also include variables that measure soil characteristics in the last column of Table 10.[7] As soil affects agricultural productivity and may be correlated with climate, its omission may bias climate coefficients. Our results indicate that some soil characteristics are significant and have a sign that is consistent with agronomic evidence. However, the sign and the magnitude of the estimated climate coefficient, in particular of the precipitation variable are invariant, thus indicating that omitted variable might not be a problem in our main specification.

The agriculture module of the survey provides detailed information on agricultural activities engaged by the households. In this section we distinguish households depending on the specific activity they conduct. In particular we define a crop-farm household, a household engaged in planting and harvesting crops only. We define an animal-farm household one which is employed in raising animals and not in planting or harvesting crops. Finally a mixed-farm household is engaged in both activities. Table 11 presents the empirical findings where the households are distinguish according to these criteria. Interestingly, none of the climate variables have a significant influence on migration among households engaged in raising animals only (column 2). Eventually, this results is consistent with the idea that animals cope better with climatic extremes than crops. Farms specialized in raising animals are less climate sensitive than crop-farms. On the contrary, families solely engaged in cropping activities display the hill-shaped relationship between migration and precipitation in the wet season.

The survey allows us to identify if family members migrated within or outside the country of origin. We define as international-migrant a household where at least one member is abroad. On the contrary, an internal-migrant household has only domestic migrants. Equation 1 is separately estimated for these two households types and the results are presented in Table 12. While precipitations in the wet season are still a strong and significant determinant of internal migration, the coefficient of rainfall is no longer significant among international migration households. Moreover, temperature in the dry season is not statistically significant in any of the specifications. International migration is a costly phenomenon. Households that own the resources to send members abroad are not influenced by any climate-related issues. Climate neither boosts nor hinders the possibility to migrate internationally. In a final regression we compute a different proxy for mi-

[7]We control for: the Exchangeable sodium percentage (ESP) in soil, measured as percentage of weight (%wt.); the electrical conductivity of soil, measured in dS/m; the organic carbon in soil, measured as percentage of weight (%wt.); the percentage of sand and clay in soil, measured as percentage of weight (%wt.); the pH of the soil, measured in concentration levels (-log(H+)); the cation exchange capacity (CEC) of soil, measured in cmol/kg; the calcium carbonate (lime) content, as percentage of total soil weight (%wt.); the calcium sulphate (gypsum) content of soil, measured as percentage of weight (%wt.). For more information on these variables see the Appendix.

gration. Rather than capturing permanent migration of members, who left but are still connected to the household by sending remittances, we analyse temporary migration. A temporary migrant is a household member who is still part of the family but who in the previous 12 months has left the households for more than one month. This form of migration is typically a temporary, circular migration, in that a person moves back and forth from origin to destination. For example, a person might move for a seasonal job. The coefficient of the precipitation variable in the wet season is positive and statistically significant (column 3). This finding indicates that both temporary and permanent forms of migration are influenced by climate.

A caveat of this analysis is that only households with at least one member still in the original location are interviewed. This issue introduces a possible downward bias in the estimates at locations with high temperatures and at the very dry and very wet regions. Entire families might have moved, either domestically or internationally, in response to climate. Unfortunately it is not possible to account for these missing families.

5 Marginal and non-marginal impacts of climate on migration

In our preferred model specification (column 4 of Table 8) we find a quadratic significant relationship between the probability to migrate and temperature in the dry season and precipitations in the wet season. For this specification we compute the marginal effects of temperature and precipitation. The non-linearity in the relationship between climate and migration implies that the marginal impacts of temperature and precipitations vary at different temperature and precipitation levels. The marginal impact also depends on the value taken by all the other control variables. Figure 2 provides a graphical representation of the impact of 1°C of additional temperature and of 1cm of additional rainfall at the average of all other control variables.

The marginal effect of temperature increase is initially positive and becomes negative at 24°C (left panel). An increase in temperature in the dry season from 23 to 24°C augments the probability of migration by eight percentage points, *ceteris paribus.* At 24°C the marginal effect is still positive, but of a lower magnitude. Finally, warming during the dry season reduces the impact to migrate at temperatures higher than 25°C.

The marginal impact of additional rainfall during the wet season is depicted in the right panel of Figure 2. Additional precipitations during the wet season increase the propensity to migrate up to about 22.5 cm per month and then they reduce migration. An additional cm per month of rain at 12.5 cm/month increases the propensity to migrate by six percentage points, *ceteris paribus.*

At the country level we find that the average dry season temperature marginal calculated at the average dry season temperature is equal to -33% in Ghana and is equal to -10% in Nigeria, as Nigeria is relatively cooler. The average wet season precipitation marginal calculated at the average precipitation level is equal to 1% in Ghana and 8% in Nigeria.

We also compute the marginal effects at district level, at the average value of all other control variables for households in that district. Figure 3 provides maps of the geographical distribution of marginal temperature and precipitation impacts (1° C and 1 cm/month). Warming in Ghana, especially in the center, reduces migration on average and *ceteris paribus*, while in some areas of northern Nigeria warming may increase migration, as those areas are relatively cool now. Higher precipitation levels are instead expected to increase migration in both Ghana and central-northern Nigeria. Additional rainfall during the wet season would instead reduce migration in the south-eastern part of Nigeria. During the wet season the south east of Nigeria already experiences a monsoon season with exceptionally high precipitation levels.

As in the Ricardian literature, we estimate the impact of non-marginal changes of temperature and precipitations on each household's probability to migrate, keeping anything else fixed. We take the difference of the estimated probability to migrate with the future climate and we subtract from it the probability to migrate estimated with the 1961-1990 climate. This difference provides an estimate of the impact of an instantaneous change of climate. We start examining a uniform (over space and seasons) +2°C temperature and +25% precipitation scenario. We display in Figure 4 the maps of the non-marginal change of the probability to migrate. In the left panel we display results at district level. For each district we display the average change of the probability to migrate over all households that live in the district. In the right panel we average over all households that live in the same region. With this Uniform scenario of moderate warming and moderate precipitation change we find that migration would decline in Ghana and in central and southern Nigeria. A moderate increase of migration occurs in northern Nigeria.

The Uniform scenario is a useful benchmark but it does not provide the realism of future climate change patterns, which are expected to be different over space and seasons. In order to provide a more realistic estimates of climate change impacts on the probability to migrate we use a set of detailed climate change scenarios produced by the last generation of GCMs for the CMIP5.

The impact on migration of climate change in 2071-2100 in the RCP4.5 and in the RCP8.5 scenarios for three representative GCMs are displayed in Figure 5. While Ghana always has a reduction of the probability to migrate, in Nigeria different climate models, or for the same model different RCP scenarios, generate different estimates of the change of migration. In northern Nigeria some scenarios suggest that migration may increase with the climate expected in 2100. The observed variation in climate change impacts across different scenarios is uniquely explained by differences in temperature and precipitation patterns across GCM scenarios. The underlying econometric model does not change. Table 2 in the Appendix provides summary statistics for all models, scenarios and RCP trajectories. Figures A-1 to A-8 display district- and regional-level maps of changes of the probability to migrate for 2031-2060, 2071-2100, for both the RCP4.5 and the RCP8.5. Results from the other models are similar to those displayed in Figure 5. There is surprisingly low variation of results across different models.

6 Conclusions

Our study shows that climate affects migration in farm households in Ghana and Nigeria. We find a hill-shaped relationship between temperature in the dry season and the propensity to migrate as well as between precipitations in the wet seasons and the propensity to migrate. None of the climate coefficients are statistically significant in the non-farm households. This suggests that climate affects migration by affecting the productivity of agriculture.

A possible interpretation is that at favorable climatic conditions for farming, families are able to find the resources to migrate. On the contrary, at high temperatures/precipitations, households may be caught in a poverty trap from which they cannot escape. While the negative link between harmful weather and migration has been documented in short-run analyses, which do not embody the full set of adaptations (Gray and Bilsborrow, 2013; Gray, 2009), our study is the first example where this link features in a long-run perspective, which accounts for a larger set of adaptation measures.

The analysis of marginal and non-marginal changes of temperature and precipitation reveals that climate change may reduce migration in Ghana and Nigeria, *ceteris paribus*. The subsistence level of agricultural households in Ghana and Nigeria can explain these findings. Adverse climatic conditions reduce the productivity of agriculture, even after including the whole set of present adaptations to climate. This productivity loss has a negative impact on the capital stock of households and reduces migration. While adaptation through migration is found to be a mechanism to respond to shocks and increased risks in the short-run by a growing literature, the long-run relationship between climate and migration seems to be more complex, as more factors affect households decisions. Our results suggest thatfor many poor households in Ghana and Nigeria migration does not appear to be a possible adaptation to climate change.

The method that we developed in this article can be replicated in other countries for which data on migration is available with a high geographic resolution. Ideally, future studies should cover areas with larger temperature variance than in our study. One of the limits of our study is indeed the limited temperature variation across all districts of Ghana and Nigeria.

If our findings are confirmed, the current narrative that climate change will generate massive migration patterns should be questioned and its policy implications reconsidered. We are aware that climate change can bring not only changes in average temperatures and precipitations. For example, it can imply an increase of the frequency of extreme climatic events, such as heat waves, droughts and floods. The present analysis does not account for such extreme events, as it solely deals with gradual changes in temperatures and precipitation in a *ceteris paribus* setting. Future work can also control for the effect of inter-annual temperature and precipitation variance, for the presence of extreme events and for other climatic variables not included in this study.

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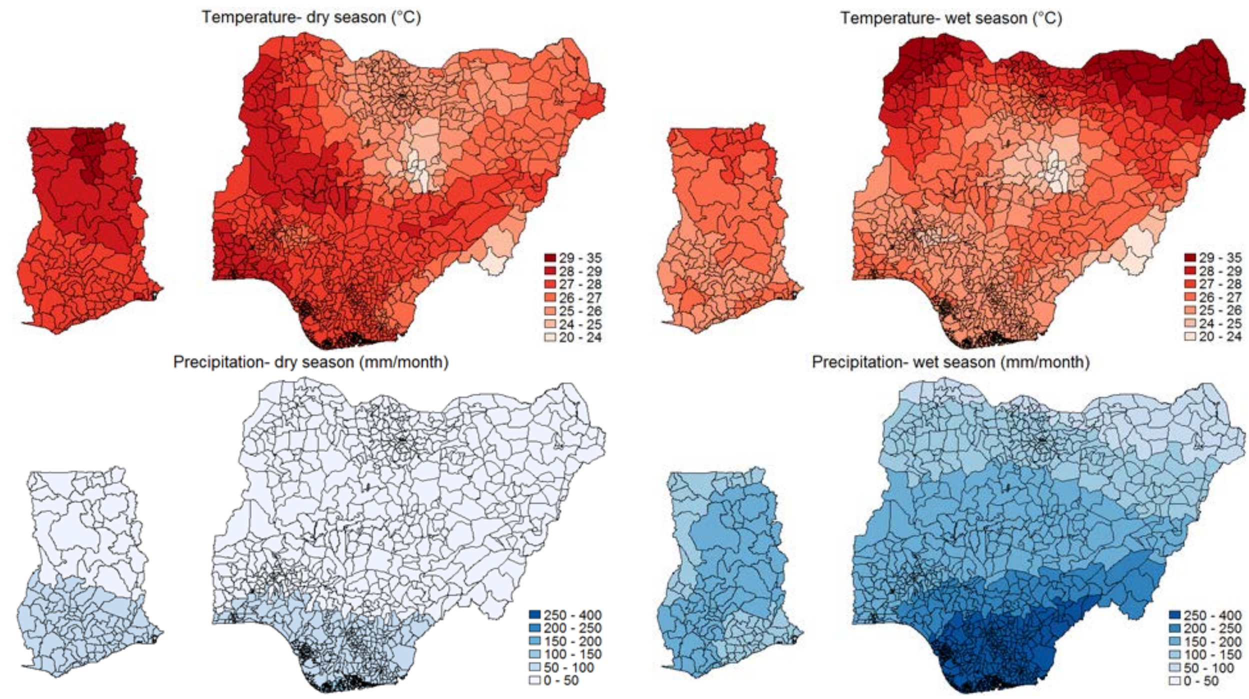
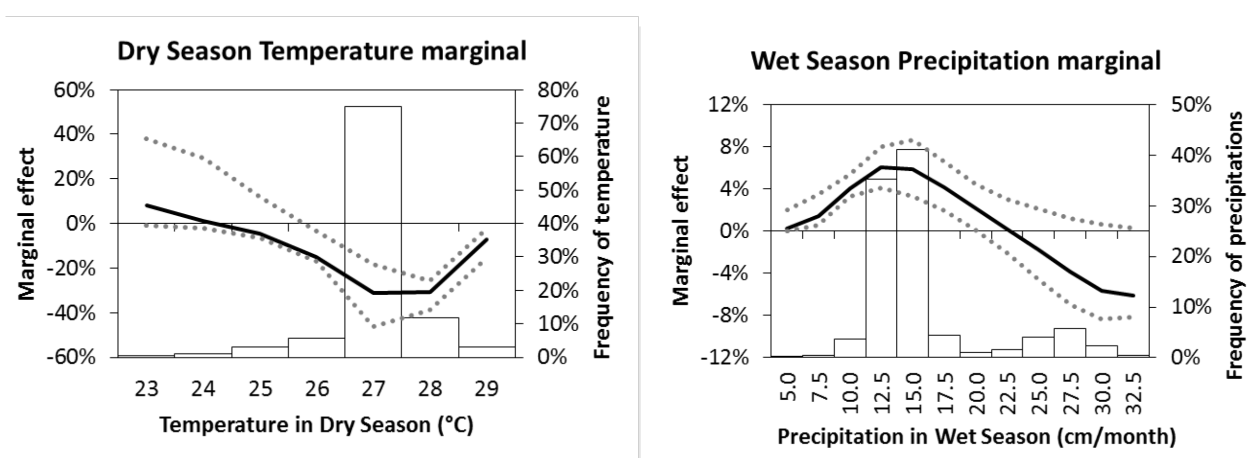


Figure 1: Temperature and precipitations in dry and wet seasons in the different districts



Notes: The solid line indicates the marginal impact at the average of all control variables at different temperature and precipitation levels. The dotted lines indicate the 95 percent bootstrap confidence interval. We sample with replacement the households in our dataset, we estimate the model and we calculate the marginal impact at the average of all control variables in the new sample. We repeat this exercise 1,000 times and we determine the 2.5th and the 97.5th percentiles of the resulting distribution.

Figure 2: Range of marginal impacts for 95% of the household within each temperature/precipitation bin.

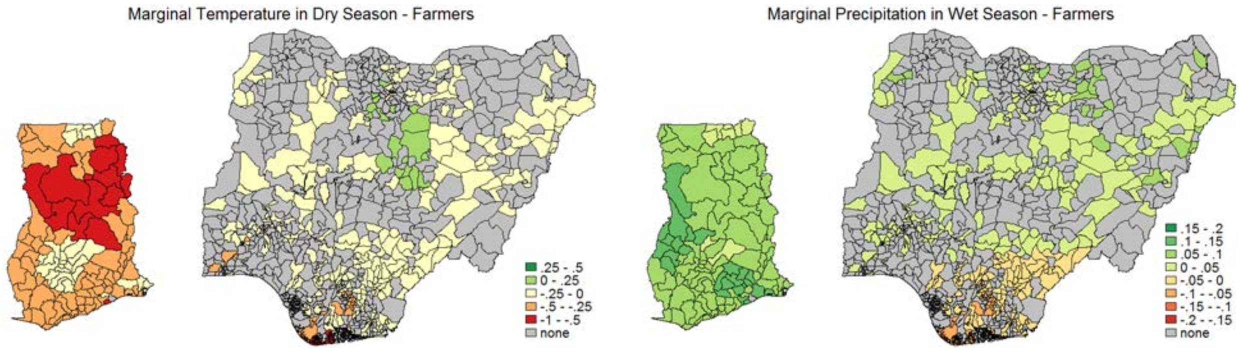


Figure 3: Temperature and precipitation marginal effects in dry and wet seasons in the different districts

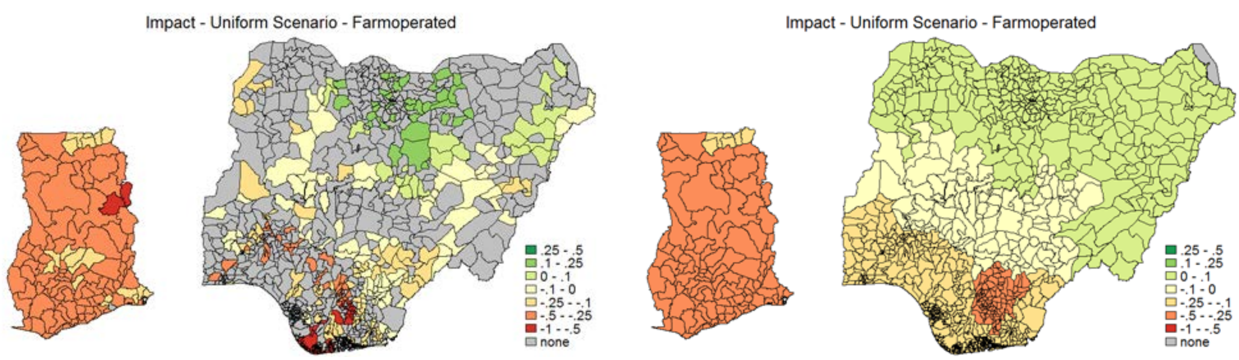
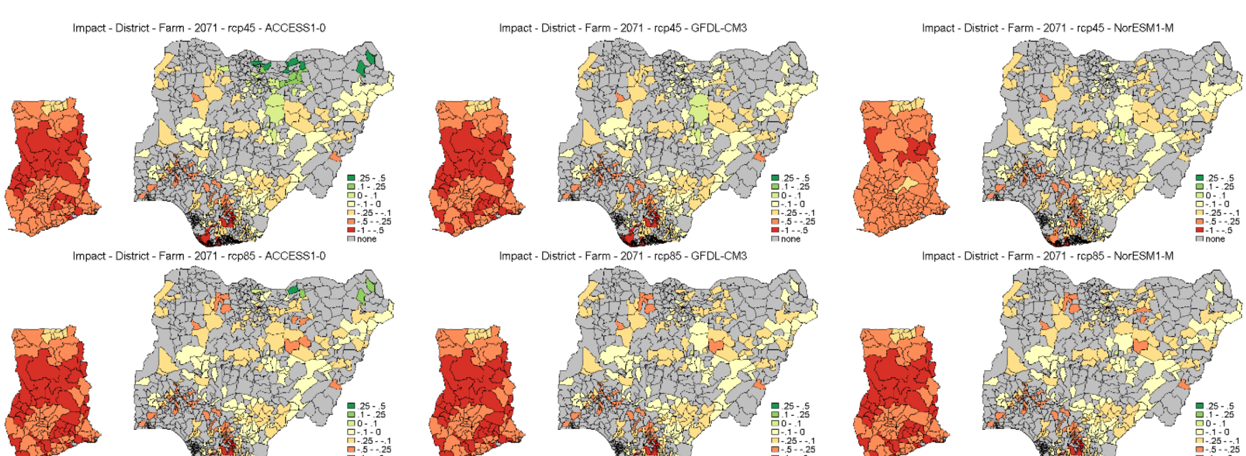


Figure 4: impact of a uniform scenario.



Notes: three representative General Circulation Models. Other models and impacts using climate of 2031-2060 available in the Appendix.

Figure 5: impact of GCMs scenarios in 2071-2100 with the RCP4.5 and the RCP8.5.

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	Migrant households (%)	Migrant households-internal migration (%)	Migrant households –international migration (%)
Ghana	43.4	11.4	3.9
Nigeria	23.3	19.2	4.1

Note: For Ghana, not all households specified the destination of the household members, whether abroad or in Ghana, and therefore the percentage in columns (3) and (4) should represent a lower bound. The summary statistics are computed using sample weights.

Table 1: Per cent of households reporting at least one migrant

	Ghana (%)	Nigeria (%)
0	56.6	76.7
1	27.5	15.8
2	9.1	5.6
3	2.9	0.9
>4	3.8	1.0

Note: The summary statistics are computed using sample weights.

Table 2: Number of family members away and sending remittances. Percent of households

	Farm operating households (%)	
	Ghana	**Nigeria**
Overall	48.5	44.1
Northern Area	73.9	72.6
Central-Southern Area	47.0	32.4

Note: Northern areas include Northern, Upper East and Upper West regions in Ghana and North Central, North East and North West zones in Nigeria. The summary statistics are computed using sample weights.

Table 3: Per cent of farm-operating households

	Ghana	Nigeria
Irrigation (%)	0.6	3.8
Tractor (%)	0.2	1.5

Note: The summary statistics are computed using sample weights.

Table 4: Characteristics of farm-operating households

	Overall country		Means			
	Mean	Standard Deviation	Poorest 10%	Richest 10%	North	South
Ghana	-0.001	1.92	-1.04	4.74	-0.61	0.17
Nigeria	0.02	1.78	-1.71	4.05	-0.55	0.48

Table 5: Scoring factors of the Asset Index

	Ghana			**Nigeria**		
	Migrant households (%)	**Migrant households-internal migration (%)**	**Migrant households – international migration (%)**	**Migrant households (%)**	**Migrant households-internal migration (%)**	**Migrant households – international migration (%)**
Farm	48.3	15.2	3.0	23.1	19.8	3.2
Non-farm	38.8	7.8	4.8	23.5	18.7	4.8

Note: The summary statistics are computed using sample weights.

Table 6: Per cent of households reporting at least one migrant. Farm operating versus non-farm operating

	T-dry	**T-wet**	**P-dry**	**P-wet**
Ghana	27.6	26.1	58.9	145.0
Nigeria	27.2	26.0	48.1	220.2

Table 7: Temperature (°C) and precipitation (mm/month) in dry and wet seasons

	Non-farm operated		Farm operated	
	(1)	(2)	(3)	(4)
T Dry Season	-0.940	0.00673	6.907*	6.814*
	[15.83]	[15.72]	[3.970]	[4.013]
P Dry Season	0.00133	-0.00549	0.0188	0.0184
	[0.0453]	[0.0434]	[0.0321]	[0.0323]
T Wet Season	-5.732	-5.985	-1.793	-1.381
	[6.889]	[6.678]	[3.276]	[3.256]
P Wet Season	0.00792	0.0230	0.0456**	0.0456**
	[0.0238]	[0.0236]	[0.0206]	[0.0204]
T Dry Season Squared	0.00663	-0.0113	-0.142**	-0.141*
	[0.285]	[0.283]	[0.0724]	[0.0731]
P Dry Season Squared	0.000141	0.000174	-0.000182	-0.000175
	[0.000371]	[0.000349]	[0.000290]	[0.000293]
T Wet Season Squared	0.106	0.112	0.0433	0.0357
	[0.126]	[0.122]	[0.0604]	[0.0600]
P Wet Season Squared	-3.72e-05	-7.01e-05	-9.92e-05**	-0.000100**
	[4.94e-05]	[4.89e-05]	[4.45e-05]	[4.42e-05]
Welfare Index		0.0541***		0.0423***
		[0.0151]		[0.0157]
Number of dependent		0.00705		-0.0227**
		[0.0175]		[0.0113]
Urban		0.230**		-0.00231
		[0.101]		[0.0916]
Gender		-0.0623		-0.0632
		[0.0716]		[0.0690]
Age		0.00288		0.00310
		[0.00272]		[0.00226]
Primary Education		0.0333		0.0414
		[0.0462]		[0.0530]
Secondary Education		0.181***		0.0253
		[0.0551]		[0.0788]
Tertiary Education		0.190**		-0.00102
		[0.0896]		[0.165]
Nigeria	-1.718**	-1.652**	-1.940**	-1.897**
	[0.808]	[0.796]	[0.776]	[0.776]
Livestock				0.200***
				[0.0675]
Constant	98.59	86.72	-69.70	-73.79*
	[219.3]	[220.3]	[43.77]	[44.16]
Observations	3,545	3,545	3,657	3,657
Pseudo R-squared	0.0582	0.0768	0.116	0.123

Notes: the dependent variable is defined as equal 1 if the household has at least one member who lives away from the origin household and sends remittances back home and 0 otherwise; standard errors are clustered at local administrative units and reported in parenthesis. * denotes significant at 10%; ** significant at 5%; *** significant at 1%. The base dummies in the regressions are rural, male headed, no education, Ghana and no livestock. All regressions include region dummies.

Table 8: Household migration and climate change. Farm operated and non-farm operated households

	Farm operated
T Dry Season	7.605*
	[3.977]
P Dry Season	0.0189
	[0.0329]
T Wet Season	-1.713
	[3.300]
P Wet Season	0.0535**
	[0.0212]
T Dry Season Squared	-0.157**
	[0.0724]
P Dry Season Squared	-0.000178
	[0.000296]
T Wet Season Squared	0.0436
	[0.0607]
P Wet Season Squared	-0.000116**
	[4.61e-05]
Network	2.73e-06
	[2.58e-06]
Observations	3,556
Pseudo R-sq	0.125

Notes: the dependent variable is defined as equal 1 if the household has at least one member who lives away from the origin household and sends remittances back home and 0 otherwise; standard errors are clustered at local administrative units and reported in parenthesis. * denotes significant at 10%; ** significant at 5%; *** significant at 1%. The regression includes controls for welfare, the number of dependents, urban setting, gender, age and qualification of the household head, ownership of livestock, a country and region dummies.

Table 9: Household migration and climate change. The network

	(1)	(2)	(3)	(4)	(5)
T Dry Season	5.925	3.778	5.897	5.143	5.138
	[4.037]	[4.126]	[4.079]	[4.157]	[3.822]
P Dry Season	0.0286	0.0342	0.0280	0.0344	0.0191
	[0.0328]	[0.0331]	[0.0330]	[0.0321]	[0.0350]
T Wet Season	-0.0212	0.374	0.182	0.534	0.710
	[3.194]	[3.174]	[3.204]	[3.210]	[3.290]
P Wet Season	0.0411**	0.0489**	0.0416**	0.0368*	0.0412*
	[0.0203]	[0.0217]	[0.0203]	[0.0208]	[0.0247]
T Dry Season	-0.122*	-0.0835	-0.121	-0.107	-0.110
Squared	[0.0730]	[0.0744]	[0.0738]	[0.0758]	[0.0692]
P Dry Season	-0.000191	-0.000238	-0.000200	-0.000212	-0.000155
Squared	[0.000285]	[0.000285]	[0.000284]	[0.000281]	[0.000333]
T Wet Season	0.0113	0.00612	0.00750	0.000662	-0.00277
Squared	[0.0585]	[0.0580]	[0.0586]	[0.0591]	[0.0606]
P Wet Season	-9.40e-05**	-0.000111**	-9.41e-05**	-8.72e-05**	-9.53e-05*
Squared	[4.32e-05]	[4.67e-05]	[4.31e-05]	[4.32e-05]	[5.35e-05]
Elevation-	0.000352	0.000273	0.000462	0.000561	
Mean	[0.00140]	[0.00139]	[0.00143]	[0.00145]	
Elevation-	0.00316	0.00302	0.00298	0.00301	
Stand Dev	[0.00223]	[0.00221]	[0.00226]	[0.00223]	
Cities (>100k)		-0.00250			
		[0.00195]			
Cities (100k-500k)			-0.000822		
			[0.00167]		
Cities (>500k)				0.000931	
				[0.00188]	
ESP					0.118*
					[0.0664]
ECE					-0.229*
					[0.118]
Organic carbon					0.416*
					[0.251]
Sand					-0.00777
					[0.0136]
Clay					0.0209
					[0.0205]
pH					0.00588
					[0.185]
CEC					-0.0670*
					[0.0361]
$CaCO_3$					0.166
					[0.201]
$CaSO_4$					0.120
					[0.693]
Observations	3,657	3,657	3,657	3,657	3,657
Pseudo R-sq	0.126	0.128	0.126	0.126	0.128

Notes: the dependent variable is defined as equal 1 if the household has at least one member who lives away from the origin household and sends remittances back home and 0 otherwise; standard errors are clustered at local administrative units and reported in parenthesis. * denotes significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include controls for welfare, the number of dependents, urban setting, gender, age and qualification of the household head, a country and region dummies.

Table 10: Household migration and climate change. Geographic controls and soil characteristics.

	Only Crop	Only animal	Both crop and animal
	(1)	(2)	(3)
T Dry Season	3.135	-32.00	6.410
	[23.18]	[29.18]	[3.917]
P Dry Season	-0.0148	0.0934	0.0146
	[0.0654]	[0.0950]	[0.0323]
T Wet Season	9.053	8.010	-2.311
	[10.48]	[20.65]	[3.341]
P Wet Season	0.0637***	-0.0289	0.0314
	[0.0234]	[0.102]	[0.0217]
T Dry Season	-0.0807	0.545	-0.129*
Squared	[0.418]	[0.518]	[0.0717]
P Dry Season	0.000157	-0.000985	-0.000170
Squared	[0.000554]	[0.000858]	[0.000304]
T Wet Season	-0.154	-0.139	0.0501
Squared	[0.194]	[0.385]	[0.0624]
P Wet Season	-0.000144***	0.000142	-6.86e-05
Squared	[4.86e-05]	[0.000319]	[4.78e-05]
Observations	1,150	355	2,048
Pseudo R-sq	0.113	0.124	0.140

Notes: the dependent variable is defined as equal 1 if the household has at least one member who lives away from the origin household and sends remittances back home and 0 otherwise; standard errors are clustered at local administrative units and reported in parenthesis. * denotes significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include controls for welfare, the number of dependents, urban setting, gender, age and qualification of the household head, a country and region dummies.

Table 11: Household migration and climate change. Household activities

	Internal	International	Temporary
	(1)	(2)	(3)
T Dry Season	2.827	-1.345	3.038
	[3.190]	[8.923]	[3.163]
P Dry Season	0.00444	0.0139	-0.0278
	[0.0307]	[0.0562]	[0.0250]
T Wet Season	-1.170	8.804	-6.470*
	[2.719]	[6.755]	[3.428]
P Wet Season	0.0274*	0.0177	0.0395**
	[0.0162]	[0.0235]	[0.0153]
T Dry Season	-0.0557	0.00161	-0.0548
Squared	[0.0581]	[0.160]	[0.0570]
P Dry Season	-3.37e-05	-0.000154	0.000203
Squared	[0.000264]	[0.000474]	[0.000236]
T Wet Season	0.0249	-0.145	0.125**
Squared	[0.0506]	[0.123]	[0.0635]
P Wet Season	-6.13e-05*	-2.74e-05	-8.31e-05**
Squared	[3.44e-05]	[5.97e-05]	[3.51e-05]
Primary	0.0279	0.192*	0.0759
Education	[0.0658]	[0.114]	[0.0568]
Secondary	-0.0445	0.458***	0.260***
Education	[0.0938]	[0.156]	[0.0833]
Tertiary	-0.370*	0.563**	0.285*
Education	[0.201]	[0.252]	[0.170]
Observations	3,657	3,007	3,647
Pseudo R-sq	0.0634	0.105	0.0702

Notes: the dependent variable is defined as equal 1 if the household has at least one member who lives away from the origin household and sends remittances back home and 0 otherwise; standard errors are clustered at local administrative units and reported in parenthesis. * denotes significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include controls for welfare, the number of dependents, urban setting, gender, age of the household head, ownership of livestock, a country and region dummies.

Table 12: Household migration and climate change. Internal, international and temporary migration.

Appendix

Description of soil variables

Soil data used in the robustness test is from the Harmonized World Soil Database (HWSD).[1] The HWSD database provides a comprehensive map of soil physical and chemical characteristics over the entire globe in GIS format. Soil data at county level is obtained as a weighted average of soil characteristics over the entire area of each county. Data is provided separately for the topsoil (0-30 cm) and subsoil (30-100 cm). In the paper we use only topsoil data. The definition of soil characteristics below are valid for both topsoil and subsoil.

AWC class – Available water storage capacity class of the soil unit, measured in mm/m.

Gravel – Percentage of materials in a soil that are larger than 2 mm, measured as percentage of volume (%vol.).

Sand – Percentage of sand in soil, measured as percentage of weight (% wt).

Silt – Percentage of silt in soil, measured as percentage of weight (% wt).

Ref. bulk density - Reference bulk density is a property of particulate materials. It is the mass of many particles of the material divided by the volume they occupy. The volume includes the space between particles as well as the space inside the pores of individual particles. Measured in kg/dm^3.

Organic carbon – Organic carbon in soil, measured as percentage of weight (%wt.). Organic Carbon is together with pH, the best simple indicator of the health status of the soil. Moderate to high amounts of organic carbon are associated with fertile soils with a good structure. Soils with an organic matter content of less than 0.6% are considered poor in organic matter.

pH – pH is a measure for the acidity and alkalinity of the soil, measured in concentration levels (-log(H+)). pH between 5.5. and 7.2 offers the best growing conditions. Agronomic limits are: <4.5 (extremely acid), 4.5-5-5 (very acid), 5.5-7.2 (acid to neutral), 7.2-8.5 (moderately alkaline), >8.5 (strongly alkaline).

CEC – Cation exchange capacity (CEC) of soil, measured in cmol/kg. The CEC measures the total nutrient fixing capacity of a soil. Soils with low CEC cannot build up stores of nutrients. Values in excess of 10 cmol/kg are considered satisfactory for most crops.

$CaCO_3$ – Calcium carbonate (lime) content soil, measured as percentage of total soil weight (%wt.). A small amount of calcium carbonate is good for agriculture. High amounts create iron deficiency and may limit water storage capacity. Agronomic limits are as follows: <2 (very low), 2-5 (low), 5-15 (moderate), 15-40 (high), >40 (very high).

$CaSO_4$ – Calcium sulphate (gypsum) content of soil, measured as percentage of weight (%wt.). Research indicates that excessive calcium sulphate can cause substantial reduction in yields.

[1] FAO/IIASA/ISRIC/ISS-CAS/JRC. 2008. Harmonized World Soil Database (version 1.0). Rome, Italy and Laxenburg, Austria: FAO and IIASA.

ESP – Exchangeable sodium percentage (ESP) in soil, measured as percentage of total soil volume (%vol.). Agronomic limits are as follows: <6 (low), 6-15 (moderate), 15-25 (high), >25 (very high).

ECE – Electrical conductivity of soil, measured in dS/m. The salt content of a soil can be roughly estimated from the Electrical Conductivity of the soil.

Variable	**Description**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
		Non-farm		**Farm**	
Household Migration	=1 if the family has at least one member who lives away and sends remittances; =0 otherwise	0.34	0.47	0.40	0.49
Temperature dry	Mean temperature in the dry season. °C	27.57	0.48	27.43	0.75
Temperature wet	Mean temperature in the wet season. °C	26.04	0.46	26.07	0.69
Precipitation dry	Mean precipitation in the dry season. mm/month	59.96	15.43	52.42	21.76
Precipitation wet	Mean precipitation in the wet season. mm/month	160.15	46.55	168.72	48.83
Age	Age of Household Head	39.34	11.39	42.71	11.18
Gender	=1 if household head is female; =0 otherwise	0.28	0.45	0.14	0.35
Welfare Index	Dwelling characteristics 5 years prior the surveys were conducted. Principal component method	0.81	2.44	-0.21	1.54
Primary Education	=1 if the household head has primary education; =0 otherwise	0.45	0.50	0.44	0.50
Secondary Education	=1 if the household head has secondary education; =0 otherwise	0.29	0.45	0.17	0.38
Tertiary Education	=1 if the household head has university or post education; =0 otherwise	0.09	0.28	0.03	0.17
Urban	=1 if the family resides in an urban settlement; =0 otherwise	0.80	0.40	0.22	0.41
Livestock	=1 if the family owns a livestock; =0 otherwise			0.67	0.47
Number of dependents	Number of family members 18 years old or younger	1.64	1.72	2.81	2.22
Nigeria	=1 if households are located in Nigeria; =0 otherwise	0.24	0.43	0.28	0.45

Table A1: Description and summary statistics of the variables.

Scenario	Model	Year	Min	Max	Mean	Median	25th percentile	75th percentile
RCP45	ACCESS1-0	2031	-56%	35%	-18%	-15%	-32%	-5%
RCP45	CCSM4	2031	-43%	2%	-16%	-13%	-26%	-7%
RCP45	CMCC-CM	2031	-70%	20%	-21%	-20%	-30%	-9%
RCP45	GFDL-CM3	2031	-54%	23%	-15%	-15%	-29%	-4%
RCP45	MIROC5	2031	-54%	8%	-17%	-15%	-26%	-6%
RCP45	MPI-ESM-MR	2031	-74%	-1%	-22%	-21%	-30%	-11%
RCP45	NorESM1-M	2031	-41%	6%	-16%	-14%	-26%	-6%
RCP45	inmcm4	2031	-46%	7%	-13%	-9%	-23%	-3%
RCP85	ACCESS1-0	2031	-67%	40%	-21%	-17%	-35%	-7%
RCP85	CCSM4	2031	-55%	3%	-20%	-18%	-28%	-9%
RCP85	CMCC-CM	2031	-70%	18%	-22%	-20%	-33%	-8%
RCP85	GFDL-CM3	2031	-64%	14%	-22%	-18%	-35%	-6%
RCP85	MIROC5	2031	-59%	13%	-18%	-15%	-29%	-6%
RCP85	MPI-ESM-MR	2031	-74%	-1%	-26%	-19%	-39%	-9%
RCP85	NorESM1-M	2031	-53%	2%	-20%	-17%	-30%	-9%
RCP85	inmcm4	2031	-56%	11%	-16%	-12%	-27%	-4%

Notes: descriptive statistics of the mean change at district level. District level change obtained averaging the predicted change for all households in the district.

Table A2: Descriptive statistics of the change of the probability to migrate – 2031-2060 vs 1986-2005.

Scenario	Model	Year	Min	Max	Mean	Median	25th percentile	75th percentile
RCP45	ACCESS1-0	2071	-70%	49%	-22%	-19%	-37%	-7%
RCP45	CCSM4	2071	-63%	3%	-22%	-18%	-33%	-9%
RCP45	CMCC-CM	2071	-73%	-1%	-26%	-21%	-37%	-10%
RCP45	GFDL-CM3	2071	-74%	6%	-25%	-19%	-38%	-9%
RCP45	MIROC5	2071	-67%	7%	-21%	-17%	-33%	-7%
RCP45	MPI-ESM-MR	2071	-74%	-1%	-25%	-21%	-36%	-11%
RCP45	NorESM1-M	2071	-53%	2%	-21%	-18%	-32%	-9%
RCP45	inmcm4	2071	-58%	10%	-16%	-11%	-30%	-3%
RCP85	ACCESS1-0	2071	-75%	26%	-26%	-21%	-39%	-10%
RCP85	CCSM4	2071	-75%	0%	-27%	-21%	-39%	-11%
RCP85	CMCC-CM	2071	-76%	-1%	-27%	-22%	-39%	-11%
RCP85	GFDL-CM3	2071	-76%	1%	-27%	-21%	-39%	-10%
RCP85	MIROC5	2071	-72%	10%	-25%	-20%	-39%	-9%
RCP85	MPI-ESM-MR	2071	-76%	-1%	-27%	-22%	-39%	-11%
RCP85	NorESM1-M	2071	-71%	1%	-26%	-21%	-39%	-11%
RCP85	inmcm4	2071	-73%	0%	-26%	-20%	-39%	-10%

Notes: descriptive statistics of the mean change at district level. District level change obtained averaging the predicted change for all households in the district.

Table A3: Descriptive statistics of the change of the probability to migrate – 2071-2100 vs 1986-2005.

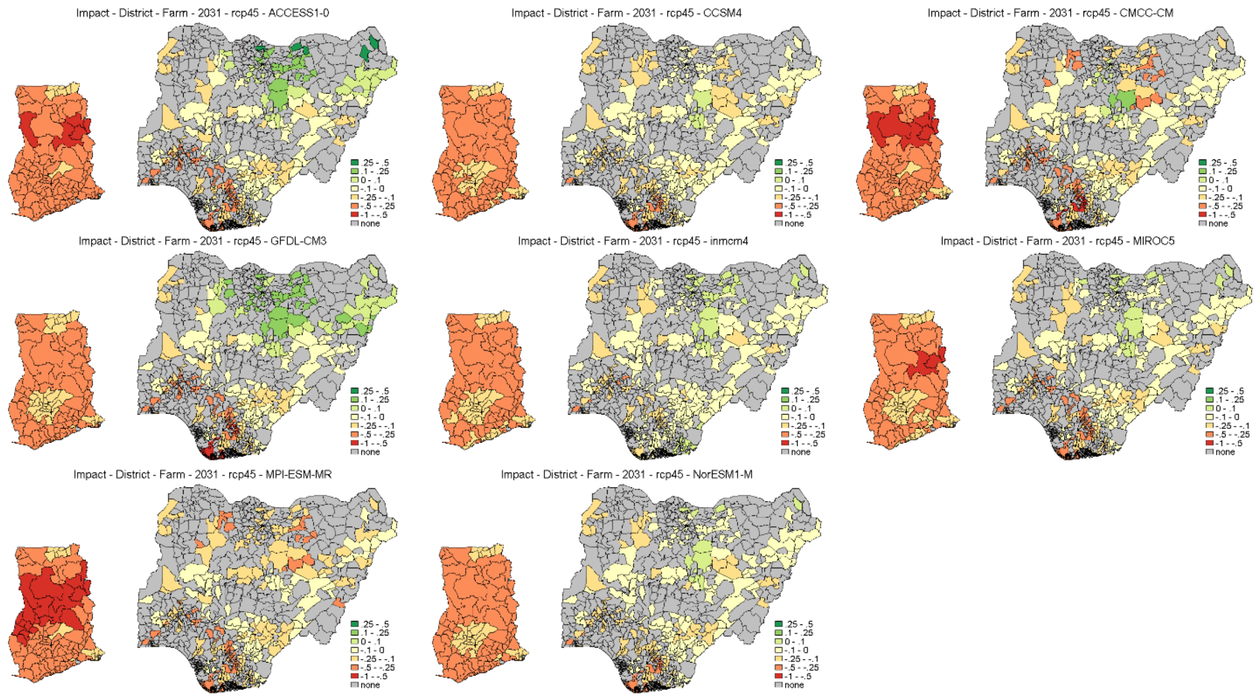

Figure A1: The impact of climate change at district level: RCP 4.5 – 2031-2061 vs 1986-2005.

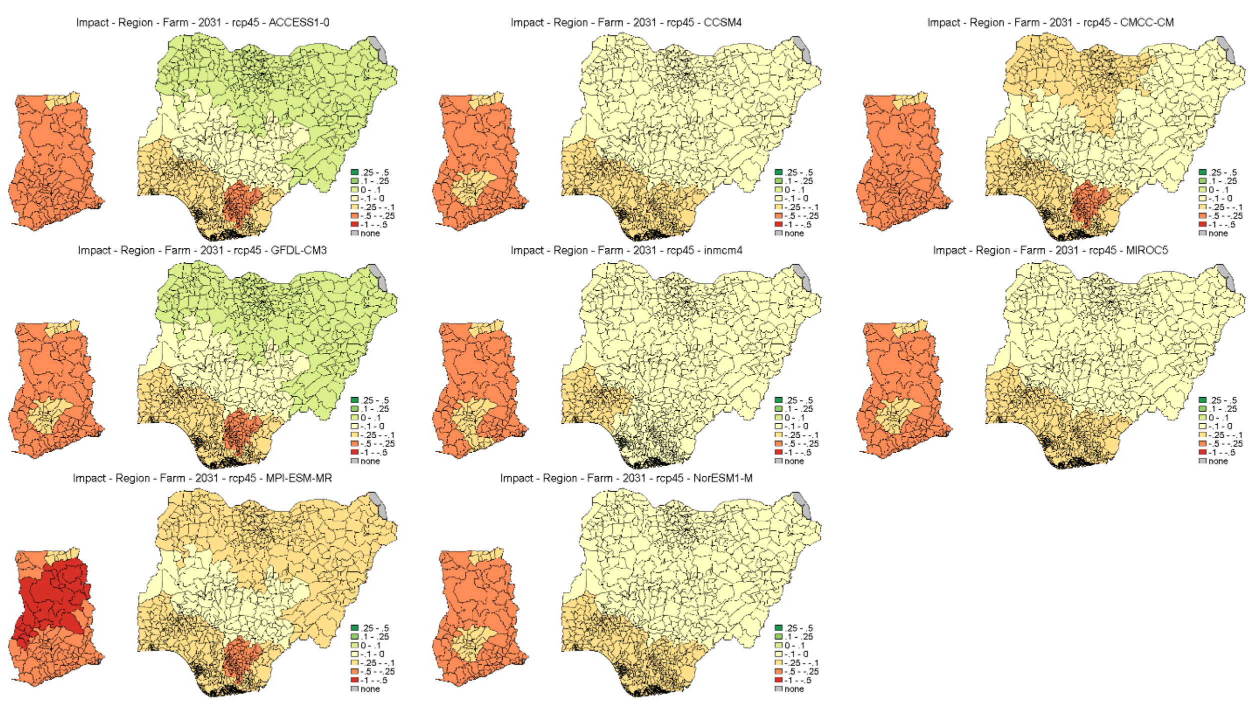

Figure A2: The impact of climate change at regional level: RCP 4.5 – 2031-2061 vs 1986-2005.

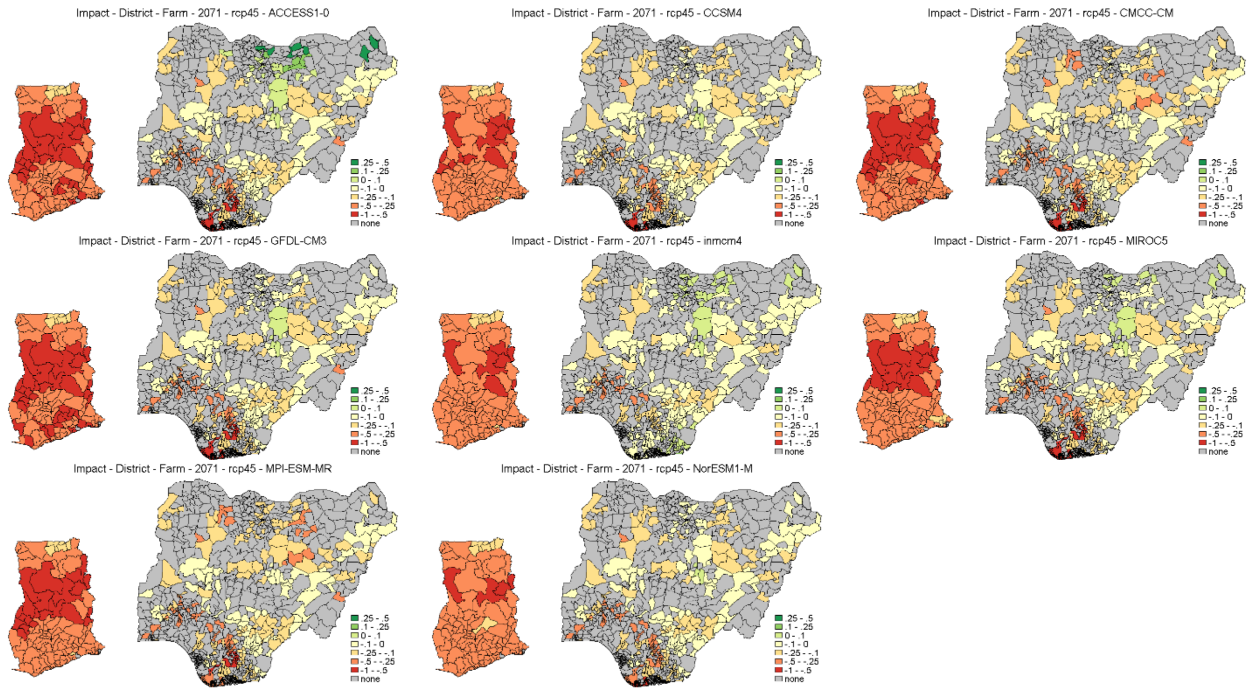

Figure A3: The impact of climate change at district level: RCP 4.5 – 2071-2100 vs 1986-2005.

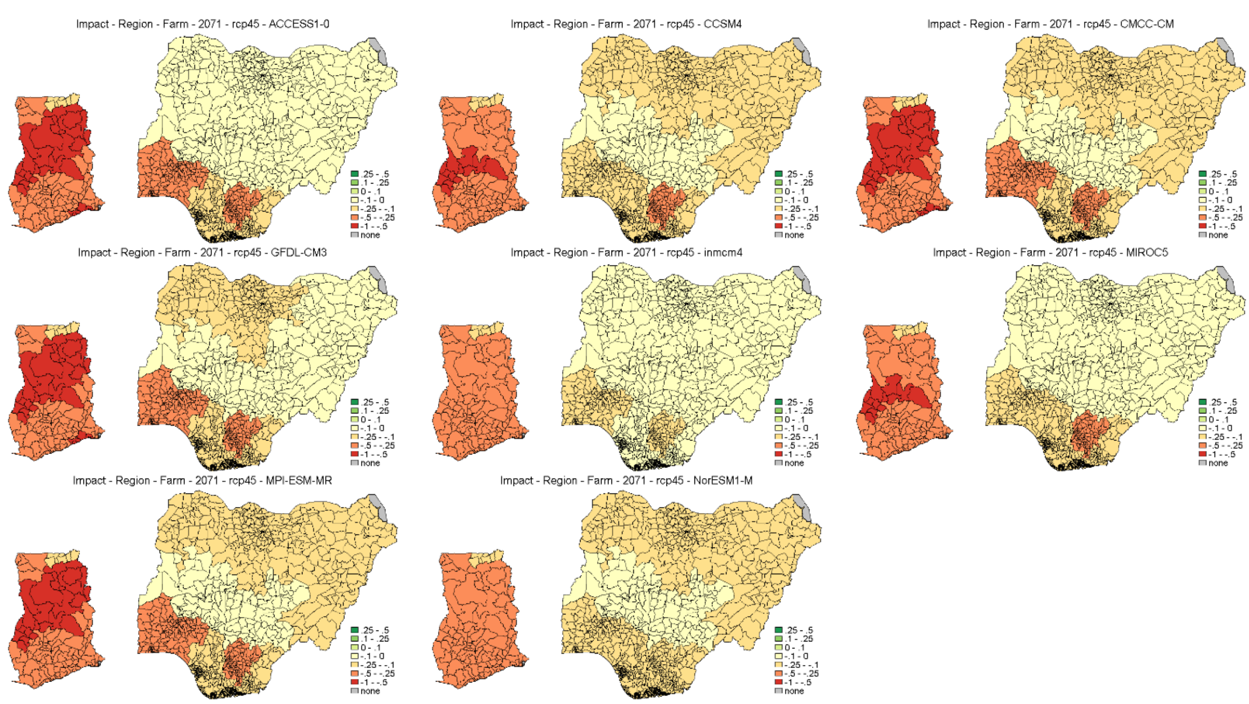

Figure A4: The impact of climate change at regional level: RCP 4.5 – 2071-2100 vs 1986-2005.

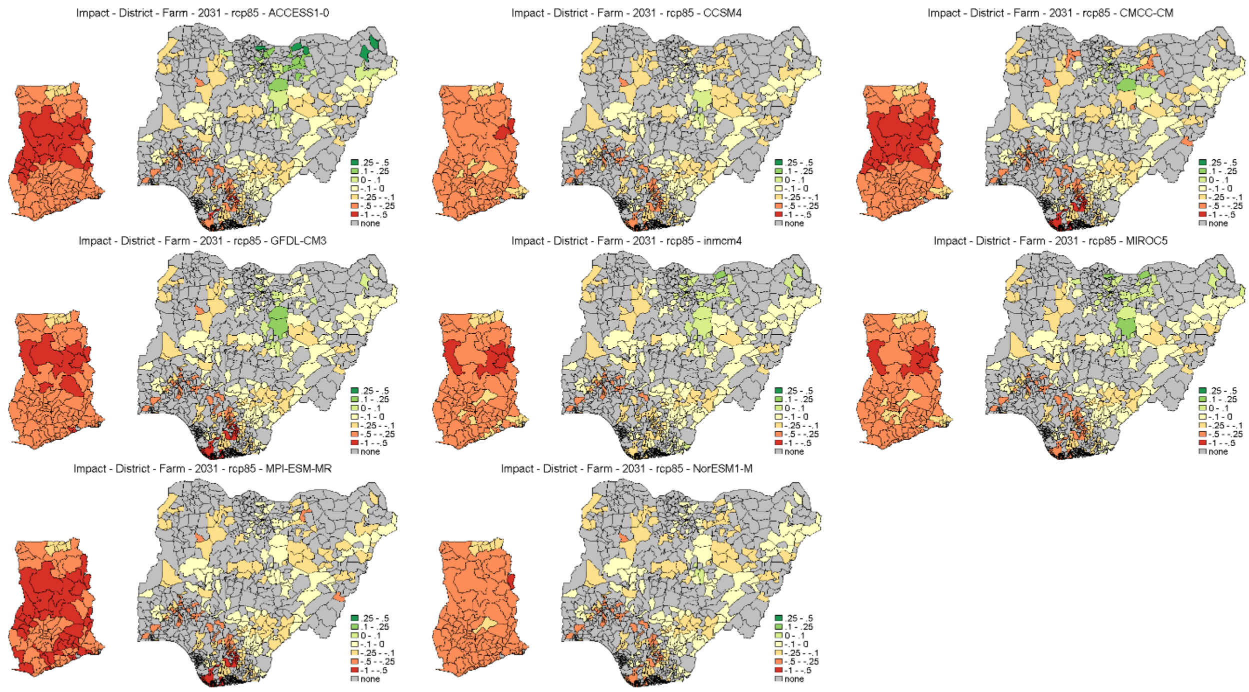

Figure A5: The impact of climate change at district level: RCP 8.5 – 2031-2060 vs 1986-2005.

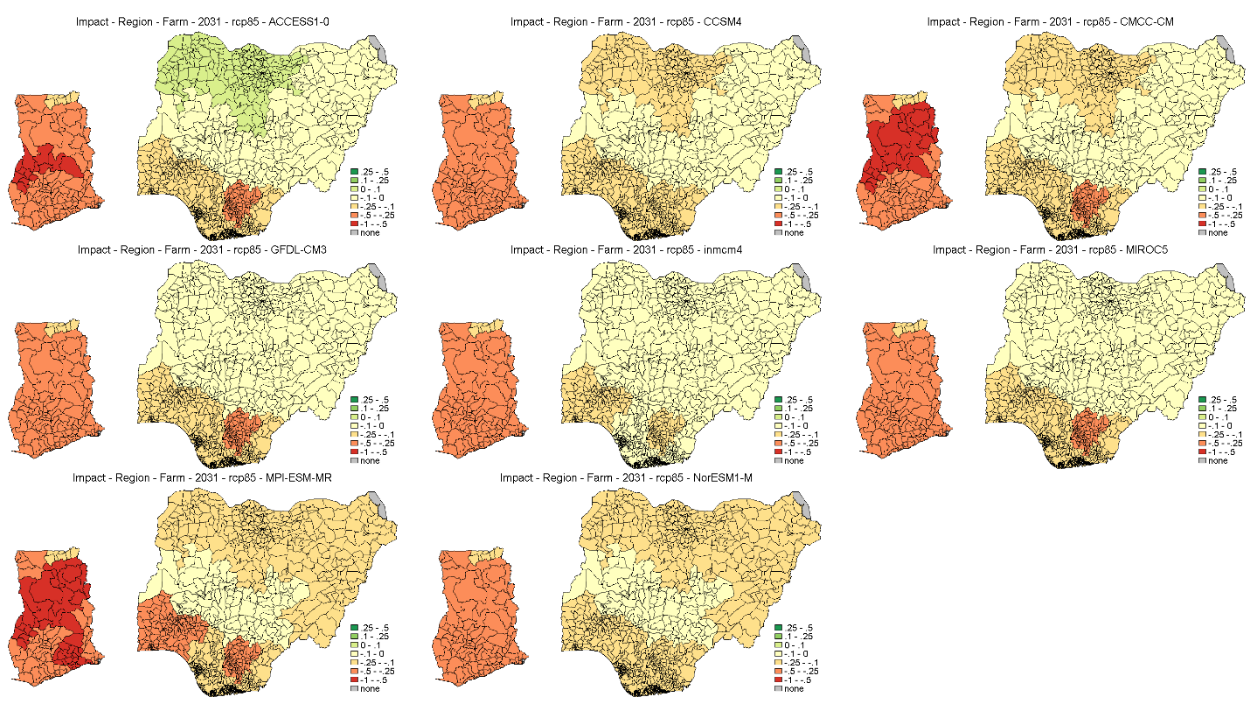

Figure A6: The impact of climate change at regional level: RCP 8.5 – 2031-2060 vs 1986-2005.

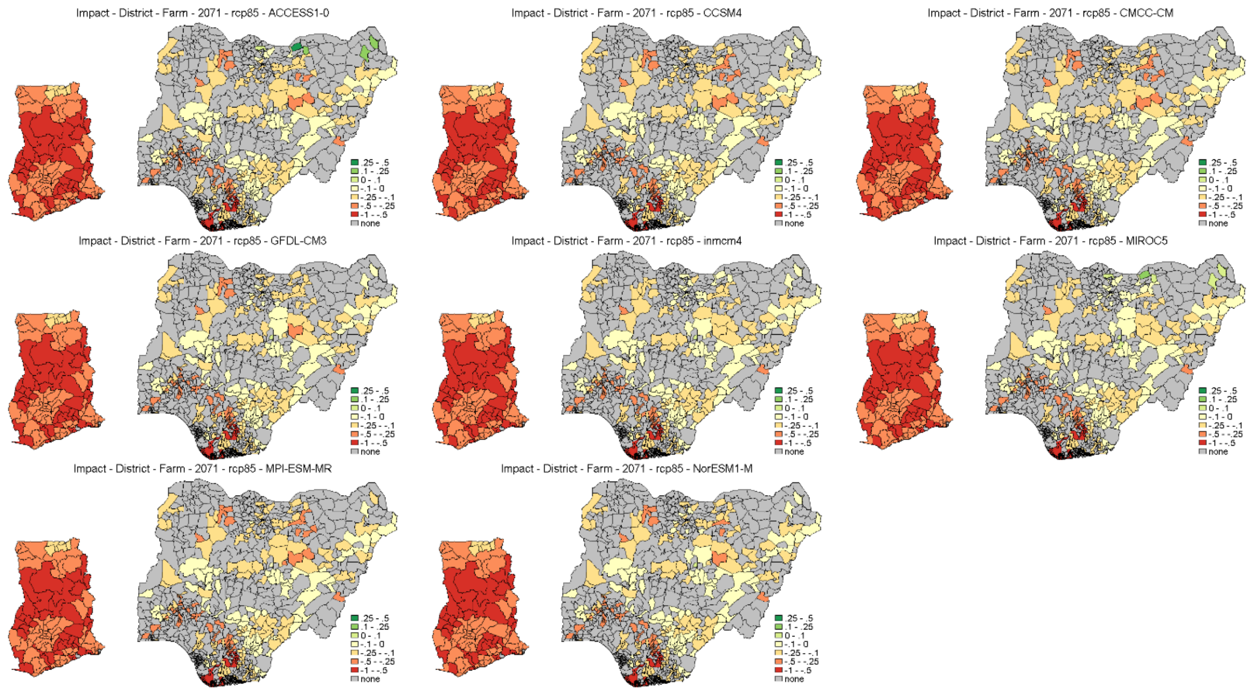

Figure A7: The impact of climate change at district level: RCP 8.5 – 2071-2100 vs 1986-2005.

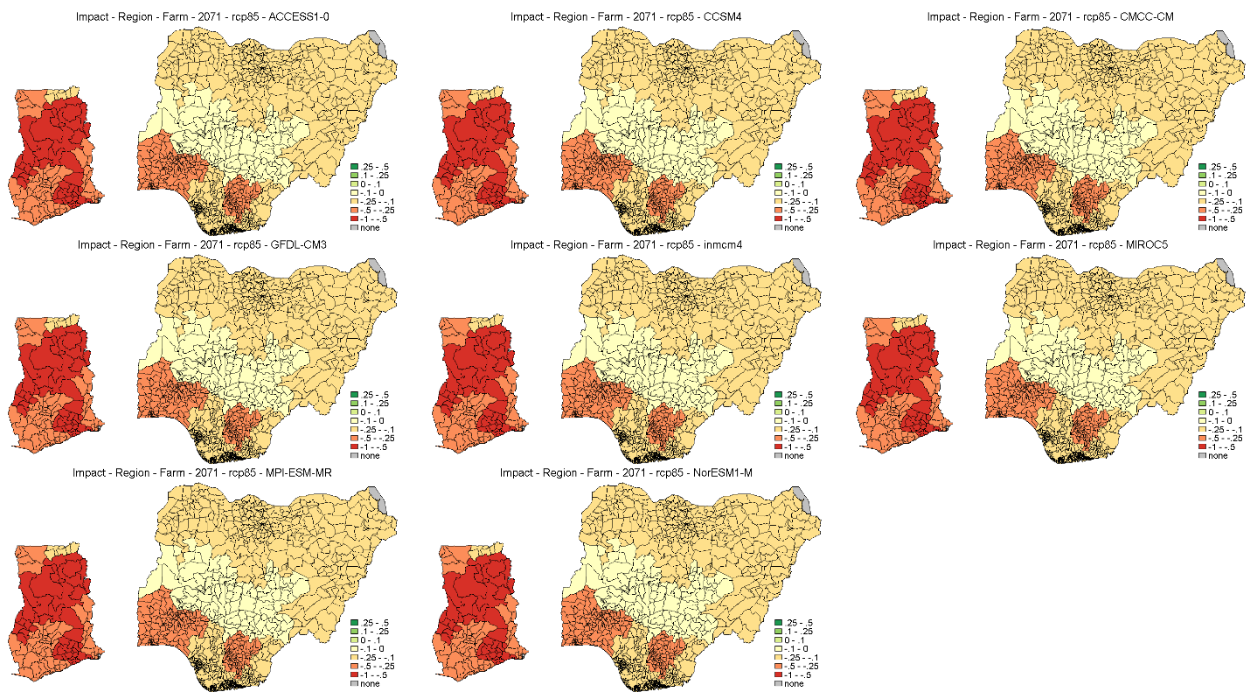

Figure A8: The impact of climate change at regional level: RCP 8.5 – 2071-2100 vs 1986-2005.

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