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Migration and environment in Ghana: a cross-district analysis of human mobility and vegetation dynamics

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ABSTRACT

Migration–environment linkages are at the centre of media attention because of public concern about climate change and a perceived "flooding" of migrants from less developed countries into more affluent parts of the world. In the past few years, a substantial body of conceptual literature about environmentally induced migration has evolved, but there is still a paucity of empirical work in this area. Moreover, the environmental causes of migration have been studied largely in isolation of the environmental consequences. In this paper, we present an analysis of migration and vegetation dynamics for one country (Ghana) to assess four migration–environment linkages. On the one hand, we look at two environmental drivers of migration: environmental push and pull. On the other hand, we look at the environmental impact of migration on source and destination areas. Census data at the district level (N=110) are used to map domestic migration flows in Ghana, which are then related to vegetation dynamics retrieved from a remotely sensed Normalized Difference Vegetation Index (NDVI) dataset (1981–2006). The analysis shows that at the national level, there are significant but weak correlations between migration and vegetation cover and trends therein. Districts with a migration deficit (more out-migration than in-migration) tend to be more sparsely vegetated and have experienced a more positive NDVI trend over the past quarter century than districts with a migration surplus. A disaggregation of data in three principle migration systems shows stronger correlations: north–south migration and cocoa frontier settlement have important environmental dimensions. Environmental factors do not seem to play a major role in migration to the capital, Accra. An important insight from this paper is that migration flows in Ghana can be explained partly by vegetation dynamics, but are also strongly related to rural population densities. This is because access to natural resources is often more important than the scarcity or abundance of natural resources per se. This study further shows that satellite remote sensing can provide valuable input to analyses of migration–environment linkages.

KEYWORDS

Environmental impact / environmental pull / environmental push / Ghana / migration / NDVI

I. INTRODUCTION

The past few years have witnessed a growing attention on the phenomenon of environmentally induced migration as a result of climate change. Journalists and "alarmist" academics often use the terms "environmental refugees" and "climate refugees"(1) and at present, heated debates are

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[1] Myers, N (2005), "Environmental refugees: an emergent security issue", Paper presented at the 13th Economic Forum, Prague, 23–27 May; also Welzer, H (2008), *Klimakriege. Wofür im 21. Jahrhundert getötet wird*, Fischer Verlag, Hamburg.

taking place about the use of these labels, not least because of the legal dimensions.[2] Estimates of the number of people who will be displaced due to adverse effects of climate change vary widely. Brown[3] labels such estimates as little more than "well-educated guesswork". We know that climate change will alter the distribution of population within countries and, to a lesser extent, also between countries, but it is impossible to achieve any degree of accuracy in the predictions. The present data and level of knowledge about the complex relation between climate change and human mobility are just too limited. Moreover, climate change is not the only threat facing millions of people (environmental and other). Deforestation, land degradation, biodiversity loss and pollution are just a few other environmental hazards that jeopardize rural people's livelihoods. In addition, some observers emphasize that natural resource scarcity and environmental degradation can cause conflicts and violence, which in turn can trigger population flows.[4]

The recent attention on environmentally induced migration does not come as a surprise. Climate change is at the top of the research and policy agenda, and so are public concerns about the migration of people from less-developed countries (LDCs) to more affluent parts of the world. After an initial phase of mostly theoretical and conceptual contributions to the migration–environment debate,[5] and repeated complaints about the lack of empirical studies,[6] gradually more efforts are being made to assess to what extent climatic changes and other environmental threats generate migration flows. The present study of Ghana aims to contribute to this emerging body of knowledge. The rationale is that we need to know how environmental degradation, scarcity and disasters have influenced migration flows in the past in order to be better prepared for the future.

As mentioned above, public concerns about migration from LDCs to "the West" may have played an important role in generating attention for migration–environment linkages. The majority of people who are most vulnerable to environmental change, however, will never make it to "the West". They are usually among the poorest in their home countries and most of them lack the resources and the contacts to migrate internationally. The bulk of people who are displaced by or who decide to migrate because of environmental problems will move to areas within their home countries or to neighbouring states.[7]

One of the problems in predicting migration flows caused by climate change and other environmental adversities is that for most regions in the world, and especially for less-developed countries, the scientific community does not have adequate data of past environmental changes and migration flows to build reliable models.[8] Also, due to the relatively recent interest in this topic, it seems that scientists have not yet fully explored and analyzed the data that are available. It is quite telling, for example, that Myers' oft-quoted

[2] Dun, O and F Gemenne (2008), "Defining environmental migration", *Forced Migration Review* Vol 31, pages 10–11.
[3] Brown, O (2008), "The numbers game", *Forced Migration Review* Vol 31, pages 8–9, page 8.
[4] For example, Homer-Dixon, T F (1999), *Environment, Scarcity and Violence*, University Press, Princeton; also see reference 1, Welzer (2008).
[5] For example, Black, R (2001), "Environmental refugees: myth or reality?" *New Issues in Refugee Research* No 34, UNHCR, Geneva; also Castles, S (2002), "Environmental change and forced migration: making sense of the debate", *New Issues in Refugee Research* No 70, UNHCR, Geneva.
[6] Jäger, J, J Frühmann and S Grünberger (2009), *Environmental Change and Forced Migration Scenarios: Synthesis of Results*, EACH–FOR, Bonn and Vienna; also see reference 3.
[7] Tacoli, C (2009), "Crisis or adaptation? Migration and climate change in a context of high mobility", *Environment and Urbanization* Vol 21, No 2, October, pages 513–525.
[8] See reference 3.

prediction of 200 million environmental refugees by the year 2050 is based on data that he first used in a 1995 publication.[9]

Time-series of satellite imagery can be an important input to studying relations between migration flows and environmental change. A dataset that is regularly used for applications in agriculture and ecology is the Normalized Difference Vegetation Index (NDVI) of the Global Inventory Modelling and Mapping Studies (GIMMS) group,[10] and it provides a worldwide measure of the presence of green vegetation at a 15-day time step for 1981-2006. Vegetation density is determined to a large extent by climatic and soil conditions. These two factors are crucial for farmers living in risk-prone and poorly endowed environments, and these people are most likely to be affected by future climate change and land degradation. Until now, the GIMMS–NDVI dataset has hardly been used by geographers and social scientists interested in population–environment linkages.

This paper aims to provide a first exploration of the relation between vegetation dynamics and migration flows in one country, Ghana. The reason for choosing Ghana is two-fold: first, Ghana has a reasonably good record of migration statistics derived from the population census; and second, the main author of this paper has 10 years experience studying climate variability and migration in Ghana. This enables an insightful interpretation of the data from the aforementioned secondary data sources. In this paper, we try to answer two questions: first, we want to find out to what extent migration flows in Ghana are environmentally induced; and second, we try to assess the impact of these migration flows on vegetation dynamics. To answer the first question, we relate average NDVI values to net migration flows. To answer the second question, we explore whether districts with high in-migration rates experience more negative NDVI trends than districts that experience more out-migration.

II. MATERIALS AND METHODS

To assess the relation between human mobility and vegetation dynamics in Ghana, we make use of Ghana's 2000 population and housing census and remote sensing data. Census data were used to determine in-migration, out-migration and net migration rates at the regional (N=10) and district (N=110) levels. The census further provided data on population densities, urbanization rates and gender and age structure that were used to better understand the nature of the migration flows. Remote sensing data were used to determine the geographic distribution and trends in green cover. Where appropriate, we relate our findings on migration–vegetation linkages to rainfall patterns and trends. The different datasets and methods of extraction are described in more detail below.

a. Migration data

The 2000 population and housing census of Ghana enquired about people's place of birth, using three categories: place of enumeration; elsewhere in the region; and outside the region of enumeration. In the third category, people were asked to specify the region in Ghana where they were born. The regional census reports[11] mention the intra-regional, inter-regional and

9 Recent publications mostly quote Myers (2005), see reference 1; this publication uses the same figures as Myers, N and J Kent (1995), *Environmental Exodus: an Emergent Crisis in the Global Arena*, Climate Institute, Washington DC.

10 Tucker, C J et al. (2005), "An extended AVHRR 8-kilometre NDVI dataset compatible with MODIS and SPOT vegetation NDVI data", *International Journal of Remote Sensing* Vol 26, No 20, pages 4485–4498.

11 Ghana Statistical Service (2005), *2000 Population and Housing Census. Analysis of District Data and Implications for Planning*, Ghana Statistical Service, Accra.

international in-migration rates per district. Unfortunately, the reports do not specify whether intra-regional migrants were born elsewhere in the same district or in another district in the region. Hence, movements between districts within one region could not be included in the district migration figures. This paper deals purely with domestic inter-regional migration.

Domestic out-migration rates are reported at the regional level. Since the census questionnaire does not enquire about birth district (only birth region), no exact out-migration figures exist at the district level. We estimated the district out-migration rates by means of a regional level regression of: percentage elderly population (65+); sex ratio (number of men per 100 women); and urbanization rate (proportion of the population living in localities with more than 5,000 inhabitants). The three variables together explain 96 per cent of the variation in out-migration rates at the regional level. District level out-migration rates were estimated with the resulting equation,(12) and subsequently corrected to match the known regional figures. The net migration rates were then calculated as in-migration minus out-migration.

Another important constraint of the birthplace-based migration data is that they just tell us something about the accumulated number of migrants per district. The data do not disclose the timing of these migrations. In theory, this problem can – to some extent – be addressed in a longitudinal analysis of district level migration figures. In the case of Ghana, however, this has not been possible. Due to continuous restructuring of administrative areas and census boundaries, district level migration data are not comparable over time.

b. Vegetation data

The GIMMS–NDVI dataset is derived from spectral measurements of the AVHRR (Advanced Very High Resolution Radiometer) sensor that was flown onboard different satellites. NDVI is calculated from the red reflection (ρ_r) and infrared reflection (ρ_{ir}) as follows:

$$NDVI = \frac{\rho_{ir} - \rho_r}{\rho_{ir} + \rho_r}$$

Vegetation has a high ρ_{ir} and a low ρ_r, thus high NDVI values indicate that green vegetation is abundant, while low values relate to bare soil. Although data are obtained on a daily basis from the satellites, cloud cover limits the usefulness of the observations. The GIMMS dataset suppresses the cloud signal by constructing bi-monthly (15-day) temporal composites. The dataset has an 8x8-kilometre resolution and ranges from July 1981 to December 2006. We further reduced remaining cloud effects by creating a maximum value composite with a monthly time-step, and applying a temporal filter to the data.(13) The final result is an 8x8-kilometre resolution monthly NDVI dataset.

To analyze the relation between migration and vegetation dynamics, we aggregated the 8x8-kilometre cells to the district level. The weighted average NDVI was calculated per district, per month, based on the percentage of the cell surface covering the district. Cells falling entirely within the district received a 100 per cent weighting, while partly overlapping cells received lower weightings. Cells that overlapped with water, especially the Volta Lake and the Gulf of Guinea, were excluded from the calculation of aggregate district NDVI values.

We calculated the average annual NDVI per district to identify densely and sparsely vegetated areas and to explore environmental causes of out-migration (environmental push) and

[12] Out-migration (%) = 175.015+(3.561* population aged over 65) - (1.715 * sex ratio) - (0.153 * urbanization rate).

[13] Chen, J et al. (2004), "A simple method for reconstructing a high-quality NDVI time-series data set based on the Savitzky-Golay filter", *Remote Sensing of Environment* Vol 91, No 3–4, pages 332–344. The source for the GIMMS NDVI dataset was the Global Land Cover Facility (www.landcover.org).

in-migration (environmental pull). We argue that average NDVI is a reasonably accurate proxy for the availability of natural resources that farmers' livelihoods in Ghana depend on, because the greenness of the environment is largely determined by rainfall and soil conditions. To explore the impact of in-migration and out-migration on vegetation cover we calculated district NDVI trends, both in source and destination areas. Since NDVI is to a large extent determined by precipitation, we also evaluate the relation between migration and vegetation cover after accounting for rainfall trends. This was done by calculating partial correlations.

c. Other data

Besides the migration and vegetation data, we make use of several other datasets to sketch a more rounded picture of migration–environment linkages in Ghana. First, we use sociodemographic data from the Ghana census 2000 to characterize migration flows in Ghana. Second, we used monthly rainfall data[14] (1982–2002) at a spatial resolution of 0.5 degrees to determine rainfall averages and trends. The 0.5 degree cell values were subsequently aggregated to the district level to enable a comparison with NDVI and census data. As mentioned above, vegetation cover is to a large extent determined by climatic conditions, and this factor needs to be taken into account when relating the NDVI distribution to sociodemographic factors.

III. MIGRATION IN GHANA

At the time of the population census in 2000 about one in four Ghanaians (26.4 per cent) was a domestic migrant. One in 10 (9.9 per cent) had migrated within the region of birth, and one in six (16.5 per cent) was an inter-regional migrant. Map 1 shows the main inter-regional migration flows in Ghana and the net migration rates per region. The regions with the largest share of in-migrant population are Greater Accra (Ghana's capital) and the Western region. Most of the people who have migrated to these regions hail from other parts of southern Ghana. The two other in-migration regions – the Ashanti region and the Brong Ahafo region – mostly receive people from northern Ghana, especially the Upper regions. As we will see below, each of these migration systems has different environmental dimensions in terms of push, pull and environmental impact of migration.

Maps 2–5 show the in-migration rates, the out-migration rates, the net migration rates and rural population densities at the district level. Several observations can be made from these maps. First, districts with high in-migration rates generally have low out-migration rates. The exception is the Northern region, which has a more static population (low in-migration and low out-migration rates). Second, the northern part of the country generally receives very few in-migrants. The settlers in the two districts in the Northern region that have higher in-migration rates hail almost exclusively from the Upper East and Upper West regions. Third, there is a belt of about 200 kilometres around the capital, Accra, with districts that have high rural population densities and negative net migration rates. Many of the former inhabitants of these districts seem to have relocated to the capital, Accra. An important alternative has been to relocate to the new cocoa frontier in the Western region. A fourth observation is that beyond the belt of densely populated out-migration districts, there is a belt of sparsely populated in-migration districts. This belt curves from the southwest through Ghana's middle belt, ending in the Afram plains (the dark-shaded district in the southeast of Ghana). In sum, it seems that the most important migration flows in southern Ghana are from districts with high rural population

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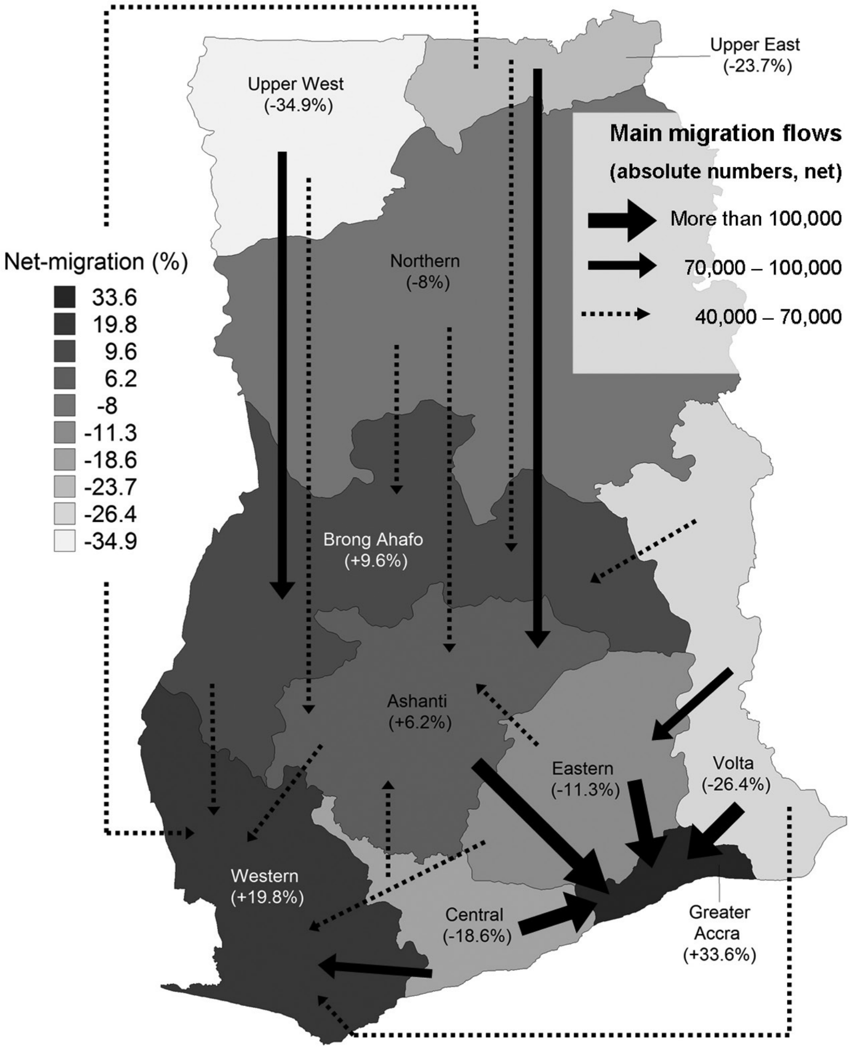
14 The rainfall data were derived from the CRU TS 2.1 dataset of the Climatic Research Unit of the University of East Anglia (http://www.cru.uea.ac.uk) and is fully based on rain gauge observations. At the time of writing this paper, the updated CRU TS 3.0 dataset, which runs up to 2006, was not yet available.

densities to the capital, Accra, or to the more sparsely populated Western region. North Ghanaians predominantly migrate to sparsely populated districts in the country's middle belt.

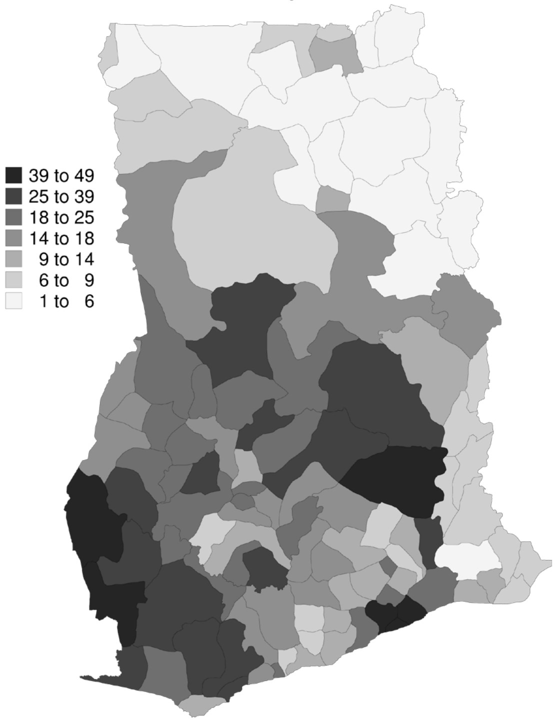
Map 1: Inter-regional migration in Ghana



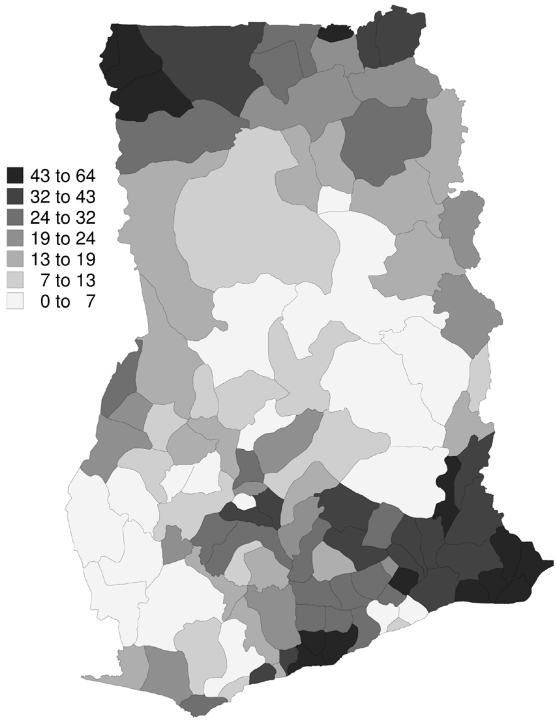
IV. VEGETATION AND RAINFALL IN GHANA

Map 6 shows the average annual NDVI values per district in Ghana. The country has four main ecological zones: the southeast coastal savannah, the forest zone, the forest–savannah transition zone and the interior savannah in the north. NDVI values are highest in the forest zone, followed by the forest–savannah transition zone, the interior savannah and lastly the coastal savannah. As shown in Map 7, average annual NDVI values are closely related to annual rainfall figures. Humid districts tend to have a denser vegetation cover than drier districts ($R = 0.659$, $p < 0.01$). Besides the average distribution of vegetation in Ghana, we also looked at vegetation trends to assess possible impacts of migration on vegetation cover. Map 8 shows that the north of Ghana has experienced a steady increase in NDVI values over the past 25 years. It should be noted that the NDVI time-series starts at the peak of the Sahel droughts in the early

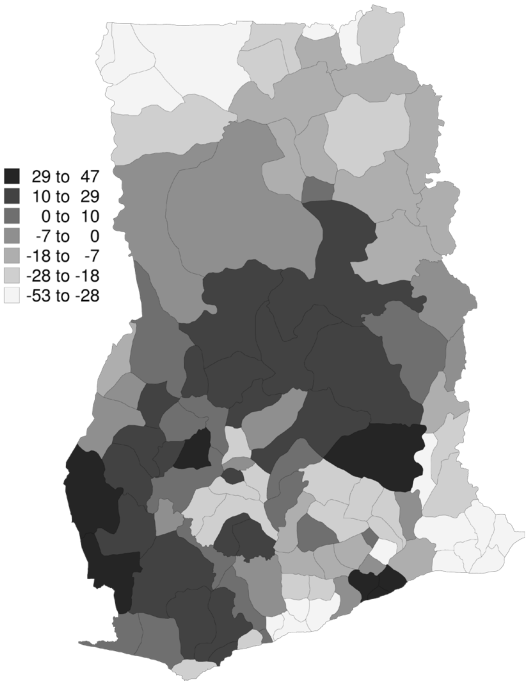
Map 2: In-migration (%)



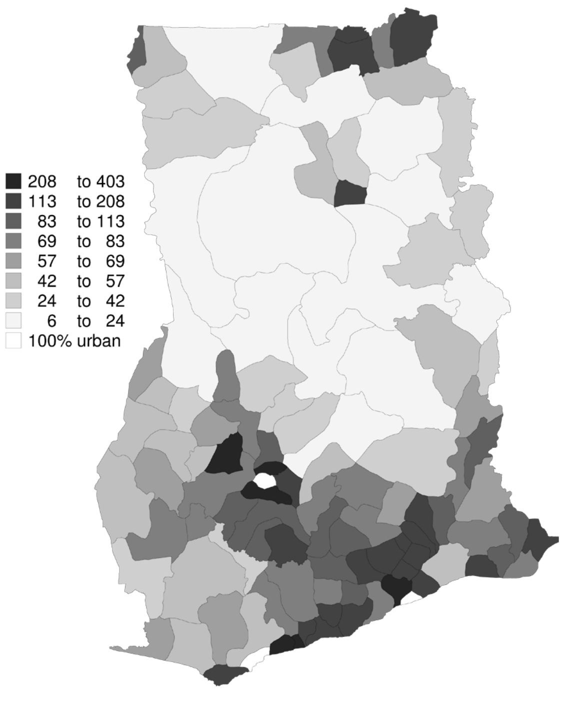
Map 3: Out-migration (%)



Map 4: Net-migration (%)



Map 5: Rural population density



Sources for map 2.2 to 2.5: Calculated from Ghana Statistical Service (2005b).

Notes: In-migration rates are calculated as the proportion of the district population born outside the region. Out-migration rates are calculated as the proportion of the population born in the district living outside the region. Net-migration rates are calculated as the difference between in-migration and out-migration rates. Rural population densities are calculated as the rural inhabitants per km^2. The Ghana census considers localities with fewer than 5,000 inhabitants as rural.

Maps by Kees van der Geest.

1980s, which also hit northern Ghana.[15] We performed a t-test on the trend and found that the increase was consistent for all northern districts ($p < 0.01$). The picture for southern Ghana is much less clear. Most Southern districts have experienced little change in average annual NDVI values, except for some coastal districts that have seen a significant decrease in vegetation cover. Map 9 shows the district trends in annual rainfall. Contrary to what we expected, we found no positive correlation between NDVI trend and rainfall trend. The positive NDVI trend in northern Ghana seems to have other causes than increased rainfall, and some coastal districts with negative NDVI trends have experienced a very positive rainfall trend between 1982 and 2002.

V. MIGRATION AND VEGETATION DYNAMICS

At the national level, there are significant but weak correlations between net migration and average vegetation cover. Districts with low average annual NDVI values tend to experience more out-migration, and districts with high NDVI values tend to have more in-migration ($R = 0.222$, $p < 0.05$). The two regions that clearly show an opposite signal are the Greater Accra region and the Eastern region. Accra has a very low NDVI and very high in-migration. Unsurprisingly, the migration pull factors of the fully urbanized capital, Accra, seem to be unrelated to the natural environment. A large part of the Eastern region combines a dense vegetation cover with quite massive out-migration. The main driver of migration here is probably the small distance to Accra, with its dynamic economy and employment opportunities. As we have seen, the national level correlation between net migration and vegetation cover is relatively weak. A stronger relation exists between average rainfall (1982–2002) and net migration ($R = 0.478$, $p < 0.001$). Humid districts tend to experience more in-migration than out-migration and districts with lower average annual rainfall figures tend to have negative migration rates. Exceptions are districts in the Greater Accra region that combine low rainfall with high in-migration, and some humid districts in the northern part of the Volta region that experience quite heavy out-migration.

Weak but significant correlations also exist between net migration and NDVI trends: districts with more out-migration tend to have a more positive NDVI trend than districts that have experienced more in-migration ($R = -0.261$, $p < 0.01$). This could be an indication that migration has a negative effect on vegetation cover in destination areas and a positive effect on migrants' source areas. After controlling for the trend in annual rainfall, the partial correlation between net migration and NDVI trend is slightly weaker, but still very significant ($R = -0.251$, $p < 0.01$). The districts that show a strong opposite signal combine high out-migration rates with negative NDVI trends. Most of these districts are situated along or near the coast, east and west of Accra.

The national level statistical correlations between migration and vegetation dynamics, although weak, are an indication that the environment matters in explaining migration flows, and that migration flows matter in explaining changes in vegetation cover. However, these statistics tell us little about the processes behind migration and vegetation dynamics. It is more informative to study the migration–environment linkages of separate migration systems, which we will do below. We study the statistical relation between migration, vegetation cover, rainfall and rural population density for sub-sets of districts in the different migration systems, but more importantly, we use supplementary sources to embed the migration flows in an historic and geographic context. In doing so, we try to tell the story behind the data, which enables a more insightful interpretation.

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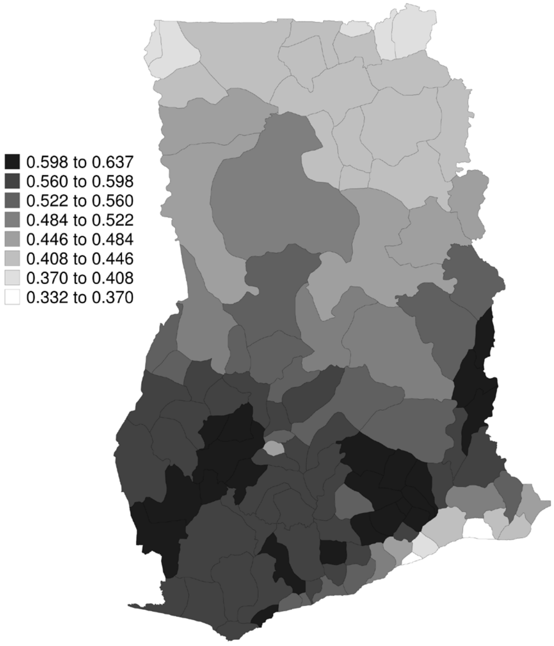
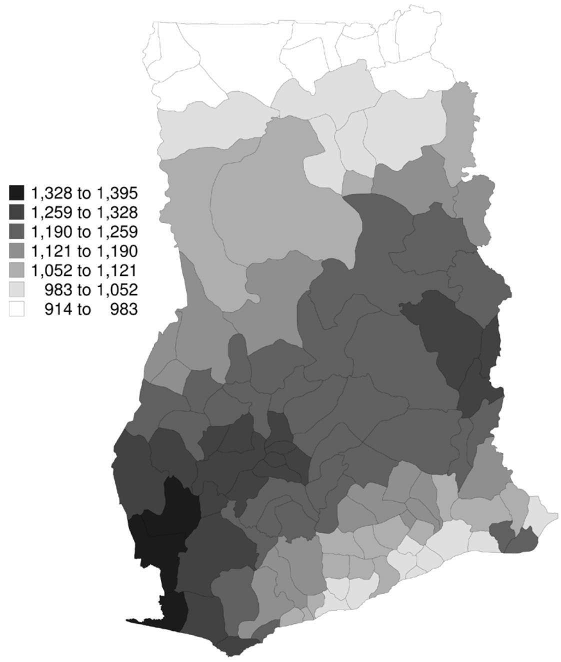
15 Dietz, T et al. (2004), *The Impact of Climate Change on Drylands with a Focus on West Africa,* Kluwer, Dordrecht.

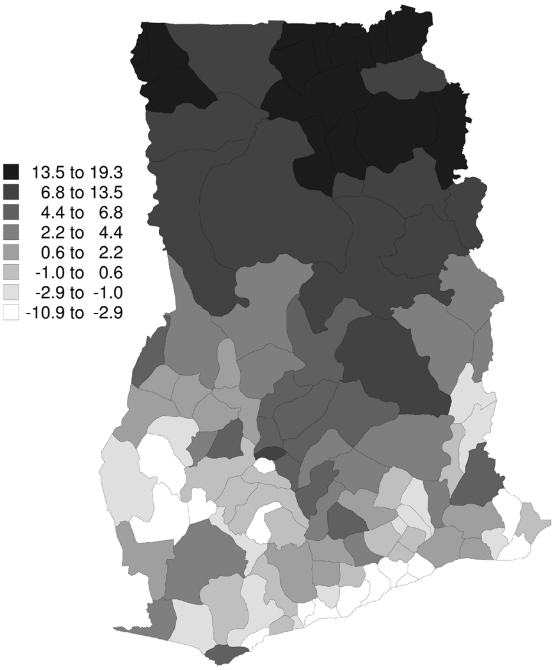
Map 6: Average vegetation density - NDVI (1982-2006)



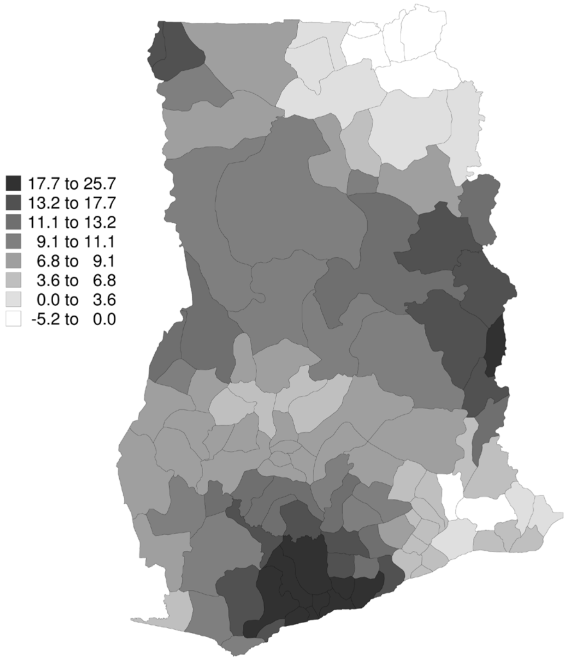
Map 7: Average annual rainfall (mm) (1982-2002)



Map 8: NDVI change (%) (1982-2006)



Map 9: Rainfall change (%) (1982-2002)



Sources for map 2.6 to 2.9: Global Land Cover Facility (for NDVI) and CRU TS 2.1 (for rainfall).

Notes: Terrestrial NDVI values range from zero to one. Values close to zero indicate barren land and values approaching one are found in densely vegetated areas such as tropical rainforests. Trends were calculated as the slope multiplied by the number of years and divided by the long-term average.

Maps by Kees van der Geest

a. North–south migration

The first domestic migration system we discuss involves the movement of people from northern Ghana to Ghana's middle belt. This movement is quite literally a migration to greener pastures: from the interior savannah zone to the greener forest and forest–savannah transition zones (see Map 6). Scarcity of natural resources is certainly not the only driver of migration from northern Ghana. Some of the root causes of underdevelopment and poverty in northern Ghana go back to colonial times, when the north became a labour reservoir for the colony's centre of economic development in the south.(16) In colonial times, most northerners migrated to destinations south of today's prime destination areas. Many of them worked in the mines, in road construction and as cocoa farm labourers. In recent decades – the 1970s seem to have been the turning point – more and more migrants from northern Ghana settled in the forest–savannah transition zone to start their own farms.(17)

Environmental push seems to play an important role as a driver in this migration system: within northern Ghana, districts with lower average NDVI values tend to have more negative net migration rates, i.e. such districts experience much more out-migration than in-migration ($R = 0.660$, $p < 0.001$). The relation between average annual rainfall and net migration is equally strong ($R = 0.686$, $p < 0.001$). For the inhabitants of greener and more humid districts, the need to migrate is clearly less pressing because their incomes are higher and their livelihoods are less risk prone.

Migrants from northern Ghana predominantly settle in the Brong Ahafo and Ashanti regions. Environmental pull does seem to play a role in attracting northern migrants to these particular regions, but low rural population density (a proxy for availability of land) is a more important environmental pull factor than vegetation cover. Districts in the Brong Ahafo and Ashanti regions that have low rural population densities tend to experience more in-migration than densely populated districts(18) ($R = -0.635$, $p < 0.001$), while districts with higher NDVI values experience less in-migration than districts with lower NDVI values ($R = -0.403$, $p < 0.05$). This can be understood as follows: in the sparser populated forest–savannah transition zone, land is less commoditized and tenure conditions for settler farmers from the north are more favourable than in the greener forest zone, with its tradition of commercial cocoa farming and individualized land-holding regimes. Moreover, the natural environment in the forest–savannah transition zone resembles farming conditions in their area of origin, with the advantage of having two rainy seasons.

To assess the environmental impact of migration, we looked at the NDVI trends in the source and destination areas of migrants. Maps 4 and 8 show that northern Ghana, and especially the Upper regions, is an area with quite massive out-migration and a very positive vegetation trend. On average, the annual NDVI values in northern Ghana have increased 12.1

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16 Plange, N K (1979), "Underdevelopment in northern Ghana: natural causes or colonial capitalism?", *Review of African Political Economy* Vol 6, No 15–16, pages 4–14; also Sutton, I (1989), "Colonial agricultural policy: the non-development of the northern territories of the Gold Coast", *The International Journal of African Historical Studies* Vol 22, No 4, pages 637–669; and Lentz, C (2006), *Ethnicity and the making of history in Northern Ghana*, University Press, Edinburgh.

17 Abdul-Korah, G B (2006), "Where is not home? Dagaaba migrants in the Brong Ahafo region, 1980 to present", *African Affairs* Vol 106, No 422, pages 71–94; also Van der Geest, K (2008), "North-south migration in Ghana: what role for the environment?", Paper presented at the International Conference on Environment, Forced Migration and Social Vulnerability, Bonn, 9–11 October.

18 Two districts were excluded from the calculation of correlations between net migration, rural population density and average NDVI. These districts record very high rural population densities, while de facto they are fully urbanized outskirts of the Kumasi Metropolitan Area.

per cent between 1982 and 2006. Massive out-migration may reduce the pressure on natural resources and thus have a positive influence on vegetation cover. Indeed, within northern Ghana, we see that the districts with greater migration deficits tend to have more positive NDVI trends ($R = -0.649$, $p < 0.01$). It would be appropriate, however, to also consider the rainfall trend. In most districts in northern Ghana, as in the rest of the country, rainfall has generally increased between 1982 and 2002 (Map 9). The exception is the northeast corner, which has experienced a slightly negative rainfall trend but similar increases in NDVI values as the rest of northern Ghana. After controlling for changes in annual amounts of rainfall, the partial correlation between net migration and NDVI becomes even stronger ($R = -0.692$, $p < 0.001$). A tentative conclusion would be that massive out-migration in northern Ghana reduces the pressure on natural resources, which has a positive effect on vegetation cover. It should be noted, however, that despite heavy out-migration, the population of northern Ghana is still growing. Population pressure increases more slowly due to out-migration, but is still increasing. Hence, other factors than out-migration are also likely to contribute to the positive NDVI trend. Some of these factors could be livelihood diversification, more sustainable farming techniques, reforestation programmes or CO_2 fertilization.

Within the main destination regions of migrants from northern Ghana, the trend in average annual NDVI values is slightly positive, and no significant correlation was found between net migration rates and NDVI trends of districts in the Brong Ahafo and Ashanti regions. This did not change after correcting for rainfall trends. This could be an indication that the in-migration of farmers from northern Ghana has not resulted in a massive conversion of forest into cropland. This hypothesis is to a large extent confirmed by unpublished case study material from the Brong Ahafo region, which shows that migrant farmers hardly ever get access to virgin farmland. They primarily farm the old fallows of the native population that increasingly moves out of agriculture and into (semi-) urban and non-farm livelihoods.

b. Migration to the cocoa frontier

The second migration system we discuss concerns the movement of people from different southern Ghanaian regions to the cocoa frontier in southwest Ghana. Cocoa was introduced in Ghana in the late nineteenth century in the southeast of the forest zone, in the present Eastern region. In the first decades of the twentieth century, cocoa cultivation expanded rapidly to the Ashanti region, the Central region, the Brong Ahafo region and the Volta region. In Hill's[(19)] landmark study of migrant cocoa farmers, the process of this expansion is described in detail, with much attention given to the role of migration, capital and social organization. An important insight from her study is that the early expansion of cocoa in Ghana occurred in an atypical way. Instead of diffusing through a government-induced process of adoption by other farmers, early cocoa expansion occurred in a process of migration from existing cocoa areas to new lands.

Important requisites of potential cocoa-growing areas were "…*favourable ecological conditions, low population densities and favourable conditions for land acquisition*".[(20)] During the early expansion of cocoa cultivation in Ghana, southwest Ghana was not very attractive because of its humidity: it lacked a short but pronounced dry period, as is common in the rest of southern Ghana. In the 1960s, 1970s and early 1980s, Ghana witnessed a severe decline in cocoa production because of diseases such as swollen shoot and black pod, ageing trees, soil fertility decline, adverse climatic conditions, low producer prices and a political environment

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[19] Hill, P (1961), "The migrant cocoa farmers of Southern Ghana", *Africa* Vol 31, No 3, pages 209–230.
[20] Awanyo, L (1998), "Culture, markets, and agricultural production: a comparative study of the investment patterns of migrant and citizen cocoa farmers in the Western region of Ghana", *Professional Geographer* Vol 50, No 4, pages 516–530.

that removed the incentives for cocoa production.(21) Farmers in the densely populated old cocoa areas were confronted with falling incomes and limited opportunities for local expansion. When the macroeconomic conditions and policy environment improved from the mid-1980s onwards,(22) and when new cocoa varieties became available that did not require a pronounced dry period, many farmers decided to migrate to the sparsely populated new cocoa frontier in the interior of the Western region and the southernmost districts of the Brong Ahafo region.(23) Since the late 1980s, the cocoa sector has recovered gradually, and between 2002 and 2006 cocoa production in Ghana more than doubled.(24) The bulk of the sector's growth took place in the new cocoa frontier, which has become the prime cocoa-producing region in Ghana.(25) Cocoa production in the Western region, contrary to the other cocoa-producing regions, shows few signs of intensification. Output growth is almost entirely due to expansion into new lands,(26) and this is likely to have negative impacts on the vegetation cover.

Map 6 shows that the average annual NDVI values of the old cocoa-producing areas are similar to those of the Western region. Hence, a superficial conclusion would be that environmental push and pull do not play a major role in this migration system. As in the case of the main destination area in the north–south migration system, however, it seems that the environmental pull factor of the Western region is low rural population density (and hence ample room for settlers) rather than dense vegetation. In sparsely populated areas, it is easier and cheaper to gain access to natural resources – in this case land to plant cocoa trees. Cocoa frontier settlement in Ghana involves a movement from areas with high rural population densities to more sparsely populated areas (Map 5). This is not the full story, however. Cocoa frontier settlement also involves a movement from areas with scanty patches of remaining tropical forest to a region that had and still has a much larger stock of tropical forest, but this is not adequately expressed in the average annual NDVI values. Mature cocoa plantations, which abound in the old cocoa areas, are evergreen and have closed canopies. The average annual NDVI values measured over mature cocoa plantations are quite similar to those of semi-deciduous forests. A geographical analysis of average annual NDVI does not identify this difference. For this we have to look at the NDVI amplitude, which is higher over semi-decidiuous tropical forests than over cocoa plantations. In areas planted with cocoa, the minimum annual NDVI tends to be higher and the maximum NDVI tends to be lower. Looking at the geographical distribution and trends in NDVI minimum and maximum (Maps 10–13), we see that over the 1982–2006 period, districts situated in the cocoa frontier indeed had high, but sharply decreasing, maximum NDVI values. In the same area, the minimum NDVI trend was very positive. Although other factors also influence the trend in NDVI amplitude, our hypothesis is that conversion from forest to cocoa plays an important role. The reduction in amplitude is especially pronounced since 2001, when cocoa cultivation in Ghana soared.

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[21] Crook, R (2001), "Cocoa booms, the legalization of land relations and politics in Côte d'Ivoire and Ghana: explaining farmers' responses", *IDS Bulletin* Vol 32, No 1, pages 35–45; also Leiter, J and S Harding (2004), "Review: Trinidad, Brazil, and Ghana: three melting moments in the history of cocoa", *Journal of Rural Studies* Vol 20, No 1, pages 113–130.

[22] Laven, A (2010), *The risk of inclusion: Shifts in governance processes and upgrading opportunities for cocoa farmers in Ghana*, PhD thesis, University of Amsterdam.

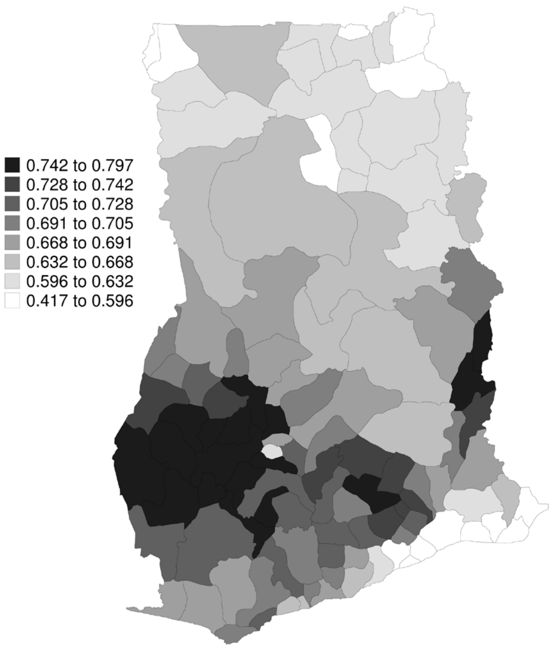
[23] Ruf, F (2007), "The cocoa sector: expansion, or green and double green revolutions", Background Note, Overseas Development Institute, London.

[24] The cocoa production data were retrieved from the FAOSTAT website of the Food and Agriculture Organization of the United Nations (www.faostat.fao.org).

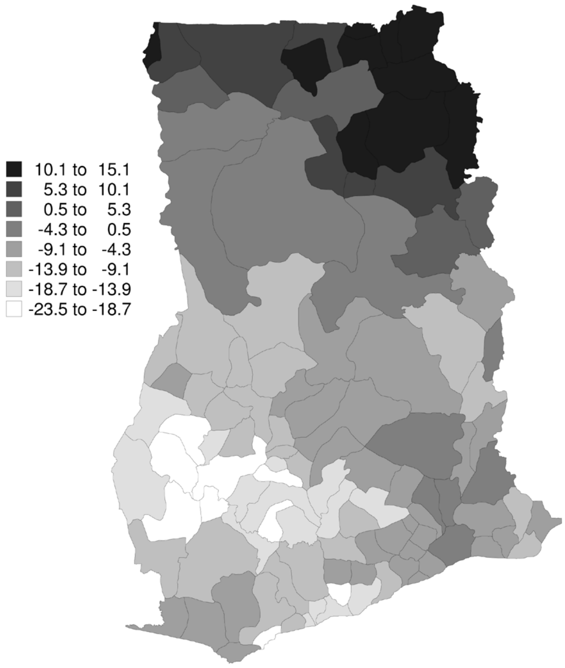
[25] Gockowski, J (2007), *Cocoa Production Strategies and the Conservation of Globally Significant Rainforest Remnants in Ghana*, Paper presented at the International Institute of Tropical Agriculture, Accra, 19 November.

[26] Teal, F et al. (2006), *Ghana Cocoa Farmers Survey 2004*, Ghana Cocoa Board, Accra.

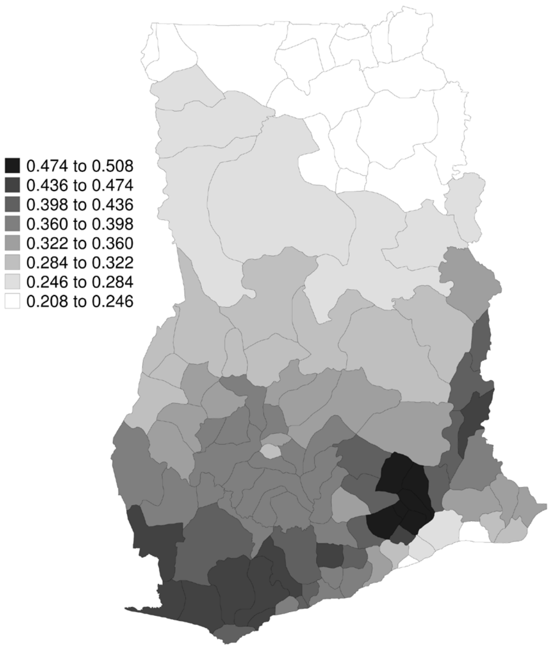
Map 10: Average Maximum NDVI (1982-2006)



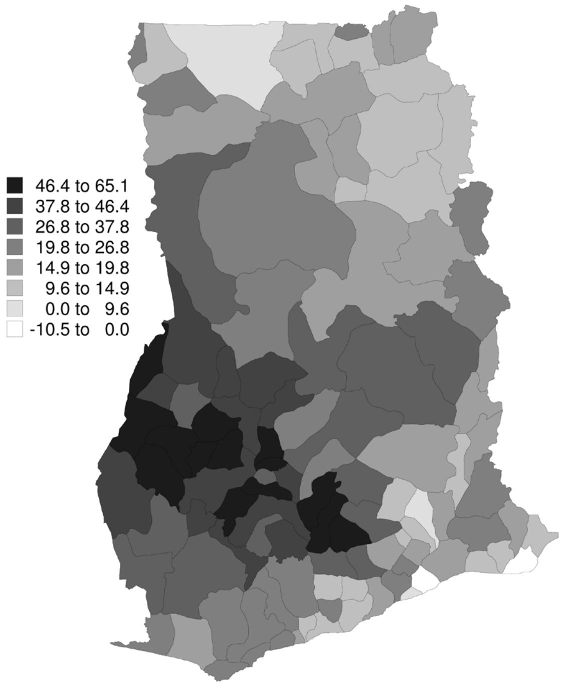
Map 11: Maximum NDVI change (%) (1982-2006)



Map 12: Average Minimum NDVI (1982-2006)



Map 13: Minimum NDVI change (%) (1982-2006)



Sources for map 2.10 to 2.13: Global Land Cover Facility.

Notes: Average maximum NDVI and average minimum NDVI are the averages of the highest and lowest NDVI values recorded per year. Trends were calculated as the slope multiplied by the number of years and divided by the long-term average.

Maps by Kees van der Geest

In a case study of the Western region, Alo and Pontius[(27)] conclude that most deforestation in forest reserves is caused by illegal logging activities, and that deforestation outside protected areas is due to cocoa expansion. Although our analysis suggests that this does not negatively affect annual average green cover, it is likely to have negative effects on biodiversity and ecosystem stability. Biodiversity loss is also a problem in the remaining forests of southwest Ghana. In this vein, Oates[(28)] writes about "the empty forests of Ghana". Such negative environmental trends are not identified by the NDVI dataset, which simply evaluates green cover.

c. Migration to Accra

The largest domestic migrant flow in Ghana consists of people who move to the national capital, Accra. At the time of the 2000 population census, more than 1.1 million inhabitants of the Greater Accra Region (41.3 per cent) were born outside the region. Most of these migrants hailed from the Eastern, Volta, Central and Ashanti regions, i.e. the regions closest to Accra.[(29)] Environmental pull does not play a major role in this migration system. The Accra Metropolitan Area is fully urbanized, and due to its location in the coastal savannah, the area was already sparsely vegetated in pre-colonial times. The natural environment did play an anecdotal role in Accra's migration history. In pre-colonial times, Accra was a small coastal fishing port situated near two European forts from where gold and slaves were traded. In 1874, the Gold Coast became a Crown Colony of the British, and in 1877 the colonial rulers decided the move the seat of government from Cape Coast to Accra because of its drier conditions, which they hoped would benefit the health of the colonial officers.[(30)] After Accra became the administrative centre of the colony, it started its impressive growth from a small town into a metropolis with almost 2 million inhabitants. Most of Accra's growth has been due to in-migration.[(31)] Although this migration is often assumed to be "rural–urban", the Ghana Living Standards Survey revealed that 89 per cent of Accra's in-migrants lived in other urban centres prior to their migration to Accra.[(32)] Due to income disparities between rural and urban areas in Ghana and the relatively high cost of living in the national capital, it is more difficult for rural people to settle in Accra. This may also explain why relatively few people from the poorer north of Ghana have migrated to Accra. In this paper's Introduction, we wrote that the people most affected by environmental scarcity and climate change are least likely to migrate to "the West" because they lack the funds and contacts for such an endeavour. In the case of Ghana, this insight also seems to be valid for domestic migration to the national capital, Accra.

Employment and prospects of wealth seem to be the major pull factors of Accra. The 2005–2006 Ghana Living Standards Survey revealed that "seeking employment" and "job transfer" were mentioned twice as often in Accra than in other parts of Ghana as reasons to

[27] Alo, C A and R G Pontius (2008), "Identifying systematic land cover transitions using remote sensing and GIS: the fate of forests inside and outside protected areas of southwestern Ghana", *Environment and Planning B-Planning & Design* Vol 35, No 2, pages 280–295.
[28] Oates, J F (1999), *Myth and Reality in the Rainforest: How Conservation Strategies are Failing in West Africa*, University of California Press, Berkeley.
[29] See reference 11.
[30] Varley, W J and H P White (1958), *The Geography of Ghana*, Longmans, Green & Co, London, New York and Toronto.
[31] Smith, L (2007), "Tied to migrants: transnational influences on the economy of Accra, Ghana", PhD thesis, University of Amsterdam.
[32] Ghana Statistical Service (2008), *Ghana Living Standards Survey: Report of the Fifth Round (GLSS 5),* Ghana Statistical Service, Accra.

migrate. Unemployment rates in Accra are substantially higher (9.8 per cent) than the national average (3.5 per cent),[33] but the potential rewards for moving to Accra are perceived to be substantial.

As mentioned above, most migrants in Accra resided in urban centres in southern Ghana prior to their change of residence. Data from the Ghana Living Standards Survey reveal that within Ghana, these localities rank second behind Accra in terms of per capita income levels and low poverty rates. Hence, it seems reasonable to conclude that migration to Accra is mainly opportunity driven, and that neither environmental push nor pull play an important role in this migration system. Within the major source regions of Accra-bound migrants (Eastern, Volta, Central and Ashanti regions), no significant correlation was found between net migration and average annual NDVI values. Turning to the environmental impact of migration, we see that the NDVI trend in Accra has been very negative over the past quarter century. This could be because the city's "empty spots" are gradually filled with houses and businesses, which is to a great extent due to fast population growth caused partly by in-migration.

In sum, environmental push and pull do not seem to influence migration to Accra. The reason why we did include a discussion of this migration system here is that it constitutes the largest movement of people in the country. The discussion of this migration system serves as a counterweight to the first two migration systems we examined, which had clear environmental dimensions. In the course of the twentieth century, the livelihoods of more and more Ghanaians have become less dependent on the natural environment. Ghanaians nowadays migrate for a large variety of reasons, including environmental ones.

VI. CONCLUSIONS

This paper aimed to contribute to the emerging body of knowledge about migration–environment linkages by exploring the multiple ties between human mobility and vegetation dynamics in Ghana. We evaluated the role of environmental push and pull in Ghana's three major migration flows, and we explored the impact of migration on vegetation cover. Our analytical approach has been to map migration flows and relate these to vegetation distribution and trends in 110 districts. A disaggregation in three domestic migration systems allowed for a better interpretation of the data, embedded in a geographic and historical context.

Despite limitations in our analysis, this paper provides an insightful exploration of migration and vegetation dynamics in Ghana. Our findings suggest that environmental factors play an important role in causing migration from northern Ghana to Ghana's middle belt, and within southern Ghana to the cocoa frontier settlement. The natural environment is not an important driver of migration to Ghana's capital, Accra.

Low rural population density turned out to be an even stronger environmental pull factor than vegetation cover. This is because access to natural resources is more important than the availability of natural resources per se. Densely populated districts in the forest zone are less popular destinations for migrants from northern Ghana because they cannot afford to rent or purchase land there. Even autochthonous farmers in these areas find it hard to get access to land to expand their cocoa plantations, and many of them move to sparsely populated new cocoa areas in the southwest.

To assess the environmental impact of migration, we related the trends in vegetation cover over the past 25 years to net migration figures at the district level. In the new cocoa frontier, strongly reducing NDVI amplitudes indicate a conversion from forest to cocoa. In the forest–savannah transition zone – the main destination of northern migrants – no clear trend was discernible in NDVI values. A possible explanation could be that most settler farmers do not get access to virgin forest. A very significant positive trend in vegetation cover has taken place in

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[33] See reference 32.

northern Ghana, especially in districts with high out-migration rates. We found a strong correlation between net migration and vegetation change, even after accounting for rainfall trends. This could be an indication that out-migration has a positive effect on vegetation cover by reducing pressure on natural resources.

Spatial–temporal data derived from satellite sensors can provide an important input for analyzing migration factors. This is especially true when longer times-series are available, which match with demographic and socioeconomic data. However, knowledge of migration systems and the physical environment is required for making useful interpretations of such satellite-derived data. This study underlines the need for more collaboration between remote sensing experts and social scientists in analyzing environmental factors for migration.

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