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Applied Geography 23 (2003) 115–136

APPLIED GEOGRAPHY

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Modelling inter-provincial migration in Burkina Faso, West Africa: the role of socio-demographic and environmental factors

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Accepted 6 August 2002

Abstract

This study analyses the factors that cause inter-provincial migrations in an African context (Burkina Faso, West Africa), focusing specifically on the role of environmental factors in driving large migration flows in ecologically marginal regions. It uses statistical methods for modelling migration data to assess the relative importance of socio-demographic and biophysical variables. The former included the percentage of the population who are male, literacy and economic activity rates, and the presence of a resettlement policy. The latter included measures of land degradation, land availability and climatic variability, which vary considerably between different regions of the country. The results demonstrate that, as expected, demographic and socio-economic characteristics of Provinces were associated with migration patterns, and that environmental variables were also significant. However, the contribution of environmental variables in the explanation of migration was slightly lower than for the socio-demographic variables. The results show that inter-provincial migrations in Burkina Faso are influenced by high literacy and economic activity rates at the origin and destination, a high proportion of men at the origin, a low proportion of men at the destination, as well as by unfavourable conditions concerning rainfall variability, land degradation and land availability at the origin, and favourable conditions at the destination for these variables.

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0143-6228/$ - see front matter
doi:10.1016/j.apgeog.2002.08.001

Keywords: Migration; Burkina Faso; West Africa; Environment; Poisson models; Drought; Desertification

Introduction

In some regions of West Africa, the economic and social effects of large-scale in- or out-migration are significant. In Burkina Faso for example, due to migration, the population growth rate in the savannah region was reduced by 1.1% while, in the forest region, it increased by 0.6% (Zachariah & Conde, 1981). The regions of departure lose labour force while the social and economic infrastructures in regions of arrival may have problems keeping up with the rapidly growing population. Migration may also increase the risk of land conflicts between migrants and longer-term residents. Adding to the difficulty of their resettlement, rural migrants often receive the less productive and most vulnerable land to cultivate. High migration rates therefore create an additional challenge for spatial planning efforts, as there is a need to predict migration flows. However, migration is usually ignored in models of land use change (Stephenne & Lambin, 2001; Shen, 2000; Verburg, Veldkamp, & Fresco, 1999), even though it is often recognized to be the dominant demographic factor influencing land use (Lambin et al., 2001). Consequently, improving our predictive ability of migration in an African context will benefit spatial planning agencies who need to anticipate large and sudden migration flows.

Migration in West Africa is known to be related to a variety of demographic and socio-economic variables, such as local marriage rates, population age–sex structure, education levels, incomes, and fertility and mortality rates (Cordell, Gregory, & Piché, 1996; OCDE and CILSS, 1998; Ouattara, 1998; Sivamurthy, 1982; Zachariah & Conde, 1981). Basic models of migration flows are often based on the gravity theory (Ravenstein, 1889; Zipf, 1946). The origin and destination populations and the distance between each pair of places are the three variables used to explain migration in such models. Other explanatory variables can then be added to represent various factors such as origin and destination educational levels, job opportunities, level of urbanisation, population density, wage levels, etc. (Barber & Milne, 1988; Brown & Goetz, 1987; Flowerdew, 1991; Gordon & Molho, 1998; Gordon & Vickerman, 1982). Fewer examples of models can be found that include variables that reflect planning policies, land tenure, market prices and environmental factors even though these are known to influence migration.

Most of the literature on migration in Africa has focussed on the characteristics of migrants (Dallaire, 1978; INSD, 1991; Lututala, 1995) and while considerable advances have been made in models designed to explain variations in regional migration, they have yet to be applied in developing world contexts. Early examples of migration modelling in Africa include the adjustment model developed by Lewis (1954), which used economic differences between the origin and destination to explain migration flows. Others have suggested that migrants are attracted by the ‘bright lights’ of cities (e.g. Deniel, 1968). More recently, Shen (1999) developed interprovincial migration models in China. Whilst Ma and Liaw (1997) used a two-level nested logit model to explain the migration behaviour of young adults in China, discerning the probabilities of departure and of chosing a particular destination.

In Africa, most studies have been concerned with migratory movements from rural to urban areas, including work using system approaches (Mabogunje, 1970), and by analysing root causes of migration such as the class position of migrants, geographical features, historical developments and demographic structures (Shrestha, 1988). However, no model to date has integrated a mixture of demographic, socio-economic and biophysical variables in an African context.

This is despite the growing assumption that the environment is becoming increasingly important in explaining large-scale movements of migrants, some of whom have been described as environmental refugees (Döös, 1997; Myers, 1997; Myers & Kent, 1995; Ramlogan, 1996). For example, the vulnerability to food shortages was shown to contribute significantly to out-migration in ecologically degraded and drought-prone regions of Ethiopia (Ezra & Kiros, 2001). Migrations driven by rapidly changing environmental factors are likely to be more massive and rapid than migrations driven by slower socio-demographic changes. On 16 June 2002, on the occasion of the World Day to Combat Desertification and Drought, United Nations Secretary-General Kofi Annan stated that "135 million people who depend primarily on land for their livelihood are at risk of being displaced". The Chairman of the Intergovernmental Panel on Climate Change recently claimed that "in 1998, 25 million people were forced from their homes for environmental reasons" (Pachauri, 2002).

While the view that environmental factors play a major role in migration is now increasingly taken for granted, it largely remains untested as a hypothesis in the African migration modelling literature. In particular, the relative role of environmental and socio-demographic factors in driving migration has never been assessed for the regions where large numbers of environmental refugees are claimed to exist. If the link between environmental change and migration was proven statistically, the case for including environmental variables in migration models would be strong and this would be especially the case in Africa where inter-regional differences in environmental attributes can be large. However, reliable regional information on demographic, socio-economic and biophysical factors in Africa, collected for consistent geographical zones and over similar periods of time, is rarely available. The aim of this study is to analyse the causes of inter-provincial migration in Burkina Faso. It also evaluates the relative importance of socio-demographic and environmental variables in driving migration in Burkina Faso, using a statistical modelling approach.

This study has access to unique information from Burkina Faso allowing us to test the relative influence of demographic and socio-economic variables compared to variations in rainfall, land degradation and land availability. More specifically: do Provinces with more abundant and more regular rainfall attract migrants from Provinces with less favourable climatic conditions? Are migrants more likely to move from areas with severely degraded soils towards regions with more fertile land? Does land availability in Provinces at the origin and destination influence

Table 1
Explanatory variables for the 30 provinces, Burkina Faso[a]

PROV	Socio-demographic variables						Environmental variables				
	POP	AGE	LITER	MALE	ACTIVE	AVV	DROUGHT	RAINVAR	SOILDEG	COTTON	CULTAREA
Bam	162,575	44	12	47	43	0	11	2	4	363	11
Bazega	303,941	43	8	47	43	1	13	3	4	300	20
Bougouriba	220,895	47	9	48	47	1	11	0	2	700	13
Boulgou	402,236	46	8	48	46	1	11	3	4	897	14
Boulkiemde	365,223	42	12	45	42	0	11	3	4	0	17
Comoe	249,967	47	14	48	47	0	9	0	2	1065	6
Ganzourgou	195,652	44	6	47	44	1	11	4	4	0	14
Gnagna	229,152	46	4	49	45	0	12	3	2	0	2
Gourma	294,235	45	7	50	45	1	12	3	1	0	2
Houet	581,722	49	27	50	49	0	9	2	2	1372	8
Kadiogo	459,826	54	45	52	54	0	14	3	4	500	42
Kenedougou	139,973	46	14	49	46	0	8	1	2	1135	7
Kossi	332,960	46	15	50	46	0	9	0	4	1062	6
Kouritenga	198,486	43	9	47	43	0	9	2	4	0	27
Mouhoun	288,735	46	14	49	46	0	11	1	3	1123	10
Nahouri	105,509	49	5	49	49	1	15	0	2	286	8
Namentenga	198,890	45	8	48	45	0	10	2	4	0	4
Oubritenga	304,265	43	8	46	43	0	10	3	4	319	22
Oudalan	106,194	52	7	49	52	0	12	7	4	0	4
Passore	223,830	42	8	46	41	0	11	4	4	0	6
Poni	235,480	46	7	48	46	1	13	1	1	697	9
Sanguie	217,277	43	10	47	43	0	10	3	3	459	12
Sanmatenga	367,724	45	7	47	45	0	12	4	4	377	21
Seno	228,905	50	5	50	49	0	11	4	3	0	7
Sissili	244,919	46	11	49	46	0	14	3	2	758	5
Soum	186,812	47	7	49	47	0	10	5	4	0	5
Sourou	268,108	43	12	49	43	0	14	2	3	783	7
Tapoa	158,859	44	5	49	44	0	12	2	1	0	3
Yatenga	536,578	41	11	46	41	0	12	3	4	0	11
Zoundweogo	155,777	44	7	47	44	1	10	5	2	827	13

[a] Definitions of each variable used in the model are in Table 3. AGE is the number of the 15–64 year old people divided by the total population. AGE, LITER, MALE, ACTIVE and CULTAREA are percentages.

migration? And how important are these variables compared to other socio-demographic variables that are well known to influence migration?

Study area

In the 1985 population census, 7,964,705 individuals were recorded in Burkina Faso, 51.9% of them being women. The age structure of the population was relatively young with 47.9% of people less than 15 years old and only 3.7% of people aged 65 and over.

The literacy rate varied from 4% to 45% according to the Province. The urban and western Provinces had the highest literacy rates (Table 1). The Centre-North Provinces differed from the rest of the country with relatively low rates of economic activity, lower percentages of males in the population, a low representation of people aged 15–64, and a high percentage of cultivated area. As for many African countries, the urban system in Burkina Faso is composed of a small number of large cities (Ouagadougou, the capital in the Kadiogo Province, and Bobo Dioulasso, in the Houet Province) and by many secondary towns. The cotton region is located in the west and south-west of the country. Burkina Faso has a gradient of rainfall conditions, from the Sahelian environment in the North where rainfall is sparse and irregular to the south-western region where rainfall is higher and more regular (Fig. 1).

The Network for Migration and Urbanisation in West Africa (REMUAO) carried out a large survey in 1993 for eight West African countries (Bocquier & Traore, 2000). In terms of international migration analysis, their study highlighted the diversity of factors that influence migration in West Africa, although whether the country was landlocked and the presence of primate cities were shown to have a particularly influential impact on international migration. Both of these attributes are relevant in Burkina Faso. Indeed, Burkina Faso is the only one of the eight West African countries with a positive migratory balance, mainly because of return migrants from Côte d'Ivoire (Traore & Bocquier, 1996).

The Burkinabe are known to be very mobile people compared to those in other West African countries. During the colonial period, severe recruitment policies forced many people to migrate from their villages to work for public and private colonial interests. Internal migration, although minor compared to international migration, played an important role by contributing to urban growth in colonial Burkina Faso. Between 1975 and 1985, the relative importance of internal migration seems to have increased slightly in comparison to migration from abroad (Cordell, Gregory, & Piché, 1996). In 1985, 4% of the population migrated during the previous twelve months, 2% of these movements being within the country.

The population census survey of 1985 reported only inter-Provincial movements. The largest migratory flows between 1984 and 1985 left Kadiogo (the Province of Ouagadougou) for its neighbouring Provinces (Fig. 1). The exchange between Houet (the Province of Bobo Dioulasso), and both the capital and the Yatenga Province were also substantial. This latter Province also sent a large number of migrants to the Kossi Province. Kadiogo had the highest emigration rate (6.41%),

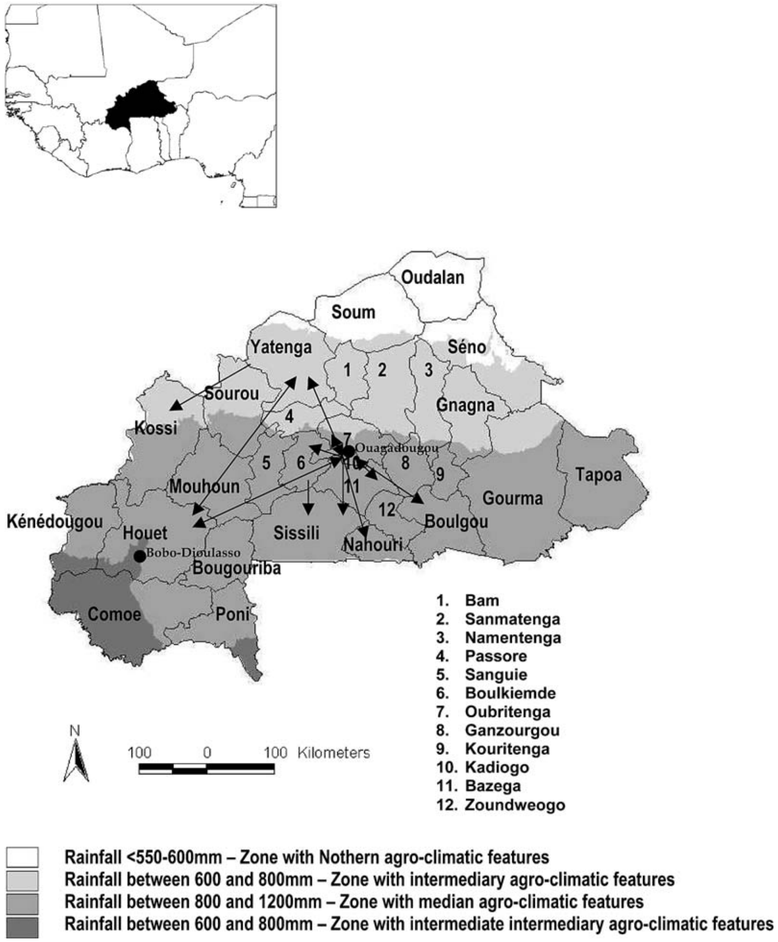

Fig. 1. Agro-climatic zones and the 15 largest migratory flows in Burkina Faso. Source: ADDS/Office de la Recherche Scientifique et Technique Outre-Mer et Ministère de la Coopération, 1976, République de Haute-Volta.

followed by Houet (2.79%) and three Centre-North Provinces: Soum (2.69%), Sanmatenga (2.04%) and Yatenga (2.00%) (see Table 2). For these latter Provinces, with an economy based mostly on agriculture and with difficult agro-ecological conditions, out-migration of the agricultural labour force can have adverse economic consequences. The five highest immigration rates concerned the Sissili (4.88%), Kadiogo (3.36%), Bam (2.60%), Bazega (2.53%) and Mouhoun (2.20%) Provinces. With large numbers of immigrants, these Provinces face difficulties related to land conflicts and access to social infrastructures. Overall, disparities within Burkina Faso with regard to migration were considerable: net migration figures show that Kadiogo lost 14,031 individuals between 1984 and 1985, and Sissili

Table 2
Arrivals, departures, immigration and emigration rates for the 30 provinces, Burkina Faso

Province	Population	Arrivals	Departures	Net migration	Immigration rate (%)	Emigration rate (%)
Bam	162,575	4221	3032	+ 1189	2.60	1.86
Bazega	303,941	7694	3081	+4613	2.53	1.01
Bougouriba	220,895	2350	1154	+766	1.06	0.52
Boulgou	402,236	4783	2550	+2233	1.19	0.63
Boulkiemde	365,223	3875	7084	−3209	1.06	1.94
Comoe	249,967	3701	2186	+1515	1.48	0.87
Ganzourgou	195,652	2870	2520	+350	1.47	1.29
Gnagna	229,152	2583	1619	+964	1.13	0.71
Gourma	294,235	4244	2646	+1598	1.44	0.90
Houet	581,722	12,578	16,220	−3642	2.16	2.79
Kadiogo	459,826	15,466	29,497	−14031	3.36	6.41
Kenedougou	139,973	2859	1051	+1808	2.04	0.75
Kossi	332,960	4463	3181	+1282	1.34	0.96
Kouritenga	198,486	1890	2188	−208	0.95	1.10
Mouhoun	288,735	6343	4329	+2014	2.20	1.50
Nahouri	105,509	2209	1193	+1016	2.09	1.13
Namentenga	198,890	2968	3366	−398	1.49	1.69
Oubritenga	304,265	3989	3795	+194	1.31	1.25
Oudalan	106,194	936	2004	−1068	0.88	1.89
Passore	223,830	3382	4310	−928	1.51	1.93
Poni	235,480	1341	1221	+114	0.57	0.52
Sanguie	217,277	3377	1268	+2109	1.55	0.58
Sanmatenga	367,724	4924	7486	−2562	1.34	2.04
Seno	228,905	3486	3823	−337	1.52	1.67
Sissili	244,919	11,945	3136	+8809	4.88	1.28
Soum	186,812	3065	5018	−1953	1.64	2.69
Sourou	268,108	3986	3457	+529	1.49	1.29
Tapoa	158,859	693	679	+14	0.44	0.43
Yatenga	536,578	7304	10,736	−3432	1.36	2.00
Zoundweogo	155,777	2002	1261	+741	1.29	0.81

gained 8809 people through migration. These geographically diverse migration dynamics pose many challenges for land use planning in Burkina Faso.

While the Central Plateau is densely populated with a highly variable rainfall (Tallet, 1993), the southwest of the country is less populated and benefits from higher and more regular rainfall. After some years of drought, families from the Centre-North plateau had begun to migrate towards the southwest. In addition, in 1974 Burkina Faso developed the 'Aménagement des Vallées des Voltas' (AVV) program to open up the valleys of the Volta rivers which had been freed from onchorcercosis (Guiella, 1996; Sidibe, 1986). Large spontaneous population movements swelled in the villages adjacent to the official migration areas and traditional land tenure systems, based on the principle of hospitality, facilitated the settlement of migrants (Totté, 1994). As a consequence, the population of some villages in the southwest has more than doubled in 20 years. The effects of this migration-driven population growth on land use were quickly visible. The newcomers tend to reproduce the same extensive farming practices followed in the centre-north and, encouraged by large private companies, are keen to produce cotton and maize (Gray, 1999). The land requirement for migrants is thus larger than for the sedente population, and land supply is being exhausted rapidly (Mathieu, 1993).

Data

The demographic data were extracted from the population census survey of 1985 (INSD, 1991) which provides reasonably comprehensive information for the whole country. More recent national scale data were not available when this study was conducted. During the census, which lasted about ten days, interviewers visited households and administered a questionnaire to the household head who responded for the other members of the household. Only Province-level data were made available. Here we use the information on migration which compares people's address at the time of the census and one year previously, in 1984. International and seasonal migrations were therefore ignored in this dataset. The former are mostly related to short-term economic opportunities in Côte d'Ivoire (i.e., young men working in large plantations for a couple of years) and the latter have always been part of livelihood strategies in the Sahelian region. This provided a matrix of 870 flows between the 30 Provinces of Burkina Faso, intra-Province flows were ignored. In total, 135,527 migrants moved between these Provinces out of a total population of 7,964,705 recorded in the 1985 census.

The explanatory variables used in the model are presented in Table 3. The standard demographic population and distance variables were included, as well as a number of social, economic and demographic variables. The distance variable was computed between population-weighted centroids derived for each Province. Since the flows between neighbouring areas are often higher than expected in such migration models, a contiguity variable was also introduced. The African migration literature suggests that migrants are more often economically active males with high literacy rates. The percentage of males in the total population, the percentage of economically active people and the literacy rate were therefore included in the list of explanatory variables. In addition, the percentage unemployed, the percentage of single people aged 12 and above, and the percentage of people living in an urban area were also included. A dummy variable was used to denote the AVV migration areas. In many studies, age is the most important personal determinant of the migration intensity and direction. However, this variable was excluded of this study because of multicollinearity with the other socio-demographic variables and as it was suspected to be endogeneous to the model. As fertility rates are very similar between Provinces the age structure was influenced mostly by migration. Age was not therefore used as an explanatory variable in the migration model.

Several climatic and land degradation variables were also introduced in the model. In Sahelian and Sudanian regions, crop yields are mostly controlled by the amount and distribution of rainfall during the growing season and we would

Table 3
Definitions of the explanatory variables[a]

Variable name	Variable description
(ln)POPI	Logged origin population
(ln)POPJ	Logged destination population
(ln)DISTIJ	Logged distance between the origin and destination
CONTIG	Contiguity of Provinces: a dummy variable with the value of 1 if Provinces have a common boundary and 0 otherwise.
Social, economic and demographic variables (from the population census survey of 1985 unless stated otherwise)	
(ln)MALEI, (ln)MALEJ	Male rate: logged number of men divided by total population.
ACTIVEI, ACTIVEJ	Economic activity rate: number of economically active 15–60 year old people divided by the total population aged 15–60 years.
LITERI, LITERJ	Literacy rate: number of literate people divided by the total population aged 10 years and above.
AVVI, AVVJ	Aménagement des Vallées des Voltas (AVV): a dummy variable with the value of 1 if the Province contains a AVV migration area, 0 otherwise (derived from Tallet, 1993).
Climate and land degradation variables	
DROUGHTI, DROUGHTJ	Drought frequency : the number of droughts between 1960 and 1984. Droughts were defined as a deficit in annual rainfall of 10% or more compared to the annual mean rainfall for the period 1960–98 (Direction nationale de la Météorologie au Burkina Faso).
RAINVARI, RAINVARJ	Decade-to-decade rainfall variability: the number of 10-day periods during the rainy season of 1983–84 with less rainfall than 50% of the mean rainfall for the corresponding decade during the period 1960–98 (Direction nationale de la Météorologie au Burkina Faso).
SOILDEGI, SOILDEGJ	Severity of soil degradation (Oldeman et al., 1990).
(ln)COTTONI, (ln)COTTONJ	Logged cotton yields in 1984 (Agristat, 1998)
CULTAREAI, CULTAREAJ	Percentage of cultivated land area (Agristat, 1998)

[a] Variable names ending in "I" are origin specific; variable names ending in "J" are destination specific.

expect that poor harvests would have driven some households to migrate further south (Grouzis & Albergel, 1989; Sicot, 1989). The mean rainfall values for 10-day periods during the rainy season of 1983–84 for each Province were therefore added to the model to quantify spatial variations in rainfall. For crop yields, rainfall distribution during the growing season is almost as important as the total annual rainfall. Therefore, the number of decades during the rainy season of 1983–84 with a deviation from the mean rainfall of more than 50% compared to the 1960–98 mean rainfall for the corresponding decade was also computed. Finally, as the decision to migrate may only be made after a succession of negative climatic anomalies, the number of drought years during the period 1960–84 was also introduced as an explanatory variable to represent the cumulative effect of drought.

Besides rainfall variability, soil degradation, defined as an impoverishment in fertility, strongly influences food production (Gray, 1999; Mathieu, 1998) and continuous declines in crop yields may be expected to encourage people to move. An index of land degradation, derived from the GLASOD map (Global Assessment of Human Induced Soil Degradation, UNEP, 1990) which is available at the 1:10,000,000 scale, was therefore introduced in the model. The map was based on a serie of indicators of soil degradation and, for each Province, an average value of degradation severity was extracted. The severity of degradation can be considered as exogenous to migration since the increase in population pressure in areas of destination is only likely to affect soil fertility over a few decades.

Two additional environmental variables which are likely to influence migration are crop yields, as a function of rainfall, and land availability for cultivation. The variable 'yields for cotton in 1984' was introduced in the model as this crop is very sensitive to climate conditions and offers opportunities for cash revenues. The proportion of the total area of each Province which was already under cultivation ('percentage of cultivated area') was introduced to estimate the amount of land potentially available for agricultural expansion by migrants. Note that these two variables are not exclusively environmental but capture some socio-economic factors as well (e.g., input use, potential for revenues from cash crops, population density, agricultural intensity).

Methods

Models of inter-regional migration flows are generally based on gravity theory (Ravenstein, 1889; Zipf, 1946). Migration is expected to be positively related to the population in the origin and destination, and negatively related to the distance between the two places. As the flows are counts of migrants, and the matrix will often be characterised by many null, several low, and few high values, a Poisson regression model is appropriate (Flowerdew & Lovett, 1989; Boyle & Flowerdew, 1993). A Generalised Linear Modelling (GLM) framework was used which allows additional explanatory variables, along with the standard gravity model variables, to be included. Examples used previously have included educational levels, job opportunities, level of urbanisation, population density, wage levels, etc. (Barber & Milne, 1988; Brown & Goetz, 1987; Flowerdew, 1991; Gordon & Molho, 1998; Gordon & Vickerman, 1982). In developed world examples, at least, environmental variables are rarely included, although Gordon and Molho (1998) included subjective preferences for different residential environments in an interregional migration model in Great Britain.

In a Poisson model , the predicted value of dependent variable for case i is modelled as the maximum-likelihood estimate of the mean of a Poisson-distributed variable Y_i. This mean is logarithmically linked to a linear predictor by using a set of explanatory variables (Boyle & Flowerdew, 1993). The basic Poisson model used here is expressed as:

$$\lambda_{ij} = \exp\left[\beta_0 + \beta_1 \ln(P_i) + \beta_2 \ln\left(P_j\right) + \beta_3 \ln\left(d_{ij}\right) + \beta_4 X\right] \tag{1}$$

where β are parameters to be estimated, λ is the mean of the Poisson distribution (in this case, the migration from the location i to location j), P_i and P_j are the origin and destination populations, d_{ij} is the distance between i and j and these three variables were logged. The remaining variables which were not logged are summarized by X. In addition to the gravity model variables, a contiguity variable was included which is a dummy variable distinguishing between those Provinces with and without a common boundary.

In the next stage, social, economic and demographic variables were also added (referred to below as the socio-demographic model), and then the model was extended to include the environmental variables (referred to below as the environmental model). For each variable, the logged fit was also tested and the form of the variable with the most significant fit was introduced in the model. Variables were tested for multicollinearity. All variables with an adjusted R^2 larger than 0.8 in a multivariate regression of one independent variable against all the other independent variables were removed.

The dependent variable was defined as the flows of migrants—i.e., the number of persons going through a migration.

The goodness-of-fit of Poisson regression models can be evaluated using the deviance, which measures the variation in data that the model can not explain (for fuller explanations see Nelder & Wedderburn, 1972; Flowerdew, 1991). This is expressed as:

$$D = 2\Sigma y_i \ln(y_i/\hat{y}_i) \tag{2}$$

where y_i is the observed value for the observation i and $\hat{y}_i$ is the value estimated by the model. The lower the value of the deviance, the better the model fits and a χ^2-test can be performed to test whether the model deviance is an acceptable fit. The deviance value of the null model (the value when only a constant and no other explanatory variable is included in the model) provides a basis for comparison with other models. Thus, the power of each explanatory variable can be tested and compared.

Results

Table 4 provides the model deviances for a series of 11 models beginning with the simple gravity model and including each pair of origin- and destination-specific explanatory variables sequentially. The deviance was reduced by 52.1% with the simple gravity model variables, and by 73.3% using all the explanatory variables (the environmental model).

Table 4
Model deviances (models including all flows)

Model	Deviance	% deviance reduction from null deviance	Gain compared to previous model
Null model	333,476.1	–	–
Gravity model (model 1)	159,587.5	52.1	47.9
Model 1 + CONTIG (model 2)	145,250.7	56.4	4.3
Model 2 + LITERI + LITERJ (model 3)	118,821.0	64.4	7.9
Model 3 + ACTIVEI + ACTIVEJ (model 4)	113,996.0	65.8	1.4
Model 4 + (ln)MALEI + (ln)MALEJ (model 5)	111,278.8	66.6	0.8
Model 5 + AVVI + AVVJ (model 6)	105,223.2	68.4	1.8
Model 6 + DROUGHTI + DROUGHTJ (model 7)	102,684.8	69.2	0.8
Model 7 + RAINVARI + RAINVARJ (model 8)	99,819.5	70.1	0.9
Model 8 + SOILDEGI + SOILDEGJ (model 9)	97,890.1	70.6	0.6
Model 9 + (ln)COTTONI + (ln)COTTONJ (model 10)	94,962.8	71.5	0.9
Model 10 + CULTAREAI + CULTAREAJ (model 11)	88,997.7	73.3	1.8

The gravity model

The gravity model had a relatively low explanatory power: 52.1%, compared to more than 70% in gravity models developed using European data (e.g. Boyle, Flowerdew, & Shen, 1998; Flowerdew & Aitkin, 1982). Thus, in Burkina Faso, this simple model is not sufficient to explain the inter-Provincial migrations. The model parameters (Table 5) showed that migration was positively related to both the origin and destination populations, and negatively related to the distance between the origin and destination, as we would expect.

Socio-demographic model

The remaining variables were regressed again each others to test for multi-collinearity. The variables 'percentage of people in the 15 to 64 age group', 'unemployment rate', 'percentage of people in the Province living in urban areas' and 'single person rate' were removed as the adjusted R^2 were greater than 0.8. The socio-demographic model reduced the deviance by 12.0% compared to the gravity model (model 2—Table 4), explaining 68.4% of the observed variation. All of the variables were significant (Table 5), and there were some interesting results. Migration was positively related to the literacy rate at both origin and destination, suggesting that migration was more likely to involve Provinces that had more educated populations. As expected, migration was positively related to the economic activity rates at both the origin and destination. Migration was negatively associated with the origin being an AVV area but, perhaps surprisingly, it was also negatively related to the destination being an AVV area. The AVV programme attracted a large number of migrants up until the completion of the programme in

Table 5
Model parameter estimates and standard errors (models including all flows)

Model	Parameter estimates	Standard errors	Pr > Chi square
Model 2 (gravity model, including contiguity dummy variable)			
INTERCEPT	−31.1569	0.1460	<0.0001
(ln)DISTIJ	−1.1615	0.0077	<0.0001
CONTIGUI	0.7843	0.0065	<0.0001
(ln)POPJ	1.3669	0.0072	<0.0001
(ln)POPI	2.0524	0.0073	<0.0001
Model 6 (socio-demograhic model)			
INTERCEPT	−43.2698	0.9072	<0 .0001
(ln)DISTIJ	−0.9672	0.0106	<0.0001
CONTIGUI	0.9968	0.0072	<0.0001
(ln)POPJ	1.1443	0.0100	<0.0001
(ln)POPI	1.4646	0.0104	<0.0001
LITERI	0.0110	0.0006	<0.0001
LITERJ	0.0015	0.0006	0.0144
ACTIVEI	0.1210	0.0022	<0.0001
ACTIVEJ	0.0060	0.0020	0.0024
(ln)MALEI	−3.7927	0.1758	<0.0001
(ln)MALEJ	7.7291	0.1590	<0.0001
AVVI	−0.6386	0.0092	<0.0001
AVVJ	−0.1916	0.0075	<0.0001
Model 11 (environmental model)			
INTERCEPT	−15.3215	1.0613	<0.0001
(ln)DISTIJ	−1.2589	0.0154	<0.0001
CONTIGUI	0.9543	0.0090	<0.0001
(ln)POPJ	1.2070	0.0105	<0.0001
(ln)POPI	1.5876	0.0109	<0.0001
LITERI	0.0327	0.0008	<0.0001
LITERJ	0.0280	0.0008	<0.0001
ACTIVEI	0.1345	0.0027	<0.0001
ACTIVEJ	0.0640	0.0022	<0.0001
(ln)MALEI	−4.4843	0.2307	<0.0001
(ln)MALEJ	−0.3178	0.1969	0.1066
AVVI	−0.4002	0.0101	<0.0001
AVVJ	−0.1556	0.0086	<0.0001
DROUGHTI	0.0542	0.0024	<0.0001
DROUGHTJ	0.1001	0.0020	<0.0001
RAINVARI	0.0858	0.0033	<0.0001
RAINVARJ	0.0584	0.0027	<0.0001
SOILDEGI	0.0956	0.0050	<0.0001
SOILDEGJ	−0.0636	0.0044	<0.0001
(ln)COTTONI	−0.0455	0.0013	<0.0001
(ln)COTTONJ	0.0451	0.0012	<0.0001
CULTAREAI	−0.0321	0.0006	<0.0001
CULTAREAJ	−0.0385	0.0006	<0.0001

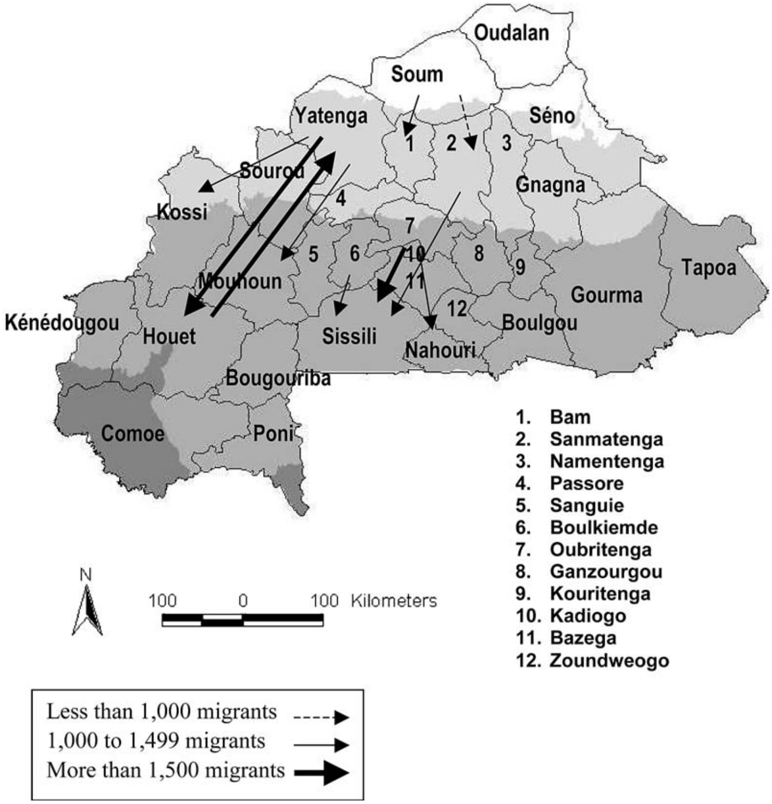

Fig. 2. Ten highest contributors to the deviance from socio-demographic model (model 6, Table 2). Differences between observed and predicted flows are indicated by thick lines for more than 1500 migrants, thin lines for 1000–1499 migrants, and dotted lines for less than 1000 migrants.

the early 1980s. Since then, only a small number of migrants have been accepted in these areas. Places with higher proportions of men were less likely to lose migrants, while these places were attractive to in-migrants.

Fig. 2 provides the 10 highest residual flows from the socio-demographic model, all of which were larger flows than expected. Four of these flows involved the sahelian Province of Yatenga, where the traditional Mossi political power was located. Two of these flows involved the Province of Kadiogo, which encompasses the capital of the country, Ouagadougou, emphasising the importance of urban–rural migration in this context. This suggests that additional explanatory variables related to socio-economic conditions in urban centers may improve the model fit.

Model with socio-demographic, climate and land degradation variables (environmental model)

The variable 'logged annual mean rainfall for 1983–84' was removed due to multicollinearity. Ten further variables were included in the environmental model, and the inclusion of these climate and land degradation variables reduced the deviance by a further 4.9%, to 73.3% (Table 4). Most of the parameters for the variables in the socio-demographic model remained in the same direction in this model (Table 5). However, the destination parameter for the male rate became negative when it was positive in the former model.

In particular, we were interested in testing whether the environmental variables were significant, controlling for the socio-demographic variables. As expected, there were positive relationships between out-migration and both intra- and inter-annual rainfall variability (i.e. rainfall anomalies within the season and drought frequency), but the relationships were also positive at the destination, which is more surprising. It is probably rainfall variability in the regions of origin with a low rainfall that causes migration more than rainfall variability in the wetter regions of destination. In the latter, variability associated with a high annual rainfall does not constrain crop yields. Also, migration was negatively related to soil degradation at the destination and positively at the origin, as expected. Migration was negatively related to percentage of cultivated area at the origin, as expected, but it was also negatively associated with migration at the destination. Finally, migration flows were larger when cotton yields in 1984 were high at the destination and low at the origin, which again supports the idea that environmental variables do influence migration.

Among the 870 flows, the 10 major contributors to the deviance are shown in Fig. 3. These ten flows were much larger than predicted by the model and were identical to the residuals for the socio-demographic model, expect for the flow from Houet to Kadiogo (the two Provinces with a large city).

Models for specific origins

To better understand the causal relationship between environmental factors and migration, two further models were fitted. The first was restricted to flows from the two northernmost sahelian Provinces of Soum and Oudalan, where biophysical conditions are most marginal and human activities are especially sensitive to climatic variability. The second was restricted to flows from the two southern Provinces of Nahouri and Bougouriba where climatic conditions are much better. These two Provinces were selected because their total population approximates that of Soum and Oudalan. In both cases, the destinations included all the Provinces in the country. Other than the population variable (ln POPI), only variables relating to the destination were retained in these models. Each model therefore included 58 flows, with a total of 7022 out-migrants from the northern Provinces and 2777 from the southern Provinces.

The analysis of the deviance clearly demonstrates that the flows from the southern Provinces were more influenced by socio-demographic variables (15.8% compared to 3.9% for biophysical variables, Table 6) than the flows from the drier northern Provinces which were more influenced by biophysical variables (16.3% with five biophysical variables compared to 4.4% with four socio-demographic variables).

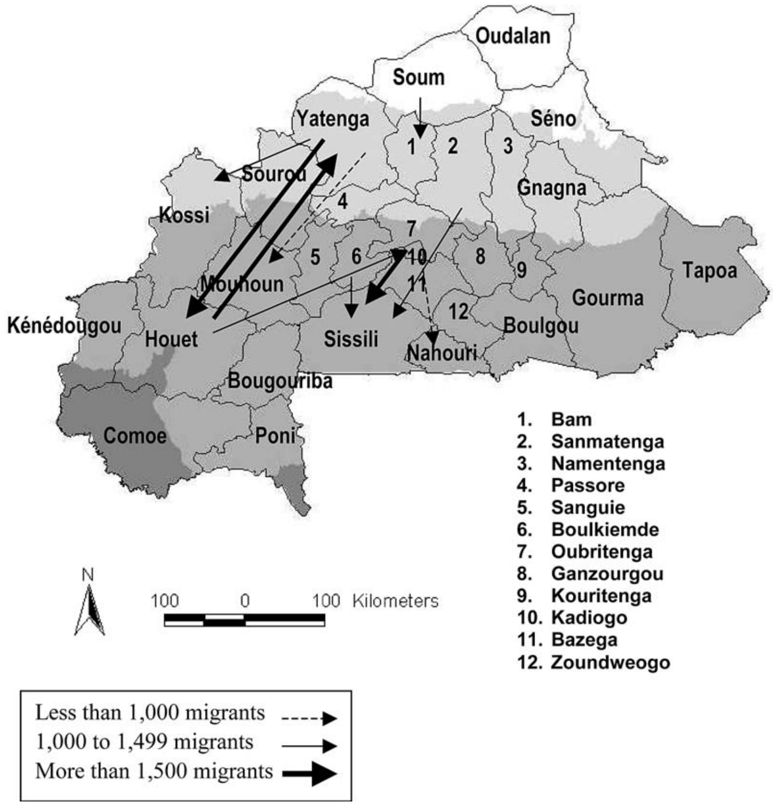

Fig. 3. Ten highest contributors to the deviance from environmental model (model 11, Table 2). Differences between observed and predicted flows are indicated by thick lines for more than 1500 migrants, thin lines for 1000–1499 migrants, and dotted lines for less than 1000 migrants.

The most noticeable difference between the parameters of these models (Table 7) is that the flows from the northern Provinces were much more likely to be over short distances into Provinces with large populations (see the parameters for lnDISTIJ and lnPOPJ). They were also more likely to be into Provinces with the lowest level of soil degradation at destination. The soil degradation variable was not significant in the model describing migrations from southern Provinces. The flows from the north were also positively associated with yields for cotton in 1984 and negatively associated with intra-annual rainfall variability at destination, suggesting that the potential for cash crops and stable climatic conditions during the rainy season at the destination drives migration originating from the northern Provinces. By contrast, the migration flows from the two southern Provinces were mostly driven by high literacy rate at destination, which may reflect pull factors associated with urban influences. In both models, migration was negatively associated with the percentage of Provinces being under cultivation at the destination.

Table 6
Model deviances

Model	Deviance	% Deviance reduction from null deviance	Gain compared to previous model
Models from Soum and Oudalan			
Null model	15,627.3	–	–
Gravity model (model 1)	7347.6	47.9	47.9
Model 1 + CONTIG (model 2)	5225.8	66.6	18.7
Model 2 + LITERJ (model 3)	5050.2	67.7	1.1
Model 3 + ACTIVEJ (model 4)	4938.0	68.4	0.7
Model 4 + (ln)MALEJ (model 5)	4684.2	70.0	1.6
Model 5 + AVVJ (model 6)	4528.5	71.0	1.0
Model 6 + DROUGHTJ (model 7)	4385.4	71.9	0.9
Model 7 + RAINVARJ (model 8)	4088.4	73.8	1.9
Model 8 + SOILDEGJ (model 9)	3454.1	77.9	4.1
Model 9 + (ln)COTTONJ (model 10)	2412.3	84.6	6.7
Model 10 + CULTAREAJ (model 11)	1981.2	87.3	2.7
Models from Nahouri and Bougouriba			
Null model	5894.4	–	–
Gravity model (model 1)	1961.6	25.9	25.9
Model 1 + CONTIG (model 2)	1729.2	70.7	44.8
Model 2 + LITERJ (model 3)	864.0	85.3	14.6
Model 3 + ACTIVEJ (model 4)	861.0	85.4	0.1
Model 4 + (ln)MALEJ (model 5)	808.6	86.3	0.9
Model 5 + AVVJ (model 6)	798.0	86.5	0.2
Model 6 + DROUGHTJ (model 7)	794.3	86.5	0.0
Model 7 + RAINVARJ (model 8)	782.5	86.7	0.2
Model 8 + SOILDEGJ (model 9)	718.0	87.8	1.1
Model 9 + (ln)COTTONJ (model 10)	717.3	87.8	0.0
Model 10 + CULTAREAJ (model 11)	565.1	90.4	2.6

Thus, migrants are always attracted by land availability. All these results are consistent with expectations.

Discussion and conclusion

In Burkina Faso, the level of internal migration is very high compared to its neighbours. A rapid and unpredicted surge in migration within a country could be a critical problem for its government. A better understanding of the factors causing migration is thus required for planning purposes, in particular concerning rapidly changing driving forces such as drought. The objective of this study was to analyse the factors causing inter-provincial migration in Burkina Faso: demographic and socio-economic characteristics of Provinces were associated with migration patterns, as expected, the relative role of biophysical variables in the model was also analysed. Burkina Faso did experience large disparities in both climatic and soil degradation conditions, causing large geographic disparities in opportunities and

Table 7
Model parameter estimates and standard errors (environmental models from Soum/Oudalan and Nahouri/Bougouriba only)

Model	Parameter estimates	Standard errors	Pr > Chi square
Environmental model, Soum and Oudalan only			
INTERCEPT	−12.0798	4.5145	0.0075
(ln)DISTIJ	−6.4184	0.1318	<0.0001
CONTIGUI	0.9629	0.0495	<0.0001
(ln)POPJ	2.1774	0.0599	<0.0001
(ln)POPI	0.4369	0.0572	<0.0001
LITERJ	−0.0164	0.0027	<0.0001
ACTIVEJ	0.1753	0.0169	<0.0001
(ln)MALEJ	4.8959	1.3134	0.0002
AVVJ	−0.3401	0.0652	<0.0001
DROUGHTJ	−0.1444	0.0145	<0.0001
RAINVARJ	−0.1123	0.0171	<0.0001
SOILDEGJ	−0.4517	0.0270	<0.0001
(ln)COTTONJ	0.2367	0.0067	<0.0001
CULTAREAJ	−0.0799	0.0042	<0.0001
Environmental model, Nahouri and Bougouriba only			
INTERCEPT	104.5781	7.8254	<0.0001
(ln)DISTIJ	−2.0701	0.2051	<0.0001
CONTIGUI	0.7771	0.1222	<0.0001
(ln)POPJ	0.6138	0.0948	<0.0001
(ln)POPI	0.2395	0.0798	0.0027
LITERJ	0.1251	0.0094	<0.0001
ACTIVEJ	0.2437	0.0258	<0.0001
(ln)MALEJ	−29.1646	2.1775	<0.0001
AVVJ	0.2939	0.0991	0.0030
DROUGHTJ	0.1311	0.0156	<0.0001
RAINVARJ	−0.0307	0.0215	0.1537
SOILDEGJ	0.0022	0.0443	0.9597
(ln)COTTONJ	0.0659	0.0157	<0.0001
CULTAREAJ	−0.0823	0.0067	<0.0001

constraints for agriculture; environmental variables improved the prediction of migration, even controlling for social, economic and demographic variables, but their contribution improved the fit less than the socio-demographic variables which accounted for about half the explanatory power. When only migration flows from the northern, ecologically marginal Provinces were taken into account, the environmental variables had a greater explanatory power than the socio-demographic variables (about four times the explanatory power). The direction of causal relationships between migration and environmental conditions at the origin and destination was generally consistent with the hypothesis that inter-provincial migrations in Burkina Faso are influenced by unfavourable conditions in rainfall variability, land degradation and land availability at the origin, and favourable conditions at the destination for these variables.

Taking into account changes in the natural environment should allow Burkina Faso to better anticipate and plan for future migratory flows. Government can mostly intervene in the areas of land tenure, and social and economic infrastructures in Provinces of destination for migrants. In areas of origin, consciousness-raising campaigns on agricultural techniques to reduce vulnerability to drought and mitigate soil degradation can help to reduce out-migration. In Ouahigouya (a northern town of Burkina Faso, in Yatenga), such campaigns (refered to as '6S' for 'Se Servir de la Saison Sèche au Sahel': to use the dry season in the Sahel) have already reduced migration flows (personal communication from Ledia Ouedraogo, mayor of Ouahigouya). Recent claims that the Sahel is 'greening' after the end of the prolonged drought of the seventies and eighties (e.g., Rasmussen, Fog, & Madsen, 2001) could also mean that migration flows will be reduced in the years to come or even that return migrations could take place. If such trends would be confirmed, more investments should be made in Provinces that have contributed migrants in the past rather than in Provinces that have received migrants.

Note that interactions between migration, socio-economic factors and changes in the biophysical environment may be more complex than represented in the model. For example, while migration is influenced by environmental change at the origin, it may also contribute to this change at the destination (Lambin et al., 2001), although this is likely to be over a long time scale. Also, environmental change may have indirect effects on economic variables, such as price fluctuations, water access, foreign aid affecting local communities, etc. This was taken into account in part by removing independent variables which were strongly related to each other.

Nevertheless, this study could be improved in a number of ways. First, the study relied upon census data that have their limitations, as the pastoral population in particular are not well recorded because of their seasonal movements (Randall, 1994). The Burkinabe census also lacked a post-census survey, which can be extremely useful in evaluating the comprehensiveness and quality of the data that have been collected. However, compared to other surveys, the census provides a large and relatively reliable source of data.

The variable describing the severity of soil degradation (the GLASOD index) has been questioned by many authors, as it identifies a very high level of degradation in the central plateau of Burkina Faso (0° to 4°W, 11.5° to 13.5°N), while trends in rain-use efficiency only indicate moderate degradation (Prince, Brown de Colstoun, & Kravitz, 1998). Nicholson, Tucker and Ba (1998) argues that GLASOD indicators are "largely extrapolated from risk factors in the environment" (p. 818). Moreover, the spatial resolution of the GLASOD database is very coarse. This may explain why the severity of soil degradation had relatively little explanatory power in the migration model. Time-series remote sensing data will allow the estimation of land degradation at a much finer spatial resolution.

The high level of spatial aggregation of the study (provincial level) might cause some ecological fallacies. This study is currently being repeated based on migration and socio-demographic data at the level of Departments for 1996. Land degradation data will be derived from time series remote sensing data for the nineties, which will be better synchronised with the migration data. An alternative approach is to consider migration at the individual or household level. Another extension of this study is looking at longitudinal survey data, collected at the individual level, allowing us to reconstruct individual migration trajectories. These personal biographies can be related to socio-economic time-varying variables at the level of the family, the community or the country, and to environmental variables.

Despite the above limitations, the results presented here clearly indicate that the relationship migration is influenced by biophysical changes in the environment, in addition of being influenced by distance, demographic and socio-economic variables. The prediction of migration flows should therefore be based on a larger spectrum of explanatory variables. This study, which quantified the relative importance of the environment on migration in Burkina Faso in the 1980s, does not support claims that environmental change *alone* is causing massive movements of so-called environmental refugees. Rather, the results show that it is the combination of socio-demographic factors and, to a lesser extent, environmental variables that explain inter-provincial migrations in Burkina Faso. Therefore, previous estimates on the importance of the phenomena of environmental refugees in West Africa appear to have been exaggerated.

Acknowledgements

The authors would like to thank D. Tabutin, B. Schoumaker and the anonymous referees for their comments. The authors express their gratitude to the Direction nationale de la Météorologie au Burkina Faso for the rainfall data and to the Ministère de l'Agriculture du Burkina Faso for agricultural data.

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