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ARTICLE

Spatiotemporal Dynamics of Internal Migration in Burkina Faso

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ABSTRACT

Migration is a complex demographic phenomenon. Its dynamics can be explained by several factors whose spatial and temporal evolution is not easy to control. That is why this article aims to understand the factors of migration from a spatiotemporal perspective to fill the gaps in the literature. The aim of this article is to analyse the spatiotemporal dynamics of internal migration factors to deduce the zones of origin and destination in Burkina Faso. To do this, several types of data were used. These included secondary, spatial, statistical and survey data. The results of this study show that the influence of internal migration factors is uneven. The spatial distribution of internal migration factors follows a north-south gradient, with favourable conditions in the south. In fact, the northern part is characterised by a large population exodus, with around 42.6% of outgoing internal migrants, and the southern part by a large population influx. This southern part of the country receives around 34.6% of internal migrants. The areas from which migrants depart have unfavourable climatic, environmental, or socio-economic conditions, whereas the areas to which migrants migrate are characterised by favourable conditions for these factors.

Keywords: Burkina Faso; Internal Migration; Factor; GIS; Multi-Criteria Analysis

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1. Introduction

Burkina Faso, a poor, landlocked country with limited employment prospects, has been experiencing large migratory flows for several years. Migration flows, which have their origins in the colonial period, have undergone progressive development driven by many environmental variations, but also by the fact that Burkina Faso's populations are culturally mobile[1] . The literature shows that migration in the Sahelian strip, particularly in Burkina Faso, was mainly fueled by the droughts of the 1970s and 1980s[2–4], but also by social factors such as conflict[5].

Burkina Faso's migration dynamic is driven by a constant need for better living conditions. As a result, migration flows are constantly moving from north to south, where climatic and environmental conditions are more favourable[6]. This migration, which was directed towards coastal countries, has been gradually reduced because of socio-political crises and has gradually given way to internal migration, directed towards localities in the south of the country[7]. In 2006, 15.4% of the resident population migrated internally. In 2019, this rate had fallen slightly to around 13.4% but was still high compared with international migration (5.8%)[8]. The scale of internal migration in Burkina has consequences in the destination areas. In the region of Boucle de Mouhoun, for example, agricultural colonisation by Mossi migrants has profoundly changed the social and demographic landscape[9]. The massive settlement of Moose farmers in the west and south of the country has had major consequences for land use and the exploitation of natural resources[9, 10]. The regions of origin are losing labour, while the regions of arrival are finding it difficult to keep pace with a rapidly growing population. It is also a source of land tensions between migrants and residents[4, 11].

The management of migratory flows is therefore becoming a major issue for regional planning. However, the reasons behind the decision to migrate are complex and need to be carefully considered. Conditions in the place of origin, socio-cultural norms and aspirations must all be considered. The economic aspect clearly plays a role in the decision to migrate, as[12] points out. Similarly, some authors cite economic insecurity and poverty as factors that encourage migration[13]. Several authors have shown that rising temperatures and rainfall variability linked to climate change encourage people to leave their places of origin[2, 3, 5, 6]. Ref.[6] consider that interprovincial migration in Burkina Faso is influenced on the one hand, by unfavourable environmental conditions (rainfall variability, land degradation and land availability) in the areas of origin, and, on the other hand, by favourable conditions at the destination. Whether it be long-term climatic variations, natural disasters, demographic or economic crises, or armed conflicts, these factors have always prompted populations to move[14]. Population growth increases pressure on land, and some people decide to migrate because of a lack of space or infertile soils[15–17]. Similarly, migration has many consequences for both areas of origin and destination.

The literature shows that climatic, environmental and socio-economic factors both play an important role in the decision to migrate. Most migrants are rural farmers who move in search of better production conditions to improve their economic situation. Thus, when environmental resources decline and climatic conditions deteriorate, production capacity decreases, leading to migration. Although there are many theories explaining migration dynamics, it should be noted that environmental factors are more predominant in Burkina Faso. This can be explained by the fact that the largest waves of migration were recorded during the periods of severe drought experienced by the country. As Burkina Faso is a Sahelian country with precarious natural resources and a population that is predominantly rural and dependent on agriculture, migration trends are towards areas that are more favourable to agricultural production. This makes Burkina Faso a dynamic country in terms of migration.

Migration is the cause of many upheavals in both the area of origin and the area of the destination. It causes depopulation in the areas of origin, resulting in a shrinking workforce. In the areas of arrival, it results in an increase in the population, with the corollary of increased pressure on resources and conflicts over the use of natural resources[18–20]. Since these changes are detrimental to both the areas of origin and destination, good territorial planning requires the modelling of potential migrant departure and destination areas in the light of changes in the factors causing migration.

Several studies have been carried out on the internal migration factors in Burkina Faso[4, 9, 21–23]. Climatic factors (rainfall and temperature), environmental factors (soil quality), demographic factors (population density, school enrolment) and socio-economic factors (poverty) are all factors that encourage people to migrate. Scientific research on migration in Burkina Faso is abundant but needs to be constantly updated as data on the phenomenon evolves. However, the literature consulted does not address the spatial component of migration. This study aims to fill this gap. It seeks to spatialise migration factors and deduce the potential departure and destination areas for migrants. Migration has many impacts that must be controlled. Conflicts, land pressure and environmental degradation are all consequences of migration in destination areas, while the areas of departure are characterised by depopulation of the young fringe. Thus, by spatialising the dynamics of migration, it is possible to pinpoint the possible impacts of migration and therefore to prevent them.

The aim of our study is therefore to analyse the spatiotemporal dynamics of internal migration factors in Burkina Faso. It will consist firstly of analysing the correlations between the factors of internal migration in Burkina Faso and secondly of analysing the spatial dynamics of the migration factors. Before carrying out these analyses, the factors driving internal migration in Burkina Faso will be identified. For this study, the 2019 data on internal migration factors will be modelled. To arrive at the results, a methodology has been adopted. This methodology illustrates the study area, and the tools and methods used. The results of this approach are presented and discussed below.

2. Study Area

This study focuses on Burkina Faso. It covers 274,000 km² in the semi-arid zone of West Africa. It is a continental country lying between 9°20' and 15°05' north latitude, 5°20' west longitude and 2°03' east longitude. The country's location at the centre of the Sahel zone gives it easy access to all the countries in the sub-region. This central location has played a key role in the migration patterns of the Burkinabe population. Burkina Faso has a tropical climate. The population is agricultural, accounting for 81% of the total population [24].

According to the National Institute of Statistics and Demography [25], the population of Burkina Faso was 20,505,150 in 2019. Most of the population is poor, with a poverty index of 43.2% [26]. In terms of education, Burkina Faso had a literacy rate of 29.7% in 2019. Weakened by poverty and climate change, Burkina Faso is facing migration challenges that are disrupting its development process [9]. The choice of Burkina Faso as the focus of the study adds to our knowledge of the migration phenomenon in Burkina Faso to minimise the negative consequences of migration. For the purposes of the study, we felt it was important to have an idea of the population's perception of the factors behind their choice to migrate and their choice of destination area. The surveys were conducted in three provinces: Oubritenga, Boulkiemdé, and Ziro (**Figure 1**).

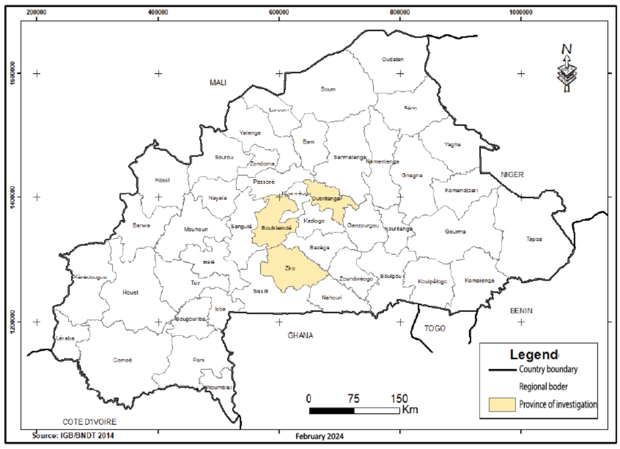

Figure 1. Study area.

In Burkina Faso, migratory movements are recorded in all administrative entities. However, the rate of migration varies significantly from one commune to another, from one province to another and from one region to another. The survey provinces were chosen based on their migration characteristics. The surveys were carried out in a province with a high proportion of emigrants (Boulkiemdé), with 11.8% of emigrants, and a province of destination (Ziro), with 6.7% of immigrants. Added to this is Oubritenga, which is both a province of emigration (1.1%) and immigration (1.1%) [27]. The choice of these collection sites is therefore motivated by the reality of population mobility in these provinces. The risks associated with the security situation make it difficult to conduct fieldwork in remote areas. In addition, the target population was migrants in the destination area (Ziro province), non-migrants in origin (Boulkiemdé province) and both in Oubritenga province.

3. Material and Method

3.1. Study Data

This study required the use of several types of data from different sources. Satellite images and statistical data were used to achieve the desired results. The satellite image data includes climate parameters (rainfall and temperature) from 1990 to 2019, downloaded from the WorldClim platform. With a spatial resolution of 1 km × 1 km, this data can be used for mapping and spatial modelling. The variables available are mean minimum temperature, mean maximum temperature and total annual precipitation. To ensure the accuracy of the data, the WorldClim images were calibrated using local data from the National Meteorological Agency (ANAM) for this study. Calibration involved running regressions to detect discrepancies or errors in the satellite estimates, correcting them and merging them with the ANAM data. Climate data from 1990 to 2019 were collected from the ANAM.

NDVI (Normalised Difference Vegetation Index) data are from the MOD13Q1 product of the Moderate Resolution Imaging Spectrometer (MODIS). NDVI data from the MOD13Q1 sensor were chosen because of its frequent use [28, 29]. Thus, annual mean NDVI from 2000 to 2022, with a spatial resolution of 250 m, was used. These data were used to understand the vegetation dynamics of the study area. It should also be noted that NDVI is an indicator of the availability of productive resources. These data are essential for understanding variations in vegetation over time and for studying ecological trends.

In addition to spatial data, statistical data, in particular socio-demographic data for 2019, were collected from the National Institute of Statistics and Demography (INSD). Data relating to school enrolment, poverty, migration, population, etc. was collected. In addition to these statistical data, data were collected from the populations of the provinces of Oubritenga, Boulkiemdé, and Ziro. To do this, a two-stage stratified sampling method was used. Each province was considered as the first sampling level. Provinces were chosen based on the scale of migratory flows to capture the main reasons for migration. The second level consisted of identifying the heads of households. Heads of households were chosen randomly. A total of 75 heads of households were interviewed, with 25 heads of households per province. The sample was made up of 66.66% migrants and 33.33% non-migrants. The survey of heads of migrant households focused mainly on the factors and origins of migrants. The aim of this data collection was to understand the reasons behind the decision to migrate, as well as the choice of destination provinces. The use of this data led to processing, the stages of which are presented below.

3.2. Data Processing and Analysis

The data collected and the results of the literature review have enabled us to identify the factors involved in migration. Far from being exhaustive, these factors enable us to define the contours of internal migration in Burkina Faso. The data collected enabled us to assess the level of perception of the factors by migrants and non-migrants. Frequencies were then calculated to estimate the level of perception of the factors. Statistical data collected from the INSD were used to calculate averages to provide the central data needed to feed the analysis model. The analysis of climatic data was based on a standardised rainfall and temperature index to take stock of their evolution. The calculation of this index was based on the formula of [30].

$$SPI = (Pi - Pm)/ð \qquad (1)$$

With Pi cumulative rainfall for year i, Pm the mean rainfall for the series and ð the deviation of the rainfall data series.

The results obtained from this operation are interpreted according to the framework presented in **Table 1**.

Table 1. SPI index interpretation scale.

2.0 and more	Extremely humid
1.5 to 1.99	Very humid
1.0 to 1.49	Moderately wet
–0.99 to 0.99	Near normal
–1.0 to –1,49	Moderately dry
–1.5 to –1.99	Very dry
–2 and less	Extremely dry

Source: [30].

The various variables were then spatialised and analysed in terms of their spatiotemporal dynamics.

The factors thus identified were crossed with the dependent variable, the number of migrants. The number of migrants (incoming and outgoing) was cross tabulated in a simple linear regression. This regression makes it possible to estimate the degree of influence or involvement of each factor determining internal migration. The regression model used is composed of one dependent variable, the migrant population, and seven (7) explanatory variables, namely rainfall, temperature, NDVI, poverty, school enrolment, demographic pressure, and water availability for off-season farming. The regression works by considering the values of the multiple independent variables available while seeking to predict the values of the dependent variable. This equation is:

$$y = bx + a \tag{2}$$

where y is a dependent variable, x is the independent variable and a and b are constants.

In addition to the linear regression, a multi-factor multiple regression was applied to all the independent variables to explain the dependent variable. The multiple regression equation is :

$$y = b_1x_1 + b_2x_2 + \cdots + b_nx_n + a \tag{3}$$

With y the dependent variable, x_1 to x_n the independent variables. b_1 to b_n and a are constants.

To determine the potential areas of origin and destination of migrants, a multi-criteria analysis was used. Multi-criteria analysis is used to combine the various factors selected to determine the potential areas of origin of migrants and the potential areas of destination. This method was developed by[31] and enables a complex problem to be broken down into a hierarchical system, in which binary combinations are established at each level of the hierarchy. In this study, it is assumed that several factors explain migration. An AHP multi-criteria analytical approach based on matrix algebra calculations was used. The combination of migration factors is carried out in two stages to take account of the effect of attractive factors in determining potential areas for the arrival of migrants and the effect of unfavourable factors that encourage people to leave the area in determining potential areas for the departure of migrants. The following formula is applied to determine is:

$$C = \sum W_iX_i * \Pi C_j \tag{4}$$

With W_i, corresponding to the weight of each factor, X_i the normalised factor i and C_j the constraint j. However, in the context of this study, there is no obvious constraint preventing migrants from moving from one point to another. This situation means that the formula can be rewritten as follows.

$$C = \sum W_iX_i \tag{5}$$

Once the factors had been identified, they were spatialised, standardised and the weight of each factor calculated.

The multi-criteria analysis model used in this study concerned seven factors of internal migration in Burkina Faso. These were rainfall, temperature, vegetation index (NDVI), presence of water resources, population density, poverty and school enrolment. In the modelling process, the spatialised migration factors were recorded in raster format and then standardised. This standardisation consisted of reclassifying the factors into classes. Thus, given the difference in the value intervals of each factor, the factors were brought back to the same scale of appreciation through reclassification. This reclassification is based on Jenks' natural break method[32]. This method assumes that the class intervals are identified in such a way as to encourage the inter-class value to be as homogeneous as possible and the inter-class value to be as heterogeneous as possible. It therefore minimises inter-class variances. Ref.[33] considers that this method is better suited to the discretisation of statistical data. The reclassification process was based on the values in **Table 2**.

Table 2. Reclassification of internal migration factors in Burkina Faso.

Scale \ Factors	Population Density (hbt km^{-2})	Poverty (Number of Poor)	Water Reservoir (Area)	Rainfull (mm)	School Enrolment	Temperature (°C)	NDVI
1	30–1.000	0–12.670	1132.74–5.960.000	0–542.9	0–10.480	0–27.90	−1–0.1
2	1.000–1.900	12.670–26.670	5.960.000–17.440.000	542.9–936.98	10.480–30.550	27.90–28.92	−0.1–0.2413
3	1.900–3.540	26.670–46.070	17.440.000–56.450.000	936.98–1.081.74	30.550–112.330	28.92–29.21	0.2413–0.3263
4	3.540–6.574	46.070–81.180	56.450.000–101.400.000	1.081.74–1.224.96	112.330–400.650	29.21–29.51	0.3263–0.4103
5	6.574–10.245	81.180–131.600	101.400.000–169.700.000	1.224.96–1.411.80	400.650–1.179.510	29.51–30.10	0.4103–0.7529

Determining the different weights of the factors involved several steps. Firstly, at the end of the field survey, the reasons for the decision to migrate were ranked. In fact, when collecting data from the population, we asked the respondents to rank the factors in order of importance while identifying the attractive and repulsive factors. **Table 3** was drawn up based on this classification.

Following this classification, we asked the respondents to compare the factors two by two. This comparison was based on **Table 4**.

Table 3. Factors classification.

Factors	Classification Order
Rainfall	1
Poverty	2
Vegetation index (NDVI)	3
Water retention	4
Population density	5
Temperature	6
School enrolment	7

Source: Field data, 2024.

Table 4. Pairwise comparison of migration factors.

Factors	NDVI	Water	Poverty	Rainfall	Population Density	Temperature	School Enrolment
NDVI	1	3	5	2	4	3	3
Water	0.33	1	3	2	3	3	4
Poverty	0.20	0.33	1	7	3	5	3
Rainfall	0.50	0.50	0.14	1	5	2	7
Population density	0.25	0.33	0.33	0.20	1	5	5
Temperature	0.33	0.33	0.20	0.50	0.2	1	5
School enrolment	0.33	0.25	0.33	0.14	0.2	0.2	1
Sum	2.95	5.75	10.01	12.84	16.4	19.2	28

Source: Field data, 2024.

The comparison considered the rank of each factor in the classification in **Table 3**. After this binary comparison of the factors, the matrices had to be normalised to generate factor weights (**Table 5**).

Table 5. Normalisation of comparison matrices.

Factors	NDVI	Water	Poverty	Rainfall	Population Density	Temperature	School Enrolment	Total	Weight
NDVI	0.339	0.522	0.5	0.156	0.244	0.156	0.107	2.024	0.29
Water	0.113	0.174	0.3	0.155	0.183	0.157	0.143	1.225	0.18
Poverty	0.068	0.058	0.1	0.545	0.183	0.26	0.107	1.321	0.19
Rainfall	0.169	0.087	0.014	0.078	0.305	0.104	0.25	1.007	0.14
Population density	0.085	0.058	0.033	0.016	0.061	0.26	0.179	0.692	0.10
Temperature	0.113	0.058	0.02	0.039	0.012	0.052	0.179	0.473	0.07
School enrolment	0.113	0.043	0.033	0.011	0.012	0.011	0.035	0.258	0.04
Sum	1	1	1	1	1	1	1	7	1.00

Source: Field data, 2024.

Each migration factor has a dual effect on the decision to migrate. Thus, while the factor X_i leads to migration when its quantitative value is high, this factor becomes attractive when its quantitative value is low. Thus, high temperatures lead to migration, while low temperatures attract migrants. Conversely, low precipitation leads to migration, while high precipitation attracts migrants. This consideration led to the development of the following synthesis equations:

$$C = \sum W_i X_i - \sum W_j X_j \tag{6}$$

With X_i the pull factor and X_j the push factor.

- Equation for determining destination zones

$$\begin{aligned} C = (0.037 * \text{“School\_enrolment”} \\ +0.144 * \text{“Rainfall”} + 0.175 * \text{“Water”} \\ +0.289 * \text{“NDVI”}) - (0.189 * \text{“Poverty”} \\ +0.099 * \text{“Density”} + 0.068 \\ * \text{“Temperature”}) \end{aligned} \tag{7}$$

- Equation for determining areas of origin of migrants

$$\begin{aligned} C = (0.189 * \text{“Poverty”} + 0.099 * \\ \text{“Density”} + 0.068 * \text{“Temperature”}) \\ -(0.037 * \text{“School\_enrolment”} \\ +0.144 * \text{“Rainfall”} + 0.175 \\ * \text{“Water”} + 0.289 * \text{“NDVI”}) \end{aligned} \tag{8}$$

4. Results

4.1. Internal Migration Factors

According to the results of the fieldwork, the imbalance in terms of agricultural potential in the regions is one of the main factors behind internal migration, which is generally characterised by the movement of people from the north and east to the south and west. The population perceives that several factors are behind this migration (**Figure 2**).

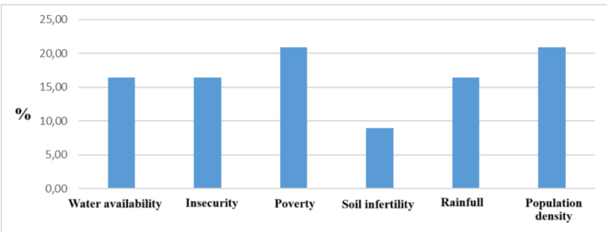

Figure 2. Internal migration factors identified by the field survey.
Source: Field data, 2024.

Figure 2 shows the determinants of internal migration identified during the field survey. Demographic pressure accounts for 20.9% of interviewed migrants, and the same proportion of poverty. The water draw, insecurity and rainfall each account for 16.42% of the migrants surveyed. Soil poverty accounted for 8.96%. No mention was made of temperature or schooling as factors in migration. However, we have retained them as climatic and social factors. According to 98% of respondents, the population is growing rapidly, while 2% said it was falling. In addition, 67.4% of respondents thought that poverty was on the rise, 31.4% thought it was falling and 1.2% thought it was constant. The quality of agricultural land is declining (97.7%). Regarding the reasons for this decline in land quality, 66.7% of those who approve of the decline believe that it is linked to human activity (deforestation, bush fires, pollution by inputs, etc.), and 33.3% explain it by climate change. In terms of climate parameters, 75.1% think that rainfall is increasing and 83.7% think that temperatures are rising. According to the population's perception, the school enrolment rate has increased (98%). 76.3% think that the amount of water reservoirs is increasing.

4.2. Correlation between Migration and Each Migration Factor

The relationship between individual factors was established using simple linear regression (**Table 6**). Two simple linear regression models were run, model 1 with 'Immigrants' and model 2 with 'Emigrants' as the dependent variable. The explanatory variables in both models are rainfall, temperature, population density, vegetation cover, school enrolment, poverty and water retention.

Table 6. Simple linear regression of migration factors.

Variables	Model 1 Immigrants		Model 2 Emigrants	
	Coef.	P-Value	Coef.	P-Value
Population density	0.2829034	0.000***	0.11381	0.000***
Water resources	–16.91168	0.861	–53.3931	0.216
NDVI	–198723.1	0.031*	–177604.7	0.000***
Poverty	2.021695	0.068	1.9279	0.000***
Rainfall	5.218732	0.665	–3.643928	0.501
School enrolment	5.327363	0.000***	2.070349	0.000***
Temperature	3885.622	0.299	2582.559	0.123

Note: Significance: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

For model 1, three factors are significant, and four factors are significant in model 2. The factors demographic pressure, NDVI, poverty, and schooling are strongly linked to the decision to migrate. Overall, the results indicate that the environmental conditions measured by the variables rainfall, temperature, and vegetation cover (NDVI) are effectively linked to migration behaviour.

4.3. Level of Contribution of Each Factor to the Decision to Migrate

This multiple linear regression model has immigrants (model 1) and emigrants (model 2) as dependent variables and internal migration factors as explanatory variables. It shows the links between the effects of rainfall, temperature, vegetation cover, water retention, and socio-demographic characteristics (demographic pressure, schooling and poverty) on the decision to leave one's place of origin. The results of the models (**Table 7**) indicate that the adjusted R-squared is 0.95 and 0.75 for models 1 and 2 respectively.

Migrant populations are generally attracted by favourable conditions in destination areas. Model 1 shows that only the education variable is significant in the model. However, according to the results of the field survey, choices of destinations are motivated by the favourable factors of climate, environmental, and economic potential. Thus, 65.7% believe that the arrival of migrants in destination areas is motivated by the availability of land, including good quality land for farming activities. This shows that areas with low land pressure attract immigrants. It emerges that the availability of land for agricultural activities enables the development of economic activities. 34.3% said that areas with good climatic conditions attract migrants.

Table 7. Correlation between migrants and the determinants of internal migration.

Factors	Model 1 Immigrants		Model 2 Emigrants	
	Coef.	P-Value	Coef.	P-Value
Population density	0.031527	0.211	0.0946076	0.001***
Water resources	–46.49239	0.206	–13.49712	0.732
NDVI	–18405.32	0.561	–145016.4	0.000***
Poverty	–0.4508593	0.192	0.063027	0.865
Rainfall	3.649012	0.480	5.857429	0.290
School enrolment	4.769282	0.000***	0.3022847	0.533
Temperature	–27373.68	0.631	–2495.526	0.026*

Note: Significance: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

Model 2 shows that population density and vegetation index (NDVI) have significant effects on the number of out-migrants, with positive coefficients for population and negative coefficients for vegetation index. This indicates that municipalities with a larger population and a lower vegetation index tend to have a greater number of out-migrants.

4.4. Temporal Dynamics of Internal Migration Factors

4.4.1. Rainfall

Rainfall data for the period 1990–2019 shows alternating wet and dry periods (**Figure 3**).

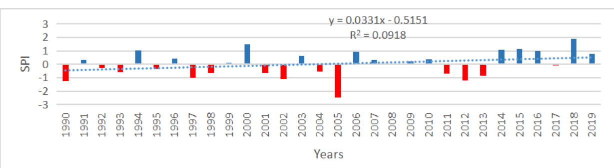

Figure 3. Standardised precipitation index trends from 1990 to 2019.

Source: WorldClim, 2023.

The graph shows that normal years account for 70% of the series, dry years for 13% and wet years for 17%. The trend in the SPI of the series is increasing despite the presence of dry years, which shows an increase in rainfall in Burkina Faso. Furthermore, the spatial distribution of rainfall (**Figure 4**) shows an uneven distribution of rainfall amounts.

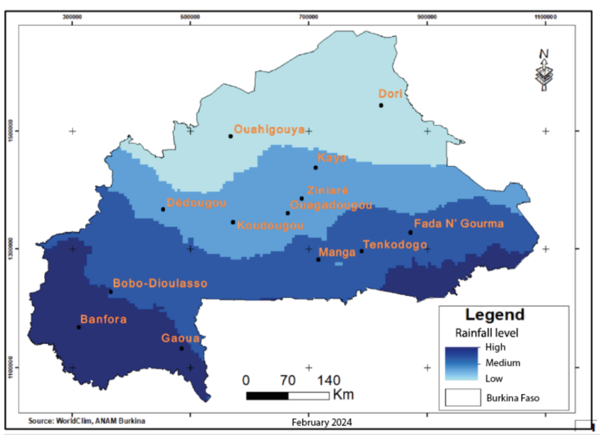

Figure 4. Spatial variation in rainfall in Burkina Faso in 2019.

The spatial distribution of rainfall shows that the southern parts enjoy abundant rainfall. Annual rainfall is estimated at 1,300 mm, while in the north it is less than 600 mm. This distribution of rainfall quantities conceals strong spatiotemporal variations in climatic anomalies (**Figure 5**).

Figure 5 shows the spatial behaviour of the standardised precipitation index for each year compared with the average for the time series from 1990 to 2019. It shows a strong variation in rainfall. The dry trend is most marked in the north of the country. These variations influence agro-pastoral production and play a role in the decision of populations to migrate.

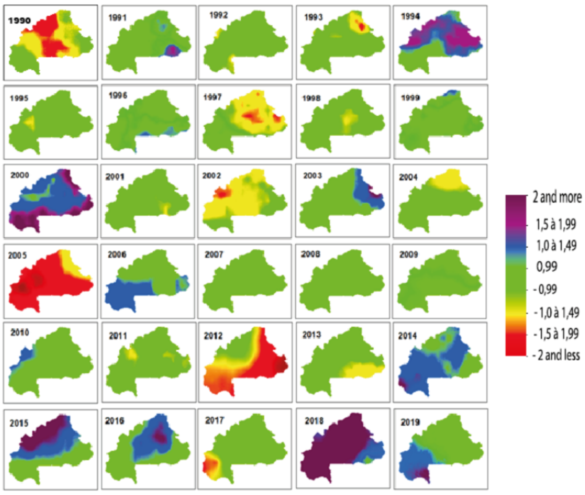

Figure 5. Average annual SPI from 1990 to 2019.

Source: WorldClim, 2023.

The results of the fieldwork show that 97.7% of respondents believe that the quality of agricultural land is declining. As for the reasons for this decline in land quality, 66.7% of those who approved of the decline thought it was linked to human activity (deforestation, bush fires, pollution by inputs, etc.), and 33.3% explained it by climate change. For displacements linked to the fertility or quality of the land, people are leaving degraded areas where the soil is poor to settle in fertile areas where plant activity is high.

4.4.2. Temperature

Figure 6 shows annual averages of anomalies from 1990 to 2019 on a national scale. Positive values of this anomaly index reflect warm years and conversely cold years.

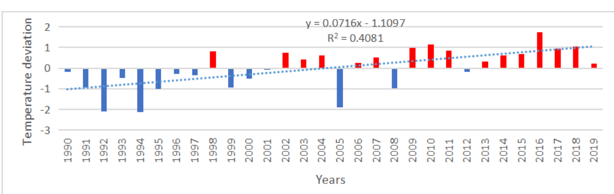

Figure 6. Annual temperature deviations from the average from 1990 to 2019.

Source: WorldClim, 2023.

The coldest year was 1994, with a difference of –2.13 °C from the 30-year average. The warmest year was 2016, with a difference of 1.75 °C from the 30-year average. The first eight years (1990 to 1997) of the time series are cold. The short alternations begin in 1998 and the last seven years (2013 to 2019) are warm. In terms of frequency, 47% of years are cold and 53% are warm. **Figure 7** is a temperature map of Burkina Faso.

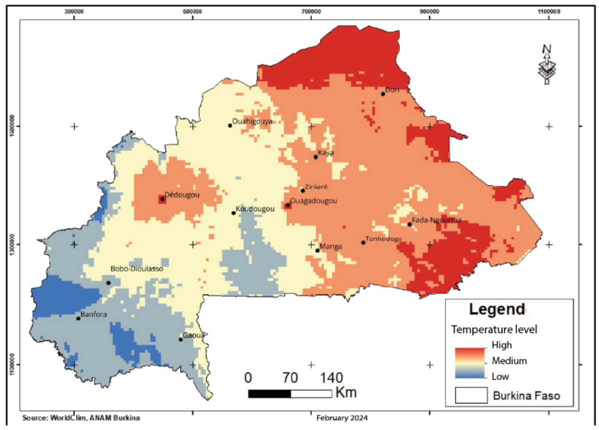

Figure 7. Temperature in Burkina Faso in 2019.

Low temperatures are located in the south, while high temperatures are found in the north and east. This situation is indicative of the highly variable climatic conditions that affect the migratory behaviour of the populations.

4.4.3. Normalised Difference Vegetation Index (NDVI)

The development of vegetation depends on the quality or fertility of the soil. Soil and vegetation are closely linked. The NDVI therefore provides further information on soil quality [34]. Consequently, NDVI trends (**Figure 8**) could be used as one of several indicators of land degradation, as defined by the United Nations Convention to Combat Desertification (UNCCD).

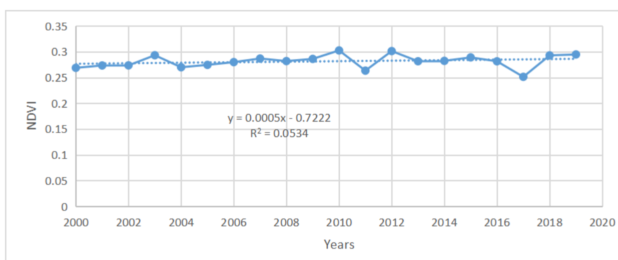

Figure 8. Trends in annual average of NDVI from 2000 to 2019.

Source: NASA/MODIS.

Over the period from 2000 to 2019, NDVI has fluctuated four times, corresponding respectively to 2000–2002, 2004–2006, 2010–2012 and 2016–2018. Climatic conditions have an impact on NDVI. The orientation of the trend line shows that over 10 years, vegetation regenerates. Vegetation development differs from one zone to another (**Figure 9**).

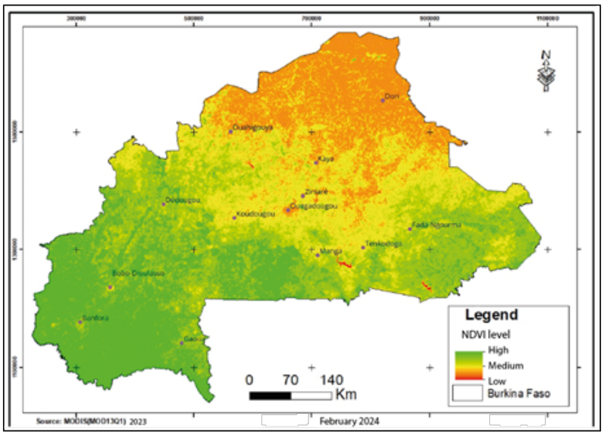

Figure 9. NDVI average for 2019.

The map shows that the southern part is more marked by high indices. The high vegetation indices suggest favourable climatic and agro-pastoral conditions.

4.4.4. Population Density

Population density has risen from 20.6 hbts km^{-2} in 1975 to 75.1 hbts km^{-2} in 2019 [25]. The distribution of the population differs from one region to another and from one year to another (**Figure 10**).

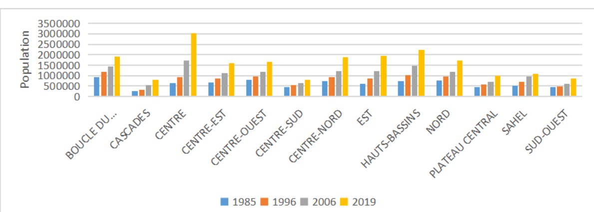

Figure 10. Population growth by region, 1985–2019.

Source: [25].

Analysis of the figure shows disparities between regions. In 1985 and 1996, the Boucle du Mouhoun region was the most densely populated, with 911,736 and 1,174,456 inhabitants respectively. This is probably due to the presence of the Sourou hydro-agricultural schemes, which attract large numbers of farmers. The Centre region, which ranked 7th in 1985 and 5th in 1996, took first place in 2006 and 2019, with 1,727,390 and 3,030,384 inhabitants respectively. The Cascades region was the least populated in 1985, 1996 and 2006, with 249,967, 334,303 and 531,808 inhabitants respectively. The Centre-Sud region ranked last in 2019 with 788,731 inhabitants. The uneven distribution of the population also reflects the uneven spatial distribution of population density (**Figure 11**).

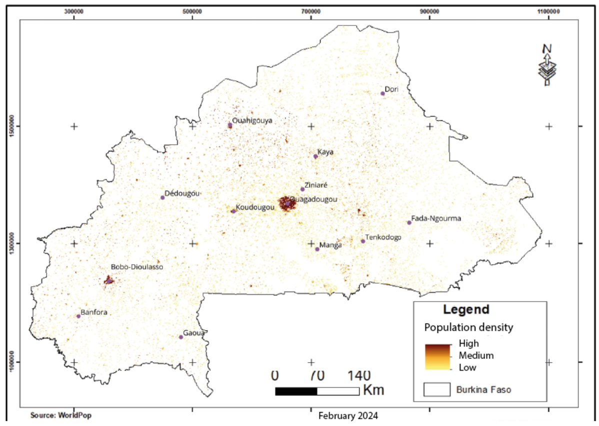

Figure 11. Population density in 2019.

The population is more concentrated in the northern part of the country. This can be explained by the high birth rate and fertility rate. According to the National Institute of Statistics and Demography [25], the regions of very high birth rates are in the East, North, Centre-North, and Sahel regions, where the comparative birth rates are above 45‰. The corollary of these high densities is a growing demand for agricultural land and natural resources. These regions concentrate the highest inactivity rates, which are the East (56.2%), Plateau-Central (61.9%), Centre-North (62.3%), North (68.7%), and Sahel (72.5%). This high inactivity rate explains both the fertility rate and the strong migration trends.

4.4.5. Poverty

At the national level, poverty is measured based on the monetary poverty line, which is 194,629 CFA francs per person per year. Based on this poverty line, the incidence of poverty (**Figure 12**) is 43.2% at the national level [26]. At the end of the field survey, 67.4% of respondents thought that poverty was on the rise, while 31.4% thought it was falling and 1.2% thought it was constant.

In Burkina Faso, the 1990s were marked by development efforts, notably the Structural Adjustment Programme (SAP) adopted in 1991. This resulted in an average GDP growth rate of around 5% in real terms for the period 1995–1998 [35], with an increasing trend until 2009. However, despite this observed growth in GDP, poverty in Burkina Faso worsened between 1994 and 2009. The poverty rate rose from 44.5% in 1994 to 46.7% in 2009. Locally, the poverty index varies from one commune to another (**Figure 13**).

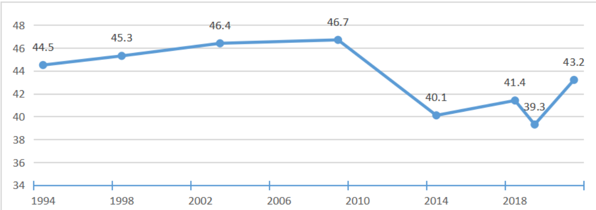

Figure 12. Change in the poverty rate from 1994 to 2021.

Source: INSD, 2022.

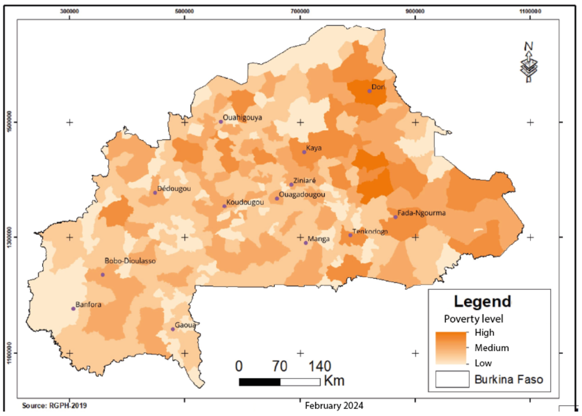

Figure 13. Spatial distribution of poverty levels by commune in Burkina Faso.

Analysis of the map shows that poverty levels are much higher in the north than in the south. This distribution of poverty is a factor that encourages people to move from the north to the south.

4.4.6. School Enrolment

According to the results of different general population censuses carried out in Burkina Faso, the literacy rate of individuals aged 10 or over has been increasing steadily over time (**Figure 14**).

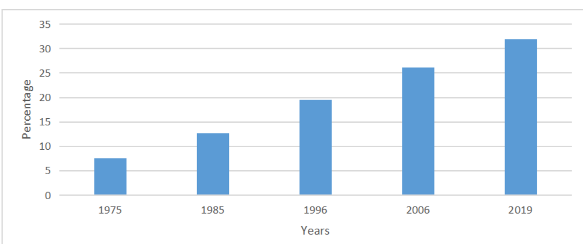

Figure 14. School enrolment trend between 1975 and 2019

Analysis of the graph shows that the literacy rate is rising steadily. The gross primary school enrolment rate rose from 42.7% in 2000/2001 to 79.6% in 2011–2012, and to 86.6% in 2019/2020. Progress has also been made at secondary and tertiary levels, but levels are still low [19]. Spatially speaking, the school enrolment rate is higher in the major centres and provincial capitals. In rural areas, enrolment remains low (**Figure 15**).

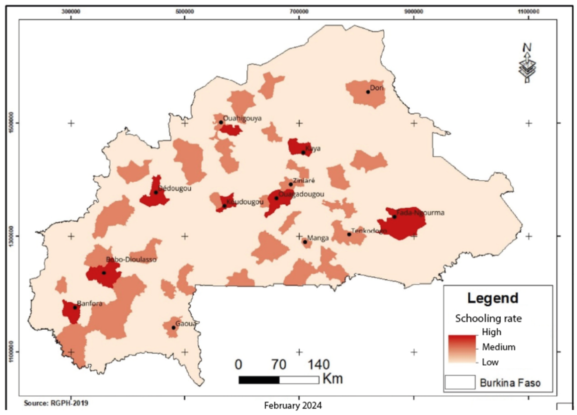

Figure 15. Spatial distribution of school enrolment in 2019.

Because of their characteristics, urban centres have more educational infrastructure and are economically more dynamic. This attracts people of school age as well as those in search of a better life. However, rural areas, which are less dynamic economically and have little educational infrastructure, are where migrants come from.

4.4.7. Spatial Distribution of Water Reservoirs in Burkina Faso

Between 2008 and 2011, the number of reservoirs rose from 1,347 to 1,794, an increase of 33%. According to the spatial distribution of reservoirs by region (**Figure 16**), the Centre-North is the region with the most reservoirs, with a total of 290. This is followed by the Sahel, the Centre West and the Central Plateau, with 241,240 and 186 reservoirs respectively. The presence of natural or artificial reservoirs such as dams, boulis and boreholes attracts agro-pastoral migrants.

The figure shows a concentration of water reservoirs in the north. This distribution is the result of heavy investment by the State and its partners to improve access to water, agro-pastoral production and economic development. However, these reservoirs are affected by rising temperatures, which cause rapid evaporation. As a result, despite this strong presence of water resources, people tend to migrate from the north to the south.

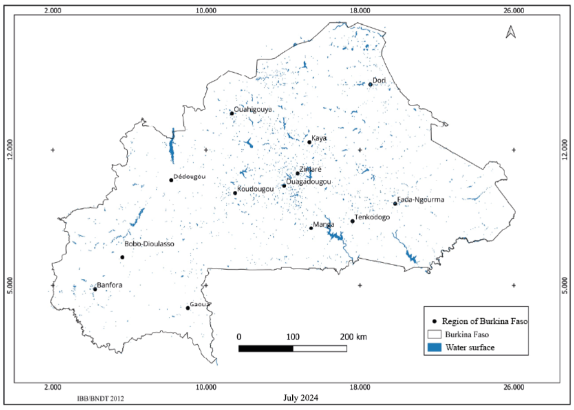

Figure 16. Spatial distribution of water reservoirs in Burkina Faso.

4.5. Spatial Dynamics of Internal Migration

4.6. Potential Areas of Emigration

Spatial irregularities in Burkina Faso's physical and human environment encourage unequal population movements from one area to another within the country. The spatial distribution of the phenomenon of migration from areas of origin is shown in **Figure 17**.

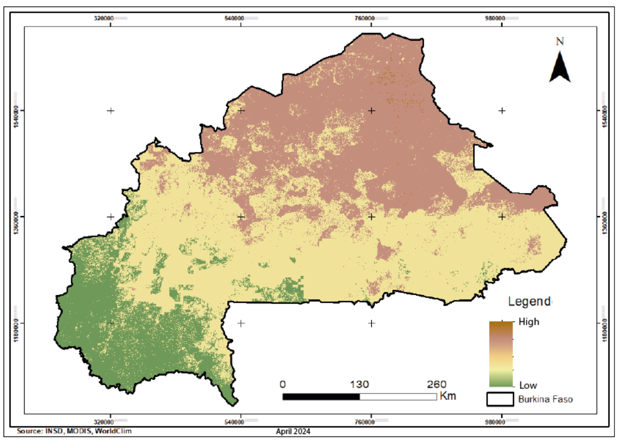

Figure 17. Potential emigration zones.

The analysis shows that the phenomenon of out-migration is significant in the northern part of Burkina Faso and follows the North-South gradient. The results of the field survey show that most of the migrants surveyed come from the Centre-North and Sahel regions. The South is characterised by a low level of migration. The physical environment in the south has good rainfall, low temperatures, and good vegetation cover. These favourable climatic conditions, combined with the fact that most of the Burkinabe population are farmers, explain the low level of migration to the south.

4.6.1. Potential Immigrant Areas

This map shows the destination areas for migrant populations (**Figure 18**). Destination areas are characterised by better production conditions and where land is available due to a low population density.

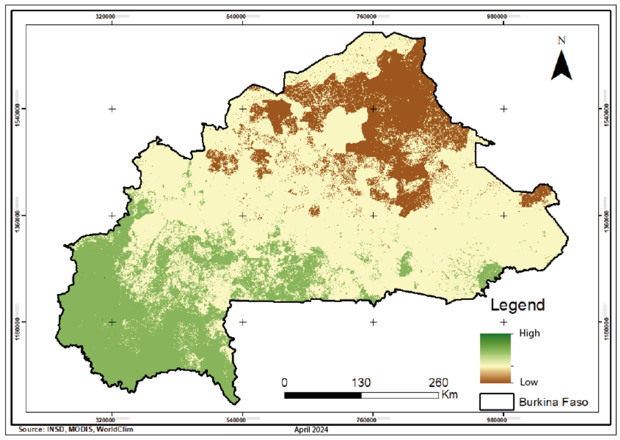

Figure 18. Potential immigration zones.

The analysis of internal migration factors used for this study shows that the southern zone is characterised by good rainfall, good plant cover and low temperatures. These conditions, which are conducive to agriculture and other economic activities, are sources of attraction for the migrant population, which may explain the large number of migrants arriving in the southern part of Burkina Faso. According to [8], the regions receiving the most migrants are Hauts-Bassins (13.6%), Centre-Ouest (6.5%), Boucle du Mouhoun (5.4%), and Cascades (4.9%).

5. Discussion

5.1. Study Data

This study mobilised a wide range of data, sometimes from different sources, formats and types. Thus, although all the factors play an important role in the decision to migrate, they are measured at different spatial and unit resolutions. However, multi-criteria analysis involves cross-referencing data collected at identical scales. This shortcoming is overcome by resampling the data to enable a proper analysis. A spatial resolution of 1 km × 1 km was chosen in view of the scale of the study (national scale). However, it should be noted that in cartographic terms, resampling leads to a generalisation of the information. This implies that the values assigned to the pixels may be sources of error[36] in the distribution and validity of the data. In addition, shape data (.shp) have been rasterised which allows the same information to be assigned to pixels in the same geographical area. This is the case, for example, with school enrolment data collected at the provincial level. To reduce the risk of error, we have considered statistical data at the commune level, which is the lowest level at which statistical data is compiled in Burkina Faso.

5.2. Methodological Shortcomings

The method used is a multi-criteria analysis based on the Analytical Hierarchy Process (AHP), whose implementation required the spatialisation of the factors. These factors are measured in different units. This situation poses problems of co-matching and discretisation for modelling purposes. We therefore used the Jenk method[32], which is based on natural breaks. This method has the advantage of excluding any form of arbitrary discretisation[37] and of creating sufficiently homogeneous classes. This method, therefore, made it possible to discretise the data into five classes to facilitate the analysis.

Implementing this method requires a pairwise comparison of factors explaining migration. In this study, the comparison was made because of the assessments of the people interviewed. This basis for estimating the weights of the factors may introduce bias, as the answers given by the respondents depend on their experiences. So, to reduce bias, we have calculated averages, which are a centrality variable that allows us to identify trends. Ideally, a specific study should have been carried out to determine the factors and classify them. In addition, the literature review helped in the comparison of factors. The work of[12] and[22], for example, deals with sociodemographic determinants, while[3, 4, 6, 15, 17, 20, 38] focus on environmental factors. However, the existing literature on migration seems to support the idea that environmental factors have a greater impact on the decision to migrate. This is even more true in Sahelian areas, particularly in Burkina Faso, where most of the population (over 80%) is engaged in primary sector activities (agriculture, livestock rearing, gathering, etc.). However, these activities, as practised in Burkina Faso, depend on the environment (rainfall, fertile land, vegetation, etc.). This characteristic of migration guided the choice of variables for the present study. However, it should be noted that in recent years, Burkina Faso has been characterised by security crises that have led to significant population displacement. This study omitted this variable because its aim was to highlight environmental factors.

5.3. Migration Dynamics

The results of our work show that the internals are oriented from north to south. The emigration zones are in the north, while the destination zones are in the south. Mapping has therefore made it possible to identify areas where migrants are likely to settle in the south of the country. The results of this mapping are in line with authors such as[10] who show that internal migration in Burkina Faso is known to run from north to south However, no spatial modelling mobilising all the factors at the origin of migration has been carried out. Multicriteria analysis does not allow us to estimate the number of migrants. Rather, it enables us to identify precisely the areas of origin and destination of migrants. Given the consequences of migration, both in the areas of origin and destination, this makes it easier for development players to intervene.

INSD data shows that major centres such as Ouagadougou and Bobo-Dioulasso attract the largest number of migrants. The Centre region accounts for 36% and the Haut-Bassins for 12% of internal migrants[8]. However, in this study, we focused on rural-rural migration while highlighting the role of environmental factors in the decision to migrate and in the choice of destination. The results obtained are therefore consistent with INSD data (2022), since the main destinations for migrants are the Cascades, Boucle du Mouhoun and Centre-Ouest regions (**Figure 19**). In addition, the results obtained give an idea of the likely location of migrants.

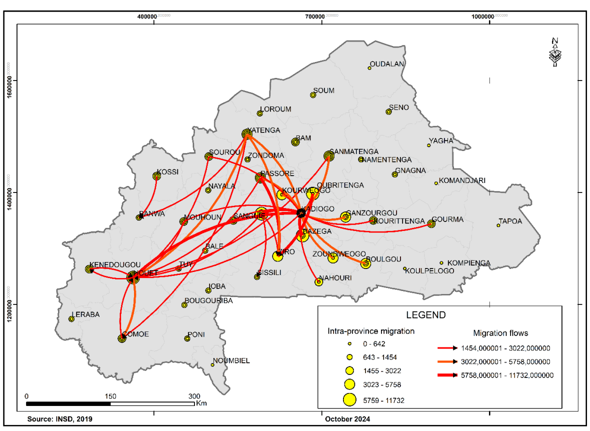

Figure 19. Internal migration flows in Burkina Faso according to INSD in 2019.

The results thus obtained confirm the assertion that rural-rural migration is guided by the search for better agro-pastoral production conditions. Indeed, the origin and destination zones defined at the end of the multi-criteria analysis make it possible to identify zones of resource scarcity (origin zone) and resource availability (destination zone). These zones have been defined based on several factors.

5.4. Migration Factors

Internal migration in Burkina Faso is motivated by several factors. For this study, the field survey identified five factors out of seven. Rainfall, poverty, vegetation cover, population density and water reservoirs were identified during the field survey. The results show that the difficult conditions faced by the population because of these factors prompt some people to decide to migrate within the country to improve their daily living conditions. Many authors who have worked on internal migration confirm the involvement of these factors in internal migration in Burkina Faso [4, 21, 23, 39]. However, factors such as schooling, and temperature were not identified by the respondents. Yet the socio-demographic profiles of migrants show that those who tend to migrate are less educated [12]. Temperature has a major influence on agricultural yields.

The temporal and spatial irregularities of the factors are at the root of the scale of the internal migration phenomenon in Burkina Faso. All factors vary over time. Over a 30-year time series (1990–2019), climatic parameters have varied considerably, with dry and wet years for rainfall and hot and cold years for temperature. The results obtained show a general upward trend in rainfall and temperature. The authors who have worked on this subject are unanimous on the variation in these climatic parameters [38, 40]. Refs. [41] and [42] show that the trend in rainfall in Burkina Faso is downwards.

Spatially, the climatic parameters show a north-south gradient. The results obtained show that the north receives less rain and is warmer than the south of the country, which is characterised by high rainfall and low temperatures. These results are like those of [6]. Alternations in the standardised precipitation index in relation to the average for the time series (1990–2019) occur over short periods. Environmental factors (vegetation cover and water retention) varied over time.

From 2000 to 2019, the NDVI trend is upwards. This result shows that there has been vegetation regeneration over these 20 years, and this can be explained by climatic factors (good rainfall) or anthropogenic factors (reforestation, reduced deforestation and bush fires). These results are like the work of [43] who state that the NDVI trend in the Sahel-Sudan as well as Burkina Faso is positive from 1982–2011. Ref. [44] found similar results on the NDVI trend in the Soudanian zone of Burkina Faso. Between 2008 and 2011, the number of water reservoirs increased. Spatially, environmental factors are marked by inequalities favouring internal migratory movements. This result shows that the southern part is characterised by good vegetation cover, while the northern part is characterised by almost bare soil. This shows that soils in the northern part are more vulnerable and are potentially deteriorating.

This result shows that this more densely populated part of the country, with its difficult climatic conditions, has necessitated the construction of several artificial reservoirs. This result is like that of [45], who states that 80% of water reservoirs are in the central part of the country, 11% in the west, the north and east accounting for 3.5% and 7.3% respectively.

Socio-demographic and economic factors (population density, school enrolment and poverty) are as irregular in time as they are in space. In terms of time, population density has been rising steadily, so the population of Burkina Faso is growing rapidly. Spatially, apart from the cities of Ouagadougou and Bobo-Dioulasso, the northern regions are denser than those in the south. High densities are in fact the expression of strong land pressure. With a predominantly agricultural population, the shortage of farmland coupled with the high population density in the north, as well as unfavourable environmental and climatic conditions, are prompting people to migrate to other areas of Burkina Faso. Ref. [46] have shown that demographic pressure has favoured the migration of farmers in areas of high population density.

The results also show that the school enrolment rate has been rising since 1975. However, the spatial distribution of school enrolment shows disparities. There is a wide gap between urban and rural areas. According to [47], the desire for more education encourages rural migration to urban centres, where educational establishments are usually located. It should also be noted that migrants, who live in rural areas, have a relatively low level of education in Burkina Faso[48].

The poverty index varied between 1994 and 2021. This variation affects population mobility. Spatially, the distribution is uneven. The results of this study show that the north has a high level of poverty. The poorer north is characterised by migration to other areas. With a predominantly farming population, this poverty in the north can be explained by unfavourable climatic conditions, insufficient arable land and poor soils. Several authors claim that poverty encourages people to migrate. Burkina Faso, for example, is characterised by a high poverty index, difficult economic conditions, such as a lack of jobs and food insecurity, drive people to seek alternatives elsewhere[23]. Individuals and families look for better economic opportunities elsewhere to escape poverty and improve their quality of life[21].

The dynamics of the areas of departure and arrival of internal migrants show spatial irregularities. The north is characterised by a large population outflow and the south by a large population inflow. Analysis of the spatial dynamics of the factors determining internal migration has shown that the northern part is characterised by low rainfall, high temperatures, low vegetation cover and a high poverty index. The southern part is characterised by favourable climatic conditions, with good vegetation cover reflecting soil fertility, and a low poverty index. These characteristics of the northern zone are forcing some people to leave the area in search of better living conditions, while the southern part, with its favourable conditions, is attracting migrant populations. Several studies have shown that population departure from the North is due to the difficult characteristics of these factors. This is the case of[4, 15, 20, 21, 32, 39]. These same authors confirm that the favourable conditions of these factors attract migrants.

6. Conclusions

Climatic, environmental and socio-economic instability is undermining Burkinabe society, prompting some people to migrate within the country. This study has highlighted the spatiotemporal dynamics of internal migration factors in Burkina Faso.

However, there were temporal variations in the evolution of internal migration factors and spatial irregularities in their distribution. Similarities in the spatial distribution of factors along a north-south gradient were observed. The dynamics of internal migration in Burkina Faso are characterised by an area of high migrant departure in the north and an area of high migrant arrival in the south. The factors shaping the spatial dynamics of migration are rainfall, temperature, vegetation cover, poverty, water retention, school enrolment and population density.

This article therefore maps the spatial behaviour of internal migrants in Burkina Faso. In view of the implications of migration for both areas of origin and destination, the results of this study enable decision-makers to intervene in the various areas to prevent the possible consequences of migration. This result also enables decision-makers to act more effectively on migration factors according to their spatial behaviour to influence the migration behaviour of rural people in Burkina Faso.

This article is an exercise in better understanding the spatial dynamics of internal migration in Burkina Faso. It has limitations related to the completeness of the results but constitutes a starting point for a new field of research on migration. Further research could be carried out based on the spatiotemporal dynamics of migration factors.

Author Contributions

G.R.N. designed and processed the data, analysed the proposed methods, and edited the manuscript; G.R.N. and D.D. analysed, interpreted, and discussed the proposed methods; G.R.N. revised the manuscript.

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Informed Consent Statement

The informed consent of all participants in the field survey was obtained for the publication of this article.

Data Availability Statement

The data that supports the findings of this study are available from the authors and are accessible upon reasonable request.

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Conflicts of Interest

The authors declares that they have no conflict of interest.

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