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FACTOR ANALYSIS AS AN ALTERNATIVE TO A LACK OF DATA WHEN IDENTIFYING URBAN SPRAWL DRIVING FORCES.

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Abstract:Nowadays, urban sprawl exists as an important phenomenon in Sub-Saharan countries like Mali. Its driving forces can vary from a region to another, or whether it is a developed country or a developing country. In this study, field survey and factor analysis method have been used to assess the urban sprawl driving forces in Bamako District from 1995 to 2025. The aim of this study is to analyze the socio–economic driving forces behind urban sprawl in Bamako. In order to achieve this aim, field survey was conducted by interviewing 150 respondents with as systematic questionnaire. Data from field survey were analyzed through quantitative analysis. Findings showed many driving forces, which were further classified into significant and main driving forces according to the levels of defined scales of respondent 's agreement frequencies, and factor analysis. The significant driving forces are: living conditions, housing policy, lack of rational planning policy. The main driving forces are: demographic growth, desire to own house, land speculation, transportation development, economic growth, rural exodus, and job opportunity. The main contribution of this study is to propose a quantitative analysis based on field survey data as a possible useful way to deal with the missing census data.
Key words: Bamako district, driving forces, factor analysis, field survey, Mali.

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Résumé: De nos jours, l'étalement urbain est un phénomène important dans les pays d'Afrique subsaharienne comme le Mali. Ses facteurs déterminants varient d'une région à l'autre, qu'il s'agisse d'un pays développé ou d'un pays en développement. Dans cette étude, une enquête de terrain et une méthode d'analyse factorielle ont été utilisées pour évaluer les facteurs déterminants de l'étalement urbain dans le district de Bamako de 1995 à 2025. L'objectif de cette étude est d'analyser les facteurs socio-économiques à l'origine de l'étalement urbain à Bamako. Afin d'atteindre cet objectif, une enquête de terrain a été menée en interrogeant 150 répondants au moyen d'un questionnaire systématique. Les données de l'enquête de terrain ont été analysées par analyse quantitative. Les résultats ont révélé de nombreux facteurs déterminants, qui ont ensuite été classés en facteurs déterminants significatifs et en facteurs principaux selon les niveaux d'échelles définies de fréquences d'accord des répondants et l'analyse factorielle. Les facteurs déterminants sont : les conditions de vie, la politique du logement, l'absence de politique d'aménagement du territoire. Les facteurs principaux sont : la croissance démographique, le désir de posséder une maison, la spéculation foncière, le développement des transports, la croissance économique, l'exode rural et les opportunités d'emploi. La principale contribution de cette étude est de proposer une analyse quantitative basée sur des données d'enquêtes de terrain comme moyen utile possible au manque de données de recensement.
Mots clés : district de Bamako, enquête de terrain, étalement urbain, forces motrices, Mali.

INTRODUCTION

Since few decades, urban sprawl has become and continued to be the most important expression of urbanization of cities around the world and Africa particularly in the cities of Sub–Sahara Africa e.g. Bamako in Mali. These cities are facing range of migratory driving forces that are more or less same in all cases. Temporally, the influence of driving forces on urban sprawl varied from one region to another (Abebe, 2013). While, urban sprawl is a "controversial topic" among researchers, the majority of planners have expressed concerns about sprawl's "environmental and social costs", and recommended policies for "sprawl control" (Forman and Gordon, 1986; Cushman et al., 2013).

Driving forces of urban can be first defined simply as factors which result in disproportional, unplanned, and dispersed spreading of urbanization. Driving forces of urban sprawl can also be defined as micro- and macro-socio-economic factors (means of transport, land speculation, demographic changes, the attractiveness of urban regions, and the application of development policies, planning of land use, housing, infrastructure, and others) which interact consciously or unconsciously leading to the modeling of urban area in a dispersed and unplanned way most often. Urban sprawl is also defined as the increased urban land coverage in developable land of fringe areas outside of cities (Fichera et al, 2012). Even, there is no "common definition" of urban sprawl but it is a "common denominator" for the majority of the definitions. However, urban sprawl is characterized as "low-density development" and "inefficient use of land" (Bahtta, 2010).

Urban sprawl is "a low density, auto-dependent land development taking place on the edges of urban centers, often "leapfrogging" away from current denser development nodes, to transform open undeveloped land, into single-family residential subdivisions, campus-style commercial office parks, and diffuse retail uses" (Donnay et al, 2001). Urban sprawl is also four dimensional having "a population that is widely dispersed" in "low-density development"; "rigidly separated homes", shops, and workplaces; a network of roads marked by huge blocks and "poor access"; and a lack of well-defined, "thriving activity centers", such as downtowns and town centers (Liu, 2014).

Numerous researches have been done on the driving forces of urbanization, in which the remote sensing data and statistical data are most commonly used (Dewan and Yamaguchi, 2009; Fichera et al., 2011; Murgante and Danese, 2011). In China, many variables have been used by previous studies to assess the urban sprawl or urbanization driving forces (Jia et al, 2019; Kaza, 2013; Abebe, 2013). These studies, using remote sensing data and regression methods, mainly investigate the driving forces by focusing on variables such as, physical conditions, economic factors or economic growth, industrialization, institutional factors, investment, trade, employees, average wages, the value of agricultural land, land market, and so on (Forman and Gordon, 1986; Peng et al., 2016; Jia et al, 2019; Feng and Liu, 2015). Another study argued the main driving forces of sprawl in China as the implementation of the strategy on land use and regional development, such as policies of "Western Development", "Revitalization of Northeast", coupled with rapidly economic development during the early 21st century. "Gross domestic product", secondary industry product, "tertiary industry product", "total population and urban population" were driving factors of urban land sprawl in Northeast China (Abebe, 2013).

About urban sprawl driving forces in Europe, four major categories of drivers were found behind sprawl, which are: economy, society, transport, and policy and regulatory framework (Donnay et al, 2001).

In Africa, many studies have been conducted on urban growth and sprawl processes, patterns, environmental aspects, and future prediction (Manirakiza, 2011; Abdulhadi, 2014; Muchelo, 2018; Jo and Fo, 2018; Mulu, 2018), but a very few studies have focused on the driving forces. Most of these studies were based on a rapid urban growth process, a high pattern changes, important environmental impacts, and continuous important of urbanization in African countries, and manly in Sub-Saharan (Akuffo, 2014; Sandborn, 2015; Sangare, 2017). In Africa driving forces of urban sprawl are mainly attributed to demographic growth, rural exodus (Soumare, 2018; Dembele, 2017). In Mali, the driving forces of urbanization were mainly attributed to demographic growth, rural exodus, facilities investment, land speculation (McGarigal, 2009; Sertel et al., 2018, Herold et al, 2002). It can be seen, if several aspects of urban sprawl are assessed in Africa, there is a very lack of investigation on urban sprawl driving forces, mainly in Mali, where most the studies cover policies aspects of urbanization. This study is the first contribution to enforce the existing literature that shows the importance of field survey in the monitoring process of socio-economic driving forces as an alternative to lacking of census data and mot impotently it is the first study assessing urban sprawl driving forces in Bamako.

Given as there are many urban sprawl driving forces, it is not easy to determine, which the most important drivers are; because drivers are "context dependent" and can vary between "regions" and "countries". Furthermore, driving forces are "often closely connected" and can interact with each other (Donnay et al, 2001).

The driving forces of urban sprawl were mainly affected by technology, industry, economic, transportation, land market development, and so on in Europe, Nord America and in Asia developed countries. While in developing countries like Africa and Sub-Saharan regions, rural exodus, population growth, natural characteristics, availability of life facilities, economic incentives, job opportunities, land demand and supply, administrative function, and lack of adequate urban management policy are more dominant.

In this study, Bamako district was chosen because it is one of the main and biggest cities of Mali that are facing faster urban sprawl process causing multiple socio-economic and environmental issues. In addition, none the studies has been conducted on urban sprawl driving forces in Bamako district. Thus, it will produce new insights for Bamako district, in particular, and would serve as reference frame for Mali and other cities in general.

The main purpose of this study is to analyze the socio-economic drivers behind urban sprawl in Bamako district from 1995 to 2025. The specific objectives of the study are to:

- provide a basis or reference frame for future studies on urban sprawl in Bamako district mainly and secondarily for the others cities of the country;
- produce perspectives and suggestions which could also serve for planners or decisions makers, as a support in decisions making or planning process;

- and identify the factors influencing the urban sprawl, which are essential to support decision makers, urban planners, economists, environmentalists and resource managers to solve problems related to this phenomenon (Herold et al, 2002; Shahfahad et al, 2020).

The main contribution of this paper is that it reveals a possible way to use quantitative analysis approach and factor analysis based on field survey method to analyze long-term urban sprawl socio-economic driving forces as an alternative to lacking socio-economic census data.

The following research questions are formulated.

Main research question

How can we analyze the socio-economic drivers behind urban sprawl in Bamako district from 1995 to 2025?

Secondary research questions

- How can provide a basis or reference frame for future studies on urban sprawl in Bamako district mainly and secondarily for the others cities of the country?
- What perspectives and suggestions can we proposed to serve planners or decisions makers, as a support in decisions making or planning process?
- What are the factors influencing urban sprawl in Bamako district?

A man hypothesis and secondary hypothesis are formulated

Main hypothesis

Field survey and factor analysis could be used to analyze socio-economic driver behind urban in Bamako district from 1995 to 2025

Secondary hypothesis

- Propose an alternative method like field survey and factor analysis to a lack of socio-economic data could be a reference frame for future studies on urban sprawl in Bamako district and for others cities of Mali
- The development of new attractive places such as creating some important secondary cities of economic and development zones could be a perspective for decisions makers to solve the problem of urban sprawl
- The factors influencing urban sprawl in Bamako district would be mainly rural exodus, demographic growth, economic growth, land speculation, and so on.

1. Methodology

The study area, the materials and data are presented. The quantitative assessment of urban sprawl driving forces and factor analysis assessing socio-economic driving forces of urban sprawl methods are presented.

1.1.Study area

Bamako District is the capital and the main city of the Republic of Mali, located in the southwestern part of the country. Bamako is further subdivided into six municipalities located in southern Mali (Fig. 1). It has maximum area of 267 square kilometers and 3,337,122 inhabitants, with a density of 1,115 people per square kilometer. It is located on both sides of the Niger River at 8 degrees W and 12 degrees 39' N. Bamako is divided into two parts, the northern bank (on the plains between the Niger River and Mount Manding) and the southern bank (more than 12,000 hectares of location is the area of Senou airport and relief from the mount Tiankoulou to the Niger River).

Bamako is entirely located in the Sudanese climate (which, by definition, is a warm climate, always more than 18 °C). The main characteristic of the Sudanese climate is the alternation of two seasons. A long dry season, and a rainy season, which starts from June to September. The dry season includes a short cold season (December to February) and a long hot season with extremes (over 38 °C). This strong heat is not totally foreign to the horizontal extension of the city. Indeed, the absence of air conditioning, the courtyard of the house is the place to cool off. That's why we always want it wider.

For its geological structure and soil, the Bamako District is located in a granite basement covered with sandstone deposits. The river is deeper and deeper into the basement of the leaf rock of granite and sedimentary layers. There are two types of surface formations: soils caused by rock change and lateralization, and alluvial formations that occupy the river's primary and secondary riverbeds and tributaries.

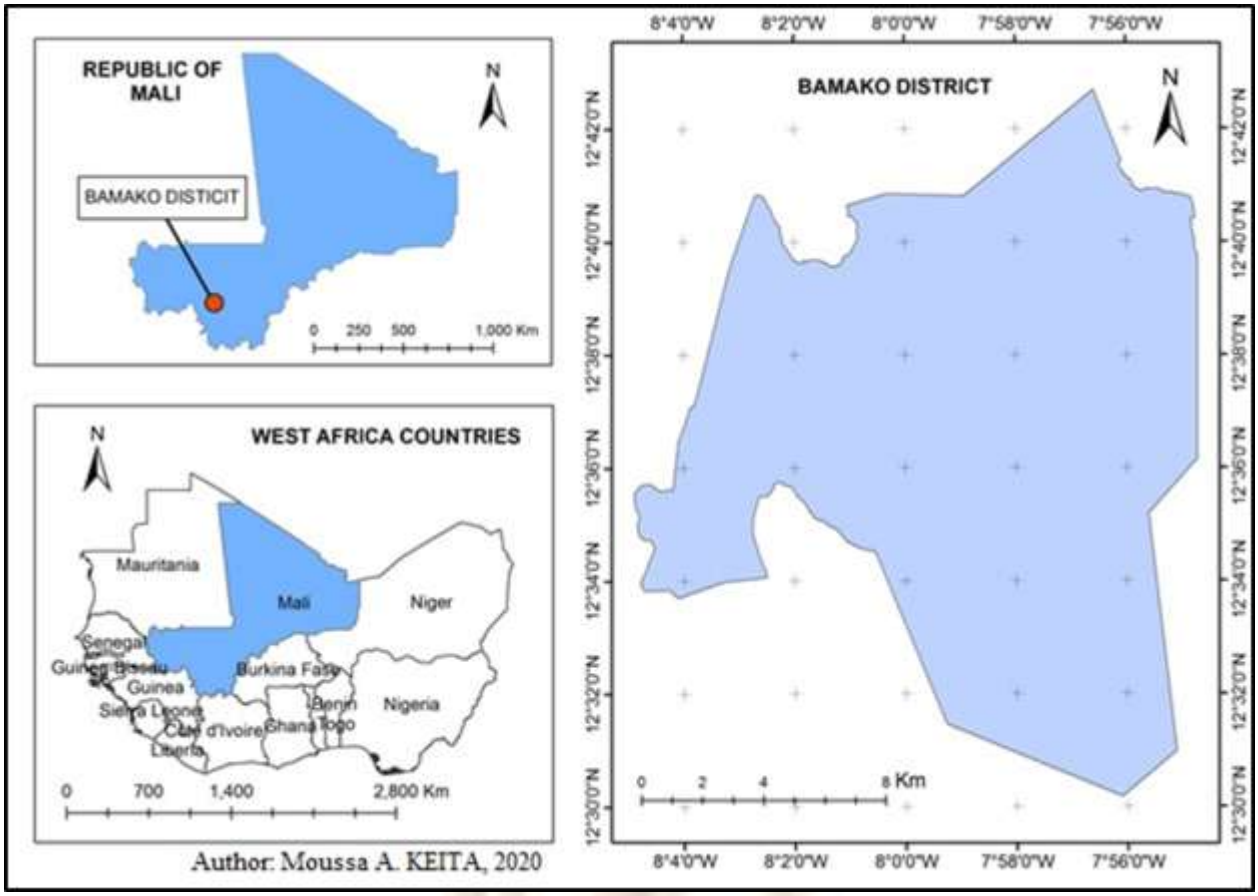

Figure 1. Study area location map.

1.2.Data and materials

The statistical program for social sciences (SPSS) were used as materials for further data processing and analysis.

Quantitative data or information about socio-economic factors used in this study were gathered exclusively form field survey investigations.

1.3.Quantitative assessment of urban sprawl driving forces

In order to assess the driving forces of urban sprawl in Bamako District, the first basic desired method was used to make correlation between geospatial data from imagery classification and socioeconomic data from census. Unfortunately, we didn't find a satisfying available socioeconomic data meeting the purpose of the study. Thus, focus on driving forces assessment method on quantitative analysis was done by a field survey. It was important to determine the significant driving forces and the main driving forces.

The survey-based approach methodology was focused on four steps which are: elaboration of questionnary, choosing survey samples, conducting survey, and treatment and analysis of collected data. A sample of 150 respondents was used for the field survey.

This sample of 150 respondents was extracted from a frame of sample which was composed of; firstly, academicians and researchers majored in urban remote sensing, urban geography, and urbanism, secondly public and private experts involved in Bamako District urban environment management and thirdly, local and traditional responsible, involved in the management of their local urban areas, municipalities, districts and common peoples. From these defined sub-groups, actual sample or the survey sample was derived.

Out of one hundred fifty (150) individuals, one hundred twenty (120) were common people. The other sub-groups were included academicians and researchers, and public/private representatives, and local representatives (10 each). The reason of choosing these individuals resides in the fact that they are able to provide the needed information for this study.

The method of sampling used in this study is the "non-probabilistic" one. This method is based on building a sample having some predefined criteria according to the purpose of the study and to the types of information have to be to collect. The importance of this method is that it allows selecting the survey sample on the basis of criteria required for desirable results. The type of the "non-probabilistic" method used in this study is the "sampling based on the initiative of the researcher" as it fits well with the objectives of the study.

The survey focused on the questionnaires administration in order to get quantitative data. Questionnaires were addressed to the 150 individuals (made up of common people and experts) in two different ways. The first method was the direct interview where the interviewer questions the respondent face-to-face and directly collects the given responses, while the second was the online survey via the mail box. The questionnaires were sent directly to the respondents through email and then send back after being responded. This was done due to the lack of time and the high cost of conducting direct fully field investigation. To analyze the produced information and to find driving forces, frequencies and relative values, Tables have been first made in order to identify the strong tendencies of results which allowed appreciating and categorizing founded driving forces from the most important to the less important. Secondly, scales have been defined between relative values distinguishing driving forces based on their importance. It has been decided to divide driving forces between significant driving forces and main driving forces by considering all relative values comprised between 70-89% percent as significant driving forces, and all relative values comprised between eighty (80%) percent and one hundred (100%) as main driving forces.

Indicators of driving forces have been used for most of the driving forces to check the reliability of respondents' advices about driving forces. This method was useful in so far as it allowed verifying other sub aspects linked to driving forces or supporting them. These proposed driving forces and their indicators are presented in Table 1.

Table 1**.** Driving forces and their indicators used for this study.

N°	Driving forces	Indicators of driving forces
1	Demographic growth	number of persons living in family.
2	Economic growth	Have monthly income, number of persons with monthly income.
3	Migration	Number of persons from elsewhere in respondent's family.
4	Job opportunity	Number of persons with job in respondent's family.
5	Development of transport	Owning of personal mean of transport, access to public transport in residence area.
5	Living conditions	Access to drinking water, access to electricity, access to important market or supermarket, access to bakery, access to leisure center, access to basic educational facilities, access to high educational facilities, access to higher educational facilities, access to basic health facilities.
6	Desire to own house	Number of houses owned
7	Land speculation	
8	Housing policy	
9	Lack of rational planning policy	

1.4.Factor analysis assessing socio-economic driving forces of urban sprawl

In this study, Principal Component Analysis (PCA), and Multiple Correspondence Analysis (MCA) were used as complementary methods to support results from field survey and to assess socio-economic driving forces of urban sprawl. It was also used to check the relationship, consistency and reliability of the 150 respondents' answers from field survey about socio-economic driving forces and their indicators between years 1995, 2005, 2015, and 2025.

- Principal component analysis

Principal components analysis is most useful if one simply wants to reduce a relatively large number of variables to a smaller number of variables that still capture the same information.

To appreciate results of PCA, indexes like the correlation matrix, Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO), Bartlett's Test of Sphericity, Communalities, and Total Variance Explained have been considered. The Correlation Matrix showed how each of the items was related to the other. Relatively high correlations indicate that two items are associated were grouped together by the factor analysis. The KMO test revealed whether or not enough items were predicted by each factor. In other words, it measured strength of the relationship among variables. Its measure should be greater than 0.70 and is inadequate if less than 0.50. The Bartlett test is another indicator to evaluate the strength of the relationship among variables. This test should be significant (i.e., a significance value of less than .05); this means that the variables are correlated highly enough to provide a reasonable basis for factor analysis. The communalities represented the relation between the variable and all other variables (i.e., the squared multiple correlation between the item and all other items) before rotation. In other words, communalities show how much of the variance in the variables has been accounted for by the extracted factors.The Total Variance showed how the variance was divided among the number possible factors. For more details, it also showed all factors extractable from the analysis along with their eigenvalues, the percent of variance attributable to each factor, and the cumulative variance of the factor and the previous factors.

- Multiple correspondence analysis

The multiples correspondence analysis (MCA) was applied in this study for qualitative data obtained from field survey. To appreciate the reliability of results, analysis was focused on Cronbach's Alpha index. Cronbach's alpha is commonly used to assess the internal consistency of a questionnaire (or survey) that is made up of multiple Likert-type scales and items.

To analyze the results of factor analysis and find driving forces, all socio-economic factors satisfying to all conditions of indexes of PCA and MCA were retained as main driving forces. The methodology used for driving forces analysis is presented in Fig. 2

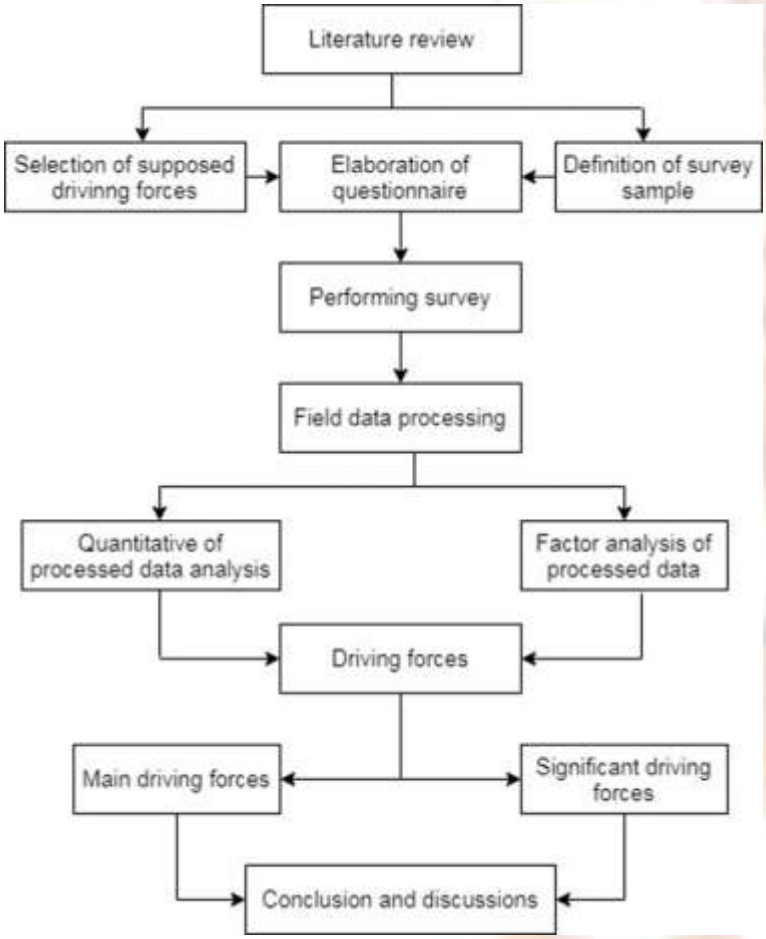

Figure 2. Flowchart of Methodology

2. Results

The results of the quantitative assessment and the factor analysis are presented

2.1.Quantitative assessment of urban sprawl driving forces

It focused on the interpretation of absolute and relative frequencies values from respondents about their point of view on suggested driving forces in the questionnaire.

- Population growth

As shown in Table 2, among 150 interviewed persons, 149 persons either a percentage of 99% agreed that demographic growth is one of the causes of urban sprawl in Bamako District. So, it can be concluded that population growth was an important driver of urban sprawl in Bamako district from 1995 to 2025. Table 13 shows details of the degree of respondents' agreement. Mali's annual urbanization rate of 4.9% per year far exceeds the overall population growth rate, which stands at 2.9% per year. Currently, 41% urbanized, the country is expected to cross the 48% mark by 2030 (Herold et 2002). The World Bank concluded that the population of Bamako District will be more than double inthe period of 2000 to 2015 and the pressure on the city is expected to increase in the future. Statistics in Table 4 and Fig. 3 about the evolution of the number of persons living in respondents' families is a good indicator of the population growth in Bamako district from 1995 to 2025.

Table 2**.** Mean and sum of persons living in respondents' families.

	1995	**2005**	**2015**	**2025**
Valid	150	150	150	150
Missing	0	0	0	0
Mean	4.45	6.47	8.65	11.91
Sum	668	971	1297	1786

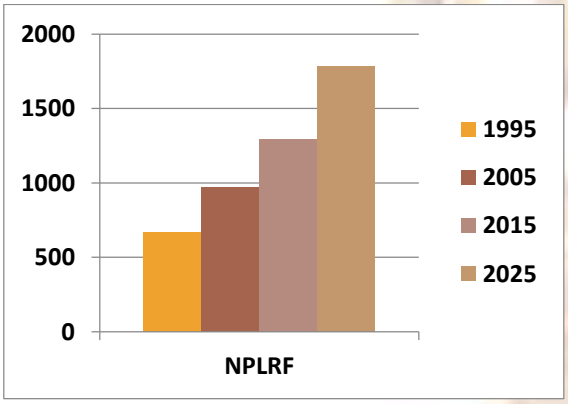

Figure 3**.** graph of number of persons living in respondents' families.

- Rural exodus.

At the end of the survey, 82% of respondents found that rural exodus was one of the causes of sprawl (Table 2).

The origins of interviewees, in Table 3, give a clear appreciation on the importance of rural exodus to Bamako. Among interviewees, 82% came from another place; either 18% are native of Bamako District. To check the importance of rural exodus, the indicator of rural exodus (the number of elsewhere persons or living or came in respondents' families) was assessed. The results are shown in Table 4 and Fig. 4. It revealed an important increase in elsewhere people in respondents' families from 1995 to 2025. Thus, based on these results, it can be said that rural exodus was important in

Bamako District, and can be considered as one the drivers of urban sprawl. It is important to note here that rural exodus is supported by job opportunities, good life standings that is offered in Bamako, and other factors faced by rural population like pauperization and decrease of rainfall which is affecting negatively agriculture productivity. If the pull factors (such as, access to jobs and services) are important in the rural exodus, the push factors, such as, poor living conditions, weather conditions, few opportunities and insecurity, are also of particular importance in Mali (Herold et 2002).

Table 3. Origin of interviewees.

	Frequency	Percent
From Bamako	27	18
From another place	123	82
Total	150	100

Source: Personal investigation, 2025

Table 4. Number of persons came from elsewhere in respondents' families from 1995 to 2025.

	1995 – 2005	**2005 – 2015**	**2015 - 2025**
Valid	150	150	150
Missing	0	0	0
Mean	1.19	1.43	1.92
Sum	178	214	288

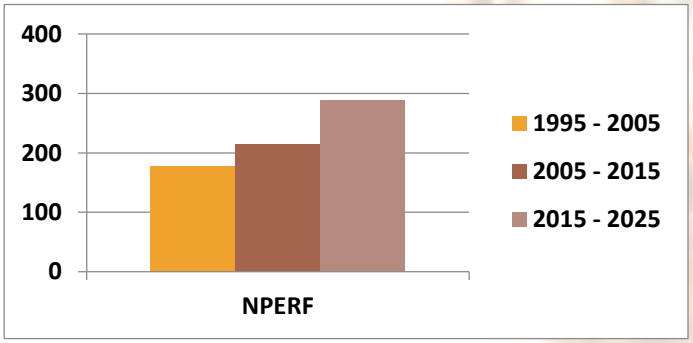

Figure 4. Graph of number of persons from elsewhere in respondents' families.

- Economic growth

Concerning economic growth, 88% of interviewees confirmed that it is one of the important causes of urban sprawl in Bamako as shown in Table 13. Moreover, concerning the most developed sector of economy (either 88%) find the tertiary sector as the most developed. This reality exists in almost all cities of developing countries. It is inferred that primary and secondary sectors are not much developed in Bamako economy. In other term, that is to say that Bamako is not an industrial city instead the other cities of Mali, which are more industrially developed. Urban economy is highly dominated by the tertiary sector. Also, indicators of economic factor like monthly income of respondents and number of persons with income in respondents' families are used to check the improvement of economic conditions in respondents' families. Results in Table 5, 6, and Fig.5,

about the mean and sum of respondents' monthly income and number of persons with income, show a good improvement of economic factor during the study period. The World Bank found the same conclusions declaring that Bamako's economy remains dominated by small businesses, which carry out activities undertaken mainly in non-tradable goods and services sectors where economies of scale and specialization are lacking (Herold et 2002).

Table 5: mean and sum of respondents' monthly income

	1995	2005	2015	2025
Valid	150	150	150	150
Missing	0	0	0	0
Mean	1.61	2.45	3.52	4.34
Sum	241	368	528	651

Table 6: sum and mean of number of persons with income in respondents' families

	1995	2005	2015	2025
Valid	150	150	150	150
Missing	0	0	0	0
Mean	1.05	1.50	2.15	2.86
Sum	157	225	323	429

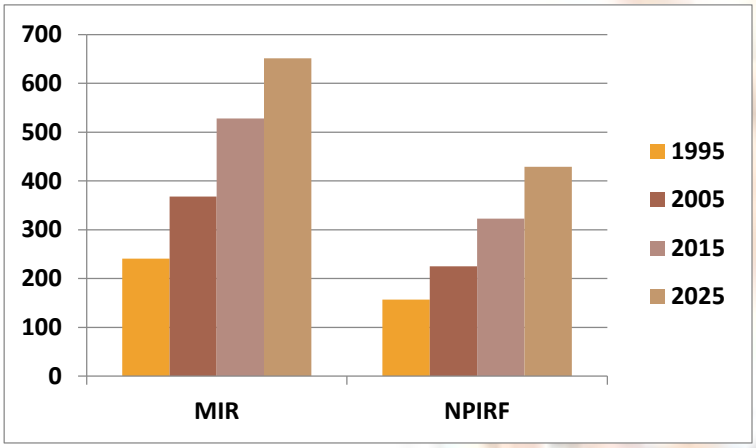

Figure 5. graph respondents' monthly income and number of persons with income in respondents' families.

- Job opportunity

Job opportunity has been declared as driver of urban sprawl in Bamako District with 85.3% of interviewees as presented in Table 13. The evolution of the number of persons with jobs in respondents' families has been used as indicator of job opportunity factor to assess the improvement of job opportunities. The results about trends of mean and sum of persons with job from 1995 to 2015, in Table 7 and Fig. 6, show that there are important job opportunities in Bamako district based on significant improvement of the means and sums. Job opportunity can be considered as an important driving force of urban sprawl as far as it is the main driver of rural exodus which is an important factor of urban sprawl.

Table 7. Mean and sum of persons with job in respondents 'families.

	1995	2005	2015	2025
Valid	150	150	150	150
Missing	0	0	0	0
Mean	1.06	1.49	2.17	2.91

Sum	159	223	326	437

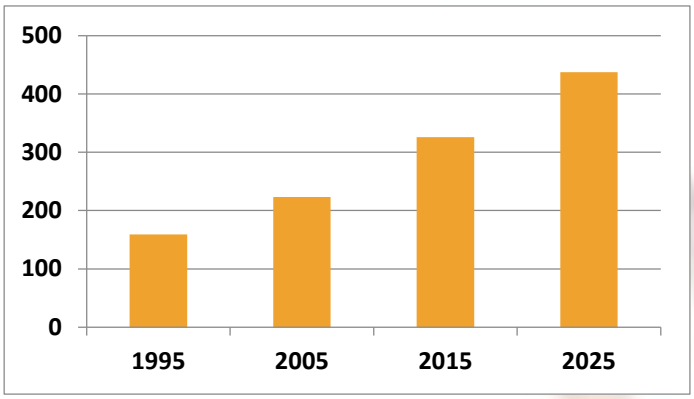

Figure 6. Graph of sum of persons with job in respondents' families from 1995 to 2025.

- Development of transport

Among respondents, 91% judged the development of transports as a cause of urban sprawl. More details are provided in Table 13

To assess more transport development factor, we analyzed indicators like owning of personal mean of transport, and access to public transportation in the area of residence.

About owning of personal mean of transportation, the evolution of frequencies or results from 1995 to 2025 is presented in Table 8. The frequency or percentage of owners of personal mean of transportation increased throughout the study period. It increased from 53% in 1995, 73% in 2005, and 90% in 2015, to 92% in 2025. Thus, it can be concluded that increase in the number of owners of personal means of transportation is a good sign of development of transport over the study period.

Regarding the access to public transports, which is an important factor to appreciate the development level of transportation in urban areas, the results showed an increasing trend of access to public transports in the residence areas of surveyed. It increased from 43% in 1995, 75 in 2005, and 96% in 2015, to 98% in 2025. Thus, an improvement of access to public transports means an important development of transportations and can be considered as one of the causes of urban sprawl in Bamako District. More details can be found below in Table 8 and Fig. 7.

Table 8. Indicators of transport development.

	Frequency												Percent											
Year	**1995**			**2005**			**2015**			**2025**			**1995**			**2005**			**2015**			**2025**		
	Yes	**No**	**Total**	**Yes**	**No**	**Total**	**Yes**	**No**	**Total**	**Yes**	**No**	**Total**	**Yes**	**No**	**Total**	**Yes**	**No**	**total**	**Yes**	**No**	**Total**	**Yes**	**No**	**Total**
OPMT	80	70	150	110	40	150	135	15	150	138	12	150	53.3	46.7	100	73.3	26.7	100	90	10	100	92	8	100
APT	65	85	150	113	37	150	145	5	150	148	2	150	43.3	56.7	100	75.3	24.7	100	96.7	3.3	100	98.7	1.3	100

Source: Personal investigation, 2025

Note: OPTM: Owning of personal Means of Transport; APT: Access to Public Transport

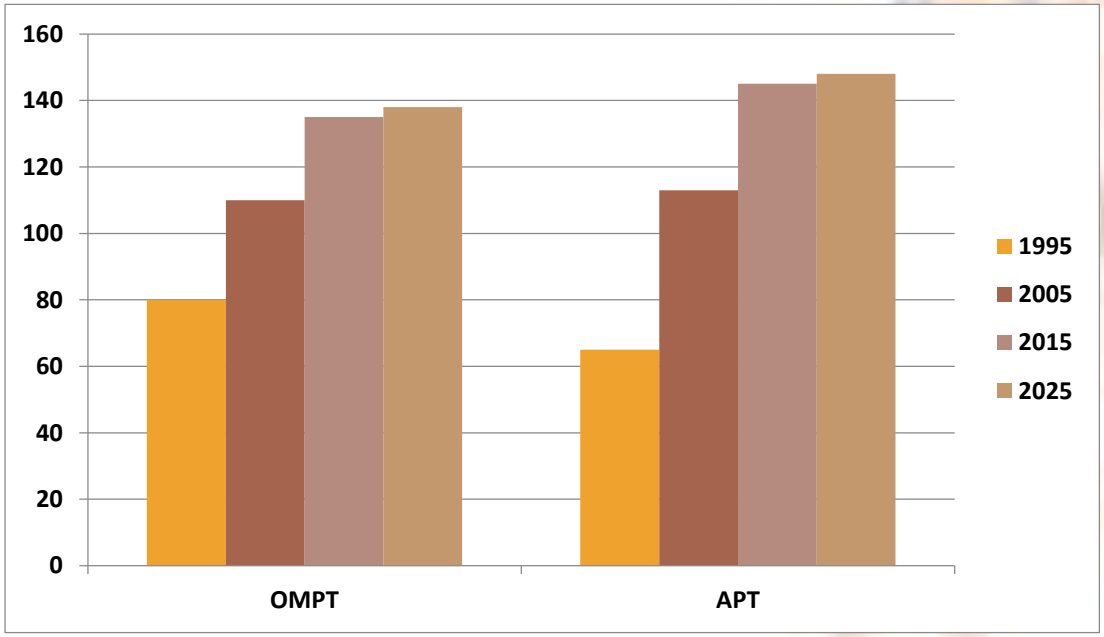

Figure 7. graph of owners of personal means of transport and access to public transport

- Land speculation

According to respondents, land speculation is a factor of urban sprawl in Bamako District. Their agreements were scored at 90.7% as shown in Table 9. In order to analyze deeply, the aspects linked to land speculation, it has been decided to investigate land acquisition methods by respondents.

Methods of lands acquisition or methods of lands buying, which is an appropriate way to assess land speculation has been analyze focusing on three mains ways which are: buying with legal authorities (State or municipalities), real estate agencies, and with a particular. The percentage of those who bought their lands with individuals is dominant with 56%. Those who bought with authorities, and with are only 12.7% of those who bought with real estate agencies. It is important to note that high level of lands acquisition with individuals is one of the key signs of the importance of land speculation, because the channels of individuals escape the control of the authorities, which contributes to soaring purchase and sale prices, hence, creating afflux of people on lands for economic purposes mainly. Bamako is facing to the inefficiency of land markets, which is at the origin of an anarchic urban development, which leads to the investments in buildings and infrastructures far from the urban centers (Herold et 2002).

- Living conditions

Regarding the living conditions as a driver of urban sprawl, the respondents are agreed at 86% that living conditions are one of the drivers of urban sprawl in Bamako district. Good living conditions in urban areas are also a driver of rural exodus, which also is an important factor of urban sprawl. That high level of agreement can allow considering living conditions as a driver of sprawl in Bamako District. Details about results of respondents are provided in Table 9.

While analyzing living conditions as driving forces, the access on certain indispensables needs in urban areas has been analyzed as indicators of living conditions factor. These are: access to electricity, drinking water, basic health facilities, basic educational facilities, market or supermarket, bakeries, leisure centers. More details about them are shown in Table 11 and Fig 8.

For accessibility to electricity, respondents' agreements were at 20% in 1995, 55% in 2005, 92% in 2015, and 95% in 2025. Thus, accessibility to electricity was improved greatly during the study period, and contributes significantly in improving the living conditions in Bamako District.

About access to drinking water, results reveal a significant improvement from 1995 to 2025. In 1995, respondents who have access to electricity were few with 33% against 55.3% in 2005, 91% in 2015, and 93 % in 2025.

Accessibility to basic health facilities has been improved in the study area based on the responses from respondents. Accessibility was 53% in 1995, 78% in 2005, 95% in 2015, and 97% in 2025, which shows significant improvements.

The access to basic educational structures was relatively good because all positives responses are more than 50%. Thus, access was to 72% in 1995, 89% in 2005, 100% in 2015 and 2025. That is to say that access to basic educational structures is not a big problem nowadays in Bamako District, mainly with the proliferation of private schools everywhere in the urban area.

About the access to an important market or supermarket, it was not good in 1995 with a positive value of 31%. Access was acceptable in 2005 with 51%. Moreover, access was good in 2015 and 2025 with a percentage of 82 and 87%, respectively. Instead the access to important market, and leisure centers was also not good in 1995 with a score of 46%, it became good enough in 2005 with 62%. The accessibility was very good in 2015 with of 81%, and in 2025 it was 83%.

To have access to a bakery, many respondents didn't have a good access to a bakery in 1995 and 2005 (26% and 48% respectively). However, the accessibility registered a high improvement in 2015 and 2025 with 87% and 94%, respectively.

After analyzing the evolution of accessibility to different needs and services needed in an urban environment, it has been remarked that the level of accessibility was improving year after year during the study period. This can be inferred that the level of access of the other needs or services was low in 1995, but high in 2025. That is to say that, the improvement of these services means also the improvement of living conditions in Bamako District, given as they are explanative indicators to analyze living conditions. Thus, it can be concluded that living conditions are an important driving forces of urban sprawl in Bamako district from 1995 to 2005.

Table 9. Access to some necessary's services and infrastructures in urban area according to respondents from field survey.

Year	Frequency												Percent											
	1995			2005			2015			2025			1995			2005			2015			2025		
	Yes	No	Total	Yes	No	Total	Yes	No	Total	Yes	No	Total	Yes	No	Total	Yes	No	total	Yes	no	Total	Yes	No	Total
AE	30	120	150	82	68	150	138	12	150	142	8	150	20	80	100	54.7	45.3	100	92	8	100	94.7	5.3	100
ADW	49	101	150	83	67	150	136	14	150	139	11	150	32.7	67.3	100	55.3	44.7	100	90.7	9.3	100	92.7	7.3	100
ABHF	79	71	150	117	33	150	143	7	150	145	5	150	52.7	47.3	100	78	22	100	95.3	4.7	100	96.7	3.3	100
ABES	109	141	150	134	16	150	150	0	150	150	0	150	72.7	27.3	100	89.3	10.7	100	100	0	100	100	0	100
AIM	46	104	150	76	44	150	122	28	150	131	19	150	30.7	69.3	100	50.7	49.3	100	81.4	18.6	100	87.3	12.7	100
ALC	69	81	150	93	57	150	121	29	150	125	25	150	46	54	100	62	38	100	80.7	19.3	100	83.3	16.7	100
AB	39	101	150	72	78	150	130	20	150	141	9	150	26	74	100	48	52	100	86.7	13.3	100	94	6	100

Source: Personal investigation, 2025

Note: AE: Access to Electricity; ADW: Access to Drinking Water; ABHF: Access to Basic Health Facilities; ABES: Access to Basic Educational Structures; AIM: Access to Import Market; ALC: Access to Leisure Center; AB: Access to Bakery

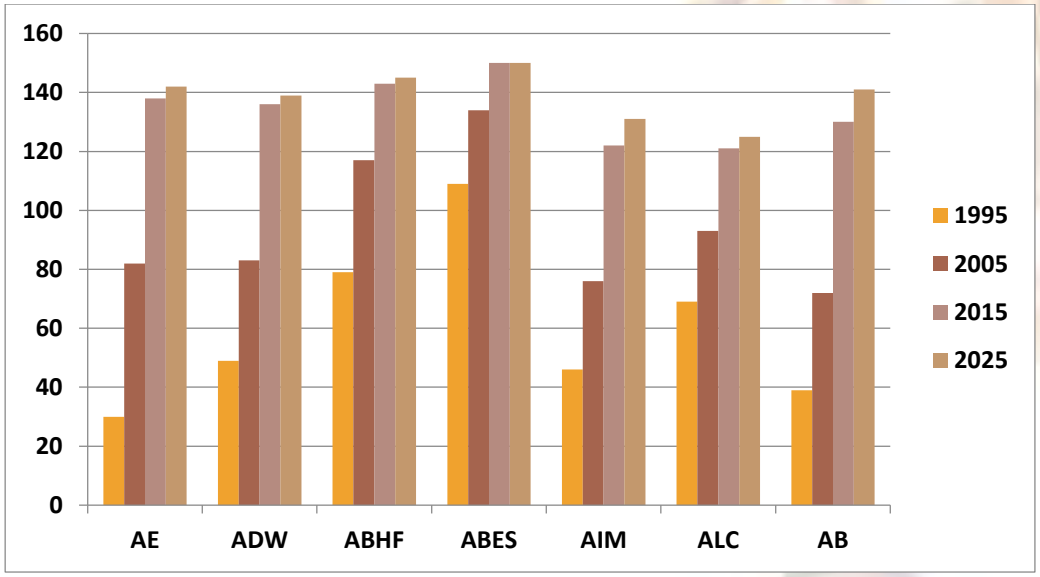

Figure 8. graph of indicators of living conditions.

- Lack of rational planning policy

About planning policies, Respondents replied mainly confirming a real lack of rational planning policy. About 72% of them think that the urban planning policy is not adequate to contain the challenges faced by Bamako District due to the high rate of sprawl nowadays. More details are provided in Table 11 below. The construction of Bamako obeys a process of uncoordinated and often unauthorized subdivisions, which leads to urban fragmentation. In fact, subdivisions are not subject of coordinated planning at the scale of the urban area, which makes its implementation incompatible with larger programs of development of serviced lands with access to public services. As a result, there is no control over how the city grows, and infrastructure and services are often very limited, or non-existent (Herold et al, 2002).

- Desire to own house

Concerning the desire to own house in Bamako, almost all respondents want to own house (based on their replies scored to 99% in Table 11 below). This high desire of respondents to own house in Bamako can be justified by following factors: 1) challenge in urban area is related to access to housing, 2) the high price of renting housing and 3) the incomes generated from renting housing. Also, the importance of evolution of the means and sums of the number of houses owned by respondents throughout the study period is a significant indicator of the desire to own house in Bamako district. For more details see Table 10.

Table 10. Mean and sum number of houses owned by respondents from 1995 to 2025.

	1995	**2005**	**2015**	**2025**
Valid	150	150	150	150
Missing	0	0	0	0
Mean	0.35	0.57	0.93	1.42
Sum	52	85	140	213

- Housing policy

Regarding the housing policy as driver of urban sprawl, respondents (82%) found that housing policy has an implication in the process of sprawl in Bamako District. So, with this high agreement, one can conclude that housing policy is an important driver of urban sprawl. Details are included in Table 13 and Fig. 9:

Table 11. appreciation of the driving forces of urban sprawl according to respondents of field survey.

	Frequency										Percent									
	DG	**RE**	**EG**	**JO**	**TD**	**LS**	**LC**	**LRPP**	**DOH**	**HP**	**DG**	**RE**	**EG**	**JO**	**TD**	**LS**	**LC**	**LRPP**	**DOH**	**HP**
Yes	149	123	132	128	136	136	129	148	142	123	99.3	82	88	85.3	90.7	90.7	86	72	98.7	82
No	1	27	18	22	14	14	21	42	2	27	0.7	18	12	14.7	9.3	9.3	14	28	1.3	18
Total	150	150	150	150	150	150	150	150	150	150	100	100	100	100	100	100	100	100	100	100

Source: Personal investigation, 2025

Note: DG: Demographic Growth; RE: Rural Exodus; EG: Economic Growth; JO: Job Opportunity; TD: Transport of Development; LS: Land Speculation; LC: Living Conditions; LRP: Lack of Rational Planning Policy; DOH: Desire to Own House; HP: Housing policy.

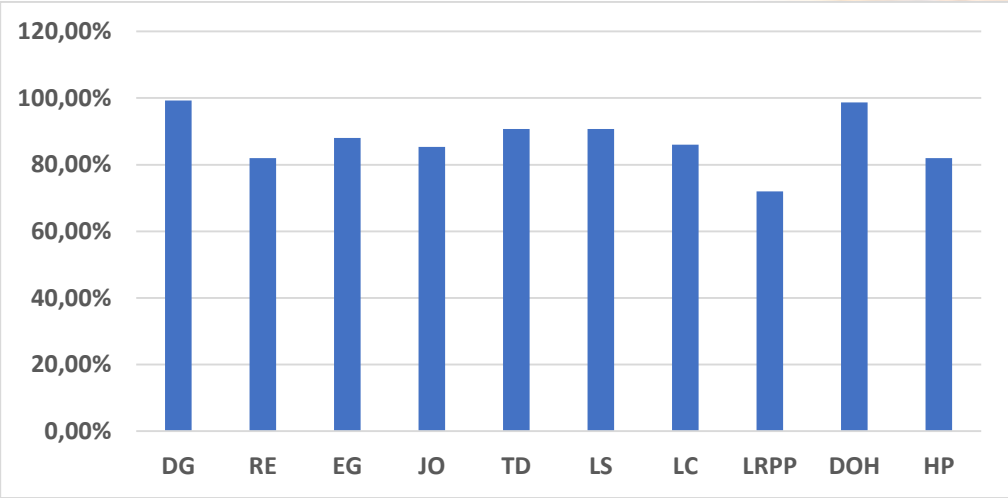

Figure 9. Graph of percentage of respondents' agreement with driving forces

2.2.Factor analysis assessing socio-economic driving forces

- Principal component analysis
  - *Population growth*

In order to assess the reliability of population growth on urban sprawl in Bamako District, PCA was focused on the evolution of the number of persons living in the respondents 'family from 1995 to 2015 as indicator of population growth factor. The results of correlation are presented in Table 13 and Table 16 for the other indices at the end this section.

Table 13. Results of correlation between people living in respondents' family variables.

Correlation matrix

		Person living family in 1995	**Person living family in 2005**	**Person living family in 2015**	**Person living family in 2025**
Correlation	Person living family in 1990	1.000	.934	.854	.774
	Person living family in 2000	.934	1.000	.944	.872
	Person living family in 2010	.854	.944	1.000	.944
	Person living family in 2018	.774	.872	.944	1.000
Sig. (1-tailed)	Person living family in 1990		.000	.000	.000
	Person living family 2000	.000		.000	.000
	Person living family in 2010	.000	.000		.000
	Person living family 2018	.000	.000	.000	

Correlation matrix in Table 13 shows strong correlation between the four indicators of population growth. To be considered as significant correlation value, the value needs to be at least 0.5 or 5%, and value close to 1 is very significant. All correlations of our study are >0.5 and close to 1. The lowest value was found for the data (0.774) between 1995 and 2025, and the highest value existed (0.944) between 2015 and 2025. The correlation between 1995 and 2015 is very strong with a coefficient of 0.934. That situation might be explained by the fact that data of the variables are increasing continuously according to years, so close years have logically close data and correlation have to be strong between them. It might also explain the pertinence of the importance of population growth over the study period.

The value of KMO which measure the sampling adequacy and the index of Bartlett's test which the degree of signification of the analysis are all significant as indicated in Table 16. KMO value need to be superior or equal to 0.5 and Bartlett's test index has to be close to 0 (zero). Herein, KMO value is at 0.767 which significant, and Bartlett's test index is 0.00 which is very significant.

The communalities' extraction values which express the quality of the representation of each component in factor analysis is excellent with all values >0.96 or 96%. Extraction values of components need to be equal or >0.5 to be acceptable and close to 1 or 100% to be more significant or excellent.

The total variance test revealed the distribution of components information between dimensions or matrix used for the analysis (97.97% of information used are represented on matrix 1 and 2). This amount of information is satisfactory to be accepted as significant result. But, 91.59% of total information is represented only on the matrix 1, thus as the most important amount of the component's information are located on the matrix 1, which is also confirmed by the component matrix given as Table 16.

- Job opportunity

To assess the implication of job opportunity as driving forces, PCA was applied to check the reliability of the evolution of the number of persons with job in the respondents' families.

Results of correlation matrix, in Table 14, show a strong relationship between components, all coefficients are more than 0.5. The sampling adequacy shown by KMO value (0.809) and the degree of signification value given by Bartlett's test (in Table 15) are also significant. The communalities values, in Table 16, also show that information for each component is strongly represented in the analysis. All extraction values are more than 92% except for 2005 (87%). The total variance values, given in Table 16 show that 92.97% of the component information is represented in the matrix 1 and 2 that is a very good value for the reliability of the analysis. The component matrix shows that a significant part of component information is represented on the matrix 1 as show in Table 16.

Table 14. Results of correlation between person with job variables.

Correlation matrix

		P.J.F 1995	P.J.F 2005	P.J.F 2015	P.J.F 2025
Correlation	P.J.F 1990	1.000	.787	.730	.661
	P.J.F 2000	.787	1.000	.829	.777
	P.J.F 2010	.730	.829	1.000	.888
	P.J.F 2018	.661	.777	.888	1.000
Sig. (1-tailed)	P.J.F 1990		.000	.000	.000
	P.J.F 2000	.000		.000	.000
	P.J.F 2010	.000	.000		.000
	P.J.F 2018	.000	.000	.000	

- Economic growth

The number of persons with monthly income in the respondents' family is used to check the role of economic development on urban sprawl in Bamako District.

All values of PCA indicators showed good results for components in the analysis (Table 16). Values of KMO, the degree of Bartlett's test signification, the component communalities, the total variance explained, and the component matrix are in presented in Table 16; all values confirms the reliability of persons with monthly income explaining the role of economic growth.

Table 15. Results of correlation between persons with monthly income variables.

Correlation matrix

	P.M.I.F 1995	P.M.I.F 2005	P.M.I.F 2015	P.M.I.F 2025

Correlation	P.M.I.F 1990	1.000	.790	.729	.676
	P.M.I.F 2000	.790	1.000	.838	.788
	P.M.I.F 2010	.729	.838	1.000	.891
	P.M.I.F 2018	.676	.788	.891	1.000
Sig. (1-tailed)	P.M.I.F 1990		.000	.000	.000
	P.M.I.F 2000	.000		.000	.000
	P.M.I.F 2010	.000	.000		.000
	P.M.I.F 2018	.000	.000	.000	

- Multiples correspondence analysis

The MCA is applied to qualitative data from field survey. In order to appreciate the reliability of results, analysis is focused on Cronbach' Alpha index. Findings of analysis are presented as follow:

- Rural exodus

To check the reliability of rural exodus as driving force of urban sprawl, PCA was applied on data related to the number of people in respondents' families that used to live elsewhere and the reason of their coming in Bamako from 1995 to 2025.

For the number of people from elsewhere, the mean of Cronbach's Alpha value was 0.95 that is an excellent value to accept the reliability of the analysis. To be acceptable the mean of Cronbach' Alpha value need to be at least at 0.7, and the total of Eigenvalue need to be at 5 or 50%. The total of Eigenvalue in this particular case is 5.47 or 54%, and this percentage of information is represented on the Dimension 1 and 2. Thus, all condition is satisfactory enough to consider the analysis acceptable. The findings are presented in Table 16 below.

For the reasons of the migration of people from elsewhere in Bamako, the mean of Cronbach's Alpha value of 0.88 is a good value to accept the reliability of the analysis. The total of Eigenvalue is 4.88 or 48.8%, which is not acceptable because less it is than 5 or 50%. However, Cronbach's Alpha value is very satisfactory. Thus, the analysis can be considered as acceptable and pertinent. The findings are presented in Table 16.

- Living conditions

Access to electricity and drinking water are two combined variables to assess living conditions in Bamako District during the study period. The mean of Cronbach' Alpha value is 0.69 that is not very satisfactory because it needs to be0.7 for a good representation. But the total mean is satisfactory with a score of 5.06 or 50.60% (16 below).

- Development of transport

Means of transport used for travel is used as variable to assess the development of transport in Bamako District during the study period. The mean of Cronbach' Alpha value (0.79) is very satisfactory. But the total mean is not significant with a score of 4.918 or 49.18%, it needs to be at least at 50% to be acceptable. However, the very good score of Cronbach's Alpha lead to

the acceptance of the pertinence of the analysis. Details on PCA results are provided in Table 16.

At the end of the factor analysis, it can be concluded than the variables of some driving forces like population growth, economic growth, job opportunity and rural exodus, satisfy all to conditions of retained factor analysis indexes greatly. Thus, these drivers are retained as mains driving forces, and those are not satisfying to all conditions are considered as significant driving forces.

Table 16. Results principal component analysis and multiple correspondence analysis.

N°	Main driving forces	MCA		PCA			
		Cronbach' Alpha	Total Eigenvalue	KMO	Bartlett's test Sig	Communalities extraction	Total variance explained
1	Demographic growth			0.76	0.000	1990: 0.98 2000: 0.97 2010: 0.97 2018: 0.98	97.97%
2	Economic growth			0.81	0.000	1990: 0.96 2000: 0.87 2010: 0.93 2018: 0.94	93.14%
3	Job opportunity			0.80	0.000	1900: 0.96 2000: 0.87 2010: 0.93 2018: 0.94	92.97
4	Rural exodus	0.95	0.54				
5	Living conditions	0.91	4.06				
6	Development of transport	0.79	4.91				

Determination of significant driving forces and main driving forces

- Significant driving forces

As predefined, all agreement values comprised between 70 and 89% are considered here as significant driving forces, for agreement values from respondents of occurred survey.

Thus, based on these scales, the following factors are retained as significant driving forces and are presented with their agreement values as follow: economic growth (88%), living conditions

(86%), job opportunities (85.3%), rural exodus (82%), housing policy (81.3%), and lack of rational planning policy (72%).

- Main driving forces of urban sprawl

All respondent's agreement values comprised between 90% and 100% are considered as main driving forces, and socio-economic factors satisfying to all criteria of PCA and MCA indexes are also retained as main driving forces.

The retained main driving forces based on quantitative analysis are presented with agreement values as follow: demographic growth (99.3%), desire to own house (98.7%), land speculation (90.7%), and development of transports (90.7).

The retained main driving forces based on factor analysis are presented as follow: economic growth, demographic growth, job opportunities, and rural exodus.

. As mentioned previously, from results of survey, economic growth, rural exodus, and job opportunities are located among significant driving forces. Thus, facing to this reality, it has been decided to consider them as main driving forces in so far as there are already significant drivers with very high scores.

The quantitative analysis of urban sprawl driving forces focused on field survey-based approach using questionnaire is a good alternative, which could deal with the lack of statistical data from census, even if the method could have influences on the degree of evidence. However, applying a complementary method, like factor analysis, on the initial results from field survey can improve or support the reliability of the results evidence. In this study, questions in questionnaire for field survey were formulated after a depth review of literature as in Kleemann (Shahfahad, 2020); and factor analysis was applied to check the consistence of the initial results from field survey. The review of literature helped to get precise idea about studied question, and then elaborate suitable questionnaire achieving the purpose of the study properly. Field survey approach in this study allowed the identification of socio-economic driving forces, which are categorized into main driving forces and significant driving forces, as it was almost the same for Kleemann (McGarigal, 2009), whom categorized the drivers into major and minor driving forces. The advantage of the factor analysis is that it confirmed some driving forces which are not confirmed by the simple analysis of initial results of field survey by checking the consistence between indicators of each driving forces. These indicators were sub-questions linked to driving forces. This study also revealed population growth, rural exodus, Job opportunities, economic growth, the desire to own house, transport development as important factors, which is revealed by other studies as well (Dembele, 2017; McGarigal et al., 2009; Sertel et al., 2018). It should be noted again that the quantitative approach assessing driving forces in this study was adopted because of the lack and unavailability of desired socioeconomic data covering the entire study period. However, the present findings are not affected by this lack of data; these are much acceptable and useful to meet the purpose of the study.

However, the field survey approach analysis can only detect socio-economic driving forces of urban sprawl. It is weak in detecting the natural or geophysical driving forces. The field survey-based approach in our study allowed to identify and to categorize the socio-economic driving forces of urban sprawl. Nevertheless, this approach based only on respondents' appreciations can be affected by some subjectivity due to the respondents' mind whether he/she is an expert or not. Furthermore, there is no study that focuses the field survey detecting socio-economics driving of urban sprawl in West African research context. More often, "household surveys" or

"farmer interviews" are conducted to identify "drivers of LULC" in the Sudanian Savannah Zone (Soumare, 2018; Shahfahad, 2020; Herold et al, 2002). Also, none of the study has used factor analysis, like the case in our study, to check the consistence of socio-economic driving forces based on initial results of field survey. The advantage of this method is that it is applicable to quantitative and qualitative data from field survey.

Nonetheless, the only survey-based approach is not very satisfactory in detecting socio-economic driving forces of urban sprawl. Complementary, quantitative analysis using geospatial data from remote sensing and socio-economic statistical data from census is needed to perform a deeper analysis of socio-economic driving forces by some authors (Dewan and Yamaguchi, 2009). Considering the need to explore more about all driving forces of urban sprawl in Bamako District, we suggest future studies focusing on all natural and socio-economic drivers based on remote sensing and census data by applying a more solid scientific model.

3. Discussion

Based on the results of our study, the socio-economic driving forces behind urban sprawl have been identified and categorized between significant and main driving factors. An analysis method applying factor analysis to the results of field surveys to verify their degree of consistency has been proposed. Field survey and factor analysis provide an alternative to the lack of census data when studying the socio-economic drivers of urban sprawl. Based on the results of field survey, the "desire to own house" was identified as a new important factor of urban sprawl in Bamako district in addition to population growth, economic development, the rural exodus, etc.

However, despite the peculiarities of our results and investigation methods, our results agree more with many authors who have used socioeconomic data from census. Thus, Sangare (2017) found rapid growth of population as main factor, land speculation, housing issues, and so on as factor of urban sprawl. World Bank (2015) and UN-Habitat (2012) also agrees with our results by revealing that population growth, economic opportunities, rural–urban migrations are the most important drivers of urban growth in Mali. As the other authors, (Kamusoko, 2017) revealed that built-up expansion in Bamako Metropolitan Area were driven by a number of socioeconomic, political, and natural driving factors.

Based on the results of most of the mentioned authors, it can be conclude that our results agree with many preview studies even if the used are different. Thus, this proves sufficiently the reliability of our results in terms of scientific reference.

Conclusions

At the end of this investigation about socio-economic urban sprawl driving forces in Bamako district from 1995 to 2025, using quantitative analysis approach to confirm or infirm the

supposed drivers; it a can be concluded that numerous drivers of urban sprawl are occurring and contributing to urban sprawl in Bamako district, but with different degrees of implications. All of the supposed driving forces are confirmed by the results of the quantitative investigation using field survey. Based on the degree of implication of each driver and taking an account of the scores of the respondents advises and factor analysis, the found driving forces are categorized into significant driving forces and main driving forces. The significant driving forces are drawn up as follow: living conditions, housing policy, and lack of rational planning policy. The main driving forces are also drawn up as follow: demographic growth, desire to own house, land speculation, development of transport, job opportunity, rural exodus, and economic growth.

The study shows that there are various socio-economic driving forces supporting urban sprawl in Bamako district with different degree of implications. Moreover, it shows the capability of field survey approach to monitor urban sprawl socio-economic driving forces when used efficiently. Hence, field survey method can act as an alternative/solution to deal with the lack of census data when assessing socio-economic driving forces.

The main contribution of this paper is that it reveals a possible way to use quantitative analysis approach and factor analysis based on field survey method to analyze long-term urban sprawl socio-economic driving forces as an alternative to lacking socio-economic census data.

The main innovations point of this research was the use of factor analysis to help the quantitative analysis of field survey data.

Finally, as recommendations in order to deal with urban sprawl and its drivers' side effects in Bamako, this study suggest the development of new attractive places such as creating some important secondary cities of economic and development zones. The economic factors influence the other factors of urban sprawl strongly e.g., rural exodus which also support urban demographic growth significantly. The main factor of urbanization and urban sprawl in developing countries like Mali and sub-Saharan countries is economic. Thus, these new areas could attract many rural populations and even those from Bamako in search of better economic and social living conditions.

References

Abdulhadi, A. A., 2014, *Analysis and modelling of urban sprawl process and its spatiotemporal patterns in Tripoli metropolitan area, Libya.* PhD thesis, Universiti Putra Malaysia.

Abebe G A. *Quantifying urban growth and pattern in developing countries using remote sensing and spatial metrics: A case study of Kampala, Ouganda,* Master thesis, University of Twente, Netherlands, 2013.

Akuffo F.A., 2014, *Evaluating the effectiveness of urban planning and administration in taming urban sprawl: a case of Kumasi-Ghana,* PhD Thesis, University of Alabama

Bhatta B. *Analysis of Urban Growth and Sprawl from Remote Sensing Data,* Springer-Verlag, Berlin. 2010

Cushman S A; McGarigal K; McKelvey K S; Vojta C D; and Regan C N. *Landscape analysis of wildlife habitat. Chapter 6 in MM Rowland and CD Vojta (tech. eds.), A technical guide for monitoring wildlife habitat, Gen. Tech. Rep. WO-89.* Washington, DC: U.S. Department of Agriculture, Forest Service, 2013, 400 p.

Dembélé, S., 2017, *Dynamique Socio-spatiale de la ville de Bamako et Environs (Socio-spatial dynamic of Bamako city and Environs),* Thèse de doctorat Université de Caen, Normandie, 357 P.

Dewan A M and Yamaguchi Y. *'Using remote sensing and GIS to detect and monitor land use and land cover change in Dhaka Metropolitan of Bangladesh during 1960-2005'.* Environmental Monitoring and Assessment 2009, 150: 237-249. http://dx.doi.org/10.1007/s10661-008-0226-5

Donnay J P*; Barnsley M; and Longley P; (Eds.), 2001. Remote Sensing and Urban Analysis, London: European Science Foundation*

Feng Y J and Liu Y., 2015, *'Fractal dimension as an indicator for quantifying the effects of changing spatial scales on landscape metrics,'* Ecological Indicators 2015, 53, 18–27.

Fichera C R; Modica G and Pollino M. *'Land Cover classification and change-detection analysis using multi-temporal remote sensed imagery and landscape metrics',* European Journal of Remote Sensing 2012, 45:1, 1-18, DOI: 10.5721/EuJRS20124501

Fichera C R; Modica G; and Pollino M. *'GIS and Remote Sensing to Study Urban-Rural Transformation During a Fifty-Year Period',* Computational Science and Its Applications-ICCSA, Springer 2011, pp. 237–252. doi: 10.1007/978-3-642-21928-3_17.

Forman R T and Godron M. *Landscape Ecology*, John Wiley & Sons, New York 1986, 619 pp

Herold M; Scepan J; and Clarke K C. *'The use of remote sensing and landscape metrics to describe structures and changes in urban land uses;'* Environment and Planning A 2002, volume 34, pages 1443-1458

Jia Y; Tang L; Xu M; and Yang X. *'Landscape pattern indices for evaluating urban spatial morphology – A case study of Chinese cities',* Ecological Indicators 2019, 99 (2019) 27–37

Jo O., and Fo A., 2018, *Geospatial analysis of land cover change and urban sprawl trend in Akure region, Nigeria.* Art Human Open Acc J.;2(1):13–19. DOI: 10.15406/ahoaj.2018.02.00028

Kamusoko C., 2017, *Bamako Metropolitan Area*. In Y. Murayama et al. (eds.), Urban Development in Asia and Africa, The Urban Book Series, DOI 10.1007/978-981-10-3241-7_14

Kaza, N., 2013, *'The changing urban landscape of the continental United States',* Landscape and Urban Planning 2013, 110, 74–86

Liu L. *Analysis of Urbanization in China by Remotely-sensed Data*, PhD thesis, University of Hong Kong, 2014

Manirakiza V., 2011*, Processus d'urbanisation de la ville de Kigali, Rwanda: relation entre la dynamique spatial et démographique ; (Urbanization process of the city of Kigali, Rwanda: relationship between spatial and demographic dynamics) de communication pour la chaire Quetelet 2011 « Urbanisation, migrations internes et comportements démographiques »*

McGarigal K; Tagil S; and Cushman S A. *'Surface metrics: An alternative to patch metrics for the quantification of landscape structure',* Landscape Ecology 2009, 24:433–450.

Muchelo R.O., 2018, *Urban expansion and loss of prime agricultural land in Sub-Saharan Africa: a challenge to soil conservation and food security,* Doctoral thesis, University of Sydney.

Mulu K., 2018, *Evaluation of urban landscape dynamics and its impact on agricultural land: the case of Gondar town, Ethiopia.* Master thesis, Addis Ababa University, Addis Ababa.

Murgante B and Danese M. *'Urban versus Rural: the decrease of agricultural areas and the development of urban zones analyzed with spatial statistics',* International Journal of Agricultural and Environmental Information Systems 2011, 2: 16-28. http:// dx.doi.org/10.4018/jaeis.2011070102

Peng Y; Mi K; Qing F T; and Xue D Y. *'Identification of the main factors determining landscape metrics in semi-arid agro-pastoral ecotone',* Journal of Arid Environments 2016, 124, 249–256.

Sandborn A., 2015, *Using High Spatial Resolution Imagery to Assess the Relationship between Spatial Features and Census Data: A Case Study of Accra, Ghana.* Master thesis, George Washington University, Columbia

Sangare, Y., 2017*, Evolution démographique et extension spatiale d'une ville moyenne, Koulikoro au Mali (demographic evolution and spatial extension of an average city, Koulikoro in Mali),* thèse de doctorat, ISFRA, Bamako, 2014 P.

Sertel E; Topaloglu R H; Sali B; Algan I Y; and Aksu G A. *'Comparison of Landscape Metrics for Three Different Level Land Cover/Land Use Maps',* ISPRS International Journal of Geo-Information, 2018, 7, 408; doi:10.3390/ijgi7100408

Shahfahad; Mourya M; Kumari B; Tayyab M; Paarcha A; Asif and Rahma A. *Indices based assessment of built-up density and urban expansion of fast-growing Surat city using multi-temporal Landsat data sets,* GeoJournal 2020, ISSN 0343-2521, https://doi.org/10.1007/s10708-020-10148-w.

Soumare, A.S., 2018, *Politiques urbaines et Changements spatio-temporels à Bamako : évolution des paysages urbains de 1992 à 2012 (Urban policies and spatio-temporal changes in Bamako: evolution of urban landscapes from 1992 to 2012),* thèse de doctorat, ISFRA, Bamako, 351 P.

United Nations Human Settlements Programme (UN-HABITAT) (2012) *The State of world's cities 2012/2013*. Nairobi, Kenya

World Bank (2015) Mali: *Geography of poverty in Mali*. PREM 4 Africa Region