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Seria GEOGRAFIE

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ASSESSMENT OF RESIDENTS' ACCESSIBILITY TO INFRASTRUCTURE IN ILORIN METROPOLIS

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Abstract: The existence of an efficient accessible and reliable infrastructure does not only serve as booster to the development of trade and interchange of a modern urban economics but it also inspires life through healthy living. This study examines the residents' access to piped water and sanitation facilities (Roro-bins) in Ilorin metropolis. Both primary and secondary sources of data including questionnaire administration, documents in government agencies and journal articles were used for the study. A systematic-random sampling technique was adopted in the selection of 408 respondents from the selected households. Descriptive statistics such as tables, cross tabulations, charts and mean were used to analyze the data. The findings of the study revealed poor access of the residents to sanitation facilities and the residents were also poorly served with piped water; these two life enhancing facilities were not evenly distributed in the study area; many of the residents are stressed before accessing the facilities as majority spend above 30 minutes and walk a long distance before getting to the nearest piped water facility. The study suggests a need for social change from poor waste disposal attitude and the provision of more boreholes within the reach of the public to serve as alternative to piped water.

Key words: assessment, residents, infrastructure, Ilorin metropolis, Nigeria

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INTRODUCTION

The word population as a whole has been experiencing an unprecedented urban growth. The rate of increase in urban population has exceeded the overall population for at least two centuries (United Nations, 2014). The level of urban growth however varies among regions of the

* Corresponding Author

world. In 1976, 38% of the world's population lives in the urban areas. Today, 55% of the world's people are in the urban areas. This proportion is expected to increase to 68 percent by 2050 (UN DESA, 2018). In Nigeria, unlike most African countries, it can be said that the nation is undergoing a period of rapid urbanization which is preceded by industrialization and rapid economic development. The growing urban population is mainly absorbed in the low paid informal sector while others are unemployed. It was noted that the level of urban growth in Nigeria rose from 4.8% in 1921 to an estimated 31.77% in 1985 (Ogu, 2009). This size of the urban population and its attendant expansion in the next few decades has huge implications for provision and access to infrastructure and development (Akinyosoye, 2011; Ogu, 2009). For instance more than 700 million people still lack ready access to improved sources of drinking water; nearly half are in sub-Saharan Africa. More than one third of the global population (some 2.5 billion people) do not use an improved sanitation facility, and of these 1 billion people still practice open defecation (World Health Organization, 2020).

In Nigeria, the growths of urban areas however are replete with several cases of inadequate infrastructure. These include irregular supply of electricity, shortage of piped water, fuel scarcity, unreliable health care services, unstable educational institutions, bad roads, malfunctioning ports and erratic telecommunications (Akinwale, 2010). The poor access to selected social indicators of improve sanitation, improve water source, health care services, transportation services among others are magnified by the inadequacies experienced in the provision of infrastructure needed in the urban Nigeria (World Bank, 2003). The replete state of sanitation facilities in Ilorin have led to sites of heaps of waste in the city and this has since became unbearable especially in the neighborhood of commercial areas such as open markets, and motor garages (Ajibade, 2008).

Dahlgren (2008) observed that accessibility to facilities is dependent on several parameters. Accessibility is defined as the cost to access a specific set of public infrastructures including piped water and sanitation facilities among others. The accessibility is measured as travel distance along a road, in time or space (Dahlgren, 2008).

One of the challenges facing Nigeria in the wake of urban growth in the past few decades is the planning and management of physical infrastructures and the urban environment. The facts of this matter are that the location of these infrastructures are rarely planned to fix the needs of the people. This essentially woke the problem of accessibility, inadequacy of infrastructure services, inequality, deprivation and the deteriorating urban environment (Ogu, 2009). It cannot be overemphasized that the quality and coverage of infrastructure services such as electricity, water, sanitation, telecommunications and transport have a major impact on living standards and economic growth **(**Penelope and Warrick, 2001). Therefore, given the importance of infrastructure services at facilitating the efficiency of production and the means through which the process of development and growth can be undertaken as noted by Rutto (1997), it becomes necessary to attempt the study of the resident's access to infrastructural facilities in Ilorin metropolis.

The Study Area

Ilorin, the capital of Kwara State is located on latitude $8^0$30'N and longitude $4^0$35'E (figure 1). It occupies an area of about 100 km^2 and is located about 300 km from Lagos and 500 km from Abuja (Oyebanji, 1993 cited in Banji, 2015). The metropolis covers about 3 Local Government Areas (LGAs) out of the sixteen LGAs that make up kwara State and it is bounded to the North by Moro LG; Asa LG to the East; Ifelodun LG to the West; and Oyun LG to the South (figure 1). Ilorin developed as an administrative centre. However in the recent times, both economic and social activities have greatly influenced its growth. The major occupations of the people are farming, pottery making and weaving. Moreover, a greater percentage of the people are involved in trading, while others are self-employed in different fields such as mechanic, carpentry, diary vendors and transporters among others. In terms of amenities, Ilorin metropolis has various financial institution and credit houses, educational institutions and health services at all levels. There are television stations and radio houses. It is connected by road with Lagos, Ibadan, and Abuja-Lokoja, Kaiama and Kaduna. There is also a railway linking the city to the core north and southern part of Nigeria. Ilorin also has an international airport.

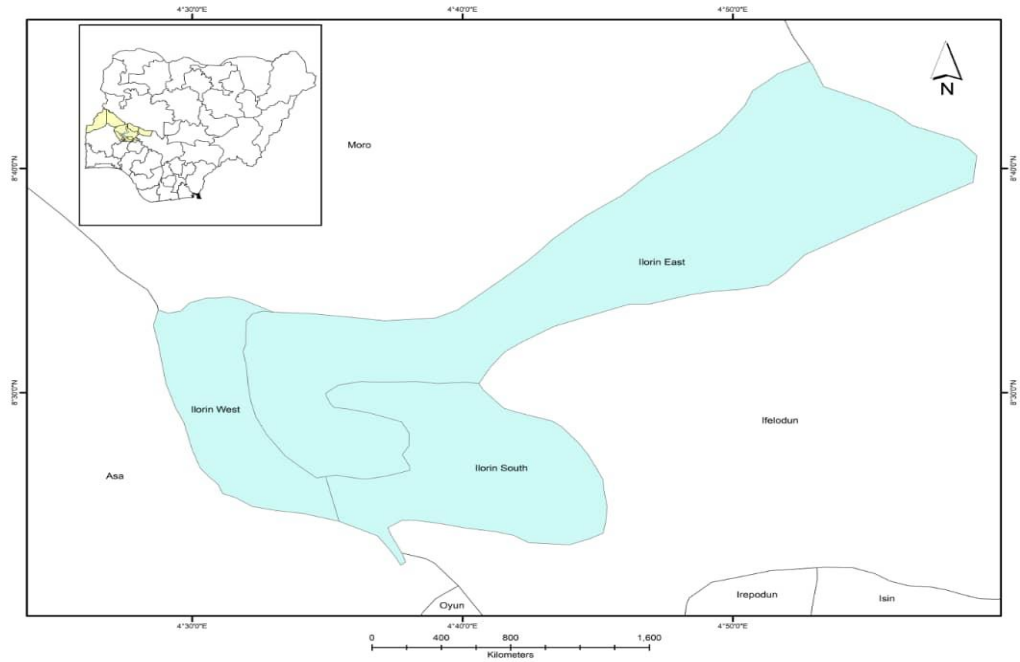

Figure 1. Ilorin Metropolis Showing the Areas Covered
(Source: Modified from Kwara State Administrative Map)

RESEARCH METHODS

This study employed both primary and secondary sources of data. The primary data sources include reconnaissance survey, field observation and the administration of questionnaire while data from Kwara State Ministry of Lands, Kwara Waste Management Company (KWMC), Kwara State Water Corporation and National Population Commission were the relevant secondary data collection sources. The sample size was determined using 2014 population projection of Ilorin puts at two million five thousand and nineteen (2,005,019). The Cochran (1963) ($n=Z^2a/2.pq.N+e^2$ $(N-1)+Z^2a/2.p.q$ was employed to arrive at 408 copies of questionnaire. The sample size for each ward is as shown in table 1. The administration of the questionnaire was carried out using systematic random sampling technique. The first household (respondent) is determined randomly and subsequently at an interval of three (3) houses. Descriptive statistics such as tables, cross tabulations, percentages and graphs were used to analyze the socio-economic characteristics of respondents, methods of waste disposal by respondents, access of respondents to water, regularity of water supply and factors influencing the method of waste disposal among others.

Table 1. Population of Wards in Ilorin Metropolis
Source: *National Population Commission 2006; **Adapted from Sanni (2014)

S/N	Wards	Population of Wards*	Total number of household*	2016 household projection**	No. of household sampled**
1.	Adewole	43,084	454	11358	22
2.	Ajikobi	65,568	502	17286	34
3.	Alanamu	65,626	567	17301	34
4.	Are	54,969	462	14492	30
5.	Baboko	29,638	338	7814	16
6.	Badari	42,341	448	11162	22
7.	Balogun Fulani	59,425	451	15666	32

8.	Balogun Gambari	37,661	421	9929	20
9.	Ibagun	33,872	405	8930	18
10.	Magajin Geri	47,614	429	12552	18
11.	Okaka	32758	365	2636	18
12.	Ogidi	25,553	303	6767	14
13.	Oju-ekun	30,307	344	7990	16
14.	Oke-ogun	29,415	336	7755	16
15.	Oloje	17,531	233	4622	10
16.	Sabon Geri. I	23,028	423	6071	12
17.	Sabon Geri II	19,314	361	5092	10
18.	Ubandawaki	66,554	513	17546	36
19.	Zango	36,324	406	9576	20
20.	Zarumi	17,085	304	4504	10
	Total	**777,667**	**8,065**	**205019**	**416**

RESULTS AND DISCUSSION OF FINDINGS

SOCIO-DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

The sex and age characteristics of the respondents revealed that 59.3% are male while 40.7% are female. This ratio could be the result of the patriarchal family system practiced in most African societies in which men are heads of household to whom the questionnaire was directed. This is in line with the result of findings of Fisher (2015) in her study on efficiency of water supply in Ilorin which showed that majority (63.7%) of the respondents were male. Similarly, the age distribution of the respondents shown in table 2 further reveals that majority (76.4%) of the respondents are within the early adulthood age bracket, while less than 30.0% of the respondents fall within the early old age bracket.

Furthermore, 32.4% of the respondents are traders, while 25.0% and 23.0% are artisan and public servants respectively. Only 8.8% of the respondents are full house wives. This implies that most of the respondents are self-employed. Also, 54.4% of the respondents earn between N18,000-N30,000, while 25.5% and 14.7% of the respondents earn between N31,000-N50,000 and NN50,000 and N100,000 respectively (table 2). The majority of respondents earned above the minimum wage of N18,000 which may be linked to the fact that a high percentage of the respondents fall within the active productive age brackets and hence they able to engage in productive economic activities that attract high income.

The family size of the respondents indicates that 57.8% of them had between four to six family member, while 16.2% and 22.0% of the respondents had between one to three and seven to nine family members respectively. This result is expected because it reveals the family type characteristic of most African communities which support polygamy, this is complemented by predominant religion practices in the study area which supports a large family size.

Table 2. Socio-Demographic Characteristics of Respondents
Source: Author's Fieldwork, 2017

Characteristics	**Frequency**	**Percentage**
Sex		
Male	242	59.3
Female	166	40.7
Total	**408**	**100.0**
Age		
18-25	134	32.8

26-45	178	43.6
46-65	92	22.5
65 and above	04	1.0
Total	**408**	**100.0**
Occupation		
House wife	36	8.8
Public Servant	94	23.0
Artisan	102	25.0
Trading	176	43.2
Total	**408**	**100.0**
Income (N)		
<18,000	16	3.9
18,001-30,000	222	54.4
30,001-50,000	104	25.5
50,001-100,000	60	14.7
Above 100,000	06	1.5
Total	**400**	**100.0**
Household Size		
1-3	65	16.2
4-6	237	57.8
7-9	90	22.0
Above 9	16	4.0
Total	**408**	**100.0**

Residents' Access to Water and Factors Influencing Accessibility to Water in Ilorin

The International Monitoring Organization defined access to safe drinking water as the proportion of people using improved drinking water sources. The organization further defined "access" as the availability of at least 20 liters per person per day from an improved" source within one kilometer of the user's dwelling. Access to safe water is measured by the number of people who have a reasonable means of getting an adequate amount of water that is safe for drinking, washing, and essential household activities, expressed as a percentage of the total population. Access to safe water reflects the health of a country's people and the country's capacity to collect, clean, and distribute water to consumers.

Table 3. Accessibility to Water Supply in Ilorin Metropolis

Time Spent on Fetching Water	Frequency	Percentage
Time		
5-10 minutes	10	2.5
11-20 minutes	78	19.1
21-30 minutes	156	38.2
Above 30 minutes	164	40.2
Total	408	100
Distance between Home and Source of Water		
0-1 km	200	49.0
2-4 km	166	40.7
Above 4 km	42	10.3
Total	408	100

Accessibility to water supply is a function of distance cover from individual household to the water point and the time taken. The result in table 3 revealed that 38.2%, 19.1% and 2.5% of the respondents claimed that they spend between (21-30, 11-20 and 5-10) minutes daily to get water for domestic uses. However, majority (40.2%) of the respondents spend above 30 minutes to get water

for daily usage. In addition, 49% of the respondents travel between 0-1 km to fetch while 40.7% of the respondents travel between 2-4 km. This implies that many of the respondents travelled above the minimum standard of 100m travel distance to major source of water supply recommended by the UN General Assembly. This supports Oyebode (1991) findings which revealed that 75% of respondents in Ilorin walked 400-800 meters from their residences to the nearest water points. This finding also complements the work of Taiwo (2014) which shows that 81.7% of the respondents in Ilorin walk between 2 km and 3 km before getting water for daily usage.

The result in figure 2 showed that 21.1%, 14.7% and 3.4% of the respondents sourced their water from well, pipe borne water and water vendor respectively. However, majority (60.8%) of the respondents sourced their water from bore hole. This implies that most of the respondents (75.5%) sourced their water from sources which cannot be easily polluted. This agrees with the Taiwo (2014) research findings which revealed that over 50.0% of the residents in Ilorin metropolis used water from protected sources such as borehole, tap and well.

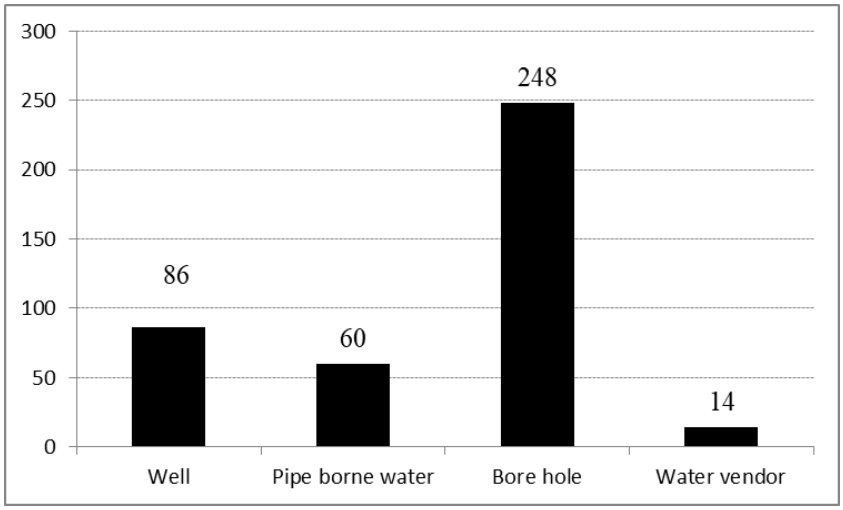

Figure 2. Sources of Domestic Water Supply
Source: Author's Field work, 2017

The respondents (44.1%) agreed that proximity of water source to their places of residences is a major factor influencing accessibility to water supply in Ilorin. This result supports the theory of distance decay which is of the idea that as distance increases, utilization of facility reduces. In addition, 35.3% and 20.6% of the respondents claimed that frequency of availability and reduced cost of sources of domestic water supply influenced their accessibility (table 3). However, majority of the respondents in the study area often disregard long distance to get water for domestic uses. This result is in consonant with figure 2 where majority of the respondents go about to get access to bore hole water that is ubiquitously spread in the study area.

Table 4. Factors Influencing Accessibility of Domestic Water Supply
Source: Author's Field work, 2017

Factors	Frequency	Percentage
Proximity of residence	180	44.1
Frequency of availability	144	35.3
Source is cheap and available	84	20.6
Total	408	100.0

Major Provider and Efficiency of Domestic Water Supply in Ilorin Metropolis

As revealed in figure 3, 13.3% of the respondents attested that individuals are the major providers of their domestic water supply, while 6.4% of the respondents identified the community as the major provider of domestic water supply in the study area. However, 79.9% of the respondents affirmed that Kwara State Water Corporation is the major water supply provider in the study area. The data show that most of the water demand in the study area is provided by the state government through Kwara State Water Corporation. This result complements that of Fisher (2015) which revealed that 56.3% of the respondents sourced water for domestic uses from the Kwara State Water Corporation, while 24.3% of the respondents got their domestic water supply from well. Moreover, government of Kwara State is so helpful to the people in the area of supplying adequate water. This is in line with the efforts of the government to achieve goal target of Sustainable Water Development Goal.

Table 4, 5 shows the efficiency of water supply in the study area. 27.9% of the respondents disagreed with the view that they have access to sufficient water for daily usage, while 9.3% of the respondent strongly disagreed to this view. Evidence to this is the result of the work of Omonona and Adeniran, (2012) which shows that only 34.4% of sampled households in Ilorin metropolis had access to adequate water.

However, 39.2% of the respondents agreed that they have access to sufficient water for daily usage, while 39.7% of the respondents strongly agreed to this view. The high percentage may be linked to the increased efforts of the government in supplying water for domestic uses in the metropolis.

Table 5. Regularity of Water Supply in Ilorin Metropolis
Source: Author's Field work, 2017

Regularity	Frequency	Percentage
Strongly Agree	48	23.5
Agree	80	39.2
Strongly Disagree	19	9.3
Disagree	57	27.9
Total	408	100.0

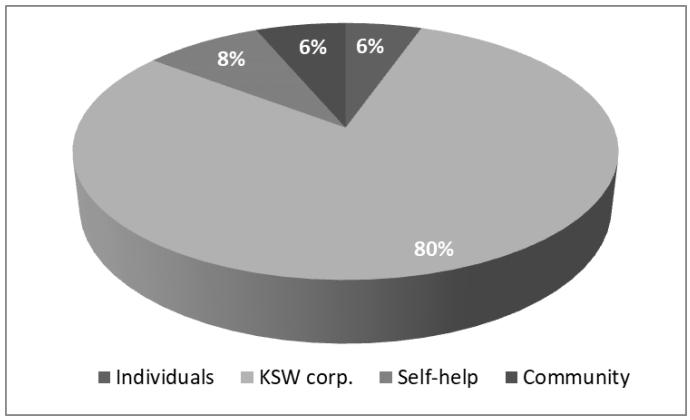

Figure 3. Major Provider of Domestic Water Supply in Ilorin Metropolis
Source: Author's Field work, 2017

Methods of Waste Disposal and Factors Influencing Waste Disposal in Ilorin Metropolis

The result in figure 4 revealed that 61.0% of the respondents claimed that they disposed their waste through waste bins provided by the Kwara State Waste Management Company (KWMC), while 20.0% and 14.0% of the respondents disposed their waste on available open

spaces within their neighbourhoods and into incinerator respectively. In addition, 5.0% of the respondents disposed their waste through private waste collectors.

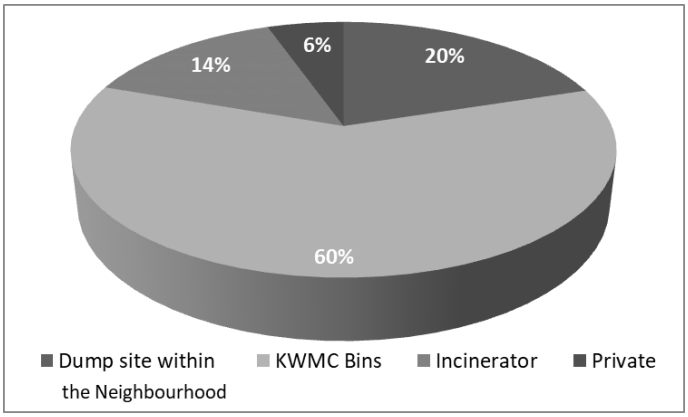

Figure 4. Waste Disposal Methods in Ilorin Metropolis
Source: Author's Fieldwork

Furthermore, the factors that influenced the choice of respondents waste disposal method in table 6 showed that 30.9% of the methods of waste disposal identified in figure 4 above were influenced by the ability of respondents to afford cost of waste disposal, while 13.2% of the respondents' choice of waste disposal methods was due to the frequency of service provided by the waste managers. On the other hand, majority 55.9% of waste disposal methods adopted by the respondents were influenced by the proximity of disposal points to respondents' places of residence. It can be observed that distance to these facilities affected waste disposal methods used by the respondents. This finding support the findings of Taiwo (2014) and Fisher (2015) which revealed distance as the major factors affecting major source of domestic water in the study area.

Table 6. Factor Influencing Waste Disposal Method in Ilorin Metropolis
Source: Author's Fieldwork, 2017

Factors	**Frequency**	**Percentage**
Proximity of residence	228	55.9
Affordability of service	126	30.9
Frequency of service provision	54	13.2
Total	408	100.0

Proximity to Waste Disposal Facilities in Ilorin Metropolis

The result in figure 5 showed that 43.1% of the respondents agreed that the distance between their homes and point of waste disposal is between 3 km and 4 km while 49.0% of the respondents agreed that the distance between their places of residence and point of waste disposal is between 1 km and 2 km. Only 1.5% of the respondents attested that the distance between their homes and point of waste disposal is above 8 km. The implication of this is that since most of the respondents walks a long distance to points of waste disposal, disposing waste may become a tedious task, hence, individuals are likely not dispose their refuse for a long period of time and this may result to environmental pollution and in turn, pose risk to public health.

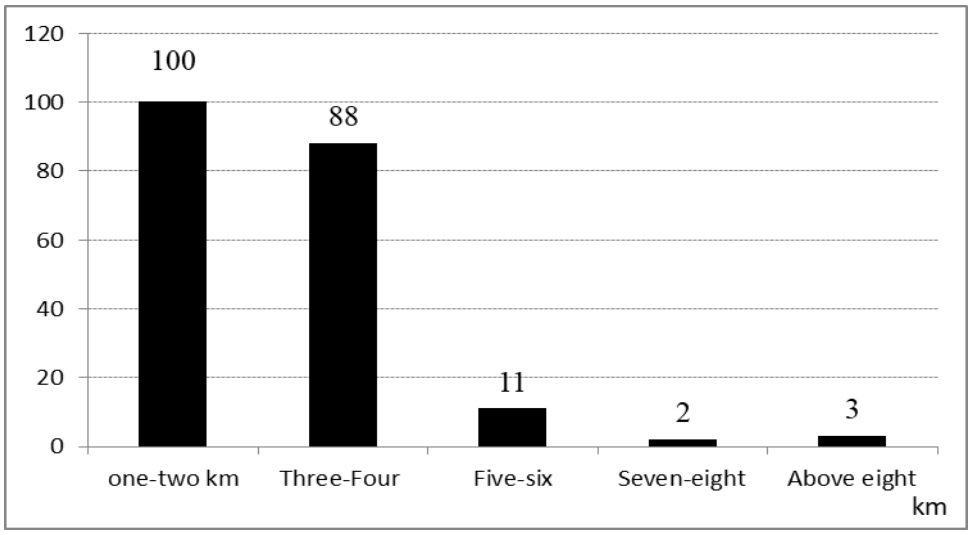

Figure 5. Proximity to Waste Disposal Facilities in Ilorin Metropolis
Source: Author's Fieldwork, 2017

Availability of Waste Disposal Facilities and Frequency of Waste Disposal in Ilorin Metropolis

The findings in table 7 revealed that 26.0% and 21.1% of the respondents disagreed and strongly disagreed respectively that there are enough waste disposal facilities in the study area. The severity of the sanitation challenge facing urban areas in Nigeria can be judged from the fact that hardly one third of the overall population has easy access to sanitation facilities. On the other hand, 43.1% and 9.8% of the respondents claimed that they agreed and strongly agreed that there are enough waste management facilities in the study area. It can be observed from this data In addition, 4.7% of the respondents agreed that wastes generated in the study area are disposed daily, while 38.7% and 27.9% of the respondents agreed that most wastes generated in the study area are disposed weekly and more than a week respectively. This may be attributed to the fact that most of the wastes generated in the study area are collected by KWMC at a specific time and day in a week.

Table 7. Availability of Waste Disposal Facilities and Frequency of Waste Disposal in Ilorin Metropolis
Source: Author's Field work, 2017

Availability	**Frequency**	**Percentage**
Strongly Agree	40	9.8
Agree	176	43.1
Strongly Disagree	86	21.1
Disagree	106	26.0
Total	408	100
Frequency of Waste Disposal		
Daily	60	14.7
Twice per week	76	18.6
Weekly	158	38.7
More than a week	114	27.9
Total	408	100

Efficiency of Access to Waste Disposal Facilities in Ilorin Metropolis

With regards to the efficiency of the services provided by waste management agencies in the study area, majority (30.4%) of the respondents considered the services as good, while 24.5% rated the service as averagely good (table 8). Also, 24.5% of the respondents were of the opinion

that the services are poor and 8.8% of them considered it as worse. This implies that about one-third of the respondents are not satisfied with the services provided by waste management agencies in the study area.

Table 8. Efficiency of Access to Waste Disposal Facilities in Ilorin Metropolis
Source: Author's Field work, 2017

Factors	Frequency	Percentage
Very Good (above 70%)	48	11.8
Good (55-69%)	42	30.4
Average (45-59%)	100	24.5
Poor (40-44%)	100	24.5
Worse (below 39%)	36	8.8
Total	408	100.0

Ways to Improve Access to Waste Disposal Facilities in Ilorin Metropolis

The results of ways to improve waste disposal facilities in the study area revealed that 25.0% of the respondents affirmed that in order to improve the quality of service provided by the waste management agencies in the study area, each community, through Community Developments Associations (CDAs) should be more involved. This may involve laying emphasis on the need for clean environments during household heads meeting at the community level. Also, figure 6 further revealed that 33.8% of the respondents were of the opinion that government should be more involved in waste management while 41.2% of them were of the view that government should be involved in adequate provision and proper distribution of waste disposal facilities in the study area.

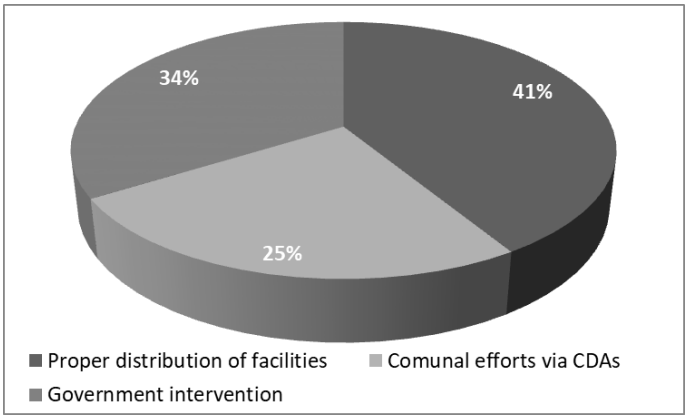

Figure 6. Ways of Improving Access to Waste Disposal Facilities in Ilorin Metropolis
Source: Author's Fieldwork, 2017

CONCLUSION

It is clear that majority of people in Ilorin metropolis depend on Kwara State Government for infrastructural facilities like water supply and waste disposal facilities. The respondents in the study area are stressed before accessing both water supply and waste disposal facilities. This is because, majority of the residents spend 30 minutes or more and walk a long distance before getting to the nearest pipe borne water facility. Furthermore, wastes generated by residents and dumped in government provided disposal facilities are collected once in a week and most government owned waste disposal bins are not easily accessible for many households. The study thus recommends the provisions of more boreholes within the reach of the public and

strengthens the existing water policy by ensuring adequate maintenance of water treatment plants. Also, the poor environmental habits of many Nigerians are embedded in their lifestyles, such as littering the streets with waste and burning of waste within the neigbourhood. Programs should be implemented to reward cash for waste cans and plastic bags supplied by individuals based on the weigh, providing incentive not to litter. This is another example of an indirect enforcement strategy.

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FLOOD HAZARD IN THE CITY OF CHEMORA (ALGERIA)

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Abstract: Floods become major concerns in most gobe regions due to socio-economic and environmental consequences caused by these phenomena in recent decades. Most Algerian cities are exposed to flood risks and suffered from its consequences. The purpose of this paper is the spatialization of flood hazard in the city of Chemora (Algeria) by hydraulic modelling in a GIS environment whose objective is prevention, which requires a set of hydrological and hydraulic informations in order to achieve a comprehensive and effective management.

Key words: Floods, Hydraulic modelling, GIS, Prevention

* * * * * *

INTRODUCTION

Flood risk is one of the most devastating natural hazards that cause loss of lives, damage to properties, resources and environmental degradation in urban areas (Forkou, 2011). In 2011, they were reported to be the third most common disaster, after earthquake and tsunami, with 5202 deaths and adducing millions of people (CRED, 2012; Sami et al., 2016). Floods are the number one natural disaster in the world, causing approximately 20,000 victims per year (Simona and Cedric, 2007). Like the rest of the world, the Mediterranean region has experienced multiple

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floods which are becoming an increasingly formidable threat (Rifai et al., 2014). Algeria has experienced floods that have caused widespread and often irreversible damage.

Often, the food management requires a set of hydrological and hydraulic informations; Firstly, hydrology encompasses all the processes which lead to the determination of flows in a river, associated with their probability of occurrence. There are two approaches in the hydrology: the deterministic approach and the statistical approach.

- The deterministic approach considers all factors that may influence the watershed response and introduces them into a model for flow estimation.

- The statistical approach allows the estimation of flows, of a given probability, from statistical laws that have been adjusted from series of measured flow data (Blin, 2001).

In this context, the flood is a very complex natural phenomenon, whose analysis requires efficient and elaborate tools, for example hydraulic models. The main purpose of hydraulic models is to simulate hypothetical or real floods numerically, which makes it possible to characterize the hazards in space and time (water levels, flow rates, times of submersion, etc.).

Secondly, Hydraulics refers to applications, calculations and treatments which allow water levels to be obtained from flow rates calculated at the scale of watercourse section.

Therefore, hydrology is the discipline which allows getting the flows and their return periods. Hydraulics is the discipline that makes it possible to obtain the water levels and the speeds corresponding to these flows.

In fine, the map of flood risk areas requires a modeling by GIS (Herman, 2009, 2010) and hydraulic simulation software.This modelling aims to quantitatively measure the risk at any appropriate division of the territory.

STUDY AREA

The city of Chemora is located in Eastern Algeria, at 41 km east of the county seat of the wilaya of Batna (Figure 1). It covers an area of 261360 km², between 35° 30' and 35° 45' north and between 6° 25' and 6° 45' east, regrouping a population of 13743 inhabitants in 2008 (Sami et al., 2020).

This city is divided into two parts by the passage of a river in their territory. The city of Chemora has undergone several rainy episodes that have generated significant flooding.

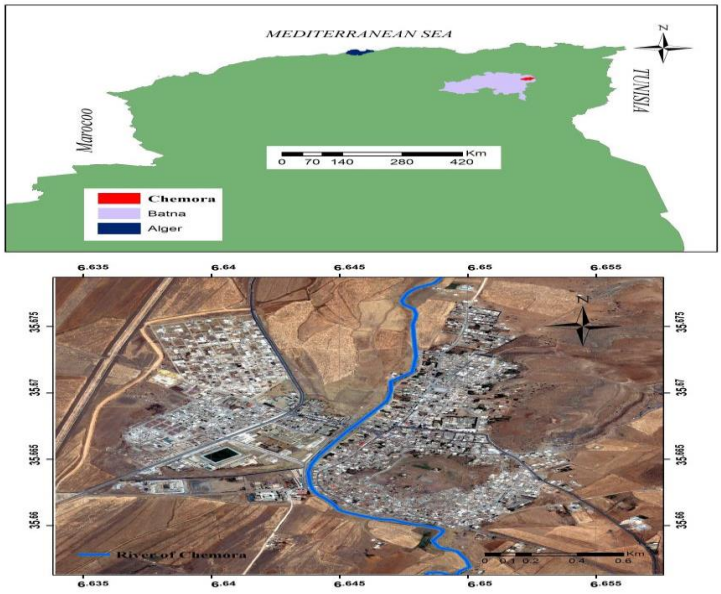

Figure 1. Study area

MATERIALS AND METHODS

Two complementary steps were carried (hydrological modelling and hydraulic modelling) to map the flood hazard in the city of Chemora.

Hydrological modeling

Peak flow estimation requires a frequency analysis of the annual flow series registered in the hydrometric station of Chemora Oued (river). This was achieved by the application of the empirical laws, namely Gumbel's law (the most widely used law in the Mediterranean region). This proceeding allowed estimating the quantiles of the extreme flows for different return periods,

The series of flows recorded at hydrometric station of Oued Chemora covers a period of 37 years 1969 - 2012 (ANRH). The sample is constituted by extracting the maximum daily value for each year.

The methodology of the maximum values for each year appeared to be generally preferred to the methodology of data above a threshold, both by researchers and by developers (Cunnane, 1987).

Table 1. Statistical parameters of hydrometric station data

parameters	Value min (m^3/s)	Value max (m^3/s)	Average value (m^3/s)	Coefficient of asymmetry (CA)	Coefficient of variation (CV)
Series of flows	5	231	122	0.030	0.203

Gumbel's law is a particular case of the GEV law or K=0, this statistical distribution is a frequency model is often used to describe the statistical behaviour of extreme values (Wilcoxon, 1945), because it allows a linear adjustment from a double exponential law according to a method described in Gumbel, 1958 and illustrated in Fallot J. M., (2013).

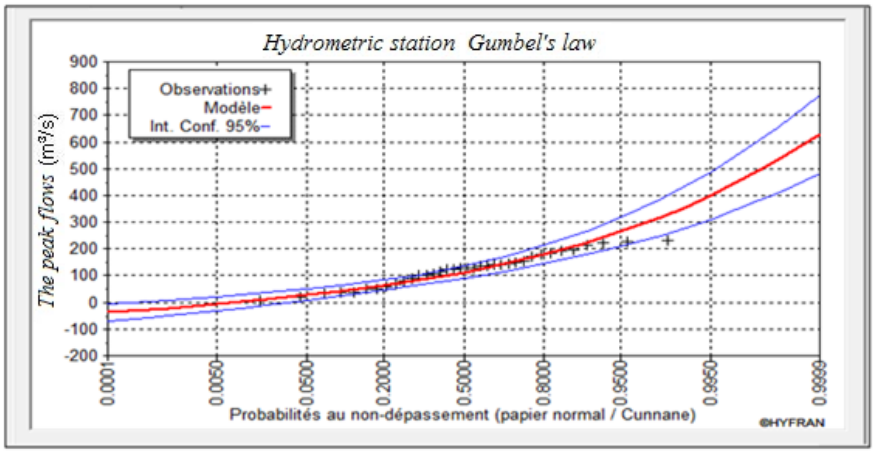

Figure 2. Adjustment of peak flows through Gumbel's law

Hydraulic modeling

The objective of this approach is to map floods for a 100-year return period and delimit areas that may be affected; this approach requires a fine analysis based on modelling in a GIS under (QGIS) with their extension (Q-RAS) and hydraulic modelling software (HEC-RAS).

Indeed, this approach is exploited to analyze flows and water levels in river beds and to identify flood areas, integrating many data entry, hydraulic analysis components, data storage in the form of tables and graphs.

After the creation of TIN (Triangular Irrigular Network) required format for analysis under QGIS from DEM (Degital Elevation Model) of 30 m resolution, the modelling of stream geometry is necessary, namely the central flow and cross sections (figure 3).

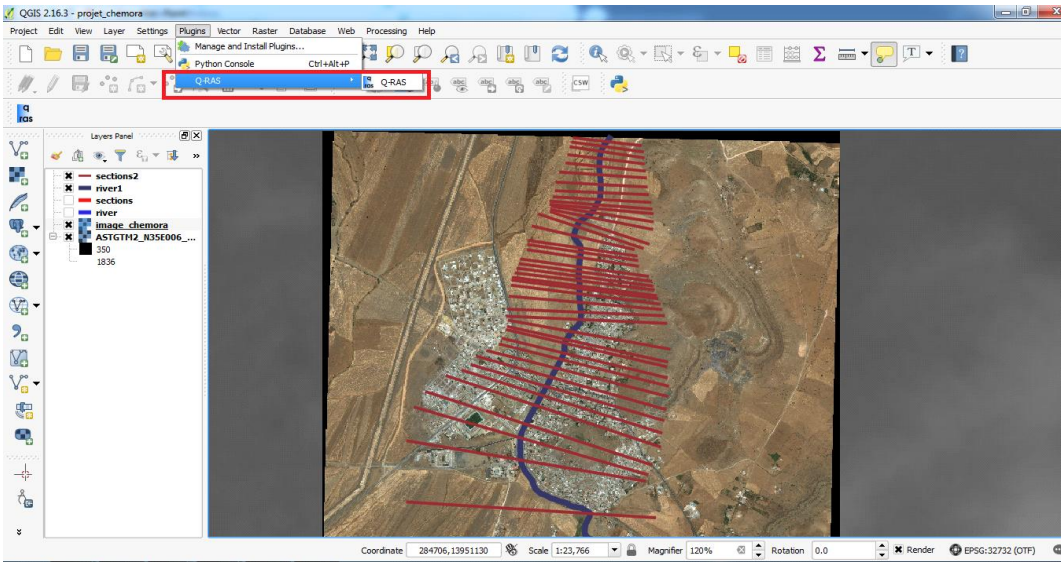

Figure 3. The modelling of stream geometry under QGIS

A land cover map has been integrated as a Manning coefficient that represents the roughness of the beds according to the nature and type of the soil.

The Q-RAS extension allows the extraction of the topography (of the entities realized) and exports it to the HEC-RAS software which ensures hydraulic simulation to integrate the 100-year flow value and boundary conditions for each section as a normal slope.

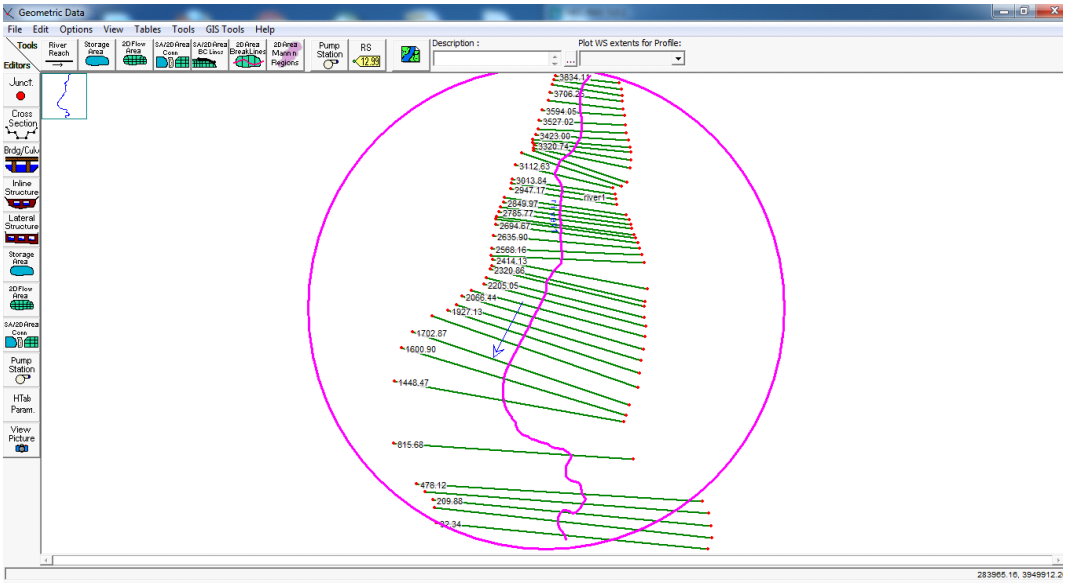

Figure 4. The stream geometry under HEC-RAS

Integration of technologies HEC-RAS (Hydrologic Engineering Centers River Analysis System) and GIS (Geographic Information System) to obtain scientifically derived information has been specified as efficient in simulating, identifying and analyzing flood events in a geo-spatial environment (Shamsi et al., 2002; Sami et al., 2016).

RESULTS AND DISCUSSIONS

The results of the hydrological modelling of the flows recorded by the Chemora stream station are summarized in the table below.

Table 2. Peak flow for different return periods

return periods	10 ans	50 ans	**100 ans**	1000 ans
Peak flow (m^3/s)	198	232	**242**	260

The results of the hydraulic simulation after the integration of 100-year recurrent flows are shown in the figure 5.

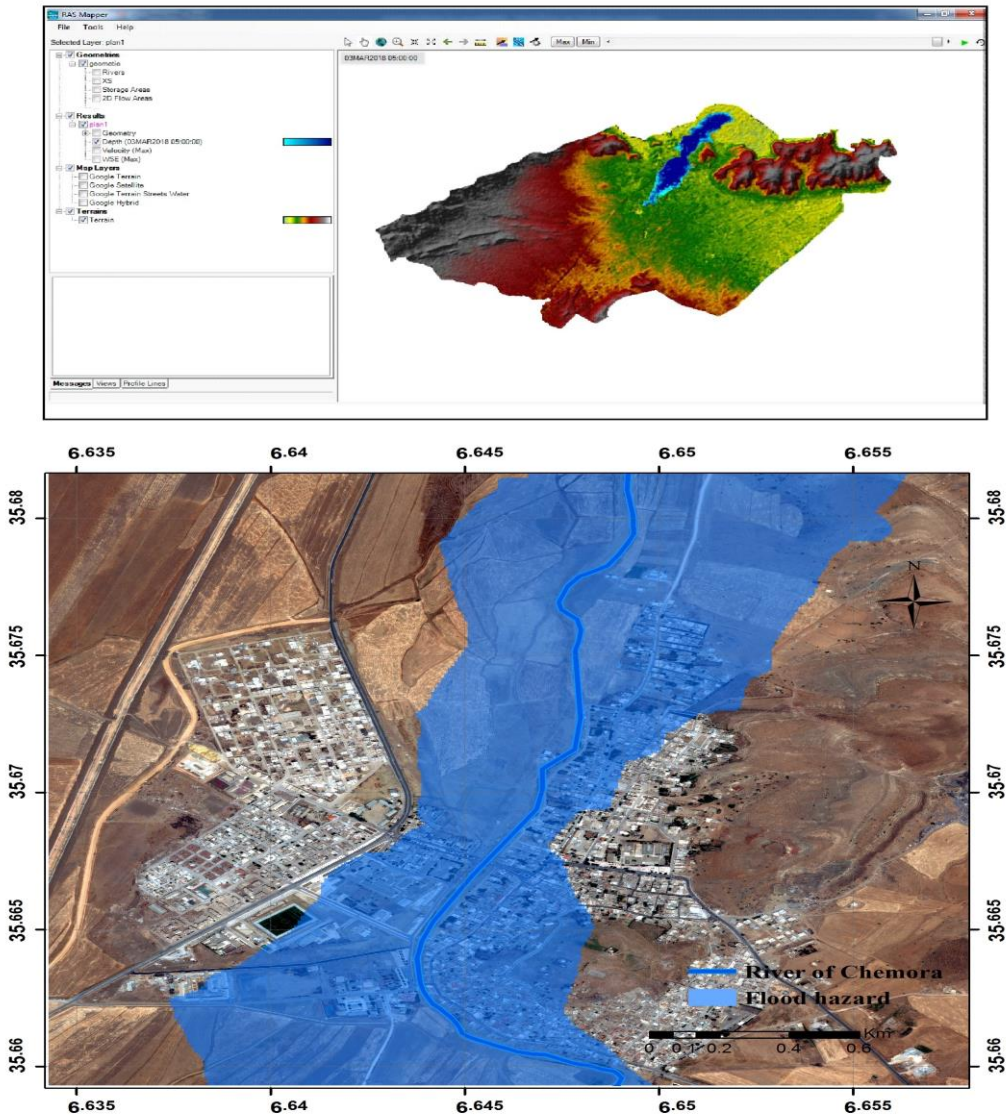

Figure 5. The results of the hydraulic simulation (100-year recurrent flows)

According to the map a several important socio-economic issues are exposed, in particular the equipment that constitutes the source areas (who are participating in crisis management) can potentially be affected which makes management very difficult in this case.

A precise knowledge of socio economic information will contribute to apprehend this risk with more efficiency.

Data availability has a very important role in the choice and the efficiency of the methodological approach used (Guellouh and al, 2016).

CONCLUSION

The objective of this study is to map flood hazard in the city of Chemorab, applied GIS and simulation software (which are pertinent tools in spatializing floods and knowledge of submersion elevation), whom helps to establish a strategy to face up to river dynamics and the damage that may result. Hydraulic modelling with this technique has proven an efficiency and effectiveness in the diagnostic of overflow of watercourses risk according to several authors and researchers.

Finally, a more accurate knowledge of territorial socio-economic data will contribute to a more effective management of this risk.

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MORPHOGRAPHIC STUDY OF BOIULUI VALLEY HYDROGRAPHIC BASIN

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Abstract: The aim of the present paper is to determine the morphometric parameters and features of Boiului Valley hydrographic basin. The basin is located in a karst area, in Pădurea Craiului Mountains, Romania, which makes it special, as the rivers flow through soluble rocks. We selected a small basin in order to analyse its morphometric elements and check if the morphometric laws of hydrographic basins are respected in the same way by the rivers flowing in karst areas. We applied the classical working method, that is processing the information from the topographic maps and with the help of the ArcGis soft we managed to measure the major morphometric indicators: the surface of the basin, the area, the shape factor, the length and width of the basin, drainage basin asymmetry factor and sinuosity index.

Key words: Boiului Valley, Pădurea Craiului Mountains, morphometric parameters, river segments, karst relief

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INTRODUCTION

The karst relief from Pădurea Craiului Mountains has been studied intensively over the years (Bordea, 1978; Rusu, 1988; Cocean, 2000; Racoviță et al., 2002; Ford et al., 2007) both for research purposes and also for its attractiveness offered by endokarst and exokarst forms as well. The karst landscape provides a wide range of forms of relief which contribute to its unique beauty and represent the main reason for tourism: sinkholes, uvalas, karren, karst plateaus, dry valleys, blind valleys, gorges, defiles, potholes, caves or karst springs.

A hydrographic basin can be studied as an open system that evolves constantly due to its exchange of matter and energy with the surrounding environment and also under the influence of the rivers and streams that shape the earth's surface (Zăvoianu, 2006). The drainage system determines the form and surface of the hydrographic basin and thus, its characteristics. The variables that characterise a basin are under the influence of the geological features (lithology, structure), morphometric elements (elevation, slope, degree of fragmentation, depth of fragmentation), vegetation (type, density) and human influence (Zăvoianu, 1978; Pradhan et al.,

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2012; Blaga et al., 2014). According to these variables, a hydrographic basin can be very small, peripheral, like the first-order ones, and huge that spread on thousands of square kilometers with one main collector and countless tributaries. The bigger the basin, the more complex the hydrographic network (Loghin, 2009). We have chosen a smaller hydrographic basin which covers mainly a karst area to assess if the morphometric rules applied to hydrographic basins in general are relevant for this network as well.

A lot of disparities may appear in a karst relief where the surface drainage is more complicated and the underground flowing is quite common because of the presence of karst springs and potholes. The configuration and dimension of the drainage system is responsible for the shape and surface of the hydrographic basin. Any hydrographic basin is unique being shaped by geologic features, morphometric variables, soil, vegetation and human intervention. All these factors are interconnected and act simultaneously (Zăvoianu, 2006).

STUDY AREA

Boiului Valley is situated in the north-eastern part of Pădurea Craiului Mountains between Brătcuţei Valley and Iadei Valley. It flows into Crişul Repede river, in the proximity of Lorău village (Figure 1).

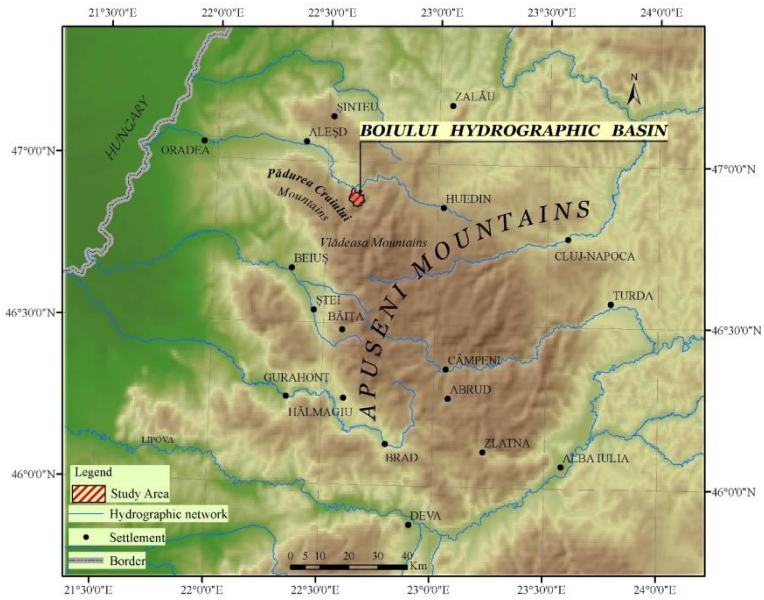

Figure 1. Location of Boiului Valley in Pădurea Craiului Mountains

It is important to take into consideration the fact that 83% of Pădurea Craiului Mountains consists mainly of mezozoic sedimentary formations belonging to three sedimentary cycles Triasic, Jurasic and Cretacic (Rusu, 1988). The sedimentary rocks formed during these stages are karst rocks which led to the appearance of a very rich and varied karst relief. The river runs through different types of rocks (limestone, dolomite, conglomerate, sandstone) creating sections of large valley with small slope or deep, narrow sections with waterfalls (Figure 2). It has many temporarily active tributaries or permanent ones. Due to the presence of positive and negative forms of relief and their horizontal and vertical layout, the relief is highly fragmented. Thus, the surface hydrographic network can be disorganized with portions of streams disappearing in the underground network. Boiului Valley is a karst valley with no gorges, that displays a seven-meter high waterfall, Boiului Waterfall, that represents the main tourist attraction of the area.

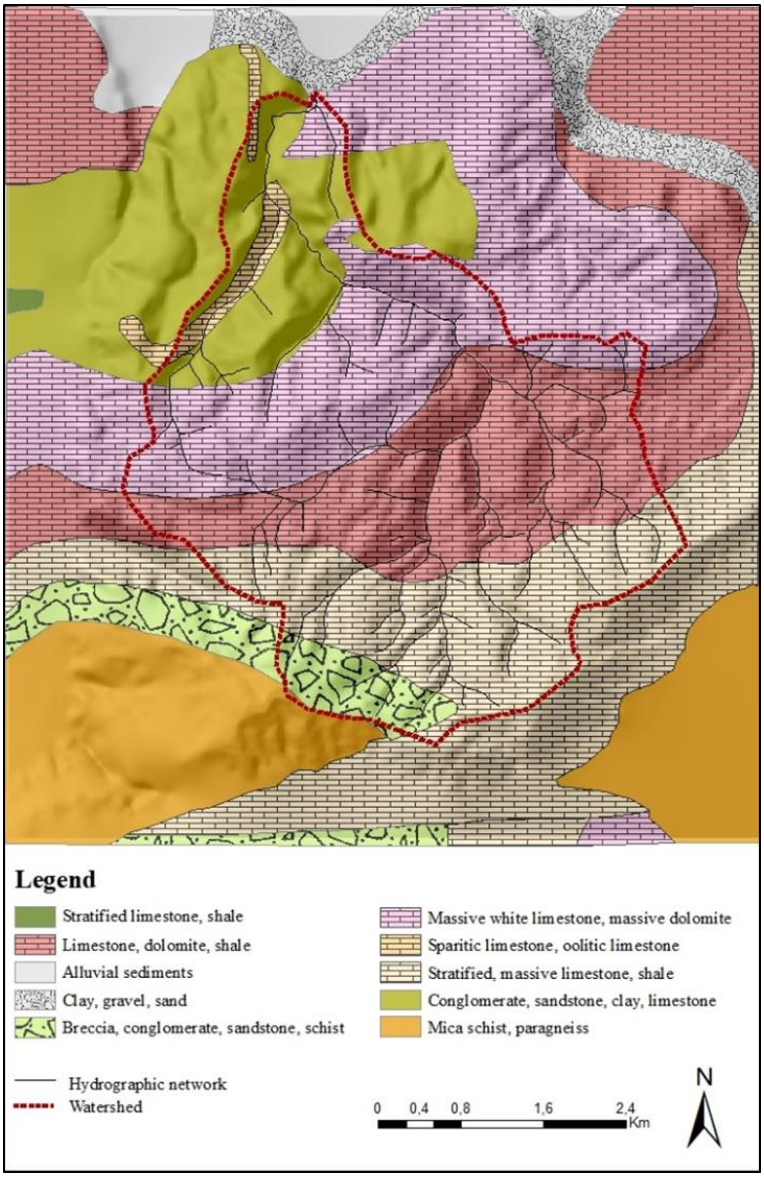

Figure 2. The geologic map of Boiului Valley basin in Pădurea Craiului Mountains
(Data source: Geologic map 1:200.000, Romanian Geologic Institute, 1978)

MATERIALS AND METHODS

For carrying out the present study, we started from the research expert studies published in the field of fluvial geomorphology and the morphometry of the river basins, among which we mention Strahler's Geografia fizică published in 1973, Morfometria bazinelor hidrografice, published by Ion Zăvoianu in 1978, Morfologia şi dinamica albiilor de râu written by Ichim and Rădoane in 1989, Relieful şi amenajarea teritoriului, by Lucian Blaga, Nicolae Josan and Dorina Camelia Ilieş, published in Oradea, in 2014.

The cartographic support was represented by the topographic map, scale 1:25.000 DTM from 1984 and the geologic map, scale 1:200.000 IGR from 1978 whose content was processed

using the instruments offered by the Arc Gis soft. We analysed the morphometric features of the basin, hypsometry, slope, slope exposure, depth of fragmentation, fragmentation density and some morphometric parameters of the basin and hydrographic network as they hold a crucial role in the formation and distribution of the elements of the river: the surface of the basin, its area, the shape factor, length and width of the basin, drainage basin asymmetry factor and sinuosity index. We used the procedure on hydrographic basins because we consider that it reflects objectively the reality of the area. The morphometric parameters were calculated according to the mathematical equations presented by Strahler (1973) and later by Zăvoianu (1978). Based on these concepts, we have calculated the number of river segments, the morphometric parameters and morphometric features of Boiului Valley hydrographic basin.

RESULTS AND DUSCUSSIONS

The number and order of the river segments

Determining and analysing the morphometric elements of a river basin represent a key factor that influences all the aspects concerning life within that particular territory. It is important to determine the river segments with permanent and temporary flow in order to calculate the main morphometric elements. The present study focuses on the determination of river segments in Boiului Valley hydrographic basin from Pădurea Craiului Mountains, in order to establish the main morphometric parameters of the basin.

The length of the river segments from the spring to the mouth is 8,5 km. The hydrographic basin of Boiului Valley has a dendritic drainage system in which most of the tributaries flow into the river in an angle smaller than 90°.When we analysed the hyerarchy of the hydrographic network in Boiului Valley, we took into consideration all the thalwegs, permanent and temporary ones.

According to the delimitation of the river segments in ArcGis, we noticed that the hydrographic basin has 64 first-order steams, which are most often temporarily active or disappear underground due to the limestone substrate they flow on. There are 20 second-order streams and 4 third-order streams (Figure 3). The overall number of the river segments is 89.

In the hydrographic basin of Boiului Valley there are 15 second-order sub-basins with a total surface of 11,41 km² and 4 third-order sub-basins that cover an area of 12,543 km². What is left of the total area of the hydrographic system (19,196 km²), that is 7.7 km², falls within the category of the interbasinal areas belonging to the fourth-order stream (Figure 3).

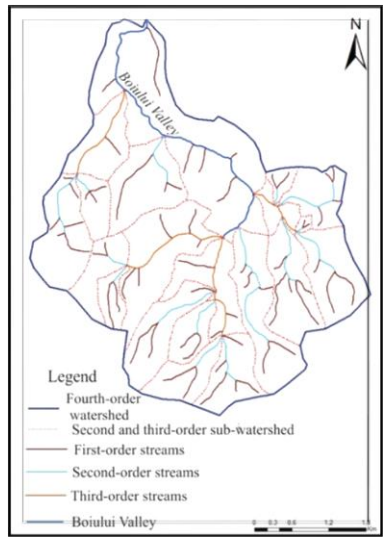

Figure 3. River segments and sub-watersheds in Boiului Valley

It is noticeable that in the studied area there are over three times more first-order segments than second-order ones; five times more second-order river segments than third-order ones and four times more third-order segments than the fourth-order which is the order of the main river. The differences among the ratio of bifurcation could be represented by the differences in the form of the river networks and by the fact that they flow in a karst area. The average of the three ratio coefficients is slightly over 4, which is a good value for the progression (Table 1). Knowing the number of river segments and their corresponding orders, we could establish the ratio of bifucation applying the mathematical formula $Rb = N_u/(N_{u+1})$.

Table 1. Number of river segments, orders and the ratio of bifurcation in Boiului Valley basin

Order (u)	Number of segments (N_u)	Ratio of bifurcation (Rb)
I	64	
II	20	3,20
III	4	5,00
IV	1	4,00

Table 2. The average length of river segments

Order (u)	Number of segments (N_u)	Average length (m)
I	64	402,319203
II	20	700,694053
III	4	1611,613525
IV	1	5357,160156

Analysing the number and the length of the river segments (Table 2) we can say that their number decreases as the order gets higher and their average length increases with the order. This observation is based on the law of the river segments, the law of the total length and the law of the average length.

Applying to Boiului Valley the Horton Law of the river segments, we can state that for an average 4 bifurcation coefficient and the main river segment being of order 4 as well, then the number of segments will be 1, 4, 16 and 64. The geometric progression of the numbers has a steady growing ratio, which means that each number bigger than 1 is the quadruple of the previous number (Table 3).

Table 3. The river segments measured and calculated according to the Horton Law

Order	Measured	Calculated
I	64	64
II	20	16
III	4	4
IV	1	1

The morphometric parameters of Boiului Valley

The surface of the basin is 19,196 km², which places it in the category of small hydrographic basins. It is an open basin, with an elongated shape from north to south and with a significant layout of the tributaries on the left side of the main river.

The area of the basin given by the watershed that delineates the surrounding basins (Brătcuţa in the west and Iada in the south-east) is 19,242 km, a value obtained using the ArcGis instruments.

The shape factor is the ratio between the surface of the basin and its square length 19,196 / 41,47797 = 2,160761 km. The length of the basin is the distance between the most remote points

on the river course and has a value of 6,44034 km. The maximum width is calculated as the maximum perpendicular on the line of its length and has a value of 5,13971 km. The average width is calculated as a ratio between the surface and the length, that is 19,196 / 6,44034 = 2,98058 km. The average width calculated on the two slopes equals 1,26574 km for the right one and 1,72236 km for the left one.

The drainage basin asymmetry factor involves the knowledge of both slopes, right and left. The distribution of the surface of the basin on the two slopes indicates a proportion of 57,78% for the left one and only 42,22% for the right one. According to this distribution, Boiului Valley hydrpgraphic basin is asymmetrical, developed more on the left side which covers 57,78% of the total area of the basin (Table 4). According to the formula $Kas = \frac{2(Supraf.Bst - Supraf.Bdr)}{Sb}$ the drainage basin asymmetry factor in Boiului Valley equals 0,30 and is due to the fact that most of the tributaries are located on the left side.

Table 4. The surface of the two slopes measured in km²

Boiului Valley	*Right slope*	*Left slope*
Surface	**8,15185 km²**	**11,0926 km²**

The sinuosity index is calculated as the ratio between the real length of the watershed and the length of the basin. For the left slope, this equals 9,071 / 6,440 = 1,408 km, and for the right one the value is 1,688 km, calculated as 10,871 / 6,440.

The morphometric features of the Boiului Valley hydrographic basin

We calculated the following morphometric features of Boiului Valley basin: hypsometry, slope, slope exposure, depth of fragmentation and the density of fragmentation.

Hypsometry

The average elevation of the basin is 650 m, the maximum elevation reaching 960 m in the south, of the basin, close to the springs and the minimum altitude is 327 m in the north of the hydrographic basin (Figure 4). This range of elevation places the basin among the mountainous hydrographic basins. Most of the basin, 9,65 km², is located at an altitude ranging between 650 m and 750 m (Figure 5). According to the data processed using interpolation in ArcGis, the average altitude of the land in 678,62 m.

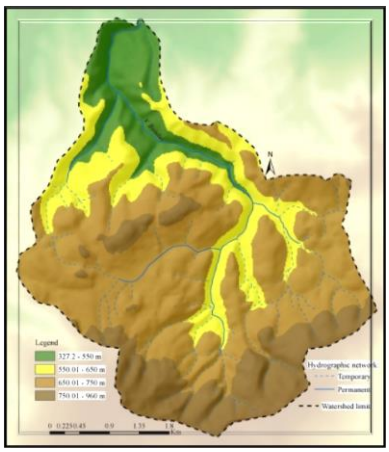

Figure 4. The elevation map of Boiului Valley hydrographic basin
(Source for elevation data: the contour lines taken from the topographic map 1:25.000, DTM, 1984)

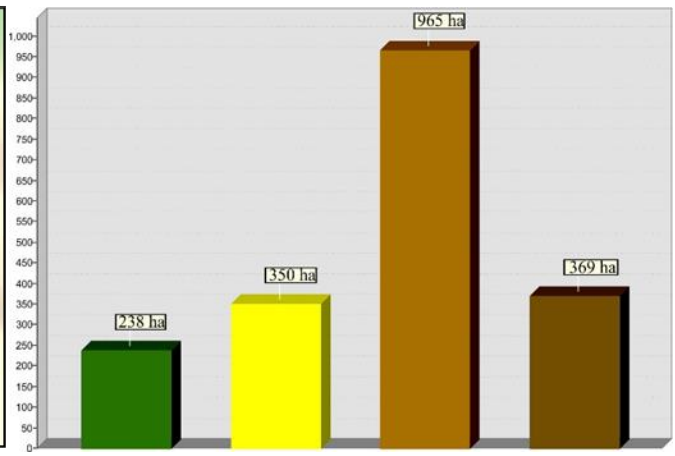

Figure 5. The histogram of elevation in Boiului Valley basin

Slope

The slope represents an important parameter for the use of land in the basin. We divided the area of the basin according to five categories of angles of declivity, as seen in table 5.

In the slope map (Figure 6) and the table below (Table 5) showing the tilt of the land, it is noticeable that the highest proportion of Boiului Valley basin covers a surface with an average tilt, between 6° şi 17°. The steepest areas are located along the main river and a few of its tributaries in the south of the basin.

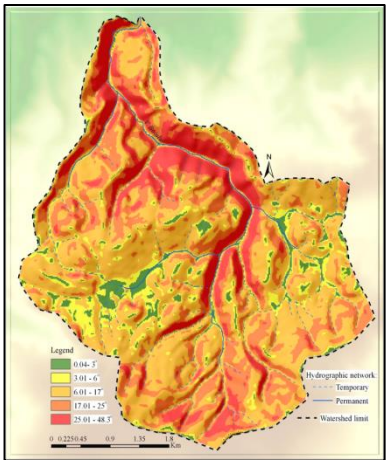

Figure 6. The slope map in Boiului Valley basin

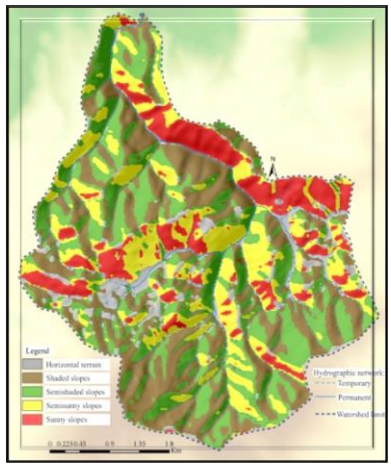

Figure 7. The slope exposure in Boiului Valley basin

Table 5. The characterization of the land from Boiului Valley basin according to the slope

Number	Slope	Characteristic of the land
1.	0° - 3°	horizontal land
2.	3° - 6°	slightly tilted
3.	6° - 17°	with average tilt
4.	17° - 25°	strongly tilted
5.	25° - 48°	steep

Slope exposure

According to Blaga et al. (2014), besides the horizontal land, there are four standard major groups for the slope exposure: the sunny slopes in the south and south-west, the partially sunny slopes in west and south-east, the semishaded slopes in east and north-west and the shaded ones in north and north-east. This ranking is clearly visible and easily identifiable on the slope exposure map (Figure 7). The horizontal land represented by the karst region is crossed mainly by a temporary hydrographic network.

Depth of fragmentation or vertical fragmentation

The depth of fragmentation shows the degree of depth of the valley and it is closely linked to the land fragmentation. We established five intervals for the depth of fragmentation, ranging from 2 m to approximately 92 m (Figure 8). The prevailing values are between 10 m and 25 m, and 25m and 50 m, respectively.

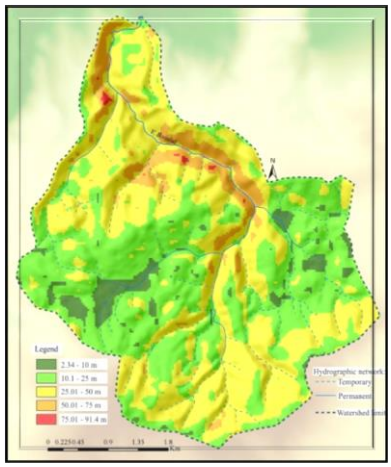

Figure 8. The depth of fragmentation in Boiului Valley hydrographic basin

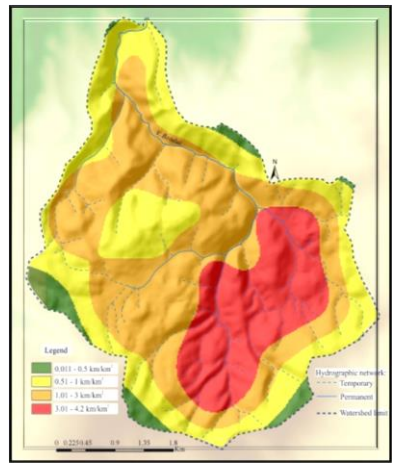

Figure 9. The fragmentation density in Boiului Valley hydrographic basin

Fragmentation density or horizontal fragmentation

The fragmentation density represents the degree of horizontal segmentation of the relief.

The fragmentation density is calculated as the ratio between the length of the drainage system and the surface of the basin, which in the present study represents 49,5987 km / 19,196 km² = 2,583 km/km². It can also be calculated taking into consideration the orders of the river segments (Figure 9). Therefore, the sum of the length of the first and second-order river segments divided by the surface of the second-order sub-basins, meaning 39,761 km / 11,418 km² = 3,482 km/km². The density of the third-order river segments in the basins with the same order equals 46,207 km / 12,543 km² = 3,683 km/km² (Table 6).

Table 6. The fragmenation density on orders of magnitude in Boiului Valley basin

Fragmentation density	**Order 2 network**	**Order 3 network**	**order 4 network**
	3,482 km/km²	3,683 km/km²	2,583 km/km²

CONCLUSIONS

For most part, Boiului Valley runs through a karst relief, thus some of the tributaries have an underground flow and the temporary surface network is active mainly during the rainy season. The land has a moderate tilt which makes it susceptible to erosion and land slides of low intensity. The morphometric laws applied to Boiului Valley demonstrate its capacity of self-organization and development even if it spreads over karst morphostructures, which usually disorganize the surface hydrographic network. The explanation lies in the fact that the studied area is quite small and located marginally within the landscape structure of Pădurea Craiului Mountains.

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ROAD CHARACTERISTICS, TRAFFIC NATURE AND DRIVERS' PROPENSITY TO USE MOBILE PHONE

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Abstract: The objective of this study was to investigate whether drivers' propensity to use mobile phone during active driving was determined by given road type, road condition and traffic nature. Naturalistic observations of vehicles were conducted on intra-city roads in Lagos, Ibadan and Ile-Ife and intercity roads between Lagos-Ibadan and Ibadan-Ife expressways. Interview was also conducted with 26 drivers purposively selected to provide narrative account of personal mobile phone use while driving. Descriptive and content analysis techniques were used to present the results of both the observation and interview. Results showed that 5.18% of a total 2627 drivers observed on the intra-city roads were seeing with their phones during active driving while 6.09% of 952 drivers observed on the intercity expressways were seeing using their mobile phones. Results also revealed that high percentage of drivers would not use their phone on high-ways (H-Ws), bumpy roads (BRs) and low-density traffic (LDT) while most drivers use their mobile phones on street-level roads (SLRs), smooth surface roads (SSRs). Factors such as exigency of calls, suitability to pick calls, consideration for speed, chaotic potential outcomes were among factors that determine their penchant to pick calls.

Key words: Mobile phones, driver, propensity, road characteristics, traffic nature

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INTRODUCTION

Since the introduction of mobile phones and its evolution into smartphones, its adoption and use has significantly increased, especially because of its capability to function as a full computer, its user-friendliness and a wide range of applications that created a world of "possibilities" to users/owners (Gretzel, 2010; Wang et al., 2012). Besides, its "carriability" confers on it a personalized attachment tendency than any other form of computer. This attachment tendency through carriability nature has created a huge measure of intrusiveness of mobile phone into virtually every facet of human endeavours. Significant of these intrusions is found in driving activities where mobile phone use has imprinted a challenging and unassailable negative influence, especially in relation to safe driving (Goodman et al., 1999; Seo and Torabi, 2004; McEvoy et al., 2006).

Since its adoption, studies have shown that mobile phone use during active driving is growing at an exponential rate (Edwards, 2001). However, studies established the deleterious

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effect of mobile phone use (Drews et al., 2009; Salvucci and Beltowska, 2008) especially in terms of its intrusion into driving tasks such as lane keeping and speed maintenance. Though questions keep evolving on various dimensional influence of mobile phone use on driving performance, observational studies have frequently revealed that mobile phones are still being used in vehicles (Johal et al., 2005; McD Taylor et al., 2003) and suggested that mobile phone use may result in hazardous increases in reaction time, and general degradation in driving performance (Horrey and Lesch, 2009). Studies including those of Klauer et al. (2006), Olson et al., (2009), Dingus et al., (2011) found that talking itself is not associated with an increase in risk, engaging in other mobile phone-related subtasks (reaching for, answering, dialing, texting, internet use and use of social networking applications) may further increase crash risk (Simons-Morton et al., 2014; Fitch et al., 2015; Irwin et al., 2015; McEvoy et al., 2006; Hosking et al., 2009; Klauer et al., 2014; Bassick, Reed and Robins, 2011). White et al. (2004) conducted two studies on risk perceptions of mobile phone use while driving. Seo and Torabi (2004) established a relationship between the frequency of use of mobile phones by drivers while driving and rate of crashes or near-crashes experienced. Crundall et al. (2005) indicated the interference deriving from the conversation itself was a potential risk indicating higher talk duration increased the risk. Generally however, all the studies support arguments that mobile phone use dramatically increases the cognitive load of the driver, which multiplies the risks for accidents. The increase on drivers' attention is explained either by the need to handle the phone device per se or by the demand to handle the conversation (Alm and Nilsson, 1995; Manalavan et al., 2002). Despite the prevailing use of mobile phones among drivers and its widely reported negative impacts on safe driving, little is known about drivers' penchant to using mobile phones on a given road type, road condition and traffic nature especially in the developing countries where studies on driving and mobile phone use linkage are scanty. This study examines whether road type, road condition and nature of traffic increase drivers' likelihood to use mobile phone.

BACKGROUND

This study is built around two main theories. One is the theory of propensity and the other is the theory of reasoned action. While the former explains the proclivity of performing a given behaviour given the prevailing condition, the latter explains performance or nonperformance of a given behavior based on the strength of one's intention to perform or not perform that behavior. According to Hozer and Doszyn (2004), propensity might be considered as a "slope of posture" towards something that makes probability of certain event higher. Propensity is considered as functional dependencies between certain variables that depend both on objective and subjective factors. Popper (1990) consider propensity as a result of all conditions that generate events, a characteristic of a whole situation and that probability of an event taking place is inherent in a given situation. By this, propensity is understood as a relative frequency which results from the intervention of various kinds of causes.

According to the theory of reasoned action, performance or nonperformance of a given behavior is primarily determined by the strength of one's intention to perform or not perform that behavior (Fishbein and Ajzen, 1975; Ajzen and Fishbein, 1980). However, intention is defined as the subjective likelihood that one will perform or try to perform the behavior. The intention to perform a given behavior is, in turn, viewed as a function of two basic factors: one's attitude toward performing the behaviour and one's subjective norm concerning the behaviour, that is, the perception that one's important others think that one should or should not perform the behavior in question.

Based on the aforementioned theories, drivers' propensity to use their mobile phones is premised on and inherent in the characteristics of a situation (now, the condition of the road, types of road and traffic density), whereas, their desire to use mobile phone while driving, even given the driving environment, is premised on the strength of their intention (desire) to use mobile phone while in active driving.

STUDY AREA AND METHODS

Study area comprised of Lagos, Ibadan and Ile-Ife (major cities in Southwestern Nigeria in their order of population and economic importance). Lagos is Nigeria's commercial nerves and providing the most important gateway to the country. Though an erstwhile administrative capital of Nigeria, it is still regarded as the commercial capital and the most important city in Nigeria. Ibadan is the administrative capital of Oyo State Study adopted observation and interview methods, while Ile-Ife provides a important city in Osun State. Natural observation and ethnography were used for data collection. Natural observation of the nature of selected roads and traffic condition on the roads were conducted (Huisingh et al., 2015). Two intercity roads and three intra-city roads were selected in Lagos, Ibadan and Ile-Ife. Intercity road connecting Lagos and Ibadan is about 138 km, while road connecting Ibadan and Ile-Ife measures 73km. Both routes are highways linking the Southwest to many parts of the country. However, Lagos Ibadan road is undergoing construction and further expansion to enhance the efficiency of transporting majority of importation from Lagos ports being the gateway to the nation. Intra-city roads selected included the Oshodi/Anthony/Gbagada route (Lagos), Iwo-Road/Adegbayi/Airport route (Ibadan) and Ede-road/Mayfair/Lagere route (Ile-Ife).

For the intercity routes, observations were made by travelling in an informal public cab between Lagos and Ibadan and between Ibadan and Ile-Ife, respectively. Researcher occupied the front seat and observed only vehicles overtaken by the researcher's cab. Only vehicles to the right of the researcher's cab were observed. This provided the researcher clearer view of drivers in the overtaken vehicles. For the intra-city observations, strategic points that posed no threat to safety of the researcher were selected in the three routes and as such that provided no obstruction to good observation.

Researcher observed if drivers were using mobile phone during active driving on these selected routes. However, vehicles with tinted windows that obscured clearer observation were excluded from the observations. Vehicle observed were classified into cars, buses and trucks. A total of 2627 vehicles were observed on the intra-city routes while 952 vehicles were observed on the inter-city routes. In all a total of 3579 vehicles were observed.

In addition, using ethnographic method, private conversation were made with 13 private car drivers and 13 commercial vehicle drivers, making a total of 26 drivers (not part of the observed drivers) who were active drivers and who possessed mobile phones with a view to providing additional support to our naturalistic observation. Drivers interviewed were included based on the possession of valid driver's license, possession of mobile phone, being active drivers up till the month preceding the conduct of the interview. Questions asked included whether they use mobile phone while driving, whether road type, road condition and traffic nature influence their use of mobile phone during active driving. By road type, we considered high-way with fast flowing traffic, city routes with medium traffic, and street-level roads. By road condition, we considered paved and rough surface roads, bumpy surfaces and by traffic nature, we considered degree of denseness of traffic on each selected road.

Results of the observation were presented using descriptive charts, while result of the interview was presented using some descriptive method and content analysis method.

RESULTS

Observed vehicles on the intercity and intra-city roads

Table 1 represents observation made on selected intercity roads (Lagos-Ibadan and Ibadan-Ife Expressways). 600 vehicles were observed during the journey along Lagos-Ibadan Expressway. Of these, 456 were cars, 131 buses and 13 trucks. 6.3%, 7.6% and 15.4% of drivers of cars, buses and trucks were seen using mobile phones while driving. In all, 6.8% of the total 600 vehicles observed had their drivers using mobile phones during active driving. Similarly, 352 vehicles were observed on Ibadan-Ife Expressway out of which 199 were cars, 123 buses and 30 trucks. 6.5% of drivers of cars were observed using their mobile phones, while 1.6% and 6.7% of drivers of buses

and trucks, respectively, were observed using their mobile phones. In all, 4.8% of 352 drivers observed were using mobile phones during driving.

Table 1. Observation on intercity roads

	LAGOS-IBADAN EXPRESSWAY			IBADAN-IFE EXPRESSWAY			TOTAL		
	Obsvd	DUP	% Freq	Obsvd	DUP	% Freq	Obsvd	DUP	% Freq
Car	456	29	6.3	199	13	6.5	655	42	6.4
Bus	131	10	7.6	123	2	1.6	254	12	4.7
Truck	13	2	15.4	30	2	6.7	43	4	9.3
Total	**600**	**41**	**6.8**	**352**	**17**	**4.8**	**952**	**58**	**6.09**

Note: Obsvd (Observed); DUP (Drivers using phone)

In another vein, table 2 showed observation made on selected roads in Lagos (Oshodi/Anthony/Gbagada), Ibadan (Iwo-Road/Adegbayi/Airport Road) and Ile-Ife (Ede-Road/Mayfair/Lagere Road). A total of 2627 vehicles were observed on all the roads. This comprised of 1110, 854 and 663 vehicles on the three roads respectively. 2015 cars, 474 buses and 138 trucks made up the total observation. 5.4% of the drivers observed in Oshodi/Anthony/Gbagada were involved in mobile phone use while driving, while 5.26% and 4.67% of observed drivers in Iwo-Road/Adegbayi/Airport axis and Ede-Road/Mayfair/Lagere axes, respectively, were seen using mobile phone during active driving. In all, only 5.18% of the drivers of the observed vehicles were using mobile phones while driving.

Table 2. Observations on intra-city roads

	OSHODI/ANTHONY/ GBAGADA ROUTE				IWO-ROAD/ADEGBAYI/ AIRPORT ROUTE			EDE-ROAD/MAYFAIR/ LAGERE ROUTE			TOTAL	
	Obsvd	DUP	% Freq	Obsvd	DUP	% Freq	Obsvd	DUP	% Freq	Obsvd	DUP	% Freq
Car	920	37	4.02	632	29	4.5	463	21	4.5	2015	87	4.32
Bus	124	16	12.9	184	12	6.5	166	7	4.2	474	35	7.36
Truck	66	7	9.4	38	4	10.5	34	3	8.8	138	14	10.1
Total	**1110**	**60**	**5.4**	**854**	**45**	**5.26**	**663**	**31**	**4.67**	**2627**	**136**	**5.18**

Note: Obsvd (Observed); DUP (Drivers using phone)

Drivers' propensity to use phone during driving

Results of interview with 26 drivers (13 commercial and 13 private drivers) revealed that all the drivers recruited for the interview use their mobile phone during active driving. However, 15.4% of commercial drivers use mobile phone whenever they feel like while 84.6% sometimes use their phone during driving. 30.8% of private drivers use their phones at any time while 69.2% sometimes make use of their phone during active driving.

With respect to whether road type increases their chance of using mobile phones during active driving, dividing road type into high-ways (H-Ws) and street-level roads (SLRs), 77.0% of commercial drivers and 61.5% of private drivers submitted that they are inclined to using their phones on the H-Ws while all the drivers agreed they use their phones on the SLRs.

Drivers' propensity to use mobile phone given road condition showed that 53.8% of commercial drivers and 77.0% of private drivers inclined to use mobile phones on bumpy roads (BRs) while all the drivers use their mobile phones on smooth surface roads (SSRs). However, in respect of traffic density and inclination to use mobile phones, 69.2% and 77.0% of commercial

and private drivers respectively, would use their mobile phone in low density traffic (LDT) while 30.8% and 23.0% would use it in high density traffic (HDT).

Table 3. Drivers' responses from personal interview

Variable	No	Yes	
Ownership of mobile phone			
Commercial drivers	-	13 (100%)	
Private drivers	-	13 (100%)	
Do you use mobile phone when in active driving?	No	Yes	
Commercial drivers	-	13 (100%)	
Private drivers	-	13 (100%)	
How frequently do you use your phone while in active driving?	Anytime	Sometimes	Never
Commercial drivers	2 (15.4%)	11 (84.6%)	-
Private drivers	4 (30.8%)	9 (69.2%)	-
Road Type and propensity to use phone	H-Ws	SLRs	
Commercial drivers	10 77.0%)	13 (100%)	
Private drivers	8 (61.5%)	13 (100%)	
Road Condition and propensity to use phone	BRs	SSRs	
Commercial drivers	7 (53.8%)	13 (100%)	
Private drivers	10 77.0%)	13 (100%)	
Traffic density and propensity to use phone	LDT	HDT	
Commercial drivers	9 (69.2%)	4 (30.8%)	
Private drivers	10 77.0%)	3 (23.0%)	

Note: H-Ws (High-ways); SLRs (Street-level roads); BRs (Bumpy roads);
SSRs (Smooth-surface roads); LDT (Low-density traffic); HDT (High-density traffic)

To buttress respondents' responses to their propensity to use mobile phone during active driving, some themes were drawn from other responses based on the driving situation. For those who are probable to use their mobile phones on the H-Ws, the significance of the incoming call, and frequency of call notification (phone ringing) inform their use of mobile phone. However, speed of the vehicle, safety condition is first put into consideration. This is demonstrated through the following comments:

Sometimes I pick calls when on highways when the call is important and/or when my phone keeps ringing showing the same number; you know, this may be a sign of emergency. But in any case, I consider my safety first and reduce speed to manageable minimum before picking the calls. Again I consider convenience, by this, I mean if the phone is within reach but if it's in my pocket and have to wriggle to get it, I suspend the idea of picking it.

For those that wouldn't use phone on the highway, safety and the need for more concentration are reasons for not using phones on the highways. This comment buttresses their claim:

My decision not to use mobile phone on the highway is simply because speed is much from every driver and as such, you need to concentrate more on wheel coordination. Don't forget that distraction or inattention will cause a chaos that may be irreparable. Laughs! If anything should happen while trying to receive the call, you know, it's your headache. Because your caller will be alive while you are dead.

In the case of using mobile phone based on road condition, speed and maneuverability were major considerations for use or non-use of mobile phone during active driving. The following comment represents the commonest reason for those who use their phone:

I receive and even initiate calls in bumpy areas because speed is reduced. I can use one hand to hold the wheel and quickly make use of the other hand for receiving or making calls.

On the contrary, for those who are not inclined to using phone on bumpy routes, the following comment represents their reason:

Bad or bumpy routes as we commonly have here considering the state of our roads require more concentration. You need to have a good grip of the steering because a lot of maneuvering is required here. Otherwise you may damage your vehicle.

With respect to propensity to use mobile phones given traffic density, speed and convenience were common factors for using phone during driving. Examples of the comments are given below:

- I use my phone when held up in traffic, especially when in a static state. At this point, I even initiate calls.

- For me, probability of using phone is high because vehicles are all moving slowly. That's even the best time for me to call or send message to people.

However, the following comment represents the common reason for not using mobile phone in traffic situation:

It's difficult for me, because one may complicate the traffic problem especially when one collides with the vehicle ahead.

DISCUSSION OF RESULTS

The results of this study provided understanding of the propensity of drivers to use mobile phone given road type, road condition and traffic density. Results showed that observation of usage of mobile phones among drivers on all the selected routes were generally low (table 1 and 2). This record may not be a true reflection of mobile phone usage among drivers during active driving task. This is because observations were not a follow-through process. Thus we could not ascertain whether or not those not found with mobile phone at the time of observation might have at any time during their driving made use of their mobile phones. However, results of the interview with selected drivers revealed that all drivers use mobile phone in active driving though with varying frequency of use. This coincides with the study of risk perceptions of mobile phone use while driving by White et al. (2004) which reported that almost half of the drivers who had a mobile phone had used it while driving. Use of mobile phones by most drivers in the study area may be attributed to their lack of awareness of the risk related to using mobile phones during active driving (Horrey et al., 2008; Rosenbloom, 2006). Reports from the results that some drivers used their phones while driving on the H-Ws because of emergency implies that where some drivers would desire not to use mobile phone during active driving, given the road type, the exigency of calls may induce the use of phones at some occasions. This alludes with the suggestion that the use of mobile phones in vehicle may not be harmful per se especially where the urgency of the call which may enhance timely response to cases of emergency is known or determined (Loeb et al., 2009; Fowles et al., 2010). Again, the consideration of speed reduction by drivers who engage their mobile phones on the H-Ws confirms studies which established that drivers modulate their driving task to increase their safety margin by reducing speed (Engström et al., 2005; Törnros and Bolling, 2005; Schömig 2011; Liang, 2015) so as to increase time headway to a lead vehicle (Hosking et al., 2009). Generally, however, there seems to be an understanding of distracting effect of mobile phone use by some of the drivers who underscored the chaotic potential outcome of using mobile phone on the H-Ws. This understanding buttresses global concern about the inattention caused by mobile phones and increasing crash risk and fatalities associated with mobile phone use during active driving (Overton et al., 2014; Backer and Sagberg, 2011). This understanding puts this category of drivers in the class of individuals regarded by Wogalter amd Mayhorn (2005) as those having strong beliefs about the existence of safety problems associated with driving.

Further, the determination of use or non-use of mobile phone by drivers given the nature of traffic is explained by the intensity of the traffic situation, and the complexity of maneuvering, which varies with journey and location. This explains why Dula et al., (2011) established that accident risk is high for both the high and low traffic density, while this risk increases with increasing exposure to traffic flow (Forkenbrock and Weisbrod, 2001).

CONCLUSION

In a time when mobile phone use among drivers has become a global issue, this study determined the propensity of drivers to use their mobile phones considering road type, road condition and traffic density. Though result of the observation revealed a low rate of observed use of mobile phones by drivers, it was considered as not being a true reflection of real situation as no follow up could be made with drivers to determine who decided to use their phone later in the course of the journey. However, interview with selected drivers revealed that majority of drivers use their mobile phone during active driving but at varying frequency regardless of road type, road condition and traffic nature. Factors such as exigency of call, complexity of maneuvering, chaotic potential outcome of combining driving with use of mobile phone, suitability of picking calls determined drivers' propensity to use mobile phones in the study area.

One limitation of this study is the difficulty of determining real-time phone use among the interviewed drivers and also to follow-through with observed drivers in order to know determine their propensity to use their mobile phone in road scenario other than where the observations were made. Thus, simulation will be recommended to determine the real-time propensity of drivers to use mobile during active driving.

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RAINFALL TRENDS ANALYSIS IN TÂRGU MUREȘ CITY, ROMÂNIA

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Abstract: The aim of this study is the detection of trends of precipitation from (1986-2020) over Târgu Mureș city. Precipitation data for 35 years were processed with MS Excel spreadsheets to find monthly, seasonal and annual variability of rainfall. The Mann-Kendall test was used for trend analysis of precipitation and the Sen's slope estimator was used for the magnitude of variation. The calculations of the two methods were performed using the MAKESENS program. The standard deviation and the coefficient of variation were used to highlight the dispersion. Results show that all three scales (annual, seasonal and monthly) show a tendency to increase rainfall. The highest monthly average of precipitation is 227.70 mm (August, 2005), and the lowest monthly average of precipitation is 0.80 mm (November, 2011). The maximum value of annual precipitation is 852.60 mm and was registered in 2005, and the minimum value was 408.70 mm registered in 2000.

Key words: trend analysis, Mann-Kendall test, rainfall, Sen's slope estimator, annual average, Z and Q-Statistics

* * * * * *

INTRODUCTION

The general geographic features of the Carpathians and the complex structure of the underlying surface are responsible for a series of local characteristics of the climate which, in broad outlines, define a multitude of complexe and elementary topoclimats (Gaceu, 2002).

Rainfall is one of the key climatic variables that affect both, the spatial and temporal patterns of water availability. One of the challenges posed by climate change/climate variability is ascertainment, identification and quantification of trends in rainfall and their implications on river flows in order to assist in formulation of adaptation measures through appropriate strategies for water resources management (De Luis et al., 2000).

Trend detection in precipitation time series is one of the interesting research areas in climatology. It is noted that the changes in precipitation are not globally uniform. Regional variations can be much larger, and considerable spatial and temporal variations may exist between climatically different regions (Yue and Hashino, 2003).

* Corresponding Author

Trend analysis of rainfall time series includes determination of increasing and decreasing trend and magnitude of trend and its statistical significance by using parametric and non-parametric statistical methods. One of the best methods which is preferred by various researchers is Mann-Kendall test (Jain and Kumar, 2012).

The aim of this study is to analyze the average monthly, seasonal and annual precipitation in the study area, over a period of 35 years (1986 - 2020) to establish possible trends.

STUDY AREA

The study area is the city of Târgu Mureș located in the center of Romania, in the Transylvanian Depression. The geographical location is lat. 46 ° 32 ' N and lon. 24 ° 32' E, altitude is 308 m. It is a medium-sized city with approximately 145,000 inhabitants. The total area of the city is 66.96 square kilometers and the Köppen Climate Classification is „Dfb" (Warm Summer Continental Climate).

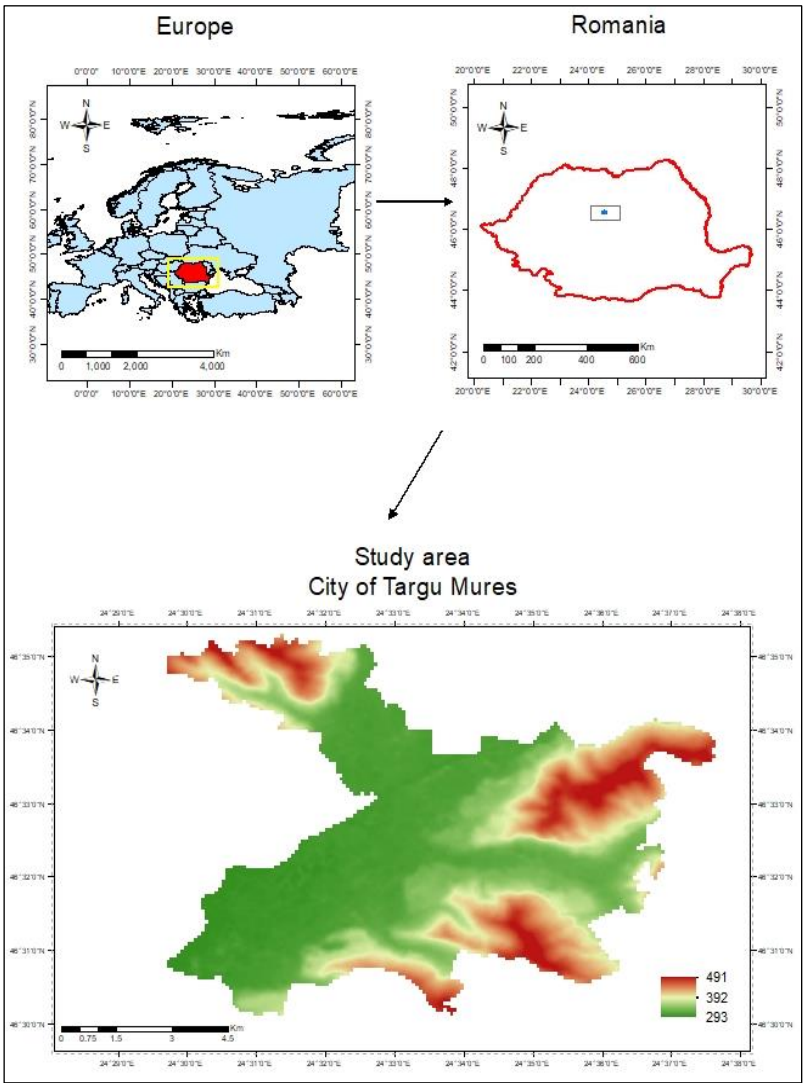

Figure 1. The study area

RESEARCH METHOD

The data used in this study were collected at the Târgu Mureș meteorological station, between 1986 and 2020 and provided from the archive of the National Meteorological Administration (ANM). In order to determine the precipitation trends in the study area, the monthly, seasonal and annual averages were calculated, using Excel spreadsheets.

Different statistical testing methods are used to evaluate the trends of the hydro-meteorological time series. These are classified into parametric and nonparametric tests (Chen et al., 2007; Dahmen and Hall, 1990; Zhang et al., 2006). Parametric trends are more powerful than nonparametric, but they require independent data which is normally distributed.

The nonparametric tests only require the data to be independent and are tolerant to the presence of outliers in the data (Funk et al., 2008; Camberlin and Okoola, 2003; Kumar et al., 2008).

Statistical analysis is used to determine the magnitude of the trend (Mann - Kendal Test, Sen's slope estimator) and the dispersion (standard deviation, coefficient of variation, skewness and kurtosis) for rainfall data of city of Târgu Mureș. Mann-Kendall test does not require that datasets to follow normal distribution and show homogeneity in variance (Duhan and Pandey, 2013).

The following tools and statistical tests were used in the present study to analyze precipitation trends:

1. Linear regression - is one of the simplest and most widely used methods to calculate the trend of data in time series. The equation of linear regression line is given by:

$$y = a + b\,x \quad (1)$$

where:

a = the intercept
b = slope line
x = explanatory variable

2. Mann - Kendal Test - the most common non-parametric tests for working with time series trends are the Mann - Kendall (Mann, 1945; Kendall, 1975). The World Meteorological Organization (WMO) has suggested the Mann-Kendall test for assessing the temporal trends in the time series of environmental data (Shi et al., 2013). The Mann-Kendall statistic S is given by:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn\ (x_j - x_i) \quad (2)$$

where:

n = length of the data
x_j, x_i = sequential data values
sgn = signum function
sgn $(x_j - x_i)$ is calculated using equation:

$$\text{sgn}\ (x_j - x_i) = \begin{cases} 1\ if\ x_j - x_i > 0 \\ 0\ if\ x_j - x_i = 0 \\ -1\ if\ x_j - x_i < 0 \end{cases}$$

The upward or downward trend of the data string is represented by the positive or negative value of the S value.

3. Sen's slope estimator - this is another non-parametric test, which is applied in cases the trend is assumed to be linear, depicting the quantification of change per unit time (Sen, 1968; Gilbert, 1987; De Lima et al., 2007). The slope (Ti) of all data is given by:

$$T_i = \frac{x_j - x_k}{j - k} \text{ for i = 1,2,3...,N} \quad (3)$$

where x_j and x_k are the data values at times j and k (with j > k), respectively.

4. Skewness - is the degree of deviation of a variable from the average value. The formula for skewness is:

$$S = \frac{\sum_{i=1}^{N}(Xi-\bar{X})^3}{(N-1)s^3} \quad (4)$$

where: N = sample size
X_i = individual score
$\bar{X}$ = mean
s = standard-deviation

5. Kurtosis - is a measure of peakedness of the data in standard deviation. The formula is:

$$K = \frac{\sum_{i=1}^{N}(Xi-\bar{X})^4}{(N-1)s^4} - 3 \quad (5)$$

where: N = sample size
X_i = individual score
$\bar{X}$ = mean
s = standard-deviation

RESULTS AND DISCUSSION

1. Monthly rainfall trend analysis - the total monthly average was 48.80 mm as shown in (figure 2).

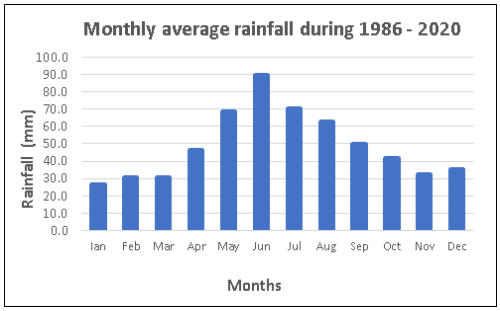

Figure 2. Monthly average rainfall during 1986 – 2020

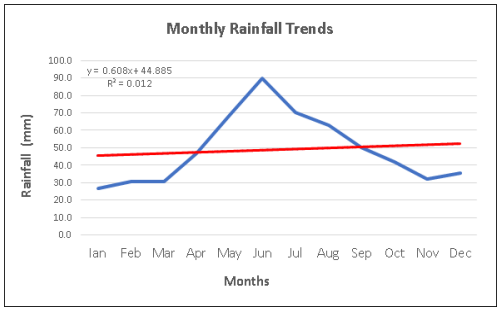

Figure 3. Monthly Rainfall Trends during 1986 – 2020

For the analysis of the monthly precipitation trend, the most representative statistical methods were used: the Mann-Kendall test for the trend and Sen's slope estimator for magnitude shown in (figure 3). It was analyzed whether there are significant variations in the tendency of precipitation to increase or decrease.

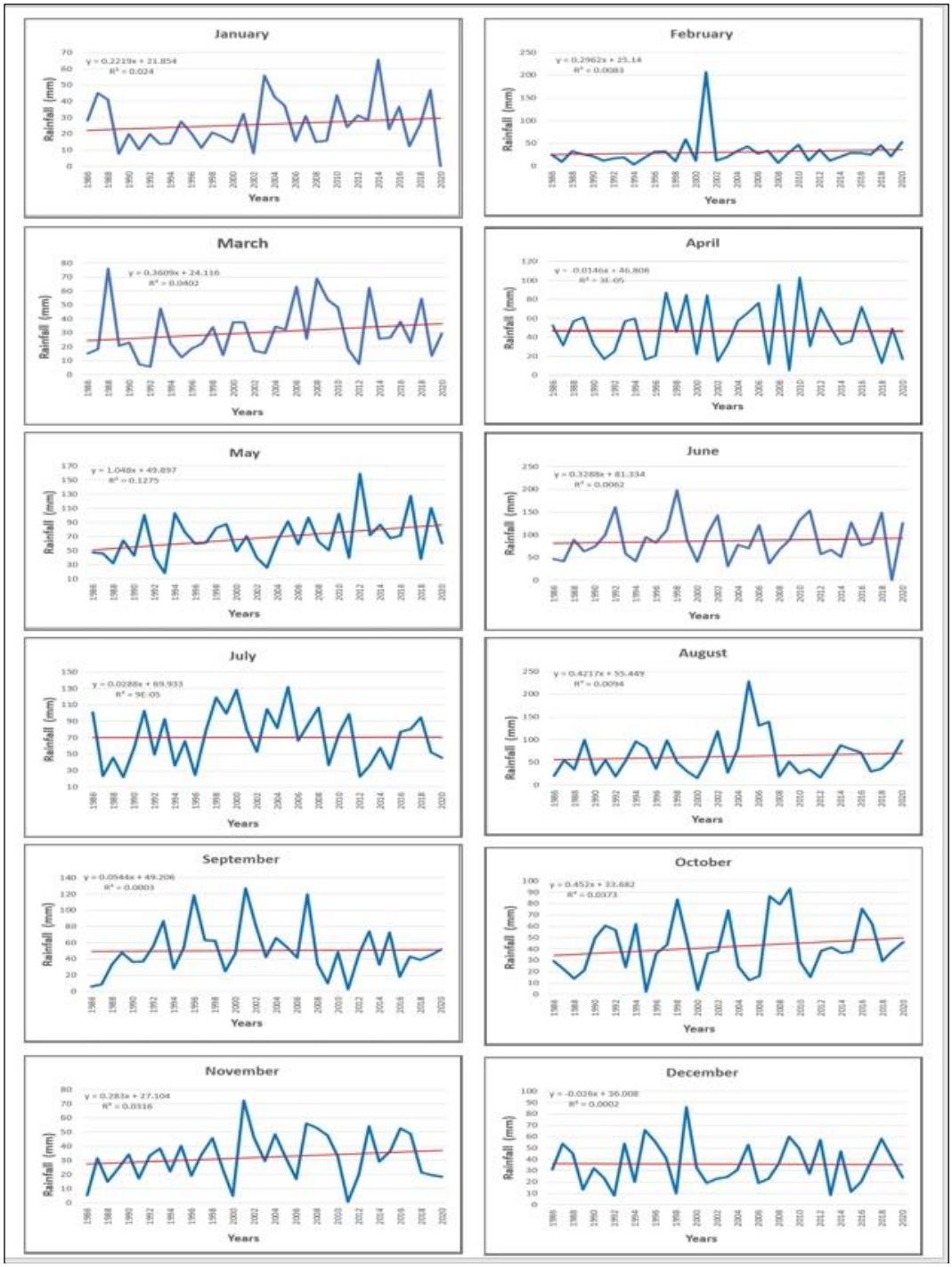

Figure 4. Monthly Rainfall Trend Analysis

Nine months (January, February, March, May, June, August, September, October, November) they had positive values which represent rising trend, two months (April, and December) represent

falling trend, July showed an invariable trend as shown in (figure 4). The Sen's slope was calculated for each month separately, and the months of January, February, March, May, June, August, September, October, November, show an increase in the declivity, compared to April and December which showed a decrease trend. In July alone, it showed no change in the magnitude of Sen's slope. The driest month was November, recorded in 2011, with a minimum of 0.80 mm, and the maximum value was recorded in 2005, August, with a maximum of 228 mm.

Eleven months (January, February, March, May, June, July, August, September, October, November and December) show positive values for Mann-Kendall Z statistics, which shows an upward trend, while only April shows negative values, representing a decreasing trend, as shown in (figure 5). The estimated Sen's Slope (Q), presents increasing variation of magnitude for January, February, March, May, June, August, September, October and November. July and December indicate non-significant increasing trend and April show significant decreasing value of Q statistics exemplified in (figure 6).

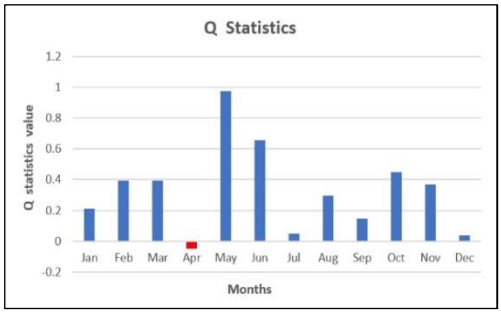

Figure 5. Z-Statistics for Monthly Trend Analysis

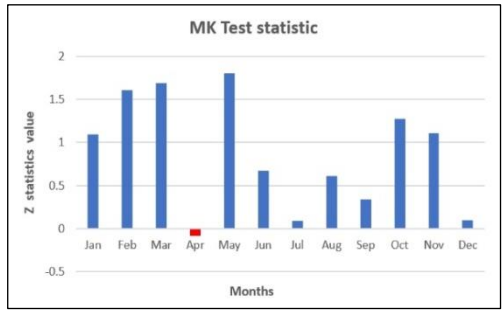

Figure 6. Q-Statistics for Monthly Trend Analysis

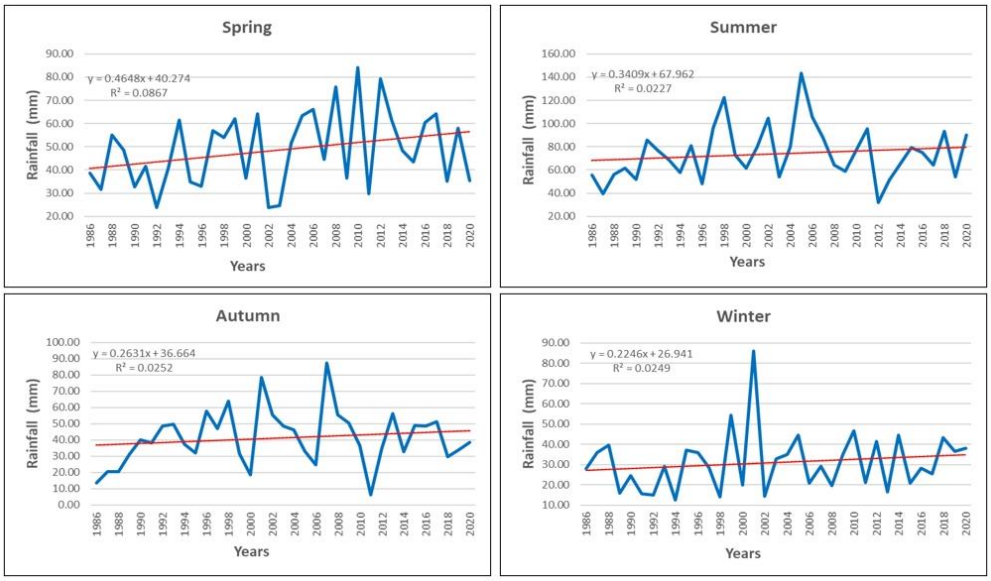

Figure 7. Seasonal Variation of Rainfall

2. Seasonally rainfall trend analysis - to analyze seasonal trends, monthly precipitation data were grouped into four seasons: spring (March-April-May), summer (June-July-August), autumn (September-October-November), winter (December-January-February).

This was done by studying the seasonal values of the non-parametric indices Z and Q-Statistics, and the result of the analysis are presented in (figure 7). The statistics for all four seasons: spring, summer, autumn and winter are positive, which showed a significant trend of increasing precipitation values in the studied interval. In the non-parametric Mann-Kendall test, the precipitation trend for all four seasons describes an upward trend, more pronounced for spring and less pronounced, but almost symmetrical for the other seasons. Seasonal distribution of mean rainfall in study area shown in (figure 8). The average most rainfall occurs during the summer season which contributes 74.40 % to the annual rainfall totals.

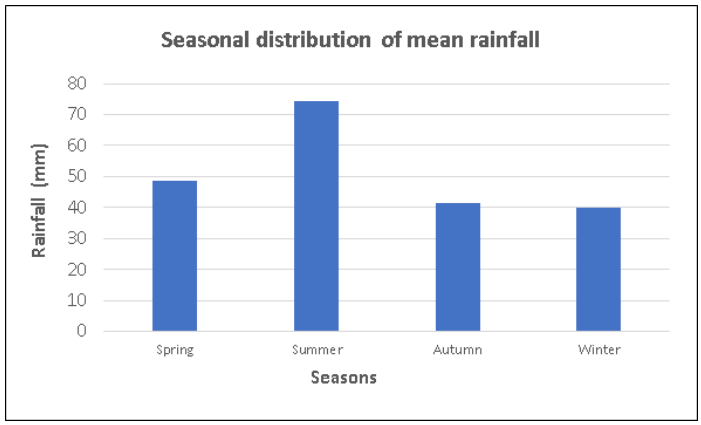

Figure 8. Seasonal distribution of mean rainfall

3. Annual rainfall trend analysis - rainfall data records were analysed for 1986-2020 period, (figure 9) shows the variation of the total amount of precipitation over the period of 35 years and shows a maximum precipitation of 852.60 mm in 2005 and a minimum of precipitation in 1987 of 384.00 mm. The highest annual average precipitation was measured in 2001 and had the value of 77.18 mm, while the lowest annual average precipitation was in 1987, with 32.00 mm as shown in (figure 10).

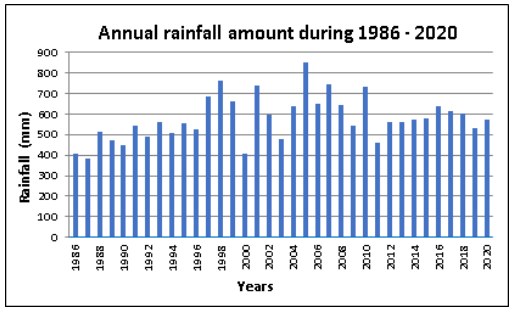

Figure 9. Annual rainfall amount during 1986-2020

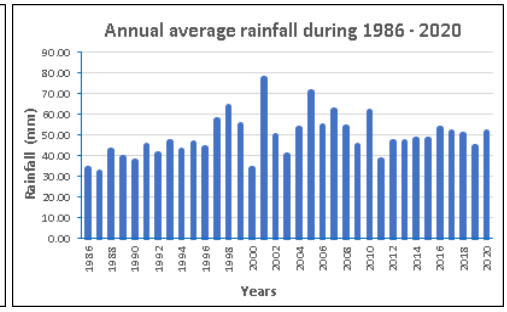

Figure 10. Annual average rainfall during 1986-2020

The trend of the total annual precipitation data of 35 years is represented in (figure 11). The positive value of the Mann-Kendall (Z) and Sen's Slope (Q) statistics indicates an upward trend of the precipitation.

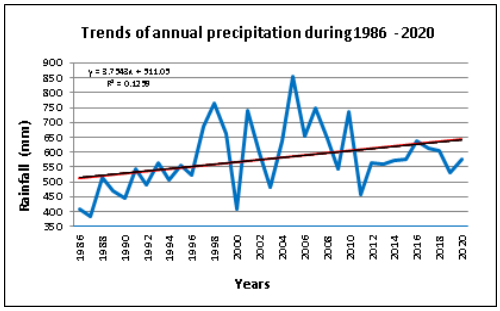

Figure 11. Trends of annual precipitation

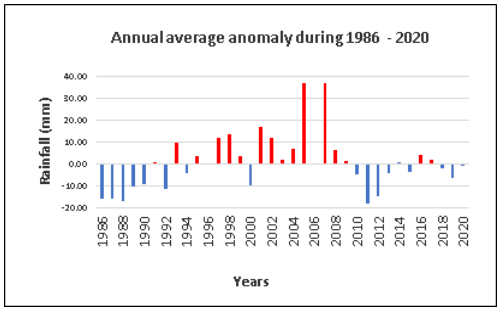

Figure 12. Annual average anomaly

Figure 12 above shows the precipitation deviations in the study area for the period 1986-2020. The results indicate a drier period of the interval, followed by a wet period with a maximum average in 2005 and 2007 of 36.80 mm, followed again by a drier period with a minimum average of -18.40 mm in 2011. Dry periods they alternated with wet periods almost after a cyclical pattern. The descriptive statistics of rainfall: standard deviation (δ), coefficient of variation (%), Mann-Kendal statistics (Z_c), significant (α), Sen's slope (Q), coefficients of skewness (S), coefficients of kurtosis (K), are presented in (table 1).

Table 1. Statistical Analysis of Rainfall data along with Mann-Kendall Trend and Sen's Slope magnitude (Data source: ANM, 2021)

Time Series	Mean (mm)	Median (mm)	Min (mm)	Max (mm)	S.D. (δ)	C.V. (%)	M.K. (Z_c)	Signific. (α)	Sen's Slope (Q)	Skewness (S)	Kurtosis (K)
January	26.6	23.5	5.8	65.6	14	53	1.094		0.211	0.884	0.358
February	30.4	24.9	3.4	207	33	110	1.605		0.391	4.645	24.606
March	30.6	25.8	5.8	76.1	18	63	1.690	+	0.393	0.879	- 0.104
April	46.5	45.7	5.3	102.8	26	58	- 0.085		-0.048	0.326	- 0.837
May	68.7	63.0	18.2	159.2	30	44	1.804	+	0.976	0.841	0.989
June	89.8	82.7	30.8	197.9	40	46	0.668		0.656	0.729	0.021
July	70.4	74.2	22.3	131.4	31	45	0.085		0.050	0.111	- 0.979
August	63.0	53.9	15.2	227.7	44	69	0.611		0.297	1.699	4.221
September	50.1	46.2	2.8	127.3	30	62	0.341		0.145	0.924	1.012
October	41.8	38.2	2.5	93.2	24	58	1.278		0.447	0.487	- 0.495
November	32.2	32.6	0.8	72.2	16	50	1.108		0.368	0.213	- 0.229
December	35.5	32.2	7.9	86.1	23	54	0.099		0.038	0.544	- 0.127
Spring (M-A-M)	48.6	30.6	5.3	159.2	16	12	1.662	+	0.423	0.322	- 0.716
Summer (J-J-A)	74.4	70.4	15.2	227.7	23	9	1.065		0.393	0.864	1.208
Autumn (S-O-N)	41.4	41.8	0.8	127.3	16	17	1.051		0.247	0.459	0.863
Winter (D-J-F)	30.9	30.4	3.4	207	14	33	1.264		0.264	1.574	4.664
Annual	48.8	44.1	0.8	227	10	18	18	*	0.367	0.807	0.969

Note: SD=Standard Deviation, CV=Coefficient of variation, MK=Mann-Kendal statistics, *Signific=Significance; (+)= 0.1 significance level having 99 % significance interval, (*)= significance level 0.05 having 95 % significance interval*

CONCLUSION

In this study rainfall data from 1986-2020 where used to identify monthly, seasonally and annually trends in Târgu Mureș. At the end of the analysis, the following observations are noted: the monthly statistical result of the study indicates eleven months (January, February, March, May, June, July, August, September, October, November and December) that show an increasing trend in the variation of precipitation. April is the only one that showed a decreasing trend. The monthly trend of precipitation in the period 1986-2020 is an increasing one, with a monthly maximum of 228 mm and a minimum of 0.8 mm, represented in table; the series of statistical data

for the four seasons, indicates a significant positive trend of increasing the precipitation values in the studied interval. From the analysis of the series of annual data on precipitation, over the period of 35 years, shows a significant positive trend represented, by the positive value of Z and Q-Statistics, and a high value of R^2.

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FLOOD VULNERABILITY AND INCIDENCE IN IBAJI LOCAL GOVERNMENT AREA OF KOGI STATE, NIGERIA

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Abstract: This study is aimed at assessing flood vulnerability of Ibaji LGA of Kogi state, Nigeria. The factors considered in this research include socioeconomic activities, rainfall characteristics, land-use pattern, drainage density, slope, soil, and elevation. The Analytical Hierarchy Process (AHP) was used to establish the relationship between flood causative factors and their role in the occurrence as well as the vulnerability of communities within the study area. Each factor was assigned weight depending on the perceived role in the occurrence of flood within the study area. The factors considered in this research and their cumulative weights are rainfall (24.4%), Drainage Density (17.9%), Slope (18.5%), Elevation (17.4%), Land Use (11.8%) and soil (9.9%). The results of this study suggest that no single factor is responsible for the occurrence of flood in the study area, a combination of the factors assessed are responsible for the occurrence of flood. The degree of susceptibility of communities to flood in the study area varies among communities dependent on the factors that predominate within the community.

Key words: drainage, disaster, environment, hazards

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INTRODUCTION

Floods are a natural phenomenon or occurrence in which dry lands are submerged with water. Flooding is a temporary condition of widespread submergence of dry lands from runoff of inland or tidal waters or from unusual and rapid accumulation of runoff (Jeb and Aggarwal, 2008). Flooding is characterized by the accumulation of excess water which rises to overflow land which is not normally inundated (Mukhopadhyay, 2010). Flood is defined as the flow of water above a channels carrying capacity (Olajuyigbe et al., 2012).

According to Disaster Management Support Group (DMSG, 2001), floods are among the most devastating hazards, resulting in significant economic and social losses. In the last three

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decades, flood impacts have increased significantly, resulting in loss of lives and properties in Nigeria. There has been an increased frequency of floods occurrence, as a result, thousands of people have been affected by flood with their agricultural field and residential areas affected (United Nation 2003). Globally, flood disasters are said to have devastating effect on economic development, health, agriculture, social and human life (Marcellinus and Joseph, 2015).

The increasing number of flood incidences coupled with the constrained sustainable development caused by flood in Nigeria suggests that much of what is known regarding floods is deficient on remedies (World Bank, 2013). Flooding occurs in Nigeria every year and potential risk exists in the low lying flood plains of River Niger, human encroachment into areas liable to flood is growing rapidly due to the huge natural resources and agricultural potentials found in such areas (Jeb and Aggarwal, 2008).

Flood affects various aspects of man's environment; this includes his economic activities, settlements and lifestyle. Several threats to livelihoods ranging from the physical threats to social and economic threats exist. Flooding also causes land pollution, epidemics and infections. A lot of emotional and social costs have been intricate to flooded regions. These costs include: the loss of personal valuables, displacement from homes, and the insecurity caused by the experience. Furthermore, in Ibaji Local Government Area of Kogi State, flooding has made the people to suffer untold hardships resulting from economic and social losses.

The aim of this study is two folds. First, it is to assess flood vulnerability and incidence in Ibaji Local Government Area of Kogi State, Nigeria; and second, it focuses on examining the factors responsible for flood occurrence in the study area with a view to proffer appropriate solution for future adherence.

Flood incidence of varying magnitude occurs yearly along River Niger which is as a result of the runoff on River Niger during the peak of the rainy season resulting in loss of valuable properties, destruction of infrastructure, livestock and crops. It is therefore important to assess the extent of vulnerability of communities that lies within this basin using Geographic Information System (GIS) and remote sensing as tools for this analysis (Herman, 2010).

The Study Area

Ibaji Local Government Area (LGA) is located south of Kogi state. The area has a land mass of about 1,377 square kilometres. It lies between Latitude: 06°52'00"N and 06°87'00"N of the equator, and Longitude 06°48'00"E and 06°80'00"E of Greenwich meridian (Kosema, 2007; (Figures 1 and 2). Ibaji LGA has a tropical climate that has two seasons namely wet and dry seasons. The wet season starts from the month of April and ends in October, while the dry season starts from November and continues till March. The soils are characterized by a sandy texture overlying a weakly structured clay accumulation (Atoyebi, 2013). The flood plains (of the Rivers Niger and Benue valleys) in Ibaji are made up of hydromorphic soils that contain mixture of coarse alluvial and colluvial deposits (Oriola, 1994).

Conceptual Framework and Literature Review

According to UNISDR 2009, there is no single approach to disaster management. There are a number of methodologies and strategies adopted in other to achieve environmental sustainability. To arrive at these strategies, there is a need to thoroughly consider the factors responsible for flood within the local context. Identification of flood hazard goes beyond identifying treats and the extent of damage caused by floods but also identifying the factors responsible for the increasing flood incidence, the vulnerability of the community and the strategies to mitigate the adverse effects of the flood.

Floods are hydrological phenomena that result from a complex sequence of natural events prediction of such events is possible only when there is an adequate understanding of causes of flood events in a basin. The frequency, duration and magnitude of floods are determined by several

factors. Flooding results from a number of factors among which are meteorological factors, geomorphic factors and anthropogenic factors (Ward, 1978).

Karmakar et al. (2010) define flood risk as the consequence of flood hazards, (the physical and statistical aspects of the actual flooding for example, the extent and depth of inundation) and the vulnerability (the exposure of people and assets to floods and the susceptibility of the elements). Flood risk is thus a combination of hazard (potential damage), vulnerability (probability of flooding occurrence) and impact of exposure.

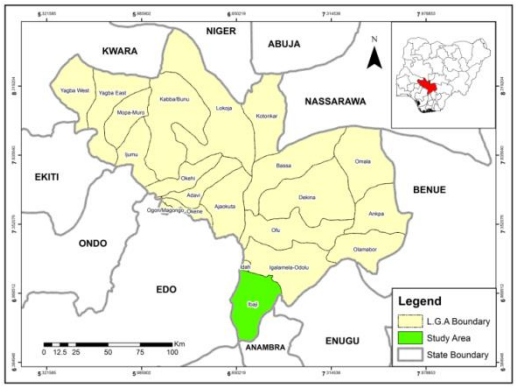

Figure 1. Map of Kogi State showing Ibaji LGA
Source: Ministry of Environment Kogi State

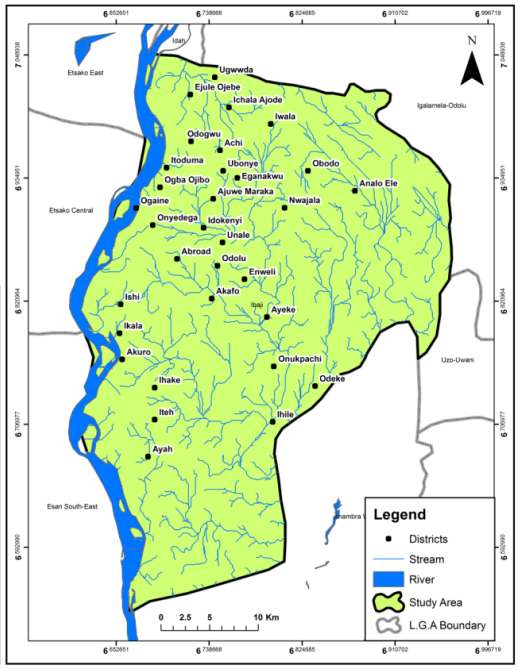

Figure 2. Map showing Drainage Pattern in Ibaji
Source: Ministry of Environment Kogi State

According to the United Nations Office of Disaster Risk Reduction (UNISDR), risk is the likelihood of an event and its consequences (UNISDR, 2009). Flood risk is the product of the flood hazards, the vulnerability and the exposure (UNISDR, 2009). Flood risk basically revolves around two main elements; hazard and vulnerability (Ward et al., 2011; De Moel et al., 2012; Kreibich et al., 2010). On the other hand, for effective flood riak analysis, it is important to understand the degree of susceptibility of elements to flood hazards. While the concept of vulnerability is still been studied, it remains an important element in risk analysis and disaster control measures (Birkmann, 2006; Herman, 2009).

Hazard is the susceptibility of a place to any human and physical risk. In this case, we look at flood hazard as all the areas that are at risk of flood occurrence. The concept of flood hazard would be more appropriate to include localized flooding due to inadequate drainage, flooding from small streams, flooding in urban areas located on major river banks and urban areas experiencing coastal flooding (Benjamin, 2008).

Flood Vulnerability and Resilience

The term vulnerability refers to the tendency of exposed elements such as humans, their livelihoods, and assets when affected by hazards to suffer adverse effects. It is often determined by the physical, social, economic, environmental conditions and circumstances of a community or

system that make them susceptible to the damaging effects of a hazard (UNISDR, 2009). Therefore, everyone may be exposed to a hazard in a certain area, but some social groups may respond better to emergencies (Steinführer et al., 2008).

Vulnerability and its various dimensions of measurements (physical, social, environmental and economic) are dynamic, with change in time and space and depend on the level of exposures and the potential hazards. With the issue of climate change in view, extreme hazards events and the continuous growing exposures through urbanization are expected to increase the level of vulnerability in many cities on the world (IPCC, 2007).

Direct measurement of vulnerability is not likely, an indicator is used to quantify the condition of a system as an essential characteristic (Balica et al., 2012). Gomez (2001) noted that indicators should focus on quantifiable and understandable small aspects of a system and give people a sense of a bigger picture. Indicators are input data that can be used to decide flood vulnerability of a region. Considering specific indicators can help to assess the systems vulnerability, which can lead to identifying actions needed to decrease the vulnerability (Balica et al., 2012). Societies are vulnerable to floods based on three main factors: exposure, susceptibility and resilience, which are explained below. In this study, it has been assumed that, the study area is vulnerable to flood as a result of these three factors.

Valuables such as infrastructure, goods, cultural heritage, and mostly people are exposed to flood as they are present at the location where the floods occurred. This factor extends to humans and their properties, which are positioned in flood risk areas. Messner and Meyer (2005) explained that the indicators of exposure supply certain facts about hazardous effect on the present elements at risk. Exposure is a necessary, but not a sufficient determinant of risk. Therefore, it is possible to be exposed to a hazard but not be vulnerable. For example, a person can live in a floodplain but have sufficient means to modify the building structure to mitigate potential losses (Cardona et al., 2012). Thus, the management of flood risk calls for a better understanding of vulnerability.

There are other concepts relating flood and its consequences. The concept of susceptibility explains how a system can be harmed potentially and the existing abilities to diminish the level of the damage. Smit and Wandel (2006) established that the vulnerability of any system is a function of the exposure and the susceptibility of that system to any hazardous event. Balica et al. (2009) discussed that susceptibility is mostly related to social aspect of flood damage and the system characteristics such as awareness and preparedness of people about the risk they live with. This study views susceptibility as elements exposed within a system and the probability of these elements harmed when a flood occurs i.e. elements that are exposed at the time of flood and the likelihood of these elements been affected.

De Bruijn (2005) expressed resilience as the system capability to resume from floods. Resilience can also be defined as the system capacity to re-achieve its balance after a reflex into a perturbation. Galderisi et al. (2005) argued that the resilience is a society or a system capacity to adapt itself to any change by resisting and modifying itself, to maintain or gain an acceptable level of structure and functioning. Pelling (2003) also explained this factor as any system or community ability to adjust to threats or mitigate the hazardous event damage.

The term resilience expands on vulnerability and may be viewed as the qualities the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management (UNISDR, 2009). Gallopin (2006) points out that while vulnerability can be seen as a fairly static concept, resilience is dynamic in nature. It contains uncertain feedback loops and interaction effects, changing with internal conditions, external forces, and with the community's ability to respond to floods. In this study, resilience is defined as the ability of a system to cope or adapt to the effect of floods.

Arguably, the rate of flood occurrence in recent times has been unprecedented. With 70 million people globally exposed to flooding every year, and more than 800 million living in flood

prone areas (Peduzzi et al., 2009), climate change with more frequent and severe rainfall events, sea level rise, rapid population growth and urbanization, the rate of development on floodplains, the level of awareness of flood risk and the ineffectiveness of efforts towards tackling flooding in many places are factors of concern (Raaijmakers et al., 2008).

In many African countries like Nigeria, flooding has impoverished hundreds of thousands of people through displacement from homes and loss of tangible properties (Action Aid, 2006). In Nigeria, flooding and means of addressing its challenges are critical issues (Obeta, 2014). Evidently, the country has experienced devastating floods which has affected millions of people and caused fiscal losses amounting to billions of US dollars (NEMA 2013). These hazards were generally linked to poor urban planning and climate change especially in increased frequency and intensity of rainfall (Action Aid, 2006; Adeloye 2011).

Quite a number of researches have been carried out in Nigeria in assessing the exposures and vulnerability of the Nigerian settlements to flooding. Onwuteaka (2014) applied GIS and digital elevation model to simulate extent of flooding exposure in the coastal areas and the vulnerability to sea level rise. At the varying sea elevation, the expected surface areas capable of being impacted by flood were identified for the modeled flooding from the sea level rise.

Nwilo et al. (2012) assessed the physical vulnerability of some communities in Adamawa State, Northern part of Nigeria by modeling the flood inundation level using Remote sensing and Cellular Automaton Evolutionary Slope and River (CAESAR) software. The output of the model shows the water heights and possible settlements at risk within the flood prone areas of the inundation. Hence, an attempt to examine the physical vulnerability of the communities was further analyzed by Mayomi et al. (2013) using Geographic Information Systems (GIS). Their study made use of Global Positional Systems (GPS) measurement to map all the settlements and integrated with the terrain model of the area to determine those areas that are within the flood plain.

Vulnerability of some coastal communities in Lagos was examined by Adelekan (2009) using both quantitative and qualitative methods by analyzing data acquired from questionnaires, interviews and focus group discussion. The study also analyzed the impacts of and vulnerability to flooding within the coastal communities based on their level of income. The results asserted that most affected people in the area are the non-employed and less income people.

In an attempt to assess the vulnerability of the exposures to flood within Ala river basin in Nigeria, Vulnerability of the affected villages and towns during 2012 flood was mapped by Ojigi et al. (2013) using remote sensing and GIS. Flood extent and the vulnerable cities and villages were identified using buffering techniques. A non-parametric approach to delineate floodplain in

Gwagwalada town was adopted by Oyatayo et al. (2014) using topographic data, quick bird imagery and GPS data. Level of vulnerability of the town was determined and classified by the elevation in meter above sea level (m.a.s.l), which revealed a gradual build-up into the floodplain area of the town.

The study carried out by Enaruvbe and Yesuf (2012) in Delta State, as part of flood risk analysis following the devastating 2012 flood event, made use of GIS and ASTER DEM to delineate the floodplain based on field survey in the affected areas. Flood affected and vulnerable zones were mapped using buffering tools in GIS environment. Geospatial techniques were applied by Nkeki et al. (2013) to map vulnerable zones within Niger-Benue basin. MODIS time series image, integrated with the digital elevation model were used to extract the flood plain within the basin. Various cities, states and communities that are vulnerable to flood hazards were mapped using population data; this was integrated with the flood hazards map to delineate the population at risk of flood disaster in the basin using overlay analysis.

In Samagba area of Bayelsa State, Mmom and Akpi (2004) determined the vulnerability of the communities to flooding using elevation and remote sensing image data. Analytical Hierarchical Process (AHP) was adopted to assign weights to various contributory factors such as elevation, land use, rivers and roads to determine the most vulnerable zones within the area; these were integrated using re-classification and overlay analysis in GIS to determine the flood affected areas.

Analysis done by Ejenma et al. (2014) over River Kaduna utilized DEM to delineate flow accumulation of the rivers; this was assumed to be the floodplain and classified to various degrees of severity and overlaid on Lands at ETM to delineate vulnerable areas within the area.

In contrast to the qualitative physical vulnerability studies by the earlier authors, Ajibade et al. (2013) examined the socio-economic impacts of flash flood on women in Nigeria using Lagos State as a case study. The authors utilized both questionnaires and focused group survey to understand the impacts of flood on lives, livelihoods and health. Their results revealed a non-gender biased impacts, however, a more severe impacts recorded within low-income neighborhood than those in high income neighborhood.

A post July, 2007 flood survey carried out by Adelekan (2011) to examine the vulnerability of the urban dwellers in Abeokuta, Ogun State in terms of their awareness and preparation for such events. The study, which made use of responses of the administered questionnaires showed a general lack of early warning systems in the study area and affirmed the high risk to flooding due to lack of pre-flood information and preparation.

Vulnerable and exposed population to flooding in River Ogun, Ogun-State was analyzed by Sobowale and Oyedepo (2013) by modelling rain-runoff to generate flood inundation model. The study identified over 1.4 million inhabitants that were at risk in the area, with suggested possible adaptation measures for future occurrences.

Studies on exposure and vulnerability to flooding in Nigeria is still at infant stage and would require more advanced studies to bridge the gap that exists, especially when compared with the developed countries. This research focuses on considering the factors responsible for flood incidence, the frequency of flood incidence in Ibaji LGA and the vulnerability of the study area. Resilience and coping capacity is dependent on the awareness about the disaster.

METHODS OF DATA COLLECTION

The methods used for data collection in this research included field observation, questionnaire administration and collection of secondary data from relevant agencies. Satellite imagery was also obtained from the United States Geological Survey (USGS) this was used to generate the land-use map of the study area Rainfall data was sourced from Nigeria Meteorological Agency (NIMET) Kogi State; this was used to ascertain the mean monthly rainfall distribution pattern in the study area over a period of 15 years. Rainfall data obtained from the Center for Hydrometeorology and Remote Sensing was used to generate rainfall distribution map of Ibaji LGA. The following applications were accessed to give wide understanding of the magnitudes of flooding in the study area.

Image Processing: Satellite imagery of Ibaji LGA was enhanced to improve the visualization of features, geometric and radiometric corrections were Orto-rectified. The images obtained were in different layers and band 4, 3, 2 was layer stacked and subset the area of interest using ENVI 5.1 Software.

Generation of Land Use Map: Landsat 7 Imagery of Ibaji LGA (30m) was orto-rectified and there was no need for any geometric and radiometric corrections. The area of interest was clipped out of the imagery. Supervised classification was then carried out into five classes (water body, vegetation, farmland, bare land and built-up area). This is to enable the researcher ascertain the land use pattern in the area and the areas that are susceptible to flood occurrence as well as how the land use pattern influences flood occurrence in the study area.

Generation of Slope and Elevation Maps: The Digital Elevation Model (DEM) of Ibaji LGA was created from Digital Elevation Model (DEM) of ArcGIS. This was used to produce elevation map and slope map of Ibaji LGA using spatial analysis tools on ArcGIS. This is to determine the influence of slope and elevation in the occurrence of flood within the study area.

Generation of Drainage Density Map: The drainage density Map of Ibaji Local Government Area was generated from the Shuttle Radar Topographic mission (SRTM). Ibaji LGA was clipped

out of Shuttle Radar Topography Mission (30m) of SRTM Nigeria 2014. The drainage density was analyzed using the Hydrology Tool box of Spatial Analyst Tools on ArcGIS software..

Generation of Soil Map: The soil map of Nigeria was scanned and imported into ArcGIS environment where it was geo-referenced using UTM Zone 32 North with datum WGS 1984. Ibaji Local Government Area was subset from the soil map of Nigeria and the soil types of Ibaji LGA were digitized.

Generation of Rainfall Map: The mean annual rainfall for 2003 to 2018 of Ibaji Local Government Area was used to determine the pattern of rainfall. Rainfall data of Kogi State was derived from the Center for Hydrometeorology and Remote Sensing as a raster file, with a resolution of 4km x 4km. points data where then created in ArcGIS with cell width and height of 4km the values each cell in rainfall data downloaded was extracted using the extract multi values to point tool in Spatial Analyst tool box. Then the extracted rainfall data was interpolated using the Spline Analyst tool box.

Steps Used in Deriving Criterion Weight Using AHP: The relationship between the six causative thematic map and their attributes were derived using Analytic Hierarchy Process (AHP) to determine the most potent factor responsible for floods in Ibaji LGA of Kogi State. The methodology used for deriving their weights involved the following steps as developed by Saaty, 1980: Step 1: Defining the problem clearly and decomposing it into various thematic layers containing the different features/classes of the individual themes so that they form a network of the model (Abah, 2014). Step 2: Generating Pair-wise comparison matrices, the relative important values are determined with Saaty's 1-9 scale (Table 3.2) where a score of 1 represents equal importance between the two attributes, and a score of 9 indicates the extreme importance of an attribute compared to the other one (Abah, 2014).

RESULTS AND DISCUSSION

Incidence of flood in Ibaji LGA

There is an increasing treat to lives and properties as a result of flood in many urban and rural communities within Nigeria (Olanrewaju and Fadiro, 2003). Prior to 2012, flood incidence was not a subject of major concern in Ibaji LGA. The unprecedented flood incidence in 2012 ravaged Ibaji LGA and other parts of Kogi State destroying farmlands, homes and villages (Jacob, 2014). According to KOSEMA, Flood incidence in Ibaji occurs mainly in the rainy season and due to the high intensity of prolonged rainfall. The communities that are mostly affected by flood in the study area are in close proximity with rivers and lie within low elevation in the study area.

Factors Influencing Floods in Ibaji Local Government Area

The factors considered in this research were rainfall, elevation, slope, soil, drainage density and land cover. The classes of the factors were further weighed using Saaty's scale of pair-wise comparison and reclassified using reclass tool on ArcGIS to identify the major factors influencing floods. The combined weights for all the factors are shown in Table 1.

Table 1. Combined Weight for Flood Causative Factors

	Rainfall	Drainage Density	Slope	Elevation	LULC	Soil	Weight (%)
Rainfall	1	2	2	1	2	2	24.4
Drainage Density	0.5	1	2	1	1	2	17.9
Slope	0.5	0.5	1	2	3	1	18.5
Elevation	1	1	0.5	1	2	2	17.4
LULC	0.5	1	0.33	0.5	1	2	11.8
Soil	0.5	0.5	1	0.5	0.5	1	9.9

Consistency Ratio CR: 0.076

Areas Vulnerable to Flood in Ibaji

This section used the results of the combined pair-wise comparison carried out for the six flood causative factors on Table 1 based on Saaty's Fundamental scale of pair-wise comparison and generated flood vulnerability map. To determine vulnerability level of communities, the factors weight from Analytical Hierarchy Process (AHP) were overlaid using the weighted sum in ArcGIS spatial tool to produce the flood vulnerability map of five levels (very low vulnerable areas, low vulnerable areas, moderate vulnerable areas, high vulnerable areas and very high vulnerable areas) as presented on Figure 3.

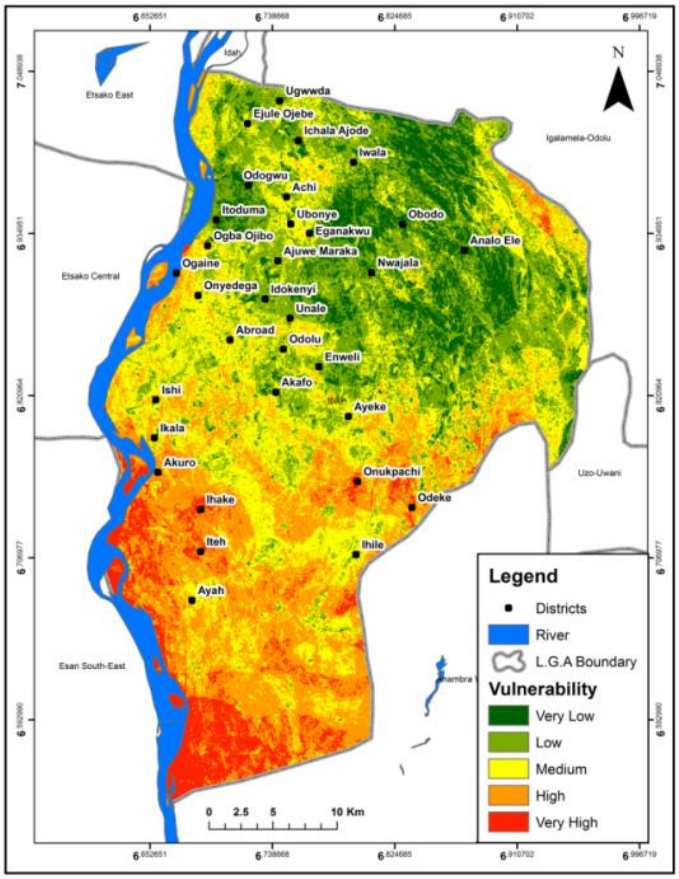

Figure 3. Flood Vulnerability Map of the Study Area

The results of the analysis carried out, showed that some communities (Odogwu, Obodo and Analo Ele) are found to be within the very high vulnerable areas which means that there is high tendency for those communities to be more liable to flooding than other communities. In the results some communities (Odolu, Ayeke and Unale) are also found within the high vulnerable areas which means that the possibility of those communities to be more liable to flooding is high than those within moderate, low and very low vulnerable areas. The communities that are within moderate vulnerable areas are; Ogba-Ojigbo and Onyedega while those within the low Vulnerable areas are; Odolu, Unale and Ayeke. The communities that are least vulnerable (very low vulnerable) are; Odogwu, Obodo, Analo Ele.

From this research, it was observed that most of the communities that are vulnerable are located close to bank of River Niger and are characterized with low elevation and slope. The

observation of this study affirms Isma'il and Iyortim (2013) that areas that lie beside a river may not be liable to flood if it is at a great height while areas that lie far away may experience floods if the intervening land is flat, gentle sloping or if the area lies in a depression.

CONCLUSIONS

The result of this study revealed that rainfall has the greatest effect on flood in Ibaji LGA, other factors such as elevation, slope, drainage density, Land Use / Land cover and soil are significant in the occurrence of flood in Ibaji LGA. The findings of this research also established that flood is more likely to occurs in areas where the effect of more than on factor is predominant for instance where there is high rainfall and at a low elevation and with a poor drainage is more likely to be flooded than areas that experience high rainfall and have a high elevation and is well drained. There is no single factor responsible for the occurrence of flooding. Flood is a product of the interplay of several factors which all vary in the level of impact they have in the occurrence of the phenomenon.

The extent of damage caused by floods is on the one hand dependent on the extent, depth and duration of flooding, and the velocities of flows in the flooded areas which are dependent on the factors examined in this research work (Rainfall, Slope, Elevation, Drainage, Soil and Land-Use). On the other hand it is dependent on the vulnerabilities of economic activities and communities. The huge socioeconomic effects of flood have a negative effect on the economy, agricultural activities, Health, Infrastructure and education of the communities affected. Displacement from one's home, loss of property, loss of livelihoods, decreased levels of security in the aftermath of floods and in temporary shelters, and disruption to business and social affairs are consequences of floods and these can cause lasting impact on the affected communities.

Based on the findings of this research work, measures to minimize the adverse effect of flood in the study area are suggested, as a result, the following recommendations are made.

1. A more comprehensive flood control and preventive measure paying particular attention to flood prone areas should be adopted and integrated in plans for States, Local Governments and Villages.

2. Existing flood plans and control measures should be reviewed to meet present realities and challenges.

3. Public enlightenment should be emphasized on the dangers associated practices that will affect the environment and create risk to individuals; and

4. Further studies on post flood assessment should be encouraged to understand the peculiarities of flood events.

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THE VERTICAL DISTRIBUTION OF THE ALLUVIAL CHEMO-FACIES OF BOUMERZOUG WADI, CONSTANTINE, NORTHEASTERN ALGERIA: PALEOENVEROMENTAL SIGNIFICANCE AND CLIMATE EVOLUTION

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Abstract: The authorities of Constantine city have been working on the redevelopment and calibration of the Rhumel and Boumerzoug wadis since 2015. The latter calebrage works caused great damage to the banks, thus affecting the Quaternary geological formations in place (alluvial terraces, flood plains). A multidisciplinary research project based on a geomorphological and sedimentological approach was quickly set up to create a scientific data base before their total destruction and loss of physical traces all along the wadis. The present study focuses on the sedimentological and geochemical analysis of the alluvial deposits of Boumerzoug wadi in order to describe the sediments, to reconstitute their nature, and to interpret both the climatic evolution and the paleo-environments of the region. Sedimentological and geochemical results confirm the succession of deposition cycles linked to progressive climate change.

Key words: Algeria, Boumerzoug wadi, alluvial deposits, geochemical facies, climate change

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INTRODUCTION

Alluvial deposits present an important archive of environmental changes through hydroclimatic cycles (Salvia-Castellvi et al., 2002). These sediments can record changes in paleo-water flow, which is an approximation of precipitation rates and climate (Salvia-Castellvi et al., 2002). Almost all the studies aimed at reconstructing the Quaternary paleoclimates in the Maghreb from geological formations were based on morphological, sedimentological and/or pedological analyses (Wengler et al., 1992). Constantine region is situated between latitude 36° 23' and longitude 7° 35' in the middle of the Eastern Algeria, 245 km far from the Algerian-Tunisian borders, Constantine considered the third largest city in Algeria.

The main wadis of the Constantine basin are part of a geographical context that clearly presents contrasting aspects from upstream to downstream: the flat and bare reliefs and rather loose river system of the high plains are followed by the low Tellian Atlas hills and deep valleys, which are extending to the north by mountainous massifs affected by a high drainage density (Keddari et al., 2019; Mébarki, 1984). This work is essentially based on a two-steps method, careful field observations, and granulometric and geochemical analysis of sediments in laboratory. The aim of this approach is to describe the sediments, identify their geochemistry and reconstitute the nature of the alluvium linked essentially to the Boumerzoug wadi's activity, also providing important information on the climate and its evolution. Then, the main objective of this work is to clarify the importance of the contribution of river deposition studies in highlighting hydrodynamic variations during sedimentation and their climatic significance.

STUDY AREA

The studied outcropping sections of Boumerzoug wadi (figure 1) are located in the central part of the high Constantinian plains, a well-individualized mountainous ensemble that presents a fragmented morphology with vast plains covered by Plio-Quaternary deposits (Rabahi, 2008).

Boumerzoug wadi, a tributary of Rhumel wadi, located south of Constantine, drains a watershed of 1,868 km^2, appearing in a collapse basin shape, dominated by isolated and abrupt horst reliefs. The 50 km long Boumerzoug wadi receives several tributaries on its path, the most important of which is the Hamimime wadi (Bourenane and Bouhadad, 2021; figure 1). Morphologically, these sections are located in the eastern plains of the Tellian Atlas, whose altitude varies between 500 and 800 m asl and it is characterized by a contrasting relief flanked by deep gorges, plateaus and hills (figure 2c; Rabahi, 2008).

Downstream from Boumerzoug wadi, the valley is cut into a raised calcareous relief, forming gorges more than 150 m high.

The highest slopes (over 30%) are mainly distributed close to the watercourses of which they form the banks. The lowest slopes (0 to 10%) represent a significant proportion of the morphology of the region (figure 2d). They essentially correspond to the alluvial terraces of the Boumerzoug wadi and its tributaries.

The downstream course of Boumerzoug wadi is characterized by the development of meanders just at the entrance to Constantine town. The widening of the valley, where the terraces and the major riverbed take a large extension, makes the sprawl of the flood in the alluvial plain more spectacular (Bougdal, 2007; figure 3). The developed meanders reveal an escarpment on the concave bank, which takes the form of a long, steep slope of several dozen of meters.

The lobe of the convex bank is highly developed and reveals different beds whose limits are materialized by the presence of slopes of the metric order (figure 2b).

From a hydrographic and climatic point of view, the plains are dotted with numerous wadis (figure 1, figure 2e), the majority of which converges towards the Rhumel wadi, the most important hydrographic element of the Constantine region.

The Rhumel wadi crosses the high plains of Constantine region following a NE-SW orientation until its confluence with the Boumerzoug wadi, then it flows through the gorges across the Rock of Constantine, NW-SE oriented (Rabahi, 2008; Farah, 1991). Two main climates types prevail in the Constantine region (Côte, 1974). The northwestern region is characterized by a subhumid climate with mild winters, dry and hot summers, while the southwestern one shows a semi-arid climate with cold winters and dry, hot summers (Côte, 1974). The combination of precipitation and temperatures helps to define bioclimatic domains. The climate of the study area is of the semi-arid type (300-350 < P < 550-600 mm). Is characterized by alternating dry seasons (June to September) and wet seasons (October to April), with a heat of 25-45 °C in summer and a cold of 0-12 °C in winter (Mébarki, 1984).

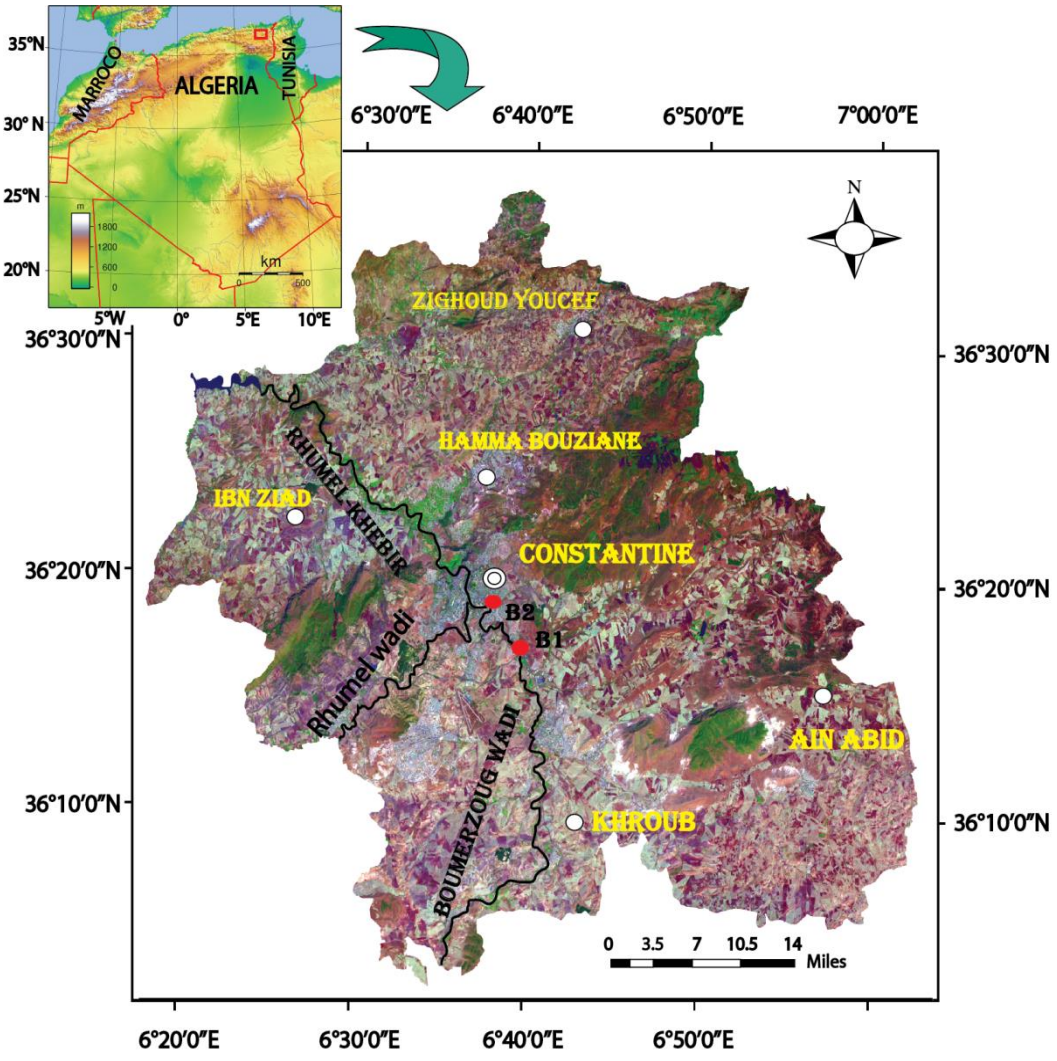

Figure 1. Photo map of the study area location (B1; section 1, B2 section 2)
(Source: Landsat Image)

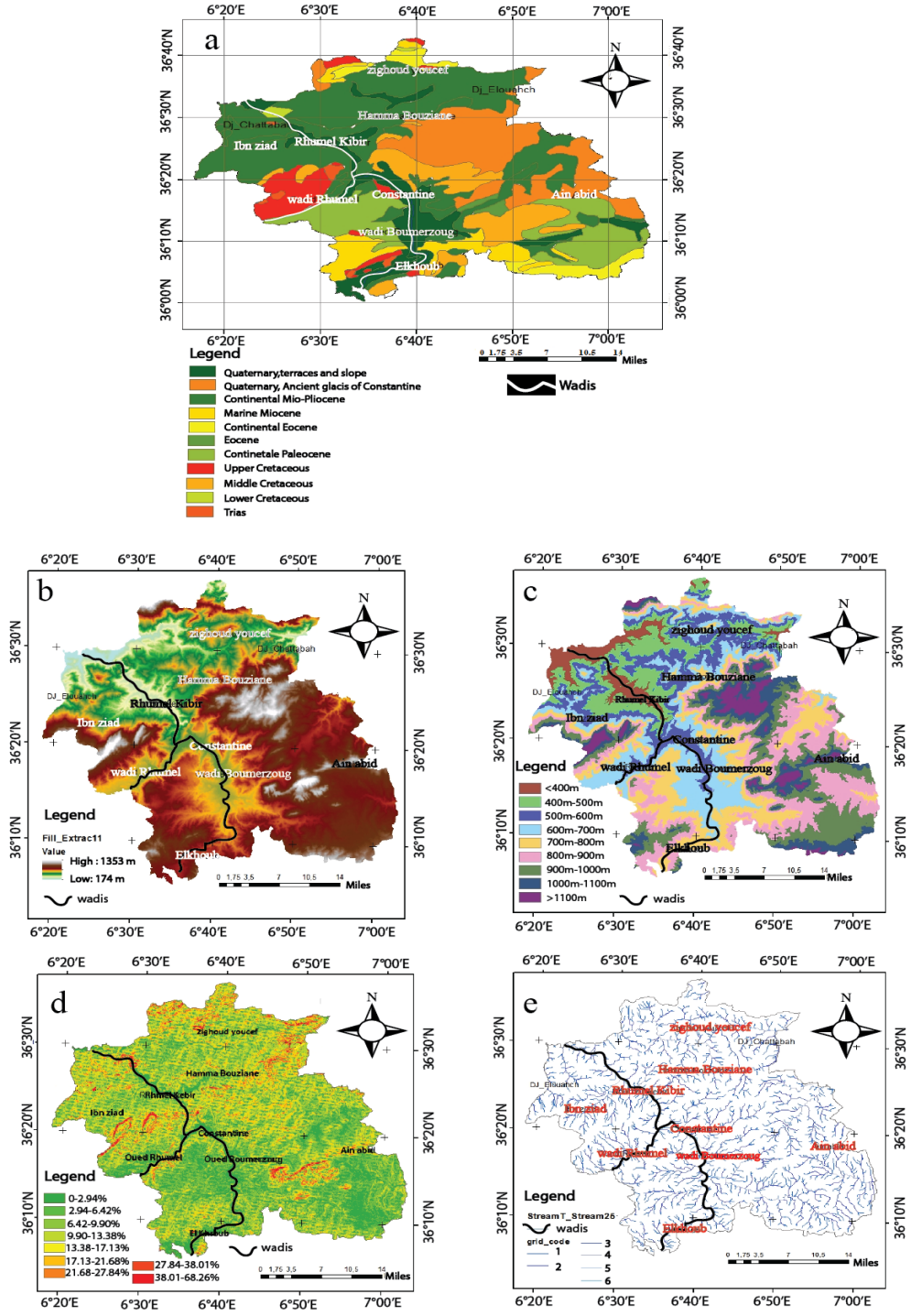

Figure 2. a) Geological map of the Constantine region1/200000, b) Digital terrain model, c) Hierarchy of the hydrographic network, d) Slope map, e) Hypsometric map
(Source: figure 2a; Villa, 1978; figure 2b, 2c, 2d, 2e; Noureddine Rabahi)

Figure 3. Morphology of the alluvial plain of Boumerzoug wadi with the different beds (a, b, c: undeveloped section of Boumerzoug wadi; d, e, f: developed section of Boumerzoug wadi)
(Source: Noureddine RABAHI)

GEOLOGICAL SETTING

To give a litho-stratigraphic overview of the different formations, and to specify their spatial distribution, the studied sections and their surrounding areas are made up of soil ranging from the Cretaceous to the Quaternary (figure 2a). The stratigraphic description concerns only the outcropping formations in the Constantine Basin (Rabahi, 2008; Farah, 1991).

According to the geological map of Constantine at 1/20000 (figure 2a), the studied section could be schematically subdivided into the following six domains.

1) The Neritic Constantine formation (Lower to Middle Cretaceous) corresponds to a succession of karstic limestone banks, found in the north-central sector of the study area.

2) The Tellian formations composed by grey, greenish marls, which may present inclusions ("young balls") related to the end of the Cretaceous period. They are well developed on the right bank of the Wadi Rhumel; their contact with the underlying formations corresponds to an erosion surface, preceding the continental deposits.

3) The Massylian flysch (Aptian–Albian age) recognized south-east of Constantine and on the left bank of the Boumerzoug wadi, are made up of alternating micro-breccia limestones and marly pelites.

4) The Miocene formations consist of clays, conglomerates, breccia, gypsum marls, pebble marls, and lacustrine limestones also, which correspond to continental deposits deposited in a subsident basin. Given their deposition method, it is hard to establish a stratigraphy, which changes from one place to another, as well as the lateral continuity of the levels, and their geographical extension does not exceed a few hundred meters.

5) The Pliocene formations correspond to the lacustrine limestones that form the wooded hills of the Djebel Hdj Baba south-west of Constantine by their sandy-conglomerate base and their reduced thickness.

6) Quaternary formations are represented by coarse conglomerates and lacustrine limestones and alluvial deposits. In particular, Ancient Quaternary is mainly represented by the lacustrine limestone and the alluvial terraces of the Rhummel and Boumerzoug wadis. The other formations correspond to heterogeneous, thin, predominantly clayey slope deposits. Finally, the recent Quaternary is represented by three stepped alluvial terraces, recognized on both banks of the Rhummel and Boumerzoug wadis. It is silty, finely sandy and sandy with heterogeneous, rolled pebbles.

MATERIALS AND METHODS

After a field prospecting along Boumerzoug wadi, between the locality of Ouled Rahmoune and the confluence of Boumerzoug wadi with Rhumel wadi, two sections B1 and B2 were chosen (figure 1). For each level, the description of each layer, its thickness, limits of deposition, color variations, petrographic nature, texture, granulometry, gradation, and sedimentary features are essential before each sampling. The studied samples were collected and placed in plastic bags, then transported to the laboratory. After removal of the coarse fraction, granulometry study focuses on washing the sediment with the 2 mm sieve to separate the sandy fractions (2 mm > 0.063 mm) and the 0.063 mm sieve to separate the silt-clay fractions (0.002 mm < 0.063 mm) (Miskovsky, 2002). Fine granulometry was performed by sedimentation analysis using Anderson's pipette to highlight the different silty fractions (0.004 mm > Ø > 0.063 mm) and clay fraction (< 0.002 mm). Geochemical analyses of the following soil parameters, pH (according to AFNOR NF T90-008), Electrical Conductivity (EC) (Rodier et al., 2009), organic matter (OM) (AFNOR XP P 94- 047), carbonates ($CaCO_3$) (AFNOR NF ISO 10693), were performed at the Agronomic Sciences Laboratory (University of Batna 1, Algeria) and Civil Engineering Laboratory (University of Batna 2, Algeria) on homogenized and sifted sediment samples on 2 mm mesh stainless steel sieve.

RESULTS

SEDIMENTOLOGY AND GEOCHEMISTRY OF SECTION B1

Section B1 was lifted in a terrace located on the left bank of the Boumerzoug wadi, with geographic coordinates 06°39.779'E, 36°19.265'N, and 564 m asl (figure 1). Over 1.90 m, it superimposes three sequences of deposits, from bottom to top (figure 4)

Deposit sequence 1, with increasing gradient and thickness of 0.50 m, begins with coarse sandy (B1-9) discordant on the Tellian formations (greyish marl intercalated with nodule limestone). The material becomes increasingly coarse, forming block pebbles (B1-8), with sandy to sand-clay matrix (B1-7) and centimetric stratification. The granulometry analysis shows a magnification from the base to the top, expressed by a sharp increase in sand contents from 50.33% to 70.76% and by a decrease in silt and clay contents from 29.07%, 10.60% to 26.70% and 3.14% respectively (figure 5). The carbonate contents are significant, ranging from 33.14% at the base of the sequence to 35.12% at the top. Organic matter contents are relatively high. They evolve inversely to those of $CaCO_3$ with 5.55%, from the base, up to 4.84% in the coarser levels towards the top of the sequence. The pH becomes more alkaline at the top of the sequence and varies very little, fluctuating around 7.0 to 8. EC, which is high at the base of the sequence, (903µS/cm) shows a slight decrease in the coarser levels towards the top (855 µS/cm) (Table 1).

Deposit sequence 2, with an increasing gradation and thickness of 0.50 m, results very homogeneous; it rests on sequence 1 by a narrow and continuous surface. It starts with more or less fine sand (B1-6), which quickly becomes gravel and pebbles (B1-5) packed in a clayey to sandy-clay matrix (B1-4). The granulometry analysis shows a slow growth from the base upwards, which is expressed by a slight increase in the sand contents from 63.15% to 68.89%, as well as the silt contents increase from 20.65% to 27.02%, while the clay contents decrease from 16.20% to 4.09% (figure 5). $CaCO_3$ contents are decreasing but remain still important, ranging from 19.89% at the base of the sequence to 18.50% at the top. The organic matter content remains relatively high, 8.08%

from the base to 7.23% in the coarser levels towards the top. The pH shows stability throughout the sequence of 7.22 to 7.80. EC is relatively high (704 µS/cm) at the base of the sequence and in the coarser levels (799 µS/cm), rising towards the top with a peak of 1070 µS/cm (Table 1).

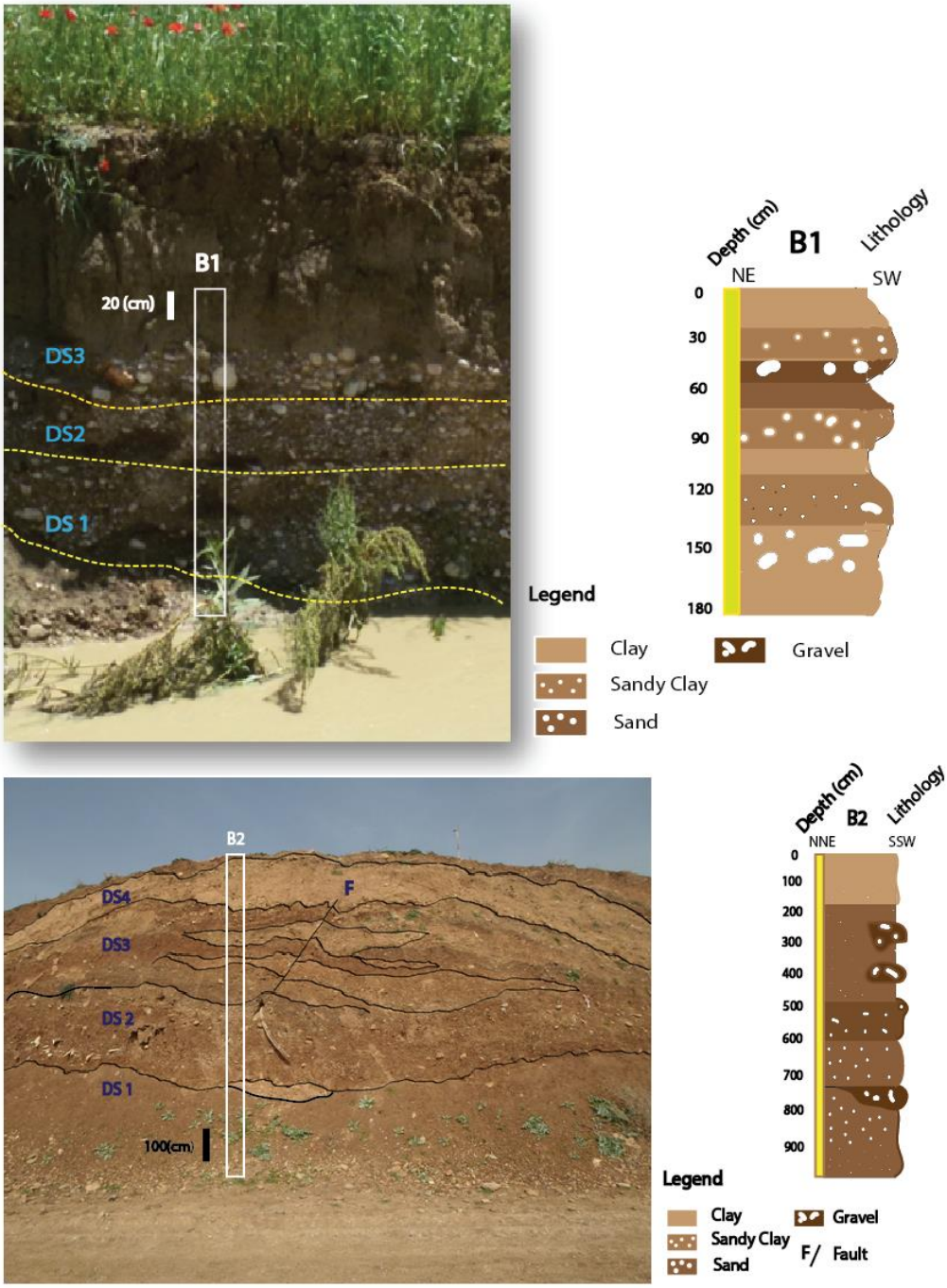

Figure 4. Sedimentary profiles and photographs of Boumerzoug wadi sections B1 and B2. Deposit sequence (DS);

(Source: Noureddine RABAHI)

Table 1. Physic-geochemical analysis of the Boumerzoug wadi sediments

(Data source: Noureddine RABAHI)

Granulometry					Geochemistry				
Sample	Clay (%)	Fine Silt (%)	Rude Silt (%)	Sand (%)	pH	pH (KCl)	EC (µS/cm)	OM (%)	$CaCO_3$ (%)
Section B1									
B1-1	14.28	28.13	25.18	32.41	7.92	8.44	821	8.70	12.36
B1-2	12.66	21.15	20.13	46.06	7.85	8.13	852	8.07	20.33
B1-3	3.15	28.13	18.91	49.81	7.06	7.58	900	6.84	23.15
B1-4	4.09	10.88	16.14	68.89	7.22	7.76	799	7.23	18.5
B1-5	11.32	9.92	12.15	66.61	7.55	8.00	1070	7.28	19.30
B1-6	16.20	14.14	06.51	63.15	7.80	8.20	704	8.08	19.89
B1-7	3.14	9.80	16.30	70.76	7.90	8.30	855	4.84	35.12
B1-8	3.77	4.05	22.48	69.70	7.23	7.71	853	5.11	32.15
B1-9	10.60	13.94	25.13	50.33	7.21	7.72	903	5.55	33.14
Section B2									
B2-1	28.98	18.12	16.71	36.19	7.0	7.50	270	9.70	10.33
B2-2	26.48	16.50	16.97	40.05	7.13	7.71	317	9.11	12.15
B2-3	15.12	11.54	15.22	58.12	7.46	7.90	403	4.80	34.04
B2-4	13.10	7.59	28.13	51.18	7.44	7.87	472	5.01	30.05
B2-5	9.87	15.26	30.15	44.72	7.53	7.92	510	5.44	26.12
B2-6	13.5	10.02	4.47	73.01	7.30	7.70	473	8.33	10.90
B2-7	6.77	16.09	7.18	69.96	7.48	7.90	500	6.01	20.13
B2-8	6.15	25.28	7.68	60.88	7.60	7.98	580	5.58	25.81
B2-9	1.22	4.22	24.43	70.13	8.00	8.03	860	6.13	26.81
B2-10	1.50	8.83	27.64	62.03	8.07	8.44	980	4.00	32.88
B2-11	2.86	7.48	28.96	59.70	8.29	8.50	1083	4.83	37.90

Deposit sequence 3, with decreasing gradation and a thickness of 0.90 m, is incomplete (figure 4). It is based on the previous sequence through a regular and continuous surface. It begins with a heterometric block pebbles (B1-3) composed of pebbles and gravel mainly carbonated and packaged in a black grey clay matrix. The sediment quickly becomes fine sandy (B1-2). It ends with a very homogeneous level of light sandy clay (B1-1), becoming very dark. The granulometry analysis shows a negative gradation from the bottom to the top, with a decrease in sand contents from 49.81% to 32.41% in favor of an increase in silt contents from 47.04% to 53.31% and clay contents from 3.15% to 14.28% (figure 5). $CaCO_3$ contents remain more or less high, with a significant decrease from the base to the top of the sequence, ranging from 23.15% in the sands to 12.36% in the sandy clay levels. The organic matter content increases in the same direction from 7.58% to 8.44%. The pH remains alkaline with values between 7.06 at the base of the sequence and 7.92 at the top. EC values still stand high, decreasing from900 to 821µS/cm (figure 5).

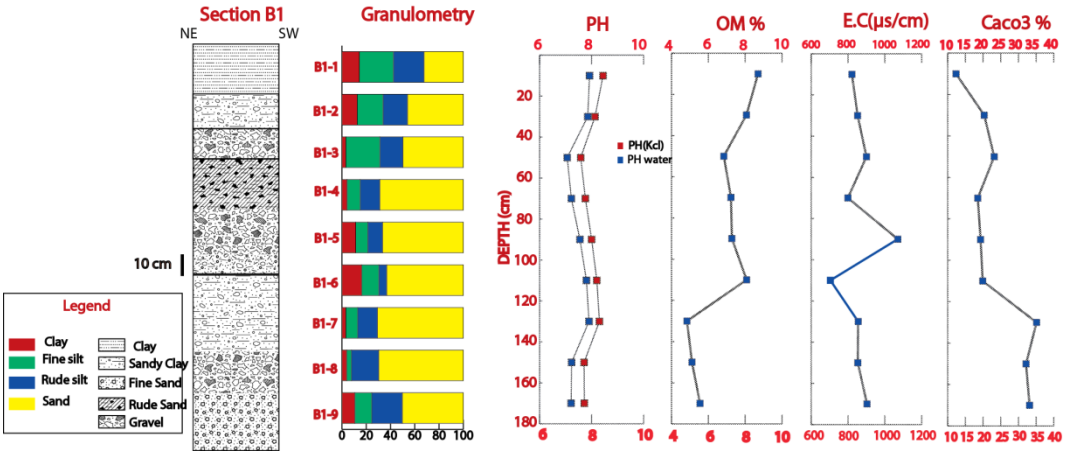

Figure 5. vertical profiles of the lithological, sedimentological and geochemical parameters of section B1 (Source: Noureddine RABAHI)

SEDIMENTOLOGY AND GEOCHEMISTRY OF SECTION B2

The B2 section was lifted in a terrace of more than 9.00 m. It is located on the left bank of Boumerzoug wadi near Chaabet El Russes locality (geographic coordinates 6°37.970'E, 36°20.486'N, 539 m asl (figure 1). It shows four sequences, three of which with increasing gradation and the fourth upper sequence with negative gradation, as described below from the bottom to top (figure 4).

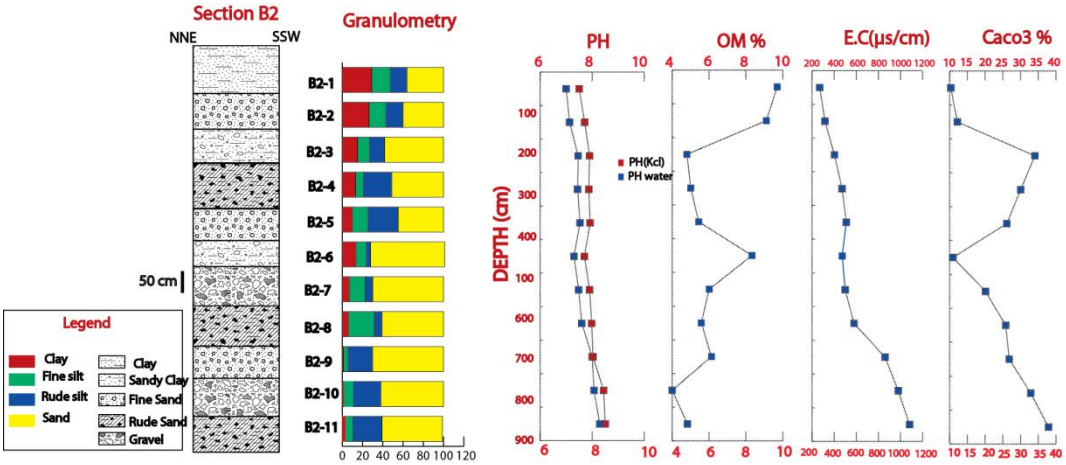

Figure 6. vertical profiles of the lithological, sedimentological and geochemical parameters of section B2 (Source: Noureddine RABAHI)

Deposit sequence 1, 2.00 m thick, begins with coarse sand (B2-11) packed in a sand, sand-carbonate matrix. The coarse material becomes increasingly heterometric (B2-10), whitish colored pebbles and gravel with carbonate cementing (B2-9) (figure 6). The granulometry analysis shows a rapid growth from the base to the top, expressed by a marked increase in sand contents. The contents pass from 59.70% at the base to 70.13% at the top of the sequence. Silt and clay contents decreased from 36.44%, 2.86% to 28.51% and 1.22% respectively (figure 6). $CaCO_3$ content is huge, going from 37.90% at the base to 26.81% at the top of the sequence. OM contents show average values of 4.83% at the base, increasing up to 6.13% in the coarser levels towards the top

of the sequence. The pH is alkaline, with negligible variations between 8.29 and 8. EC, which is high at the base of the sequence (1083 µS/cm), shows a slight decrease in the coarser levels towards the top (860 µS/cm) (Table 1).

Deposit sequence 2, 2.30 m thick, is in the form of beds (B2-8) with a more or less coarse material, very homogeneous and of varied color. It lies on the lower sequence with an irregular surface (figure 6). This sequence, starting with more or less coarse sand (B2-7), quickly becomes gravel and pebbles packed in a clay-sand matrix (B2-6). The granulometry analysis shows a rapid growth from the base to the top which is expressed by a marked increase in sand contents from 60.88% to 73.01%. This analysis also shows a decrease in silt contents from 32.96% to 14.49% and an increase in clay contents from 6.15% to 13.5% (figure 6). $CaCO_3$ content is still important, ranging from 25.80% at the base and decrease rapidly to 10.90% at the top. OM contents are relatively high, from 5.58% at the base to 8.33% towards the top of the sequence. The pH shows stability throughout the entire sequence, from 7.60 to 7.30. EC remains relatively high (580 µS/cm) at the base of the sequence, rapidly decreasing (473 µS/cm) in the coarser levels towards the top (figure 6).

Deposit sequence 3, 3 m thick, begins with more or less fine sand (B2-5) that quickly becomes coarse sands (B2-4) packed in a grey clayey-sandy matrix (B2-3) (figure 6). The granulometry analysis shows a positive gradation from the base to the top with an increase in sand content from 44.72% to 58.12% in favor of a decrease in silt content 45.41% at the base of the sequence, 26.76% at the top and an increase in clays from 9.87% to 15.12% (figure 6). The carbonate content is around 26.13% in the fine sands at the base of the sequence and increases to 34.04% in the clay-sand level at the top. Organic matter contents decrease slightly from 5.44% to 4.80%. The pH remains alkaline with values between 7.53 at the base of the sequence and 7.44 at the top. The electrical conductivity shows a stability of around 510 µS/cm and 403 µS/cm.

Deposit Sequence 4, 2.00 m thick, is generally represented by laminated fine sands (B2), which pass to light yellow clays (B2-1) (figure 4). The granulometry analysis shows a negative gradation from the base to the top with a decrease in sand contents from 40.05% to 36.19% in favor of a slight increase in silt contents from 33.47% to 34.92% and clay contents from 26.48% to 28.98%, which remains quite significant in this sequence (figure 6). $CaCO_3$ content is equal to 12.15% in the sands at the base of the sequence, showing a decrease to 10.33% in the clayey level at the top. OM content remains very high at 9.11% to 9.70%. The pH keeps alkaline values ranging between 7.13 at the base of the sequence and 7.00 at the top. EC decreases and gives values between 317 µS/cm and 270 µS/cm (figure 6).

DISCUSSION AND CONCLUSION

Lithological and sedimentological studies of sections B1 and B2 highlighted that the lower deposit sequences show increasing gradation. They generally begin with clays, sandy clays, and fine sands on which the deposits progressively become coarse, and pass to gravel and pebbles. Variations in sediment texture can be interpreted in terms of current energy (Djerrab et al., 2012). Thus, the presence of high proportions of gravel and pebbles at the top of the sequences would be associated with setting up under stronger dynamic conditions (Djerrab et al., 2012). Conversely, the robust presence of silty sands and clays at the base of the sequences (figures 5, 6) indicates flows with lower competence and a more regular regime (Ballais and Benazzouz, 1994). The upper deposit sequences in both sections B1 and B2 show a decreasing gradation starting with heterometric pebbles which gradually becomes fine sands (B1), passing to clays (B2). The tops of the upper sequences are predominated by silty-sandy sediments, indicating sedimentation by rolling or saltation under the effect of a low to moderate current, with a slowing of sedimentation in coarse elements at the sequence bases. The levels of gravel and coarse sand were probably deposited during flood periods.

The pH values recorded in the alluvial deposits of Boumerzoug wadi underline their alkaline characters, sometimes tending towards neutrality. Alkalinity reflects the nature of the sediments,

dominated by a limestone source rock and silty-clay soils (Nassali et al., 2002; Keddari et al., 2019). The EC high values of the alluvium in the Boumerzoug wadi are due to the enrichment with monovalent and bivalent ions (Nassali et al., 2002). EC is fairly consistent with the conductivity of freshwater sediments despite a few peaks exceeding 1070 µS/cm and 1083 µS/cm (Keddari et al., 2019). These values reflect a sometimes-high mineralization that can be attributed to the presence of sebkhas upstream of the sub-basin in the Ain M'lila region. The OM high levels, ranging from 4.84% to 8.70% in section B1 and from 4% to 9.70% in section B2, are probably due to the degradation of dead cells of the river's fauna and flora as well as to the leaching of the surrounding soils (Abdallaoui, 1998). From a climatic point of view, this probably denotes a climate change, with a shift from a humid to a semi-arid climate (Djerrab et al., 2012).

The vertical increase in carbonate contents and the decrease in organic matter contents would be controlled by the conditions of sediment placement by hydrodynamics of the water, besides their lithological origins. Indeed, the fine sedimentation comes essentially from the erosion of the Tellian marls of the Upper Cretaceous and the clayey-marly-gypsum formations of the Miocene. These fine particles charged with mineral and organic particles are associated to flooding periods of Boumerzoug wadi and runoff from mountain slopes. In effect, the study of the different geochemical parameters converges to the same direction as those of the sedimentological ones, generally showing a negative evolution towards the higher sequences, thus confirming the hydrological and climatic changes.

In general, alluvial formations can be divided into two deposition phases, translated in two climatic cycles. The first one, which affects the lower part of the alluvial formations, characterizes a subhumid to humid climate with more or less important rainfall, with intercalations of dry periods. The second cycle, with dryer climatic conditions and medium to low rainfall, is probably similar to a semi-arid climate.

Finally, the temporal fluctuations of the geochemical parameters would result from the hydrodynamics of the water, as well as their higher concentration in the dry season and its dilution in the wet season.

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GROUNDWATER MANAGEMENT FOR IRRIGATED AGRICULTURE IN SOUTH-EASTERN ALGERIA BY APPROACHING CROP WATER NEEDS

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Abstract: The demand for irrigation is growing and will continue to grow in the future due to increasing food demand and climate change. Data on current and future demands are essential for better management and planning of water resources use. The province of Biskra is ranked as the largest consumer of irrigation water in the cities of South East Algeria with 42% of annual consumption. Under the arid climatic conditions of this region, it is inevitable to irrigate and the majority of irrigation water comes from groundwater. The objective of our study is to evaluate the irrigation water withdrawals in the region using the agro-meteorological model CROPWAT for the 2014-2015 campaign over the entire province, and to compare them with the official data of the Directorate of Water Resources Services (DRE) and the Sahara River Basin Agency (ABHS). Our results were superior to their data and the water consumption per hectare of water was also superior to the results of the SASS (2015) but similar to the Döll (2010). With increasing withdrawals and a decrease in recharge, we could fear economic and ecological problems in a region under severe water stress.

Key words: Biskra, crop need, water abstraction, Algeria

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INTRODUCTION

It is widely known that water is an essential element for the existence of all forms of life. Water is now considered a central element in the sustainable management of natural resources (Kadi, 2014). The agricultural sector alone captures about 70% of the world's freshwater (up to 90% in some high-growth economies, UNESCO-WWAP, 2012), as irrigated land provides more

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than 40% of food production (OECD, 2002; Lejars 2017). In addition, over the last fifty years the area of agricultural land has doubled and this can be interpreted as increasing pressure on water resources (Zingaro, 2017). Indeed, population growth leads to higher and higher demands in terms of quality and quantity of water resources (Funk and Brown, 2009; Belaqziz, 2014).

This growing demand is largely met by groundwater, especially in regions that often face surface water stress (Wada et al., 2010). With a global abstraction rate of 800 to 1,000 km^3/year (Jarvis, 2012; Margat and van der Gun, 2013; Velis, 2017), these extractions mean that groundwater reserves are declining, with about 20% of the world's aquifers in a state of over-exploitation (Gleeson et al., 2012). If, however, groundwater withdrawals cannot be compensated by recharge or reduced flow over a number of years, groundwater depletion will result (Döll, 2014). Increased water abstraction exacerbates already widespread water scarcity conditions in semi-arid and arid regions (World Water Assessment Programme, 2003; Hanasaki et al., 2008; Döll et al., 2009; Kummu et al., 2010; Vörösmarty et al., 2010; Wada, 2014). By 2050, global agricultural production will probably need to double to meet demand, according to Tilman et al., 2011; Alexandratos and Bruinsma 2012; Valin et al., 2014; Falkenmark (2015) and Jägermeyr et al., (2016) call for a high level of international consideration of integrated irrigation water management. Hydrogeologists agree that the current development of groundwater-based agriculture is unsustainable (Leduc et al., 2017).

Already Döll and Siebert (2002) had estimated the average net irrigation needs for North Africa at 66.4 km^3/year. Algeria is one of the largest countries in North Africa, with a surface area of 2,381 741 km^2 . The steppe occupies 8.5% of the total area, the coastal fringe (mountains and plains) 7.5% and the Sahara, 84%, i.e. the majority of the country. Water resources abstracted in 2012 are estimated at 8,425 million m^3, of which 4,800 million m^3 is surface water, 3,000 million m^3 is groundwater, well above the annual renewable volume, and 615 million m^3 is desalinated water (Eurostat, 2015). According to the statistics of the Ministry in charge of Agriculture (MADR), the irrigated areas of the country would have thus multiplied by 3.7 over the last two decades, from 350,000 ha in 2000 to 928,955 ha in 2008 and to more than 1.3 million hectares in 2017 (Bessaoud, 2019). The water withdrawal rate for the agricultural share seems to correspond to 59% (Eurostat, 2015). Provinces of Biskra and El Oued in the south-east of the country alone have nearly 17 per cent of the irrigated area in Algeria (Bessaoud, 2019). Annual water consumption levels for domestic needs in the provinces of Biskra and El Oued are respectively 42% and 18% (OASS 2015). Biskra is the gateway to the Sahara; its economic development is essentially based on the availability of water for agriculture. Groundwater is a non-renewable resource in the fragile regions of the world's arid ecosystems, and its exploitation requires sustainable management of these resources (Hashim, 2012). Their non-reasoned exploitation by farmers generates a risk of overexploitation, for the aquifers of Northern Algeria, with an average exploitation rate of 80% (Faysse, 2011).

This intensification generates a certain number of problems, mainly the regular drop in water levels, the increase in pumping costs and the weakening of artesianism (OSS, 2003). Consequently, groundwater management is essential to ensure its sustainable use (Dalin, 2019). It is necessary to estimate the pressure on these water resources for irrigation. It is in this context that our study aims to evaluate the abstraction of irrigation water in the Biskra region and compare the results obtained with the abstraction data of the Water Resources Services Directorate (DRE) and the Sahara River Basin Agency (ABHS). There are many studies to estimate water abstraction for irrigation, such as field surveys that require a budget, energy consumption and estimation of crop water requirements. Our study assumes that in the absence of fairly binding rules on the use of groundwater resources for agriculture, crop water needs are more or less met. Based on this assumption, we apply an efficiency coefficient to our estimate of total annual water requirements that approximates the actual amounts withdrawn in a year. The approach adopted for the estimation of water requirements is based on the calculation of crop evapotranspiration through the use of the CROPWAT model.

MATERIAL AND METHOD

Presentation of the study area

The province (Willaya) of Biskra covers an area of 21,671 km^2. The whole province is divided into several agro-climatic zones (plain and steppe). The study area is located between latitudes 33.0° and 35.5° north and longitudes 4.0° and 7.0° east (figure 1). The average altitude is 87 m above sea level. The region is characterized by its arid climate, hot summers and cold winters. Aridity has been defined as the ratio between the annual sum of precipitation and the annual sum of potential evapotranspiration (Middleton and Thomas, 1997; CGIAR-CSI, 2014; Siebert, 2014). The mean annual temperature is 22°C. July is the warmest month of the year, while January is the coolest. The average annual precipitation is 148 mm; there is almost no precipitation during the summer months. Potential evapotranspiration is high and can reach 10 to 20 times the amount of water falling (Margat, 1985; Sedrati, 2010).

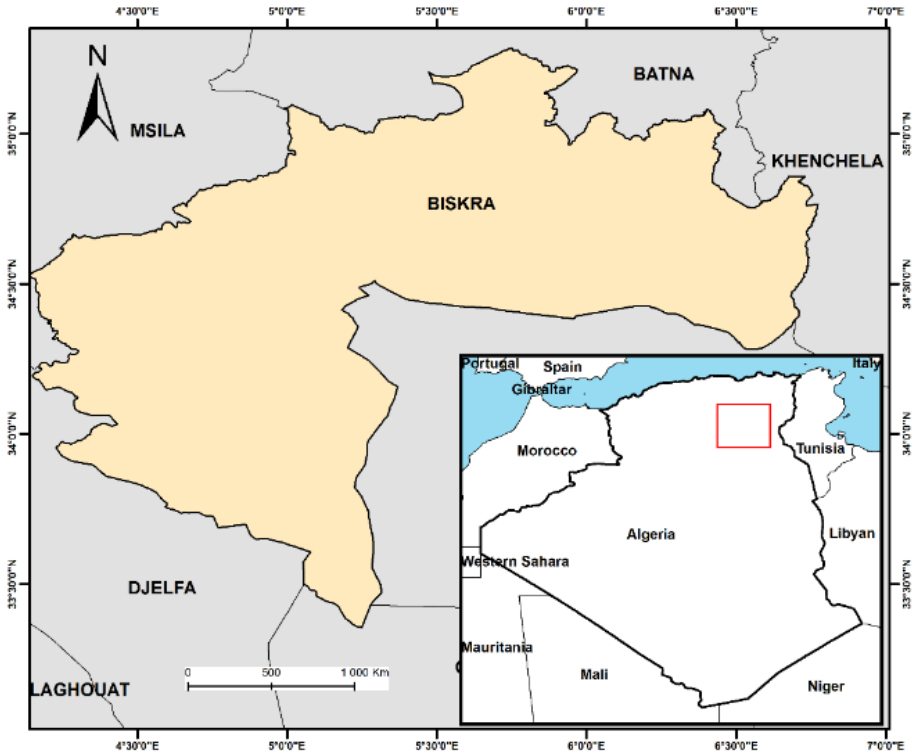

Figure 1. Location of Biskra region

Biskra is one of the Saharan provinces where land reclamation has enabled spectacular agricultural development on a broad pioneer front (Petit et al., 2017). This development is due to irrigation water drawn more than 94% from groundwater (see Table 1) (MRE, 2009). Farmers also irrigate with surface water. We can enumerate two sources of surface water: run-of-river irrigation using the rivers (often dry, except when it rains) that run through the province, but also water that occasionally runs off from the surrounding mountains (Ould Baba, 2005); and two dams: Foum El Gherza and Fontaines des Gazelles. In Biskra, two main confined aquifers of the Continental Terminal are exploited (Massuel, 2017). These are the Continental terminal (CI) and the Terminal Complex (CT) formations. The term Intercalary Continental refers to the continental episode located between two marine sedimentary cycles: at the base, the Paleozoic cycle which completes

the Hercynian orogeny, and at the top, the Upper Cretaceous cycle. The Terminal Complex is an inhomogeneous ensemble comprising carbonate formations from the Upper Cretaceous and detrital episodes from the Tertiary, notably from the Miocene (OSS, 2003). The exploited aquifers have shown a general decrease in piezometric heads over the last 40 years, by 90 m (ANAT, 2003). The region is characterised by a diversification of the crops grown (date palm, cereals and market gardening crops, etc). Biskra is one of the Saharan provinces where land reclamation has enabled spectacular agricultural development on a broad pioneer front (Petit et al., 2017). This development is due to irrigation water drawn more than 94% from groundwater (see Table 1) (MRE, 2009). Farmers also irrigate with surface water. We can enumerate two sources of surface water: run-of-river irrigation using the rivers (often dry, except when it rains) that run through the province, but also water that occasionally runs off from the surrounding mountains (Ould Baba, 2005); and two dams: Foum El Gherza and Fontaines des Gazelles. In Biskra, two main confined aquifers of the Continental Terminal are exploited (Massuel, 2017). These are the Continental terminal (CI) and the Terminal Complex (CT) formations. The term Intercalary Continental refers to the continental episode located between two marine sedimentary cycles: at the base, the Paleozoic cycle which completes the Hercynian orogeny, and at the top, the Upper Cretaceous cycle. The Terminal Complex is an inhomogeneous ensemble comprising carbonate formations from the Upper Cretaceous and detrital episodes from the Tertiary, notably from the Miocene (OSS, 2003). The exploited aquifers have shown a general decrease in piezometric heads over the last 40 years, by 90 m (ANAT, 2003). The region is characterised by a diversification of the crops grown (date palm, cereals and market gardening crops, etc).

$$Pd = \frac{|A\text{-}B|}{(A+B) \div 2} * 100 \ \#(1)$$

D p: Percentage difference
A: Calculation Method 1
B: Calculation Method 2

Calculated water requirements

In this study, groundwater abstractions for crop irrigation are calculated according to the water needs of plants for the 2014-2015 agricultural seasons. It is assumed here that crop water needs are met and irrigation is carried out with an average efficiency of 70% (FAO, 1997; Döll, 2010). In our study the simulation of the water needs of the listed crops (41 in total) was carried out using the CROPWAT 8.0 software. This model considers that all crop water demands refer to theoretical evapotranspiration (Aldaya, 2010), which represents the main crops in the province. Some crops could not be considered due to lack of sufficient agronomic data and parameters. These are extrapolated to 100% of the total cultivated area.

The calculation of irrigation needs by the CROPWAT model uses the approach of Allen et al. 1998 with a single crop coefficient to calculate crop evapotranspiration (etc.). The availability of 26 years of climate data (1989-2015) from the Biskra metrological station was used as a basis for the calculation. The crop parameters (cropping calendars in the area, sowing dates, length of plant growth stages) required for modelling were determined both on the basis of a questionnaire to farmers and communal extension agents and on the basis of the FAO guide by Allen et al. 1998. Crop coefficients were extracted from the same guide. Statistical data on cultivated areas for the 2014-2015 crop years were provided by the Biskra Agricultural Services Directorate (DSA) and the Ministry of Agriculture and Fisheries. These data concern: date palm (42, 666 ha), cereals (24,120 ha) including wheat (16, 243 ha), market gardening (20133.75 ha), fruit trees (9,681 ha), olive trees (4154 ha), alfalfa (10 ha), including alfalfa (10 ha), and industrial crops (1251 ha)

including tobacco (47 ha). As a simplifying assumption, it was assumed that each type of crop was planted throughout the region at approximately the same time and covered 100% of the planned area (figure 2).

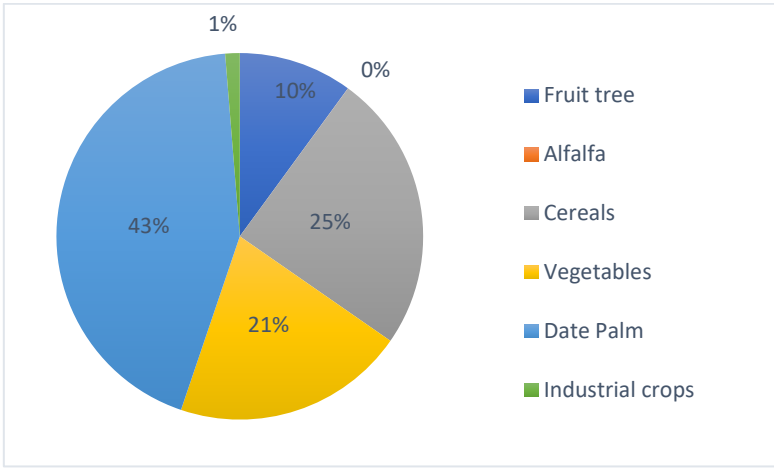

Figure 2. Percentage of area by crop sector

RESULTS AND DISCUSSION

In Algerian Saharan cities, intense evaporation leads to allocations of up to 10,000 m^3/ha/year (Mutin, 2011; Taabni and El Jihad, 2012). This explains the high potential evapotranspiration in the province of Biskra, over 26 years, estimated at 2.177 mm/year, according to our calculations the greenhouse reference evapotranspiration is lower than the external reference evapotranspiration, i.e. 993.79 mm/year. The annual irrigation needs for all crops combined are about 1,027 mm^3/year for the 2014-2015 seasons without taking into account irrigation efficiency (i.e. 70% efficiency). Setting the efficiency at 70%, the total groundwater consumption for irrigation is estimated at 1.4672 mm^3/year. Figure 3 illustrates the theoretical annual water needs per channel: date palm accounts for more than 69.45%, followed by cereals 13.4%, fruit trees more than 10.02%, market gardening full of fields and under shelter 6.36%, fodder 0.01%. Industrial crops account for only about 0.67% of total requirements. Whatever the species, agricultural water consumption is seasonally dependent and increases due to evaporative demand until harvest (Allen et al., 1998).

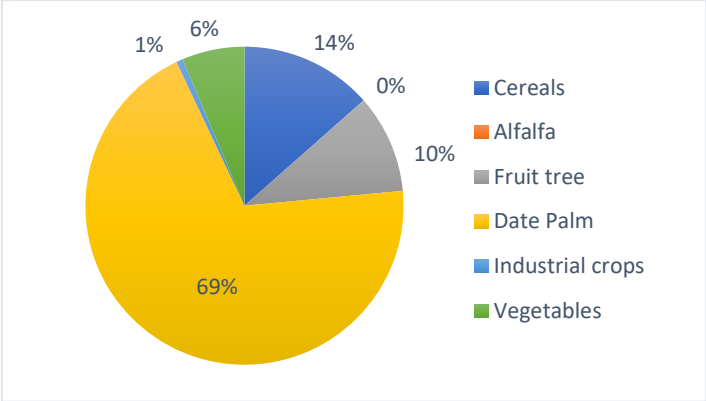

Figure 3. Percentage of Annual Water Requirements by Type of Commodity

The results of theoretical consumption for agriculture are 1.467 mm^3 (Net of irrigation is 1.027 mm^3). For the 2014-2015 campaign, for the same period, the data on water consumption provided by the ABHS (i.e. 1.141 mm^3) are higher than those provided by the DRE for the same agricultural campaign 2014-2015, which are of the order of 822 mm^3, of which 810 mm^3 is for groundwater and 12 mm^3 is for surface water. In order to analyze and compare the results with the data provided by the DRE and ABHS sources, we used the percentage difference method (see Table 2).

Table 2. Percentage difference between estimates of groundwater withdrawal, by 3 sources

	Saadi et al.*	ABHS	DRE
Saadi et al.*	-	25	56,35
ABHS	25	-	32.5
DRE	56,35	32.5	-

The largest discrepancy between estimates of groundwater withdrawals for irrigation is found between the data provided by the DRE and our results. Between our results and the data provided by the ABHS, the difference is relatively smaller. Differences revealed in the comparison of estimates may be due to different calculation methods. The DRE is based on statistical data on the number of authorizations to drill allocated, which are 8219 boreholes. This total does not take into account the pumping points of illicit boreholes, or the contribution of the 3249 wells surveyed by the ABHS during the 2014/2015 campaign, nor run-of-river irrigation, which may explain the underestimation of actual water consumption.

For the ABHS data, the Algerian State is very conscious of the preservation of water resources, which is why it carries out an inventory of water abstraction points every 10 years, as well as the quantities abstracted. These quantities extracted are estimated on the basis of the product of the estimated flow rates in the field and the annual duration of pump operation declared by the farmers. Given the absence of meters, the method is based on the farmer's declarations, which may either underestimate or overestimate the number of hours of pumping.

During 2008, the ANRAH (National Agency for Hydraulic Resources) in a study, estimated the abstractions of irrigation water, in the order of 505.61 mm^3 of water, extracted from 6481 boreholes (Sedrati, 2010). During the 2014/2015 campaign, the ABHS carried out another study showing that the withdrawals for irrigation are 1.141 mm^3.

It is necessary to highlight the constraints for carrying out these inventories, namely the extent of the region with 21671.2 km^2 and 33926 farms (Sogreah, 2009). These constraints make it impossible to inventory all the boreholes. The inventory method requires a great deal of investment and human mobilisation. In addition, farmers can apply more or less irrigation than the crop requires, such as farmers in palm groves (using individual boreholes) who stop irrigation from September to December. This period coincides with the end of the maturity of the dates and the dormant phase of the palms. A survey conducted by the Northern Sahara Aquifer System. (SASS) in 2012 on the cities of South-East Algeria showed that 66% of the irrigators belong to farms equipped with individual wells (OSS, 2015). Both methods (ABHS and calculated crop water requirements) indicate high water consumption per hectare 11 644 m^3/ha/year and 14 969 m^3/ha/year (with net irrigation of 10353 m^3/ha/year) respectively for the 2014/2015 season. According to Döll (2010) who used the CROPWAT approach, net irrigation in arid and semi-arid regions is above 1000 mm/year; in the same study, the Biskra region is between 800-2000 mm/year. As for ABHS water consumption per hectare of water which is 11 644 m^3/ha/year, it is close to that of SASS (2015) which is: 12383 m^3/ha/year and which used the pumping method during its surveys in Biskra province in 2012. However, the volume of renewable groundwater resources that can be exploited is 260 Mm3/year (MRE, 2009; Lejars, 2017). The estimation of irrigation water use using the CROPWAT model is based on the reported areas The use of remote sensing is recommended, which is of obvious interest for verifying irrigated areas, otherwise the

water estimate leads to an underestimation or overestimation of the water actually withdrawn by irrigators (Weatherhead and Knox, 2000; Maton, 2006). Two of the methods for estimating water consumption presented can be coupled so that they are complementary: the method by estimation of water needs, which we propose, and the method by estimation of pumped volumes (method known as "by pumping"). The pumping method measures the impact of irrigation water withdrawals and gives information on the entire region without specifically designating the plots where there is poor water management. Moreover, over-exploitation of the water table is only noticed after comparing the refills and withdrawals of water from the water table. Moreover, this method, based on an inventory, is carried out at a frequency of ten years. Conversely, the evapotranspiration method can deal with water management at each site, since water requirements can be calculated for each farm depending on the crops grown. With good extension, the farmer can learn how to manage the irrigation of his farm, which can lead to a rationalization of water use and reduce annual water consumption, thus generating on a regional scale, an economic impact (reducing the cost of pumping), and an ecological impact (saving soil and water). The complementary role of the "pumping" method would be to provide information on the evaluation of water management by agriculture. Finally, it should be highlighted that water optimisation, the irrigation system chosen by the farmer, as well as the efficiency of this system, have a great influence on the levels of water abstraction for agriculture. The use of a drip irrigation system can reduce water losses by up to 50% (Hochmuth and Hanlon, 2010).

CONCLUSION

The exploitation of groundwater in the province of Biskra over the last decades has led to considerable economic development. It is essential to assess water resources with regard to their use in order to avoid overexploitation and to ensure their sustainability. Data provided by two national institutes allowed us to have a first approximation on water withdrawals for irrigation. It appears that there are significant differences between our results and those of these two institutes, as each method used has its own biases. However, it must be admitted that the management of groundwater exploitation (Continental Intercalary and Terminal Complex), presents a major challenge between a structural configuration and the climate of the region, which means that the reserves of these two aquifers renew themselves very little. Management must be integrated in terms of quantity and quality. Decision-makers and irrigators must guarantee sustainable water use. Today, most water resources experts agree that water conflicts are not caused by physical water scarcity, but are mainly due to poor water management, since rational groundwater management cannot be based exclusively on a set of laws.

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