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THE SOURCES OF SUPPLY OF FRUITS AND VEGETABLES IN NOVI SAD (SERBIA)

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Abstract: The paper talks about the facts that were established in the research of the origin of fruits and vegetables in the markets of Novi Sad. The results of the research are presented using graphic and cartographic methods. Observed illogicalities are clarified in communication with consumers and sellers. The

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obtained results were compared with foreign works. One of the goals of the work was to determine the extent of suburban agriculture, which should be the most competitive with others further away from the city. Economic factors have a decisive influence from where the city will be supplied with fruits and vegetables.

Key words: fruits, vegetables, origin, Novi Sad, market

* * * * * *

Introduction

Vojvodina Region, the northern part of Serbia is a region that represents a large food producer (Ćirić, Kalenjuk, & Janković, 2020). Agricultural products occupy a high share in the external trade of the Republic of Serbia. Among them, fruit and vegetable products stand out (Marković & Marjanović, 2021).

The paper examines where the markets of Novi Sad, the second city in terms of population in the Republic of Serbia, are supplied. Why is it important what the people of Novi Sad eat? According to the data of the Public Utility Company "Informatika", the city of Novi Sad has 406,672 inhabitants (https://nsinfo.co.rs/cir/broj-stanovnika-po-naseljima), which makes up 6.0% of the population of the Republic of Serbia. 71.0% of the mentioned number live in the city itself. These are people who do not produce food.

Why is the emphasis on fresh fruits and vegetables? Because they are the only products that are not created by mixing substances that can originate from different parts of the world. In addition, fresh fruits and vegetables are healthy and their consumption is recommended for the entire population, without exception. Based on this, everyone is expected to use them without reservation, in accordance with the possibilities of the household budget.

How do economic factors affect what is eaten? This question was included at the end of the survey. It was imposed from the comments of customers and people who are employed in fruit and vegetable stores. During the research, it was determined that fruits and vegetables are procured from different parts of Serbia, Europe, and the world. Originally, this was expected in view of the season and vegetation periods. However, other economic reasons began to be discovered, which will be discussed in the paper.

The following hypotheses were established and tested:

The supply of Novi Sad is decisively influenced by economic factors (H1).

World-renowned fruit and vegetable producers can also be found on the Novi Sad market (H2).

Suburban agriculture is the main supplier of the city (H3). How far does suburban agriculture extend in the case of Novi Sad?

The research on the origin of fresh fruits and vegetables was also initiated for the reason that the results of the research can be applied in several scientific disciplines. The obtained facts can be used in the economics of agriculture, the geography of the local environment, economic geography, but also represent a contribution to the development of urban geography. Since no similar research has been found so far, this will serve to organize similar ones in the areas of other cities, which will enable a comparison for which funds will also be requested from European institutions.

Materials and methods

The data required for the realization of the research was obtained through field observations of fruit and vegetable declarations that are available in markets, grocers (stores specialized in the sale of fruits and vegetables) and shopping centers. Field observations were conducted during the summer (July and August) of 2022. In addition, the origin of fresh fruits and vegetables that

temporarily appear near city intersections was taken into consideration. Fruit and vegetable declarations were analyzed from six out of eight Novi Sad markets (Limanska, Riblja, Futoška, Kvantaška, Detelinaska and Satelitska), several sawmills and seven large markets (Maxi, Aman, Univerexport, Idea, Mikromarket, Lidl, Metro).

Large supermarkets display the origin of each product individually. Some countries of origin are illogical, because it is known that they do not have the physical-geographic characteristics for large-scale production of certain crops. That is why the obtained data had to be approached critically. They were necessarily checked. It was concluded that the country of origin often means that the product was imported through that country, and not that it was produced there. In some declarations, it is stated that the origin of the product is from the country of Serbia and the name of the supplier's company is stated. In such cases, we resorted to contacting the mentioned companies. Contacting did not give the expected results. Some of the respondents did not want to cooperate; some stated that they were on vacation, while some said that they were not authorized by their employers to provide the requested information. Therefore, further research into the origin of that product had to be abandoned.

It often happened to come across the same country of origin, the name of the supplier or the town where the fruit or vegetable was purchased. Therefore, 501 articles where the declaration was repeated at least three times were selected. In the absence of declarations, communication with sellers was initiated. Information was obtained from them that clarified numerous observed illogicalities. The data were processed using mathematical and statistical methods. As a function of transparency, the results of the research are presented cartographically.

The explanation of the established illogicalities was obtained through interviews. The interlocutors were producers, sellers and buyers. Women aged 41-50 and with a high school diploma, most often agreed to be interviewed (Table 1).

Table 1. Socio-economic structure of the interlocutors interviewed
(Data source: Survey)

	Categories	Number	Share (%)
Gender	Male	5	25
	Female	15	75
Age	21-30	3	15
	31-40	6	30
	41-50	8	40
	51-60	3	15
Education	Elementary school	3	15
	High school	15	75
	Faculty	2	10
Function	Producer	4	20
	Seller	12	60
	Buyer	4	20
Total		20	100

Results and Discussions

After the entry into force of the SAA (Stabilisation and Association Agreement) and liberalization of trade in foodstuff with the EU and CEFTA (Central European Free Trade Agreement) countries, followed with broadening of the network of wholesalers and supermarkets, which distribute imported agricultural products and food to Serbian consumers (Jovanić, Cogoljević, & Pejović, 2018).

The last written markets in the scientific literature on the procurement of fruit date from 2021. Namely, during that year, almost 294,000 tons of fruit were imported, worth almost 266.8 million euros, which is 7% more than the value of imports in 2020. In the period January-April 2022, fruit worth 94.3 million euros was imported. Most citrus fruits are imported, and the value of

this purchase was 77.5 million euros, which is a decrease of 5% compared to 2021. Oranges cost 25.7, lemons 22.0, and tangerines 25.3 million euros. Bananas were imported in the amount of almost 58.0 million euros, which is 6% more. Frozen raspberries, blueberries, strawberries, currants, and fresh apples were also imported. The fruit arrived from Greece, Spain, Turkey, Argentina, South Africa, Ecuador, Colombia, Costa Rica (Gulan, 2022). After listing 501 articles whose origin is repeated at least three times, the following conclusions were reached.

Imported items

In the market of Novi Sad, there are more imported fruits than vegetables (Table 2). Of the 157 fruit items, two thirds are of foreign origin. In Novi Sad shops, fruit is sold mainly from Greece, Italy and Spain, and then from the Netherlands and Turkey (Figure 1). The other twenty-two states make up the relative majority. Less than five products found originating from the same country. The relative majority are European countries (Albania, Croatia, North Macedonia, Poland), but also some Asian (Israel, China, Malaysia), African (Egypt, South Africa, Burkina Faso, Ivory Coast, Zimbabwe), or South American (Argentina, Brazil, Chile, Ecuador, Colombia, Costa Rica, Panama, Venezuela). It is expected that fruit that, due to the lack of adequate climatic characteristics, is procured from countries where it is possible to grow it. It is also expected that fruit that can grow on the territory of the Republic of Serbia will be imported at a time when it is not in its growing season. However, the import of fruit also occurs when that fruit appears in the orchards of Serbia. Radosavljević (Radosavljević, 2008) also noted that Serbia imports what it can produce.

Table 2. The origin of fruits and vegetables on the Novi Sad markets
(Data source: Survey)

Category	Fruit from… (total: 157)				Vegetable from… (total: 344)			
	Abroad	Serbia	Suburban	Unknown	Abroad	Serbia	Suburban	Unknown
Number	104	19	34	0	89	40	123	92
Share (%)	66.2	12.1	21.7	0.0	25.9	11.6	35.8	26.7

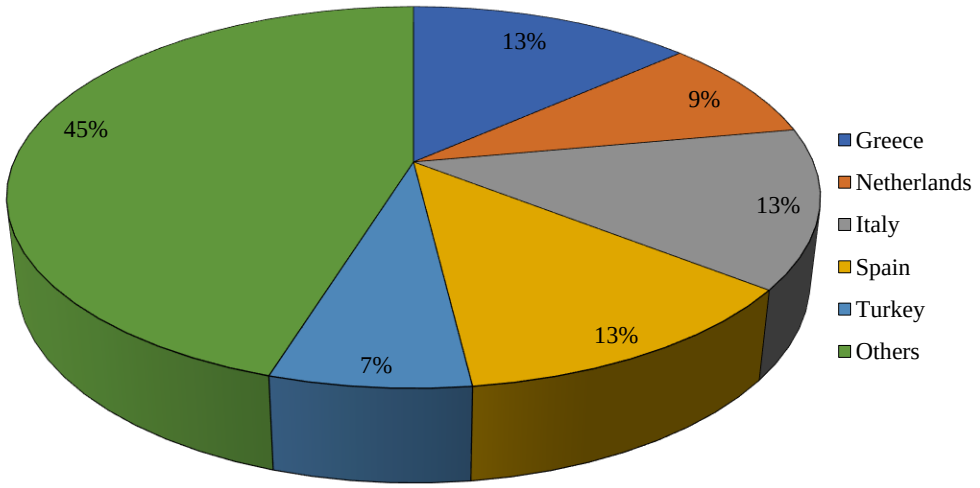

Figure 1. Countries from which the largest amount of fruit that is offered at Novi Sad stores is imported
(Data source: Survey)

From European countries, southern fruits, citrus, and continental fruits arrive on the market of Novi Sad, which, due to more favorable climatic characteristics, manage to ripen earlier than in the territory of Serbia. There are numerous clues in the scientific literature about the countries,

regions and regions where certain fruits are produced. Grapes arrive from the central regions of western Albania (Kopali, Libohova, Teqja, & Owens, 2021), the southeastern part of North Macedonia (Nickova, 2021). For many years, Poland has been a leader in apple production in the EU (4 million tons in 2021). It is ranked third in the world in terms of apple production after the USA and China (Głos, Bryk, Michalecka, & Puławska, 2022). Apples from Poland are available in Novi Sad markets. Plantations of nectarines (1.5% of cultivated area), grapes (4.0% of cultivated area) and southern fruits do not occupy significant areas of Greece (Paschalidis, et al., 2021), but they manage to reach the people of Novi Sad. Only citrus fruits arrive on the Novi Sad market from Turkey. They are an important product group for Turkey in terms of local production and global trade intensity (Gültekin, et al., 2022). Mediterranean countries, especially in Europe, because of their proximity to export markets and the advantage of EU member basin countries such as Spain, Italy, and Greece in international trade contributes to the increase of competitive power in citrus fruits (Duru, Hayran, & Gül, 2022). Therefore, the natural-geographical characteristics preconditioned and helped some countries to cultivate certain cultures.

Continental, mediterranean and tropical fruits are procured from Italy and the Netherlands. Although it is not geographically located in the region, the Netherlands is one of the five largest suppliers of fruit to the Novi Sad market. As Mediterranean and tropical fruits cannot be produced in the Netherlands due to natural-geographical characteristics (De Mulder, De Pater, Fortuijn, De Klerk, & Van Dijk, 2019), it can be said that it is also a large reseller of these items. This fact was unreservedly agreed by the sellers at the new markets.

Asian fruit species are used by very few consumers. Lemon, pomelo and Japanese apple come from China, and carambola from Malaysia. China is one of the largest producers of pomelo and among the top five exporters in the world (Makkumrai, Huang, & Xu, 2021). China has the largest cultivated area and annual production of persimmons in the world (Dong, et al., 2022). Malaysia is famous for the production of carambola (Vargas-Madriz, et al., 2021). These statements support the second hypothesis (H2), which assumed that world-famous fruit and vegetable producers can also be found on the Novi Sad market.

Bananas come from Latin American countries. According to FAO (FAO, 2020) and Olivares et all (Olivares, et al., 2022), this fruit is an important source of income for producers, which indicates the volume of production that manages to reach the market of Novi Sad. Greenhalch (Greenhalch, 2021) testifies to the production of citrus and other tropical fruits in South American countries, which are also on offer in Novi Sad stores. The apple, for example, is a completely redundant import. In Serbia, it is grown on an area of 26,658 ha (Dašić, Stanić, & Živković, 2022). Although there are conditions for its preservation, it arrives from Chile, one of the world's largest producers (Federica, Sophie, & Pasquale, 2021).

It is unexpected to determine the origin of a fruit originating from the African continent. There is a common perception that this area lacks food (Adeyeye, Adebayo-Oyetoro, & Tiamiyu, 2017; Otekunrin, Otekunrin, Sawicka, & Ayinde, 2020; Suri & Udry, 2022). Burkina Faso appears on the declarations of both fruits and vegetables. The literature shows that tillage skills are being introduced into the education system of Burkina Faso (Schreinemachers, et al., 2019). In Burkina Faso, according to Carrico et al. (Carrico, Okoko, & Klaver, 2021) large investors, The Agricultural Development and Nutrition teams at the Bill & Melinda Gates Foundation, in collaboration with the UK's Department for International Development (FCDO), see opportunities for interventions to further develop the fruit and vegetable sectors. The literature also testifies to the successes in the production of fruits and vegetables in other African countries. The names of those countries are found on the fruit declarations of Novi Sad hypermarkets. Rukasha and all, (Rukasha, Nyagadza, Pashapa, & Muposhi, 2021) write about exports from Zimbabwe, Coulibaly et all (Coulibaly, Koné, Djina, Berté, & Yapi, 2021) from Ivory Coast, and Cramer and Chisoro-Dube (Cramer & Chisoro-Dube, 2021) from South Africa. Scientific considerations on the export of Egyptian oranges can be found in the work of Hassanain and Gabr (Hassanain & Gabr, 2020).

Every fourth vegetable that does not originate from Serbia was imported from the Netherlands. This knowledge is supported by the fact that they state (Donati & Tukker, 2022) that with an agricultural export of EUR 95.6 billion (over 10% of Gross Domestic Product, GDP), The Netherlands is, after the US, the largest exporter of agricultural products globally. Almost one in five comes from Italy, one in ten from Burkina Faso in Africa, followed by Spain and Turkey (Figure 2). The Netherlands and Spain, and then the other mentioned countries, are at the very top of the world's vegetable exporters (MEA, 2019). Italy is the fifth largest organic food producer in the world (Rahman, Mele, Lee, & Islam, 2021). Turkey has an advantageous position in the world. Because there are fruit and vegetable production in almost every season and every region (Kaya, A., Budak, D. B., 2021). The price determines the country of origin, not its distance from Serbia. More than a quarter of the states identified in the declarations are made up of twelve other states. That is a dozen less compared to the number of established countries from which the fruit comes. Most are from European countries (Albania, Belgium, Bulgaria, France, Greece, Croatia and North Macedonia), but there are also Asian (China, Kyrgyzstan), South American (Costa Rica and Brazil) and African (Kenya) countries.

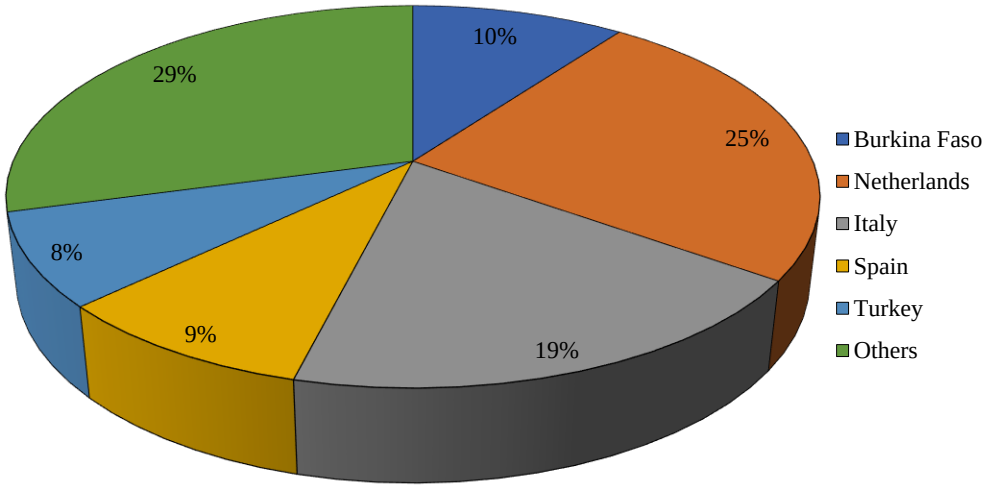

Figure 2. Countries from which the largest amount of vegetables that is offered at Novi Sad stores is imported (Data source: Survey)

Compared to fruits, vegetables do not come from great distances. Names of countries from other continents are rarely found in his declarations. Garlic from China is clearly different from the domestic one in terms of its size (Šćepanović, 2020) and appearance. Li and all. (Li, et al., 2021) state that the main garlic producing area of China is Jinxiang County. About the beans from Kyrgyzstan (Figure 3), which was found in Novi Sad markets, there are also scientific clues that talk about the problems of its branding. According to Suhrob (Suhrob, 2022) Talas region of Kyrgyzstan is famous for the production of beans. Vegetables found with South American origins are watermelons and melons. Brazilian watermelons from the distant provinces of Bahia and Rio Grande do Norte (Silva, et al., 2021) first precede, and then are simultaneously offered with those originating from the region of Southeast Europe (Northern Macedonia, Albania, Greece, etc.). The market position of vegetables will still be fluctuations and variability of their prices over the years (Mihajlović, Vukelić, Novković, & Mutavdžić, 2019). This is one of the reasons why they resort to importing something that already exists in Serbia.

The map, which shows the countries of origin from which fruits and vegetables are sourced, warns domestic producers in which direction to redirect their production. In addition, it is necessary to improve the production in order to exist even when it is not usual for certain products

to be found in the geographic latitudes of the Vojvodina Region. The improvement of production refers to the more frequent use of the geothermal potential of the Vojvodina Region (Košić, Pivac, Romelić, Lazić, & Stojanović, 2011; Bubalo-Živković, et al., 2018; Pešić, Brankov, Denda, Bjeljac, & Micić, 2022). In addition, increasing the area under greenhouses, irrigation and anti-hail protection systems; cold storages, dryers, storage capacities and related equipment; equipment for processing of primary agricultural products; purchases of used machinery and equipment (Popović, Janković, & Žaklina, 2018).

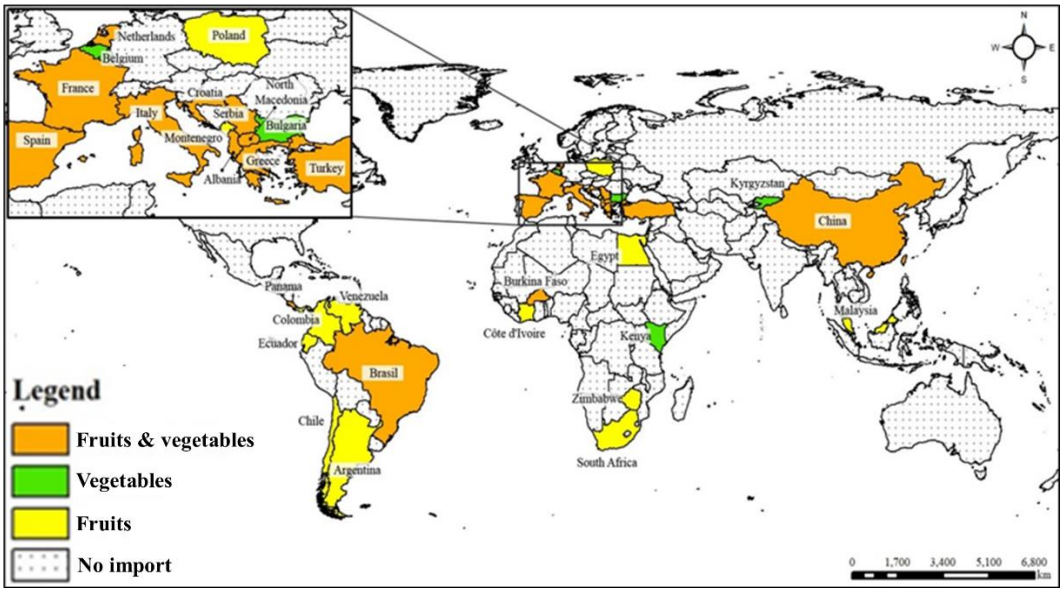

Figure 3. Countries from which products arrive in Novi Sad
(Data source: Survey, Author: Dajana Bjelajac)

Producers usually strive to produce healthy and safe vegetable products. Well-organized and well-adjusted (timely) vegetable crop production helps create the space for continuous production throughout the whole year. By including more vegetable species into production as well as using crop rotation, we provide production security (Medić-Pap, Červenski, & Danojević, 2019). In communication with resellers, it could be heard that the price is influenced by "how many hands it passes through". This means that the price will be lower if the imported goods are directly on the market, instead of being resold several times.

Customers noticed a similar quality of goods in different hypermarket chains. The research, based on available declarations, revealed that fruits and vegetables in large retail chains often, but not entirely, have the same country of origin. The sellers mentioned the names of the same companies, importers. Some of them specialize in the import of one, and others import several types of fruit and vegetables. They distribute and sell the products of major importers and domestic producers.

Fruits and vegetables from the territory of the Republic of Serbia

Special attention during the research was devoted to determining from which regions of Serbia fruits and vegetables are procured and where are they most often sold? Analyzing the data from the declarations, it was found out that most of the fruit comes from areas near Belgrade, i.e. they belong to the Belgrade municipalities of Sopot, Mladenovac and Grocka. In other words, the fruit is procured from the suburban agriculture zones of Belgrade. Somewhat further away are the orchards near Smederevo, Šabac, Valjevo and Užice (Figure 4).

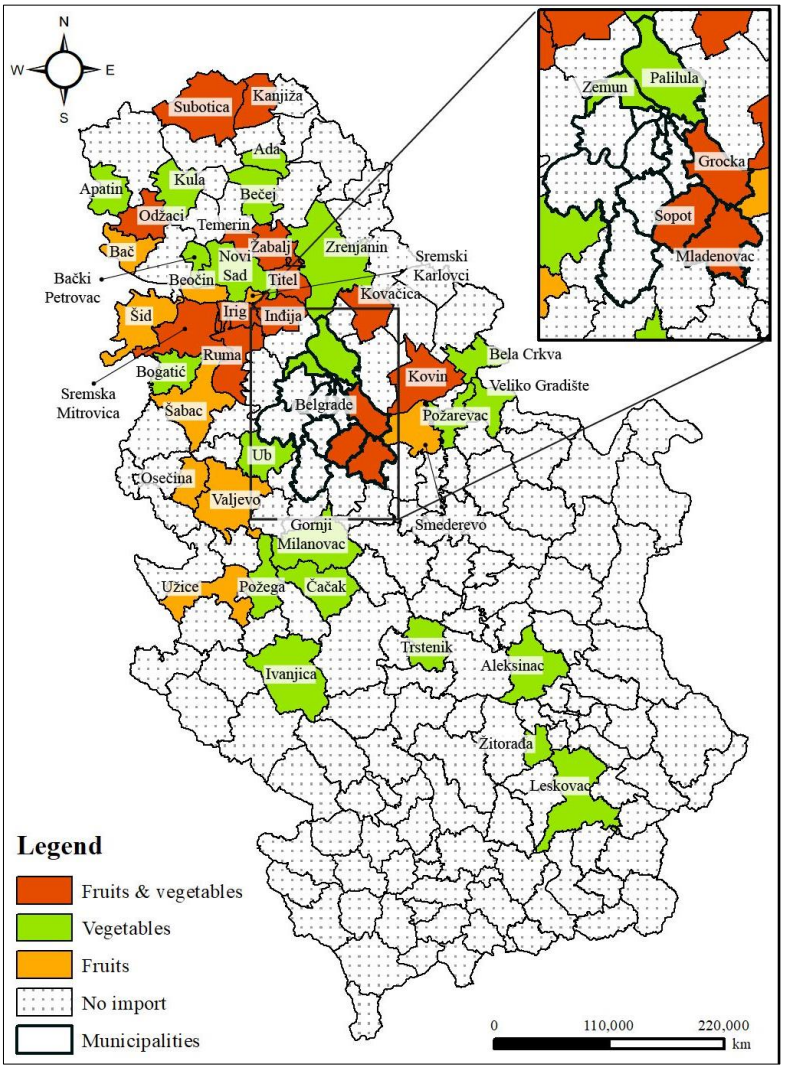

Figure 4. Municipalities in the Republic of Serbia from which Novi Sad is supplied
(Data source: Survey, Author: Dajana Bjelajac)

Due to the importation of fruit species that cannot be grown in the latitudes of Serbia, the suburban agriculture of Novi Sad, according to Table 2, is not the main supplier of fruit to the city. Almost two-thirds (64.7%) of suburban settlements where fruit is produced for the Novi Sad market are located in Srem, the rest, except for one settlement in Banat, are from Bačka (Figure 4). In Bačka, on the fertile chernozem, absolutely everything that thrives in the conditions of a moderate continental climate can be produced. The land of Srem is not suitable for all plant species due to more diverse soils and hypsometric differences, which condition the sloping and sloping slopes. The fruit turned out to be something that matches the energy of the relief and loess and other pedological substrates.

Vegetables arrive at the Novi Sad market from several locations that are much further away from the city. The most distant are Žitoradja, Leskovac, Ivanjica, Čačak, Požega, Trstenik, Gornji Milanovac and Aleksinac. Leskovac could be called the most important supplier, because every fifth listed product was from the territory of its municipality. Closer vegetable gardens are in

Bogatić, Požarevac, Veliki Gradište, Smederevo, Ub and in the settlements of Belgrade municipalities (Mladenovac, Surčin, Zemun, Palilula). The municipality of Palilula, i.e. the settlements of Slanci and Veliko Selo, also provide a fifth of the listed products.

Compared to the number of suburban settlements from which fruit comes, about four times more suburban settlements produce vegetables for the Novi Sad market. Among these settlements, settlements located on the territory of Bačka predominate (67.4%). A quarter of them are in Srem (25.2%). Vegetables come from only nine settlements located in Banat. Looking at the origin of vegetables found in Novi Sad markets, the share of suburban agriculture in Novi Sad has a relative majority. Based on these facts, it can be said that the third hypothesis is partially confirmed (H3). The frequency of products grown around the city was higher in the markets. Organic products are more often found in large supermarkets. There are differences in the supply of large supermarkets and others that sell fruit and vegetables. Large supermarkets are often supplied from suppliers of the same origin. These facts were suggested by consumers and confirmed by sellers. Differences in supply come from differences in demand for certain quantities. Producers who have a smaller volume of production place their products on the markets (Grusovnik & Rozman, 2020), because they do not meet the needs of large supermarkets. And this fact supports the hypothesis about the importance of suburban agriculture.

Interview

Fruits and vegetables are supplied from all over the world, but also from nearby settlements. According to Beslać and Janošević (Beslać & Janošević, 2014), Serbia imports what it has. Marković (Marković, Zašto Srbija uvozi proizvode koje može sama da pravi: Ako kaniš pobjediti ne smiješ izgubiti [Why Serbia imports products it can make itself: If you want to win, you must not lose], 2021) writes that in addition to potatoes, garlic, and apples, Serbia also imports raspberries, which are a traditional export product. The interlocutors confirmed that one of the factors that affects the origin of fruits and vegetables in Novi Sad markets is the weather. A certain fruit or vegetable may or may not be in season during the year. If it is not, it is procured either from regions where it thrives at the time or is purchased from large European suppliers.

According to the declarations on which the country of origin is written, it was concluded that some fruits and vegetables are procured even when they are not needed, that is, when they grow in the territory of Serbia (Figure 5). Suppliers explain this phenomenon that it happens because of the price. Some exporters have an interest in reducing the price so much due to the volume of purchases that it is more profitable for suppliers to import an agricultural product than to purchase it in the Republic of Serbia. This claim is supported by the fact that in 2021, Serbia brought down the prices of domestic production by excessive import of tomatoes (Đurić, 2021). A more favorable price suited the customers, but it had a negative effect on the income of domestic farmers. Therefore, in the background of the phenomenon is an exclusively earnings.

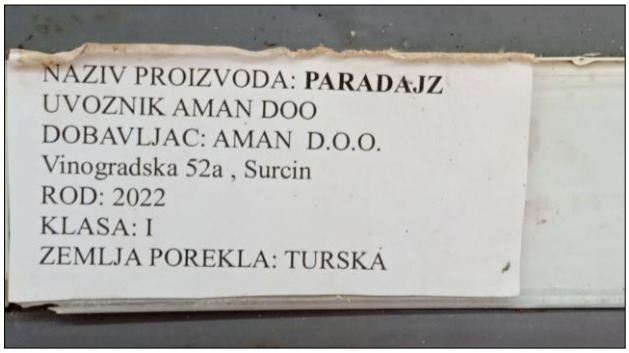

Figure 5. Tomato from Turkey
(Data source: Survey, Photo by: Tamara Lukic, September 2022)

Producers are rarely encountered in the markets. They explain that jobs are "waiting for them at home" and that most of them don't have time to stand around and wait for a customer. Most often, as soon as they arrive at the market, they sell goods to buyers. The resellers form the price by including the cost of renting the stall and their own earnings.

Producers also state that often the prices of annual plant products motivate more mass cultivation in the following season. Depending on the weather during the year, it happens that some fruit species give smaller yields. Numerous works (Subić, Nastić, & Jeločnik, 2015; Dozet, et al., 2019; Nalwanga & Belay, 2022) talk about exactly that. This is why it happens that they cannot satisfy the demands of the market. More demand than supply increases the price (Mason-D'Croz, et al., 2019; Li, et al., 2020).

When talking about the price of the product, all respondents noticed more of the same phenomena. Organic products are more expensive than those that are not (Radojević, 2018). The survey showed that all the respondents are familiar with the advantages of organic products, but first of all, they point out that it is a high price that they will not or do not have to pay. Therefore, according to the comments of consumers, organic products are for the rich or the seriously ill who believe that healthy food can help them, and at the same time they can afford it. It often happens that products are bought by the piece, which (Ozon, 2022) also writes about. All respondents linked this phenomenon to the decline in purchasing power. The prices of fruits and vegetables are the highest, according to the interviewees, in sawmills specialized only in their sale. However, everyone notices that those places have the best offer and the best quality of fruits and vegetables. If the focus is on markets and large markets, everyone is indecisive about the question of where it is more convenient to shop. Older customers are more loyal to the markets. Pensioners, for example, are able to shop at a time when a significant part of the workforce is at work. Some of the respondents stated that the prices in the markets are not fixed and can often be reduced in the case when a larger quantity is taken.

Perishable fruits and vegetables or those that are waiting for a customer for a long time can be obtained at a lower price. Some of the respondents stated that they visit the markets near the end of the working hours and then buy fruits and vegetables at a lower price. One interviewee said that she is constantly supplied at the same market and that products are often given to her "on credit or waiting until the new pension payment". In markets, they are not discounted randomly, but only as part of the promotion. The quality of products in markets depends on the management. Some supermarkets that "keep to themselves" have better quality products than others. Respondents noted four main advantages offered by supermarkets. The first is proximity. There are several markets, and supermarkets are closer and more accessible. Another advantage is the working hours. Markets usually end early at 3 pm or during the summer at 5 pm (https://www.nstrznica.co.rs/), and you can make purchases in supermarkets until 10 pm. The third advantage is the ability to pay by card. For the markets of Novi Sad, you must have only cash. The fourth advantage is saving time. In addition to fruits and vegetables, all other necessities are also purchased in supermarkets, thus saving the time required for procurement.

Sellers have noticed that customers prefer to hear that a product originates from the territory of Serbia. "Buy local" is a slogan used by some supermarkets, because they believe that this is the reason why some customers would decide to shop with them instead of a nearby competing supermarket. Customers who agreed to give their opinion on this survey also mention some facts that were not assumed.

The residents of Novi Sad, who are of rural origin, bring fruits and vegetables from the areas where they come from. There are also residents of Novi Sad who produce fruit or vegetables on their cottages, farms, etc. Some stated that they often buy fruits and vegetables while driving their own vehicle on the roads leading to the city. During the growing season, producers bring out fruits (more often on the Fruška gora Mountain) and vegetables in front of the houses, near the roads and sell them at better prices. Customers know that the prices are favorable and that the products are local (from the villages where they are sold). The respondents conclude that prices are

lower, because producers do not rent sales space, do not have transportation costs, and do not waste time waiting for customers. Zarić et al. (Zarić, Vasiljević, & Anđelković, 2018) explain the benefits of roadside vending. These facts "go" in favor of the existence of suburban agriculture and the third hypothesis (H3).

However, it often happens that the products of suburban agriculture are brought closer to the urban population by wholesalers, by selling them at city intersections. This trade is temporary, seasonal and without fiscal accounts. The municipal police are fighting against it, but experience shows that such points still exist around the city (Figure 6).

Figure 6. Illegal trading of vegetables at intersections,
(Data source: Survey, Photo by: Tamara Lukic, September 2022)

Conclusions

According to Vojnović et al. (Vojnović, Cvijanović, & Rodica, 2013) research such as this at the micro level has significance for overall development events. As one of the methods of marketing research, this kind of market research is a contribution to the knowledge of the organization of sales. It leaves a trace of the origin of the fruits and vegetables offered in Novi Sad stores at the beginning of the third decade of the 21st century. In support of this research is the fact that no similar ones were found by studying the literature.

Suburban agriculture is the dominant supplier of vegetables to Novi Sad markets, but not of fruit. This partially confirms the third hypothesis (H3). Fruit most often comes from the territory of Srem, while more vegetables are produced in Bačka. This is also influenced by the natural geographical characteristics of the area, among which the quality of the soil dominates. Fruit products arrive from distant parts of Serbia, mainly the river valleys of Velika and West Morava, Posavina and Danube. The rural municipalities of the Belgrade region are large suppliers of fruits and vegetables. Other vegetables arrive from the south of Serbia and from the area of the West Moravian Rift. Well-known European fruit and vegetable producers are also available to the residents of Novi Sad. Scientific literature leaves traces of exotic fruit production regions outside of Europe. The presence of fruits and vegetables originating from those regions on fruit and vegetable declarations was also found in Novi Sad markets, thus proving the second hypothesis (H2).

Identified sources of supply are both expected and unexpected. The expected ones arrive from suburban localities where fruits and vegetables are specially grown for the needs of the city. They should be more competitive in the market, because their delivery requires minimal costs. Bringing products from distant parts of the Republic of Serbia is expected, because the purchase prices for larger quantities are lower. In addition, there are areas that, due to their specific microclimatic characteristics, traditionally cultivate large areas of certain monocultures. For fruits and vegetables that cannot grow on the territory of the Republic of Serbia, the sources are expected to be outside its borders. The existence of products of African origin in the offer of Novi Sad markets was not expected. It shows how important the price is to importers, due to the effort to achieve higher profits, and not the origin of the food.

Unexpected sources mostly refer to products that can be produced in Serbia and which, even during their growing season, are supplied from other countries in the region, Europe or even from other continents. Behind that illogicality are economic reasons, among which the lower purchase price stands out. It is the result of lower labor costs, higher volume of production and demand. Therefore, the basis of everything is the price, as assumed in the first hypothesis (H1). That's a price that as many consumers as possible can pay. Suppliers and traders are in a constant process of searching for the lowest possible purchase price, which can enable them to make as much profit as possible.

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THE LIMITS OF GREEN INFRASTRUCTURE DEVELOPMENT IN URBAN SOUTH AFRICA: THE CASE OF GREEN ROOFS

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Abstract: With the advance of urbanisation many cities are confronted with environmental problems including air pollution, the absence of green spaces and urban heat island effects. The expansion of green infrastructure is viewed as an important aspect of urban sustainability agendas. One dimension of green infrastructure is green roofs. The objective in this article is to examine the development and challenges of green roofs in South Africa, presenting the results of a survey of the suppliers of green roofs. The findings show for South Africa the relative underdevelopment of green roof systems, the geographical unevenness of such developments and the challenges that confront the emergence of green roof systems in the South African context. Key issues relate to current high costs associated with green roof construction, absence of government support in the form of financial incentives, and lack of awareness of the sustainability benefits of green roof systems.

Key words: Green roofs, green infrastructure, urban, South Africa

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INTRODUCTION

By 2050 projections made by the United Nations suggest that approximately one-third of the world's population will live in cities (United Nations, 2018). Many growing urban areas are struggling with environmental problems, such as local climate change linked to global warming, air pollution, energy shortages as well as a range of natural hazards (Zhang & He, 2021). Shao and Kim (2022) pinpoint that rapid urbanisation is triggering land-use change, replacing green spaces and vacant land with built urban infrastructure. Furthermore, the march of global warming and climate change has exacerbated, according to Shao and Kim (2022, p. 1), "the frequency of extreme climate events and the intensity of heatwaves, which has strongly impacted the urban thermal environment, resulting in higher land surface temperatures and higher thermal absorption of solar radiation". Currently, therefore, city ecosystems are experiencing urban heat island effects, air and water pollution as well as flooding in part due the absence of green spaces. Accordingly, a critical challenge for urban sustainable development is to significantly transform the manner in which urban spaces are built and managed (Joshi & Teller, 2021). As pointed out by Manso et al. (2021) greening

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the urban environment can be a significant strategy to address the challenges of urban densification and to strive towards the United Nations Sustainable Development Goals. Indeed, as is observed by Joshi and Teller (2021, p. 1) unprecedented rates of global urbanization have precipitated "enormous challenges with energy consumption, social inequality, air and water pollution, and resource depletion resulting in a massive strain on urban systems".

Policy-makers in several countries are placing green infrastructure on the agenda as part of urban planning and design. Among others Liberalesso et al. (2020, p. 1) observe a global trend that "green infrastructure is increasingly used to mitigate the impacts of dense urban areas, contributing towards the naturalization of the built environment". Green roofs – also referred to as eco-roofs or living roofs - are defined as living vegetation planted on the roofs of buildings (Berardi, Ghaffarian Hoseini, & Ghaffarian Hoseini, 2014; Shafique, Kim, & Rafiq, 2018; Zhang & He, 2021; Ávila-Hernández, Simá, & Ché-Pan, 2023). As building roofs are abundant within urban ecosystems and may occupy as much as 20-25 percent of urban surfaces nature-based solutions such as green roofs "are increasingly gaining popularity due to their positive effect on urban ecosystems" (Joshi & Teller, 2021, p. 1). Against this backcloth it is the aim of this paper to draw together the existing evidence concerning the development and challenges of green roofs in South Africa, including insights from the supplier survey results of green roofs.

GREEN ROOFS – INTERNATIONAL DEBATES

The phenomenon of green roofs has a long ancestry. For some observers its application can be traced back to the Gardens of Babylon and the Roman Empire when planting vegetation on rooftops was undertaken (Jim, 2017a; Jim, 2017b). The archaeological studies by Jim (Jim, 2017a; Jim, 2017b) track the historical origins and development of green roofs as a human invention. The contemporary practice of developing green roofs is differentiated into a number of different types in respect of being fully or partially planted and in terms of the planting medium that is utilised (Claus & Rousseau, 2012; Zhang & He, 2021). The first category of 'extensive green roofs' are known for the simplest structure and requiring the least maintenance during its lifespan. This system though has only limited options in terms of plants that can be grown due to the thinness of the soil. Benefits in order to undertake an extensive green roof are its lower initial cost and the need for only limited additional support. Often extensive green roofs are recommended for building retrofits because of their lighter weight as compared to other options. In addition, they are also often recommended for projects with only a limited budget. 'Extensive' green roofs have a shallow substrate and low-growing plants (Oberndorfer, et al., 2007; Jaffal, Ouldboukhitine, & Berlarbi, 2012). By contrast 'intensive green roofs' are costlier, require additional structural support but as roof gardens have a wider variety of plants and can provide recreational spaces for the public (Claus & Rousseau, 2012; Mahdiyar, Mohandes, Durdyev, Tabatabaee, & Ismail, 2020). A third category of 'semi-intensive' green rooftop system is also recognised with its defining characteristics being a growing medium of 15-25 cm, vegetation consisting of small shrubs and the requirement of some maintenance (Labuschagne & Zulch, 2016).

According to Berardi et al. (2014, p. 411) the core benefits of green roofs relate "to the reduction of building energy consumption, mitigation of urban heat island effect, improvement of air pollution, water management, increase of sound insulation, and ecological preservation". Further, Berardi et al. (2014, p. 411) maintain that "green roofs have been proposed for sustainable buildings in many countries with different climatic conditions". This said, it is acknowledged that "the performance of green roofs in attenuating temperate extremes is dependent on local climatic conditions" (Fitchett, Govender, & Vallabh, 2020, p. 5025). For Joshi and Teller (2021, p. 1), green roofs can improve the energy performance of buildings and assist in combating the urban heat island effect both by reducing the atmospheric temperature as well as enhancing human thermal comfort. Arguably, however, the effectiveness of green roofs in delivering ecosystem services is "largely dependent on context-specific parameters such as weather conditions and existing construction or

design-related parameters" (Joshi & Teller, 2021, p. 1). Green roofs have been demonstrated as effective at reducing urban stormwater development pressures, reducing energy consumption, improving air quality, and above all mitigating the urban heat island effect (Liu, et al., 2021). It is observed that green roofs provide several ecosystem services and support urban transitions "toward circularity and resilience" (Calheiros & Stefanakis, 2021, p. 395). Arguably, green roofs are known for the benefits they contribute to the triple bottom line of the sustainability of urban environments (Teotónio, Silva, & Cruz, 2018). According to Chen et al. (2019, p. 1) it is accepted from the international experience that "green roofs have a variety of environmental, economic and social benefits". Mahdiyar et al. (2020) point to such environmental benefits as addressing the urban heat island, reduction of air pollution and improved air quality, economic benefits are seen in terms of increases in property values and energy savings whilst social benefits are defined in terms of beautifying spaces for human interaction and a quality indoor environment (Williams, et al., 2019) argue that research investigating the psychological benefits of green roofs highlights aesthetic enjoyment and improved concentration and that such outcomes are becoming significant objectives in green roof design.

For Liu et al. (2021, p. 1) green roofs represent "an effective nature-based solution to eco-environmental problems arising from climate change and rapid urbanisation because they provide multiple ecosystem services and can have a significant positive impact on human well-being". Calheiros and Stefanakis (2021, p. 395) stress that green roofs are garnering interest as nature-based solutions "to counteract with several environmental and socio-economic problems associated to urban sprawl and climate change". The direct ramifications of green roofs on carbon sequestration are identified by Shafique et al. (2020, p. 1) as involving "vegetation and soil media which can capture and store air pollutants on a building scale". Indirect impacts encompass the so-termed 'long-run green roof effect' which can reduce building energy consumption and in turn lead to a reduction in the consumption of fossil fuels (Shafique, Xue, & Luo, 2020, p. 1). Overall, the strengths of green roof adoption can play a vital role "in making cities safe, sustainable and resilient to climate change" (Shafique, Kim, & Rafiq, 2018, p. 757). According to Zhang and He (2021) important drivers for the implementation of green roofs therefore are policy pressure for energy efficiency, urban heat island mitigation, urban infrastructure improvement as well as innovation and technology advancement.

A critical global research issue is to understand the root causes and barriers to the implementation of green roofs (Chen, Shuai, Chen, & Zhang, 2019). It is observed that most extant studies on the barriers to implementation of green roofs in cities have been conducted in developed urban areas of countries in the Global North. Among others Bianchini and Hewage (2012) pinpoint that the cost of green roofs has been one of the biggest challenges for the development of the green roof industry. Likewise, according to Liberalesso et al. (2020) there are major challenges in promoting green infrastructure as private investors point to the need for substantial upfront costs for installation and in many cases also of significant maintenance costs. The review undertaken by Shafique et al. (2018) highlighted issues of initial high construction costs, high maintenance costs and roof leakage challenges as the main barriers associated with the application of green roofs in many countries. In addition, Teotónio et al. (2018) attribute their limited implementation to the absence of a clear understanding of the economic value of green roofs. Zhang and He (2021) stress that green roof implementation programmes can be inhibited by a complex of multiple barriers in economic, technical and political dimensions. These encompass lack of government policy, unsound technological level, poor economic benefit assessment methodologies and individual unwillingness to innovate.

Across the Global South there is acknowledgement of the environmental problems of large urban areas and that "one of the methods of mitigating electricity consumption and reducing the temperature in buildings is green infrastructure" (Ávila-Hernández, Simá, & Ché-Pan, 2023, p. 1). For example, the importance of green roofs in terms of reducing energy consumption in buildings

and the urban heat island effect is well-recognised in Mexico (Ávila-Hernández, Simá, & Ché-Pan, 2023). In sub-Saharan Africa, a region of the world which is experiencing rapid rates of urbanisation, obviously there is great potential for securing benefits from green roof systems. Overall, however, as noted by Chen et al. (2019) there is a paucity of research about the challenges in developing countries or the Global South where "implementation of green roofs is still at the initial stage" (Chen, Shuai, Chen, & Zhang, 2019, p. 742). In a developing country context Durdyev et al. (2022, p. 1) observe that the implementation of green roofs "is yet to hit a sufficient level" to make a significant contribution to sustainable urban environments. As is stressed in the case of Malaysia by Mahdiyar et al. (2020) the adoption of green roofs has been inhibited by a series of barriers. The research in Malaysia reveals that critical constraints relate to 'high initial costs' and 'lack of awareness and knowledge'. Barriers hindering the adoption of green roofs in Malaysia included lack of standard or industry guidelines, albeit such barriers were acknowledged as different between extensive and intensive forms of green roofs (Mahdiyar, Mohandes, Durdyev, Tabatabaee, & Ismail, 2020). In China the major explanations offered for the laggard progress of green roofs on new buildings in urban areas surround increase of maintenance cost, increase of design and construction, poor arrangement of the use of green roofs and lack of incentives from government for the development of green roofs (Chen, Shuai, Chen, & Zhang, 2019). The study by Durdyev et al. (Durdyev, Koc, Karaca, & Gurgun, 2022, p. 1) recommends in the context of developing countries that the essential strategies needed to speed the progress of green roofs are financial incentives, low-cost government loans and the offer of tax rebates. International reviews confirm that incentive policies in terms of financial subsidies are mainly concentrated in the Global North, especially Europe and North America, for the promotion of green infrastructure including green roofs.

Overall, a decade ago, Blank et al. (2013, p. 23) could state that "green roof research is a multidisciplinary and new research area". Indeed, Blank et al. (2013) noted that green roof research is a comparatively new area of science. Since 1981 Liu et al. (2021, p. 1) identify that "the amount of research on green roofs has steadily increased". Research on green roofs experienced a take-off with a burst of publications beginning in the 1990s (Blank, et al., 2013). An early influential review of evidence for the benefits of green roofs and the provision of ecosystem systems was produced by Oberndorfer et al. (2007). Ten years on the work of Shafique et al. (2018, p. 757) reflected that research concerning "the green roof has been raised expeditiously over the past decade". Of note is also a sharp increase in the number of different countries where green roof research is conducted (Blank, et al., 2013). Berardi et al. (2014, p. 411) present a state of the art synthesis of green roofs literature emphasizing current implementation, technologies and benefits. Similarly, Shafique et al. (2018) review the history of the green roof, green roof components and its multiple benefits as a significant sustainable practice to mitigate the effects of urbanization. According to Joshi and Teller (2021, p. 1) whilst a significant amount of international research already has been undertaken on green roofs "research covering more geographical locations and contexts is needed". This analysis turns to the case of South Africa, a country where published scholarship on green roofs is relatively small (Labuschagne & Zulch, 2016; Fitchett, Govender, & Vallabh, 2020; Sucheran & Sucheran, 2021).

GREEN INFRASTRUCTURE AND GREEN ROOFS IN SOUTH AFRICA

The need to plan for green infrastructure is acknowledged as a critical issue for South Africa's growing cities (South African Cities Network, 2016). The vital importance of green assets and greening urban infrastructure and the built environment has been identified in several academic studies about the urban landscape, property development (Rogerson, Green commercial property developments in urban South Africa: emerging trends, emerging geographies, 2014; Burton & Rogerson, 2017; Fitchett, Govender, & Vallabh, 2020; Van der Walt, 2018; Sucheran & Sucheran, 2021) and especially for the hotel sector (Rogerson & Sims, The greening of urban hotels in South Africa: Evidence from Gauteng, 2012; Rogerson, Green commercial property developments in

urban South Africa: emerging trends, emerging geographies, 2014; Ismail & Rogerson, 2016). With evidence of the advance of the impacts of climate change there is an acceleration in policy interest in South Africa about the greening of the country's cities. For example, the role of the South African Cities Network is to promote shared-learning partnerships between different spheres of government in support of the management of the country's cities. One report issued by this organization points to the critical need to further embed sustainability thinking into city planning in South Africa (South African Cities Network, 2016).

One facet of sustainability thinking is to consider the role that green roofs might assume in improving the urban built environment. In one recent study conducted in South Africa a technical analysis by Fitchett et al. (2020) reported that green roofs have been shown to enhance the comfort levels of rooms directly below them since they function as insulators. The green building concept is not a new phenomenon in South Africa. Organisations such as the South African Property Owners' Association (SAPOA) and the Council for Scientific Industrial Research (CSIR) have been promoting the adoption of green building practices since the Green Buildings For Africa (GBFA) programme in 1997 (Rogerson & Sims, 2012). The aim of the Green Building Council of South Africa (GBCSA) is to ensure that all buildings in South Africa are designed and built in an environmentally responsible way (Rogerson, 2014). GBCSA's objectives are to promote green buildings, to enable the measurement of green practices in buildings (rating system) and to improve skills and knowledge in the green building industry (Rogerson, 2014). In one recent investigation Sucheran and Sucheran (2021) assert that green infrastructure within the South African context mainly focuses on issues of preservation of biodiversity. Indeed, these authors go so far as to argue that the implementation of "green roofs in South Africa has not been seen as a priority, with the only motivation for the implementation being the additional points allocated by the Green Building Council of South Africa when a building is being assessed" for its green rating (Sucheran & Sucheran, 2021, p. 177).

Although the concept of green building in South Africa can be traced back to the 1990s the phenomenon of green roofs seemingly is of more recent origin. The pioneer developments in South African buildings include two municipal projects namely a roof top vegetable garden in Johannesburg, part of an initiative for improving food security, and a green roof pilot project in Durban which was part of a municipal climate protection programme focused on addressing the effects of climate change (South African Cities Network, 2016; Allen, 2019). Early private sector initiatives include the establishment of green rooftop systems at two of Johannesburg's leading upmarket hotels in order to offer recreational space and relaxing space as well as at the showpiece Sandton Convention Centre which has vegetation on the side of the building for aesthetic reasons (Rogerson, 2014; Labuschagne & Zulch, 2016). Beyond such commercial developments there has been a small number of green roof developments as part of upmarket eco-residential complexes which have been established in Gauteng, South Africa's economic heartland around the cities of Pretoria and Johannesburg. One such development is the mixed-use mega development of Waterfall City which is located midway between Johannesburg and Pretoria. Murray (2015) describes this as 'privatized urbanism in extremis', a master-planned holistically designed urban enclave which was built on vacant land. Waterfall City, according to Murray (2015, p. 503) is an expansive city building project which "combines a hyper-modernist stress on 'smart' growth, cutting-edge technologies, and state of the art infrastructure" which includes a human-scale built environment that incorporates an element of green roofing.

The minimal footprint of green roof developments prompted the observation made in 2016 that "green rooftop systems are a new concept in South Africa" (Labuschagne & Zulch, 2016, p. 710). Nevertheless, evidence exists of a latent demand for green roof development which is driven by its potential benefits. The most important factors relate to contributions towards improved air quality, aesthetic satisfaction, provision of recreation space, habitats and its potential for job creation in a country with one of the highest unemployment rates in the world. Set against this potential

demand the small extent of green roof developments occurring in South Africa requires further interrogation. The research conducted by Labuschagne & Zulch (2016, p. 710) disclosed that in South Africa "there is a lack of knowledge amongst the professional team members in the construction industry regarding the construction of green rooftop systems". Accordingly, "professional members of the construction industry do not recommend the development" of green roof constructions (Labuschagne & Zulch, 2016, p. 710). Indeed, the lack of an established green roof industry has the consequence of making more problematic and costly the retrofitting of existing buildings than in other countries (Van der Walt, 2018). Overall, it was suggested that of the three different types of green roofs the findings of Labuschagne & Zulch (2016, p. 714) were that "the semi-intensive green rooftop system is the most feasible for South African circumstances and the intensive green rooftop systems to be not feasible at all". The preference for the semi-intensive green roof system was explained as follows: "due to the structural changes to existing buildings being minimal, affordable and possible to accommodate the system".

METHODS

Supplementing these investigations are the results presented here of recently completed work undertaken in South Africa's major metropolitan areas. The study methods involved a national audit of green roofs and relevant legislation which was followed up by 44 semi-structured interviews (conducted in 2016-2017) with a range of companies engaged in the supply chain for green roof systems. These enterprises included architects, green building consultants, landscape architects, landscapers, green roof specialists, waterproofing specialists as well as representatives of the Green Building Council of South Africa (GBCSA). The interviews targeted information concerning details of the implementation of green roofs, the amount of green roofs completed, and perceptions of the challenges of green roof development in South Africa.

RESULTS

An initial finding was the revelation that no current specific legislation exists in South Africa concerning guidelines for the implementation of green roofs systems, albeit there is certain legislation which indirectly supports the use of green roofs (Cuthbertson, 2017). One example is that of eThekwini Municipality (Durban) which has specific bylaws relating to buildings and water supply regulating storm-water management, wasting of water, roof coverage and the prevention of the pollution of water all which can be applicable to green roofs (Sucheran & Sucheran, 2021).

The results concerning the supply of green roofs point to the fact that nationally there are only five companies that specialise in and are dedicated to the supply of green roofs in South Africa. This said, a range of other suppliers are engaged with rooftop developments as part of a broader portfolio of construction projects. In terms of South Africa's leading metropolitan centres there is observed a geographical unevenness in the numbers of green roofs that have been supplied. The results from Cuthbertson (2017) suggest that companies in Johannesburg have supplied approximately 100 green roofs, Cape Town 65 green roofs, Pretoria 60 green roofs, Durban 29 green roofs and Gqeberha (former Port Elizabeth) only three green roofs. It should be appreciated that these totals include commercial properties as well as residential developments, mostly eco-residential estates located in the surrounds of Johannesburg and Pretoria. Further, it must be added that the majority of these constructed 'green roofs' are not always placed on the roof itself but rather on terraces. The leading role of Johannesburg and Pretoria links to their function in the South African urban system as respectively commercial hub and administrative capital of South Africa. Johannesburg and Pretoria are in Gauteng province, South Africa's richest province and economic heartland. The city of Cape Town is a secondary business/commercial centre but a major focus for international tourists as well as foreign investment in new property developments. The coastal centre of Gqeberha (former Port Elizabeth) with minimal green roof developments is the major city of Eastern Cape, the poorest of the South Africa's nine provinces.

According to the suppliers the main reason for clients choosing green roofs was for the aesthetic value that green roofs can provide. The results are shown on Figure 1. It was apparent that the South African market for green roofs is therefore driven by image and aesthetics rather than environmentally considerations. Suppliers found clients wanting a recreational space which can be used as an entertainment area. Green star grading points from the GBCSA was a widely expressed reason as green star rated properties have a market premium. This said, certain international companies have certain standards that the South African branch was expected to follow. A building being viewed as 'sustainable' can be seen as marketable to the environmentally conscientious market and could attract more clients. Creating a natural space or an entertainment area on the top of a building, creates a comfortable environment that employees can enjoy thus supporting employee well-being and potential staff recruitment. The core market for green roof suppliers is commercial rather than residential property developments. Of the sampled enterprises 96 percent targeted commercial buildings. The small market for residential green roofs was accounted for by high costs and lack of incentives which has restricted residential green roofs mainly to upmarket eco-estates and high-end residential developments which have terraces with green roofs. It was evidenced that in the commercial building sector initiatives were ongoing to incorporate green roofs into new designs. The embrace of green roofs in commercial buildings was primarily driven by the desire of developers and tenants for natural space as opposed to a commitment to the environmental benefits from green roof systems. In the commercial property developments therefore the driver is 'natural space' for tenants and securing green star points in certification processes of the GBCSA.

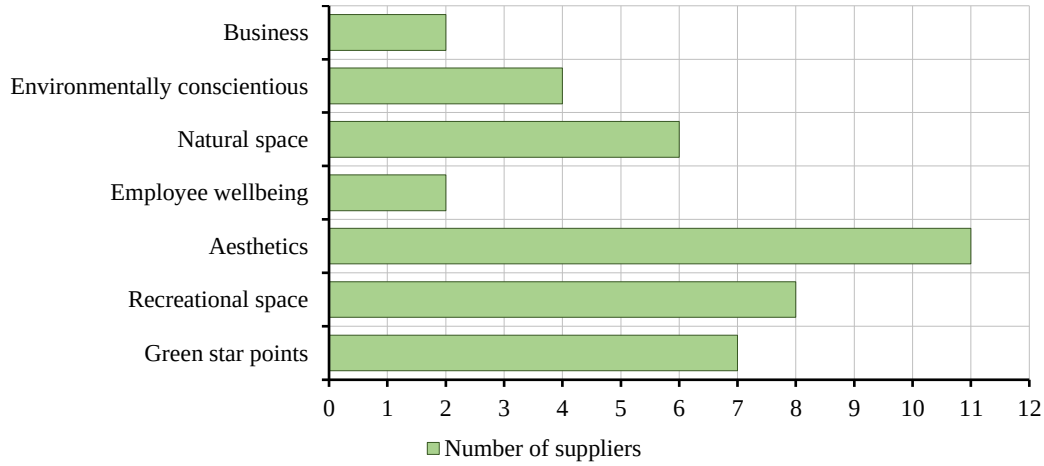

Figure 1. The reasons for supply of green roofs in South Africa
(Source: adapted from Cuthbertson, 2017)

Variations were disclosed in terms of types of green roofs that were available. The majority (44%) of the companies that supply green roofs offer all three types of green roofs, 30% offer only intensive green roofs, 19% offer extensive green roofs and the least type of green roof offered in the semi-intensive (7%). The purpose of the green roof is important in deciding the type of green roof. For example, most of the green roofs in Johannesburg, Cape Town and Pretoria are rooftop gardens (intensive), which are used to create a space in which the occupants can enjoy and often used as entertainment spaces for the commercial and residential buildings. This space which can be on various levels, which means that the occupants do not have to leave the building to experience green space. Of note is that the five companies that are dedicated to green roofs prefer to supply only extensive green roofs due to the perceived benefits these might offer as compared to intensive green roofs. Respondents gave several reasons for choosing the particular type of green roofs utilised in

South Africa. The type of green roof depends on the building, its location, height and what the client expects from the green roof. In addition, the weight of the green roof plays an important factor in deciding which type of green roof should be supplied as the building needs to be designed to carry potential extra weight. Further, the availability of space on the terrace as well as the availability of the materials such as the drainage system or the plants that will be used impacts the selection of the green roof type.

The interviews with 44 suppliers in green roof systems disclosed an array of challenges surrounding the implementation of green roofs and associated building projects. The most significant cluster of challenges that were profiled related to cost considerations, logistics and waterproofing. In addition, a constant issue highlighted by green roof specialist and landscape architects is a lack of client awareness of the benefits of green roofs. Respondents confirmed that green roof systems are costly endeavours and vary in cost per square metre dependent on type of installed green roof, plants used, the materials such as the filters or drainage systems, amount of soil, and the size of the green roof. It was stressed that in commercial projects a high cost item is the use of high reach machinery which is deemed a necessity as it assists in creating green roofs in such commercial buildings. Maintenance of green roofs is another cost issue that suppliers have to deal with clients; indeed, the imperative for maintenance was signalled as the leading negative factor surrounding green roof systems. Waterproofing of the roof for the green roof was highlighted by 25 percent of respondent suppliers. Leakages from damaged or incomplete waterproofing have been central problems. The supplier companies expressed the view that clients often queried waterproofing and its complex of issues but the companies that specialised in green roofs inform clients that green roofs protect the waterproofing layer from exposure to sunlight.

Another critical challenge is the logistics attached to green roof system construction – flagged by one-quarter of respondents – as many of the roofs have limited access thus necessitating the use of expensive heavy machinery (such as cranes) to move materials and soil. A further challenge of building logistics surrounded access to the roof as buildings without lifts to transport the materials results in time-consuming manual transfer of materials to roof sites. Beyond logistical issues surrounding access to roofs for many suppliers the weight of the green roof is critical as weight is a determining factor as to whether buildings can support a green roof. If the building cannot, reinforcement is needed which once again can be a high cost consideration. In the absence of reinforcement, the green roof design needs to be specifically undertaken to handle the roof's weight and especially of the soil cover. Other matters highlighted by respondents surrounded project timing and of client's often unrealistic expectations about project completion schedules. The positioning of plants was an issue for landscape architects as too much or too little sunlight can cause the plants to die. The choice of materials is also seen as a challenge as type of drainage system or filter used needs to be considered to prevent blockage as well as the combination of different growing mediums as some products are expensive or are too heavy to use solely.

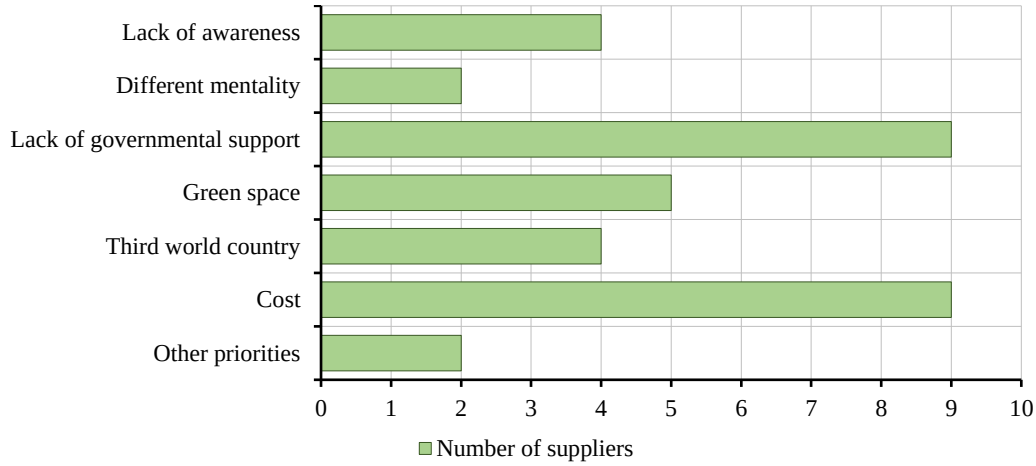

Figure 2. Reasons for lack of uptake of green roofs in South Africa
(Source: Adapted from Cuthbertson, 2017).

Finally, the 44 respondents were probed as to their perceptions for the lack of uptake and limited progress of green roof initiatives in South Africa. The results from the Cuthbertson (2017) study are captured on Figure 2. As is evidenced the two most significant issues which account for the underdevelopment of green roof systems in urban South Africa relate to cost considerations and lack of any government financial support for green roofs. The absence of any government incentives in South Africa contrasts with the availability of green roof incentives or subsidies available in several countries in the Global North (Liberalesso, Cruz, Silva, & Manso, 2020). Other explanatory factors that were raised concerned the greater broader availability of green space in South Africa as compared to other countries, its status as a developing economy and an overarching lack of awareness of the potential benefits that might accrue for urban sustainability from the growth of green roof systems. Lastly, there was clear acknowledgement among respondents that the lack of government support might be understood (and partially excused) on the grounds of massive urban challenges faced in South Africa around basic service and infrastructural provision.

CONCLUSION

Green infrastructural developments are an integral part of planning for urban sustainability and dealing with the multiple problems surrounding climate change (Zhang & He, 2021). In light of the projected concentration of rapid urbanisation in cities of the Global South there is a particular imperative in these areas for advancing sustainable urban development agendas (Ávila-Hernández, Simá, & Ché-Pan, 2023). One critical aspect of this agenda is the development of green roofs. Arguably, there is an accumulating body of research which is confirming that green roofs have significant potential for addressing a part of the environmental challenges that are facing cities (Jim & Hui, 2022; Scolaro & Ghisi, 2022; Wooster, Fleck, Torpy, Ramp, & Irga, 2022; Tafazzoli, 2023).

This study has investigated the limits of green infrastructure in a Global South context. In the South African case the findings in respect of green roofs show the relative underdevelopment of green roof systems, the geographical unevenness of such developments and the challenges that confront the emergence of green roof systems in the South African context. Key local issues relate to current high costs associated with green roof construction, absence of government support in the form of financial incentives, and lack of awareness of the sustainability benefits that attach to the roll out of green roof systems. These findings underline the urgency for further research investigations to be conducted into the green infrastructural challenges that face urban development in the Global South and most especially in the challenging environment of contemporary urban South Africa.

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ECONOMIC PROCESSES OF INCREASING GLOBALIZATION IN THE STRUCTURAL AND SPACE MUTATIONS OF ALGIERS TERRITORIES, IN THE WAY OF METROPOLISATION

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Abstract: Algiers is experiencing spatial and structural changes in its economy, as a result of globalization working in the world's metropolises, targeting the tertiary activities of the new global economy. The metropolis of Algeria, concentrates: population, activities and wealth, at the head of its network at three scales: urban, regional and national providing an international position in the Mediterranean basin on its south shore. Gateway to Globalization, Algiers is transforming the economic organization of its national urban system. This new tertiary sector concerns higher services, and calls for metropolitan functions (high level) and attaches to reinforce the higher level of the urban hierarchy. Our approach is based on GIS to capture changes; territorial and metropolitan movements (overconcentration and deconcentration) take place between central and peripheral neighborhoods, producing a new organization, which is the global metropolisation, linked to economic internationalization, the official beginning of which dates from 1997.

Key words: Urbanization in the region of Algiers, Urban network, Primatial city, Small towns under the influence of the capital city, Territorialization, Urban hierarchy, Metropolisation, Territorial command, Polycentrism

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INTRODUCTION

Under the effect of modelling, spatial, architectural and organizational changes occur in metropolises. The most visible aspects of these recent developments affect the organization and structure of tertiary activities in the concerned agglomerations. The tertiary sector is undergoing a profound structural transformation, accelerating the rise of services, especially those linked to new and rare higher services. Thus, the activities of the services are no longer the prerogative of the city centers or the mother agglomeration of the metropolises; the peripheries take part in this evolution by reinforcing these activities (Ascher, 1998). The striking aspect is reflected by a glass architecture that characterizes the urban landscape, giving it a triumphant global archetype in the global cities or metropolises of the advanced countries. This striking phenomenon expresses the advent of a logic that had its effect in the historic urban fabric, but in other aspects, it remains marked by a dynamic process and the philosophy of capital, in metropolises between their center and their peripheries. Thus the location, factors of tertiary economic activities in the metropolitan territories, changes and seem to organize space differently (Paquot, 2000). Recall that the tertiary sector encompasses all transactional activities: trade, transportation, and services, opposing the areas, primary (agriculture, raw materials) and secondary (processing and manufacturing). Spatial and structural changes in the economy that have the effect of strengthening the tertiary sector from other economic areas, i.e. primary and secondary, are also observed in the Algerian capital. The classification of activities considers other changes in from which new industrial sectors are born. The structuring of economic activities involves the consolidation of activities that were included in the agriculture sector such as research, administration, management, and sales. Paradoxically, activities of a secondary nature were found in tertiary companies such as repair and packaging. In the Algerian metropolis, like its "southern" counterparts, the tertiary sector is perpetually inflated, because of small trades and informal activities. In the past, this sector was dominant because of the underdevelopment situation and is currently growing due to the changes imposed by globalization. It focuses both on the very structures of economic activities and on the re-launching of the market economy, namely capitalism, which is the required model.

Among the economic processes of globalization, whose work is advancing in Algiers, as in most metropolises in the north and south, the restructuring of tertiary economic activities is pre-eminent. It is at the same time a process purely related to the new structural and spatial economy and disrupts the sectoral structure itself, by bringing in new sectors emerging from traditional industries or not. It calls into question the conventional organization of the agglomeration economy. The old spatial model of agglomerations: Centre/periphery renewed and profoundly modified by the reversal of hierarchical networks of urban territories into parallel systems. The new model must structure the areas of the agglomeration in polycentrism, where relations cease to begin from the top of hierarchy downwards and encourage the lateral ties between the cities of the system crowned by the metropolis that makes the decisions. This large city concentrates population, activities and wealth while being head of the network at different scales: regional, national whose prospects forecasting its international articulation in the Mediterranean basin, whose identification aims an advantageous position on the southern shore of the Mediterranean. It is in a way a front door to globalization. Its development continues to benefit as much from the dynamism of its region, the economic logic as by government measures. The analysis of this phenomenon in the metropolis of Algiers will show the evolutions in question. The primary hypothesis revolves around these questions: This metropolis affected by this phenomenon: where is the actual situation? What is the degree of impact in the internal structure of the organization of the economy itself and the spatial arrangement? In the general case and mainly through an active process the tertiarization is very influential. The previous centralized system shows its importance; will it bear its impacts and introduce the establishment of the new economy?

METHODOLOGY

This work is part of the study and research of current events, some aspects of which are under discussion, of the organization of the urban space, which, under the effect of globalization,

passes from a classical structure to another. Always under the impact of globalization, the ordinary tertiary sector transformed into a new tertiary sometimes-called quaternary, specialized in higher services. Metropolitan functions that are likely to grow: those of high-level management, particularly those related to the economy, attracted by the concentration of other activities. Metropolis-globalization processes seek to strengthen the higher level of the urban hierarchy while monopolizing a varied growth ranging from demography, economic development; the polarization of flows disadvantaging its hinterland (rural, urban network) (Diméo, 2010). Our approach based on GIS (Geography Information System) to understand better all the evolutions, notable aspects and changes that have occurred (Achraf, 2021). Tertiary functions focused on new services are organized in a different way than regular services. These high-level services are exercised in offices, old and new, hence the advent of the geography of offices, which highlights impact, changes both in the activity itself and in the landscape where it is localized (Rasha, 2020). GIS analysis contributes not only to embracing all the suspected factors but especially allows multiplication of crossover and combination tests to arrive at realities that make it possible to affirm or refute the hypotheses determined upstream of the research (Abdelmoumene & Mahdi, 2020). The element that allows its changes is the land and real estate offer; this allows the spatial approach of tertiary activities, in the context of geographical or spatial economics. The transformations create and effect geographical movements (Carroué, 2001), particularly in the metropolitan territories by the process of over-concentration of certain neighborhoods of the city Centre and the periphery, favoring a new structuring of space giving a new organization of urban regions. After having been exclusive to advanced countries, the process in question is expanding to all nations, even the least developed. Globalization is launching and determining the model marking the new urbanization, which concerns both the questioning of the spatial organization of tertiary activities and the acceleration of the logic of the real estate market, which leads to the change of the classical factors of the localization (Nacer & Dridi, 2021). Earlier the approach of tertiary activities was strictly functional. A significant dispersal movement towards the peripheries abandoned these activities in the city Centre as shown in this study. These mutations send to other spatial logic that needs to be explored. It should be noted that the apparent element of economic transformations in metropolitan areas is real estate, which symbolizes spaces where the headquarters of the main higher-level service activities Business Center District (CBD) are concentrated. This model is being expanded to the least developed countries, as part of their articulation to a global market by creating trans-nationalization relays for the modern economy around the world (Koop, 2007).Thus, real estate has become an indicator of the degree of services development in metropolitan areas (Paquot, 2000). It explains and confirms the logic of the spatial organization of service activities based on the maximization of information exchanges, which raises our apprehension of Algiers case, the principal city of the frame or command network that generally exceeds the regional framework. The processes concerning the settlement dimension and the rupture of the city with its former territories are acquired (Spector & Theys, 1999); it is the world urbanization linked to economic internationalization has just officially started since 1997. Our analysis by GIS revolves around the dynamics of the tertiary sector, which favors the metropolis towards an evolution touching first the production of the services, the pivot of this sector, and especially the possibility of capturing and redistributing the economic development. Big cities are considered agents of change, in addition to inserting the daily operating area in its territories (Huriot & Perreur, 1995), while territorializing it (Ferrier, 1999).The analyzes are based on official statistics from the National Register of Commerce Center (CNRC), the equivalent of (Business Directory Identification System**)** SIRENE in France. The cartography is somewhat thematic and spread over a period from 1996 to 2013, i.e. almost two decades, structured in two: 1996-2006 and 2006-2013. As for the territory of the metropolis, it extends over the small region of Algiers well individualized morphologically (Sahel and Mitidja), and covers four cities, that of Algiers surrounded by three others (Blida, Boumerdes and Tipaza). As for the operating territory, it spreads over the north-central region of the country covering ten cities.

RESULTS & DISCUSSION

Changes in economic structures: establishment of the geographical economy (Direct impact of globalization)

The financial processes of globalization underway in Algiers, the southern metropolis, are first affecting the restructuring of tertiary economic activities. They are part of the new structural economy and disrupt the sectoral structure of the economy itself, bringing new sectors emanating from traditional industries or not.

Economic situation before the opening in 1996

A glimpse of the case on the opening eve requires first to indicate the place of the tertiary sector in 1996. This sector has always been the most important of the economy, to such an extent that it qualifies itself as hegemony and accretion in developing countries. Its weight is high and often exceeds 60%. The tertiary sector is not as identifiable as earlier; it brings together many activities (division encompassing the other two old) and usually escapes economic analysis. The following map shows its tertiary distribution (Figure 1).

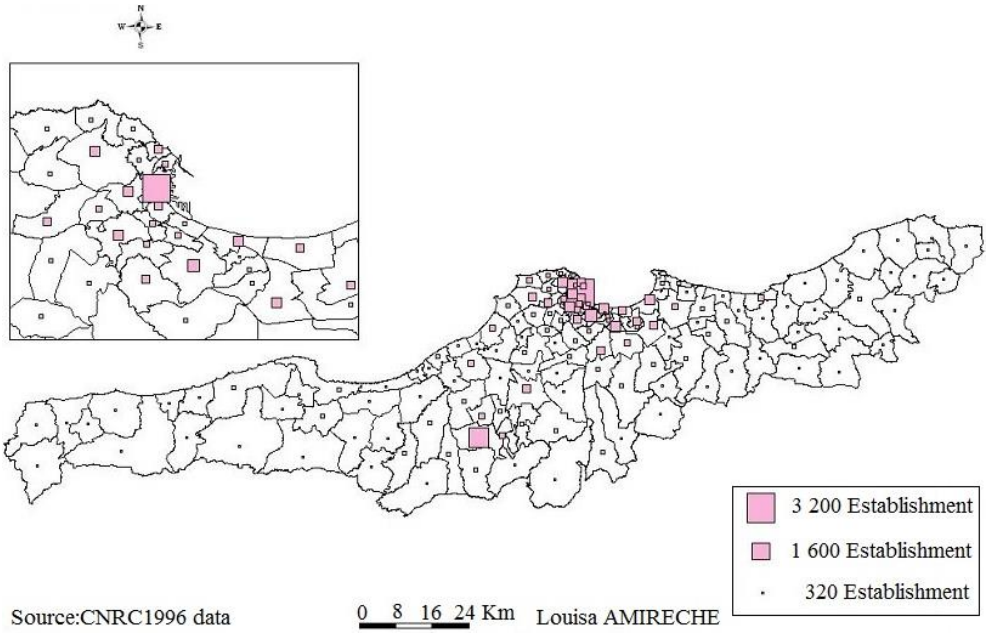

Figure 1. The services sector in Algiers in 1996
(Source: Authors)

Importance of the tertiary sector in the economy

The tertiary industry was particularly crucial in Algiers, where it accounted for more than 80%, as in the country, it often exceeds 70% of the total economy. It is hegemonic in the classical metropolises. To clarify its economic importance, we calculate it by the geographical unit as shown in the following (Table 1).

Table 1. The tertiary sector's share in the market
(Data source: Authors)

Territories	The tertiary sector's share in the economy
Algiers's agglomeration	89%
Metropolis regions	81%
Algeria	79%

Despite the value of services in this sector, other economic activities are more important, such as trade. It brings together a more significant share of jobs and industrial units.

A tertiary-specific tertiary school

The tertiary part was hegemonic for two reasons: first by the place of the country's capital, and primarily by the old socialist economy or state's capitalism. The proportion of this sector was the most important, considered, as in all the countries of the "south" exceptionally, inflated. It does not represent superiority; on the contrary, there is an accumulation of small-undeveloped activities in this sector compared to the secondary industry, although Algiers was a balanced economy city in its former businesses. It is estimated at more than 70% in its periphery, and it approaches the 80% in its central districts (Figure 2).

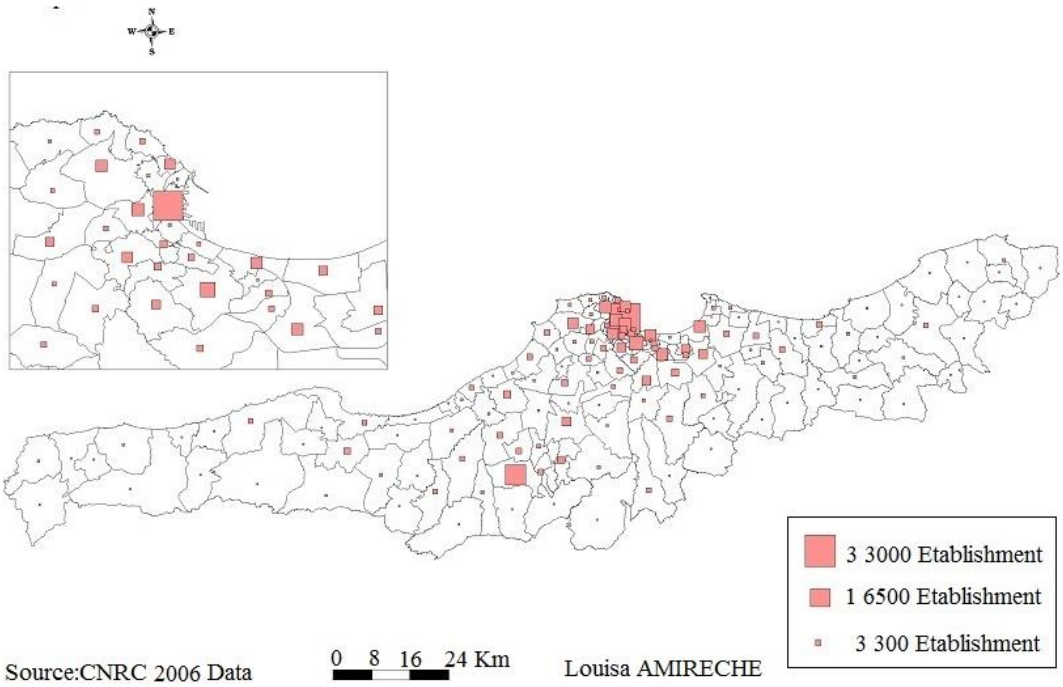

Figure 2. The tertiary sector in Algiers, 2006.
(Source: Authors)

The economic situation after the opening in 2006

In a decade: from 1996 to 2006, the economy was restructured according to the directives imposed by globalization. First, after the creation of NRC (National Register of Commerce Center), new terminology was put in place. Instead of Clin Clark's three traditional sectors, seven new industries were created in the N.A.A. **(**Nomenclature of Algerian Activities), equivalent to the Nomenclature of Franc N.A.F. While some activities still do not exist, a seventh sector has been registered to receive the content later. This structuring of the economy is the basis of the new geographical economy. Partitioning into new oriented industries brings synergy both to the economy itself and to the new spatial organization of all the metropolitan areas so that the economic take-off finds an adequate framework for the external market. In other words, the model in sight finds ready the new form of spatial organization, which will serve well for a real economic take-off of the metropolis towards the market economy. The changes will strengthen the urbanization by increasing the services-creating sector, which will reinforce its position as a service Centre. In addition, its administrative functions play a role of training on an essential attraction of the services.

The new place of the tertiary sector in the economy: renewed and strengthened structure

As the following table shows, the position of the tertiary sector has been partially enhanced, but its structure is by no means the same as other services that have emerged, such as business services, financial services. Other more recent data from the same organization NRC (National Register of Commerce Center) attest and strengthen the position of the tertiary sector and its activities 2009 and 2013 (Table 2).

Table 2. The tertiary sector's share in the economy in 2006
(Data source: Authors)

Territories	The tertiary sector's share in the economy
Algiers's agglomeration	87%
Metropolis regions	84%
Algeria	81%

The proportion of this sector is growing because of the regular services rise, in addition to emerging services from the industry sectors that maintain production and take out design services. The following map shows, in the territory of the metropolis, the evolution of the tertiary sector in a decade. The double effect of the new processes namely its internal restructuring and especially its greater distribution in this territory: among others the phenomenon of suburbanization, which means its exit from the agglomeration to spread beyond its purely urban limit (Figure 3).

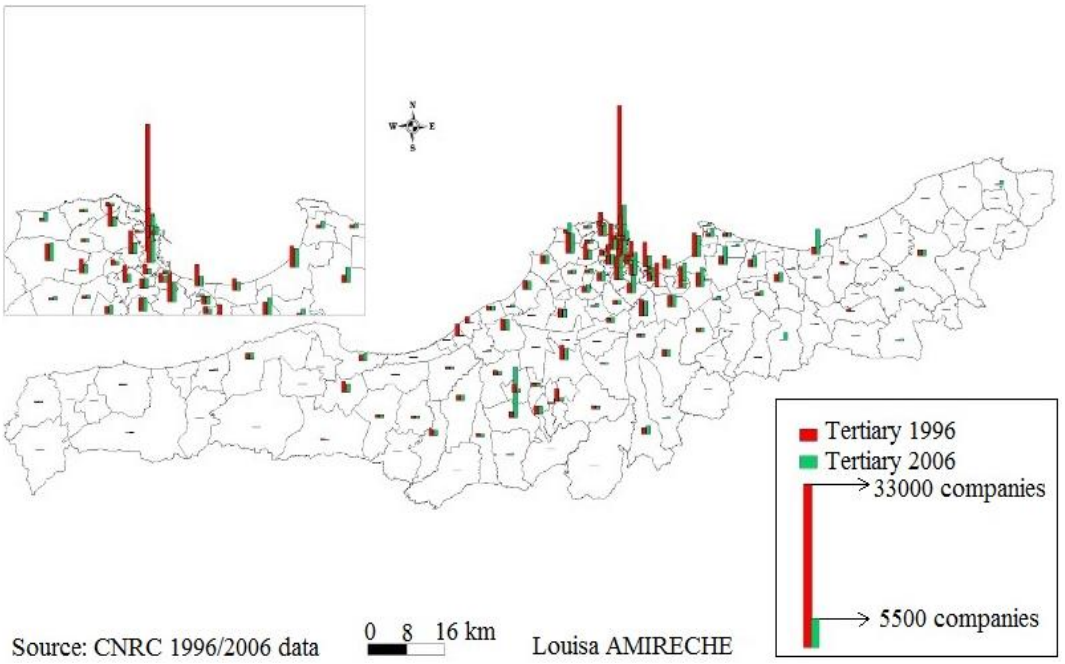

Figure 3. The evolution of the tertiary sector in Algiers region between 1996-2006
(Source: Authors)

New tertiary activities emerge from superior services

The weight of Algiers metropolis is overwhelming in the country. It is imperative regarding services NRC (National Register of Commerce Center) with 15% of the country and above all 14% higher services, represented by social services, communication services, land and real estate, transportation, and financial services.

The rise of services of essential and varied composition

Particulate services have become vital to population growth and the new needs of the new economy. As for new services, they are more related to urbanization-globalization and the new economic structure (Table 3).

Table 3. Total services during the analysis period
(Data source: Authors)

Structure	Services in 1996 Number of establishments	Services in 2006 Number of establishments	Services in 2013 Number of establishments
Agglomeration	9.877	29.836	33.313
Algiers region	18.772	78.927	117.548

The new tertiary sector revolves around the importance of services

We first demonstrated the rise of services in a general way. According to the temporality: the establishments multiplied by folds of three times in the agglomeration and more than six times in its regional territory, this verifies the hypothesis in its first part of the produced mutations, with an increase of 23436 and 98776 establishments respectively in the agglomeration and the region. This brief analysis of the evolution of services over almost two decades (17 years: 1996-2013) shows an accelerated rise. The following map shows a more considerable increase and distribution (Figure 4).

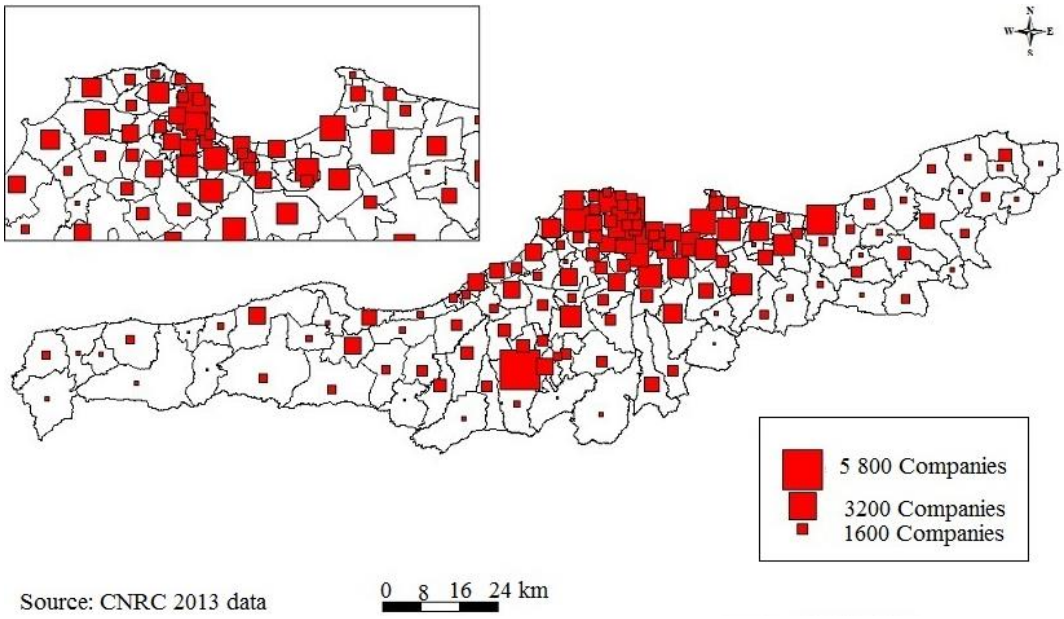

Figure 4. The services sector in Algiers in 2013.
(Source: Authors)

The importance of the services (nature, composition)

It is useful to recall the definition of functions. A set of activities in the tertiary sector, facilities consist of benefits for companies, public authorities or individuals. Services are different from businesses in that they do not transfer goods, but knowledge and work. We distinguish the market services (those of the liberal professions, the spectacles, and the hospitals, the activities of the council, management, and advertising) and the nonmarket services (schools, libraries, police, administration, social action).

Emergences of higher services

The importance and evolution of more top services are growing. The development of services is compelling, for over four decades, it has broad prospects with the expansion of tourism in advanced countries. At the same time, it is linked to the occupations of free time, and especially to the needs of corporate performance (consulting, technology transfer, advertising, management, information and even financial investments). The distribution of services is an indicator of the validity of the places. Several levels of service are recognized by scarcity and quality, which is measured by value added in a particular branch. Thus, the whole of the rare services forms the "tertiary superior" also said quaternary sector. The abundance of unique high-level services measures the quality of a city and especially the metropolis, and its place in the networks; because these services are performed in specialized premises either on the ground floor or in rooms, often called offices (Bonnet, 1985). The weight of Algiers territory is the largest with 15% of all services in the country and 14% of the country's top facilities. Its influence in the north-central region of Algeria is overwhelming: 71% of services; 52% of financial services; 55% of the business, and 64% of services related to land and real estate. It is useful to indicate the concentration of the administrative and diplomatic command in the agglomeration. Therefore, government institutions are almost universally located in the metropolis with 93%. This map highlights the density of units and broader distribution (Figure 5).

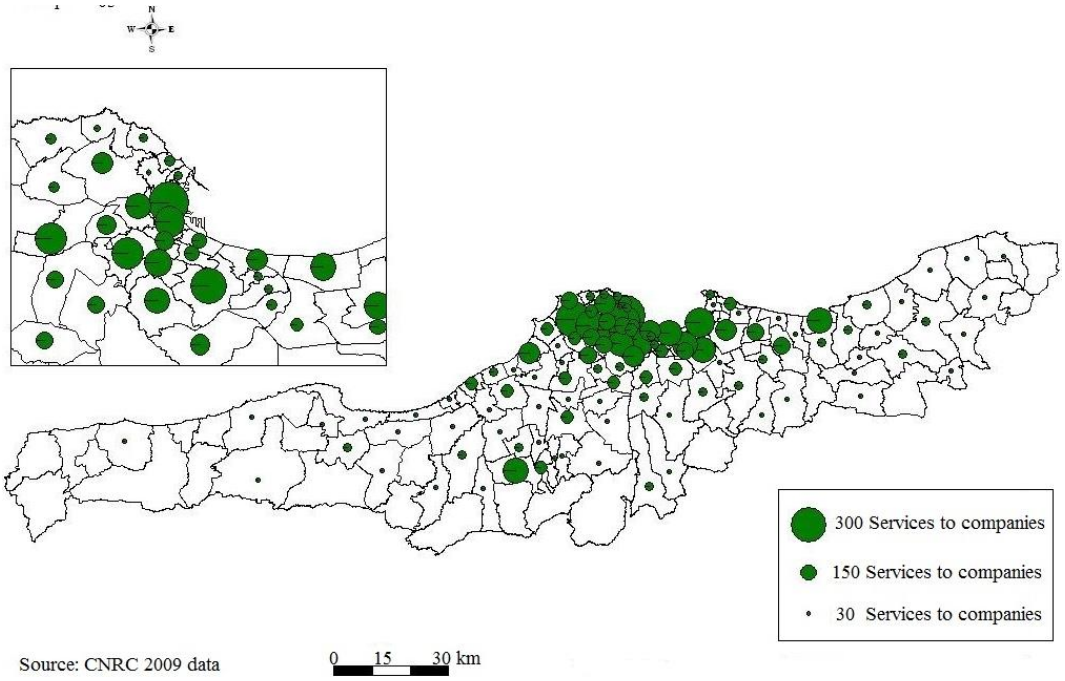

Figure 05. Total companies services in the Algiers region in 2009
(Source: Authors)

Revaluation of the financial services

The importance of the financial services is very significant and remains concentrated in the agglomeration and central districts. There are more than twenty social seats of national banks and branches of international banks, the majority of which are focused on the agglomeration. Insurance is also concentrated on the agglomeration with a slight dispersal in the first quarter recently. Financial activities are the services that oversee the economy. Their growing importance marks the most recent and most striking evolutions of the economy as well as those relating to the domestic

economy (increase in demand associated with the growth of the local population), as well as that under the impact of globalization (see next card) (Figure 6).

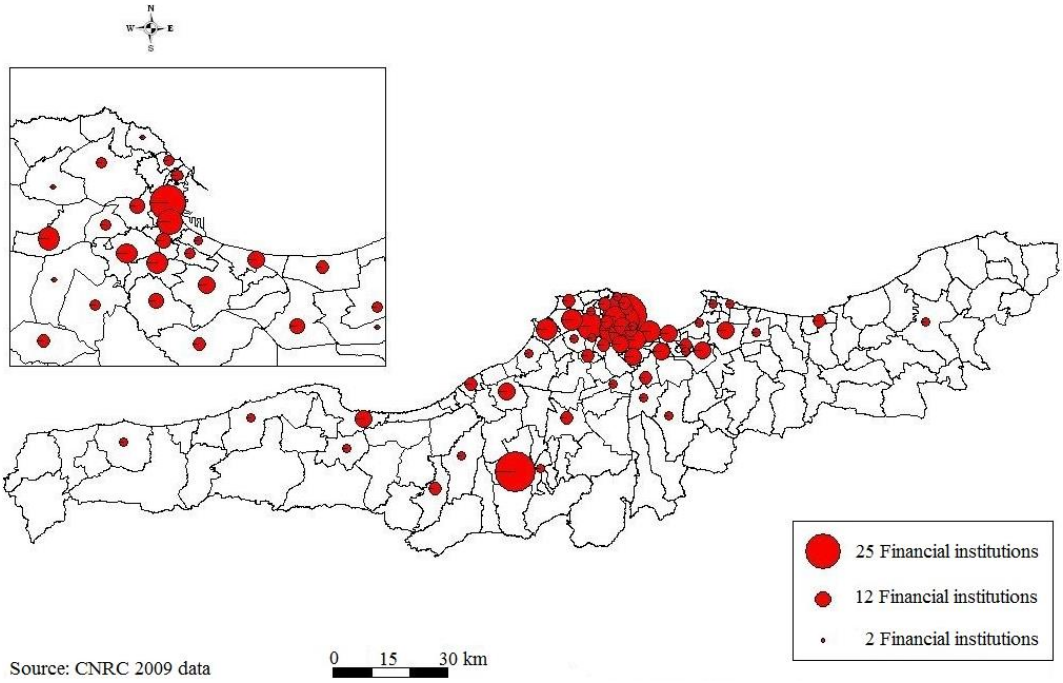

Figure 06: Total financial institutions in the Algiers region in 2009
(Source: Authors)

A factor become dynamic of tertiary location: land and real estate

Through the changes taking place, the supply of property and real estate seems to play an essential role in the position of tertiary activities. This striking phenomenon expresses the advent of a logic that had a visible impact on ancient fabrics with different aspects, but the dynamic process operates according to the Centre/periphery relationship and the capital logic. Thus, the factors of the location of economic activities in the metropolitan territories change and seem to organize the space differently (Malézieux & Rudrauf, 1994). In this sense, an over-concentration of areas of former concentration, and decentralization in the peripheral areas of services and especially higher services, is being set up (Dollfus, 2007).

Freeing land manifested by the land emergence and the proliferation of real estate agencies

Property and real estate are an indispensable factor in the spatial dynamics of the tertiary. Numerous are the theories that have plagued the literature on industrial locations, central places, transport, information and location of real estate (spatial economy). Thus, the city centers of the metropolises have concentrated tertiary activities by offering the maximum of factors favorably the ground rent, conditioned by the value of the ground and the actors' game who direct the organization of the city. It is the tertiary activities, which, by reinforcing the process of concentration, increase the value of the land, hence the development of urban territories. This land-based logic enhances both the process of polarization and the focus of tertiary activities in urban areas. Spatial and financial, logics join the polarization and the concentration of these activities, which is why the value of the soil becomes pre-destination of the real estate development that is in the most central zones or the zones of polarization (activity poles). The real estate market and the business market cause

imbalances and especially new forms of economic excesses. However, it plays an essential role in the resumption of urbanization as a new capitalist world economy (Malézieux, 1995). From the opening to the market economy, the laws on land and real estate organize their liberalization according to the requirements of the market (Paulet, 2010). Immediately real estate agencies are born and carry out their transaction activities, across all territories and mainly urban areas, where land and real estate strengthen more the market. Real estate is one of the most active metropolitan factors that increase the urban character of some spaces (Paulet, 2000). Once the locations of the activities factors have changed, the urban spaces adopt the new organization and restart according to the center/periphery theory. The number of real estate agencies, an indicator of spatial dynamics, is constantly increasing and expresses the recovery of the market as shown on this map (Figure 7).

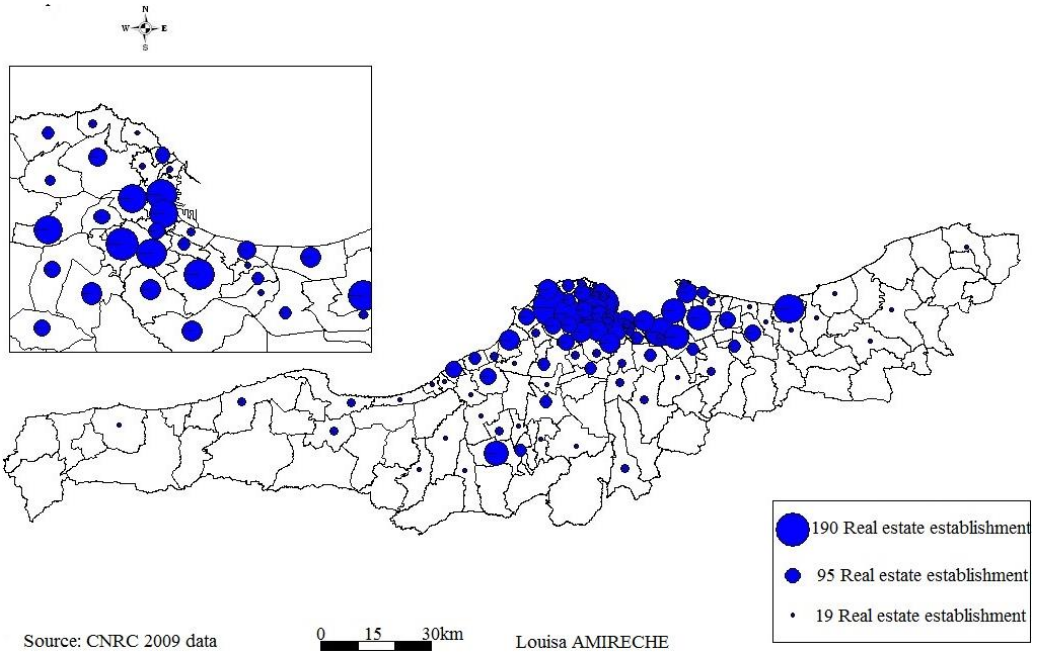

Figure 7. Total real estate institutions in metropolitan area of Algiers in 2009
(Source: Authors)

The new spatial structuring of the Algiers territories (another impact of globalization)

The evolution of the tertiary and its services from 1996 to 2013, reorganize the importance of the structure of the metropolis territories. It is in this sense that the agglomeration declines partially in front of its periphery. These are distinguished by a location of greater importance in the nearer boundary of the agglomeration (first crown). However, the territories of the second crown can only strengthen two old poles of services in addition to the new ones. The analysis discriminates these poles by a value of more than five thousand tertiary units and more than two thousand units for services, as shown by the two following (Figure 8, 9).

In a general way, the anatomy of the metropolis territory consists of a dominant Centre, a first suburban crown and a second peripheral ring. In the course of its evolution and its extended configuration, a hierarchy of active centers in the perimeter of its agglomeration and other more or less hierarchical poles as well in its first and its second crown. We have expanded the volume of services in the new structure by further analysis by borrowing new recent data (2013) for all services (graph 3); then business services (graph 4). A breakdown of business services by structure shows a preferential location in the first ring, despite the maintenance of the metropolitan agglomeration,'s importance (Figure 10, 11).

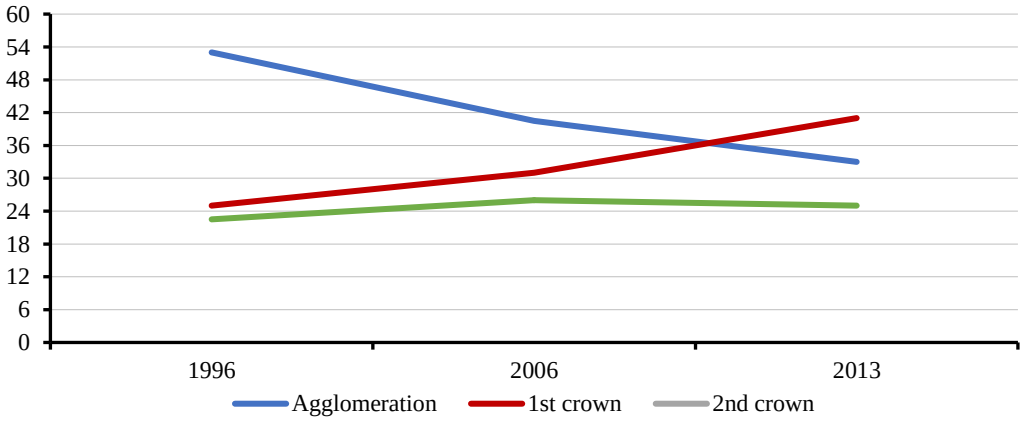

Figure 8. Tertiary evolution by structure in three stages
(Source: Authors)

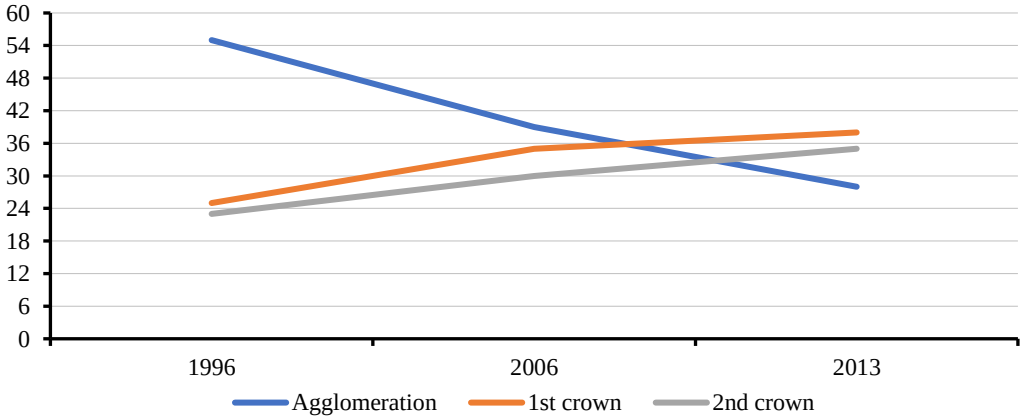

Figure 9. Evolution of services by spatial structure in the Algiers region
(Source: Authors)

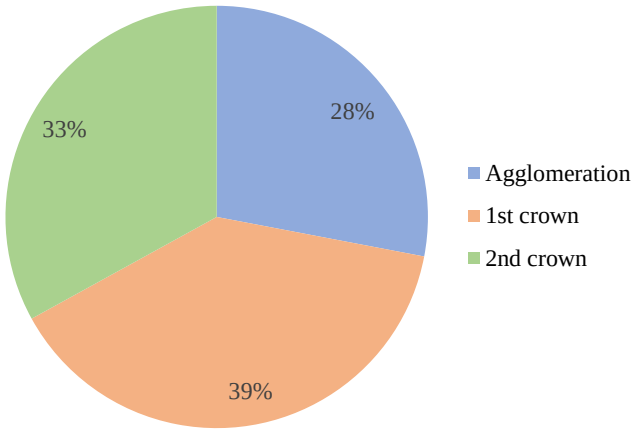

Figure 10. Distribution of services by metropolitan structure of Algiers (2013)
(Source: Authors)

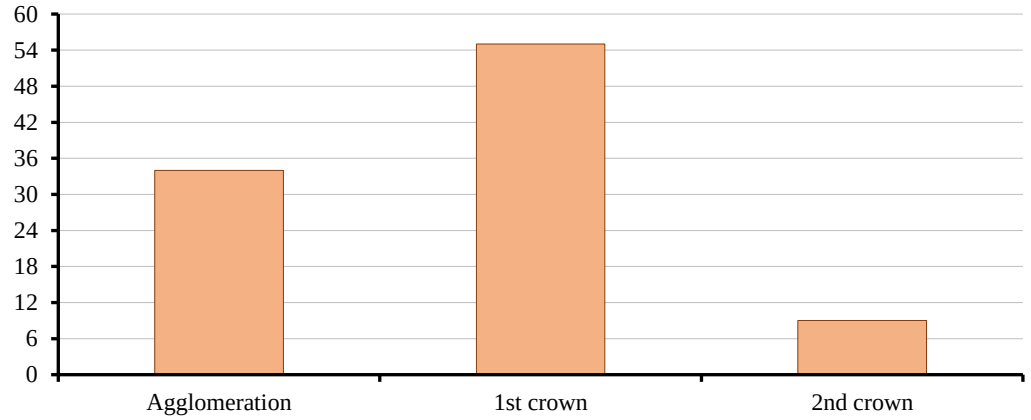

Figure 11. Business services by territorial structure in 2013
(Source: Authors)

A hierarchy of the centers in the conurbation with reinforcement of the hyper-center

To demonstrate the emergence of the concentrations produced by the processes in question, we have established a value range for services over two thousand to distinguish the rise of centers in the agglomerations we have named secondary centers that reinforce the hyper-saturated center and lack of area in its space (Figure 12).

The new tertiary centers in the Algerian agglomeration reinforcing the hyper-centers in search of appropriate space. The ranking of these centers in the Algiers agglomeration shows the supremacy of its central municipality with a much higher concentration of higher services. The center of Kouba, the nearest district, is ranked second before the precentral area: sidi m'hamed. The others are located in the suburbs of the Algerian agglomeration, constituting the fronts of urbanization.

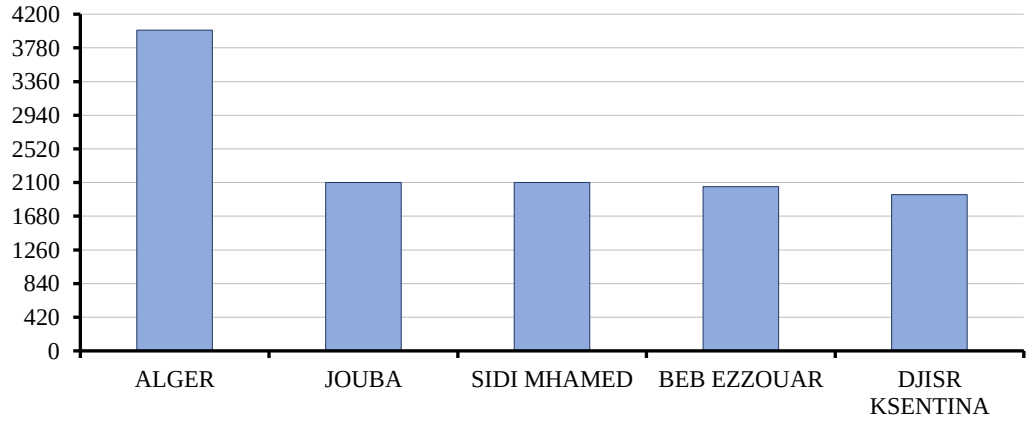

Figure 12. The service centers of the agglomeration of Algiers 2013
(Source: Authors)

The emergence of structuring poles in the near peripheries

The second impact of the tertiarization - structuration of the metropolis territories after the emergence of centers in the agglomeration is the consolidation and strengthening of the first crown's poles. The first pole of the near periphery to the east is Bordj el Kiffan then Cheraga to the west. As for the pole of Rouiba, it is in the last position compared to the others. The industry that was

supposed to make it the most massive peripheral pole still suffers from the resumption of this activity; this is planned incessantly but has not started yet. It also partly explains the delay in the new structuring and the new services acquisition (Figure 13).

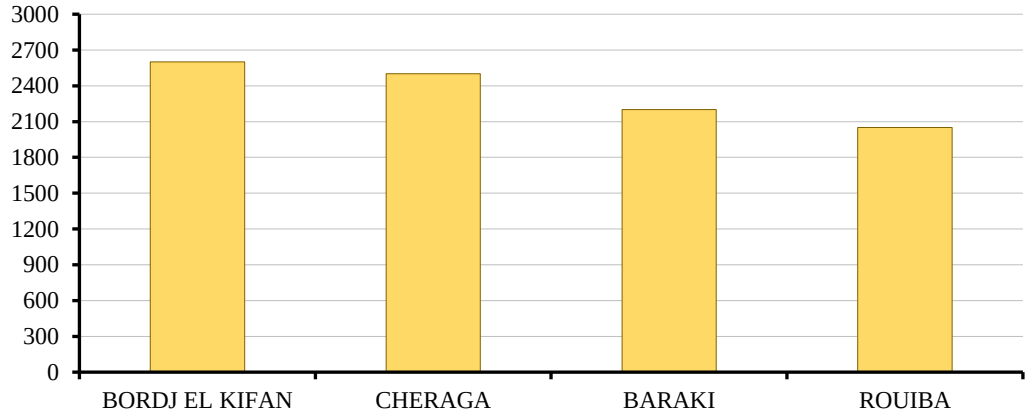

Figure 13. The service centers in 2013 of the first suburban crown
(Source: Authors)

From a center/periphery structure to a polycentric structure

Structurally, we end up with a new, different structure model where there has been emergence and strengthening of centers and poles both in the agglomeration and in its two crowns. Thus was born a different polycentrism from a hierarchical origin that functional relationships have renewed.

The supreme place of the hyper-center of Algiers strengthens only two poles of the second peripheral ring: Blida and Boumerdes

Always according to the classification, tertiary, and services; in the second ring; two large poles are strengthened due to the hyper-center command and the old network hierarchy, which reinforces the lateral, poles relations of particular importance, considering they are already service centers because of their administrative functions. On the other hand, the impact of urbanization-globalization is by selection, mainly through the Blida pole, whose evolution activates a certain less critical urbanization, so much that it comes after Algiers directly in the ranks (Figure 14).

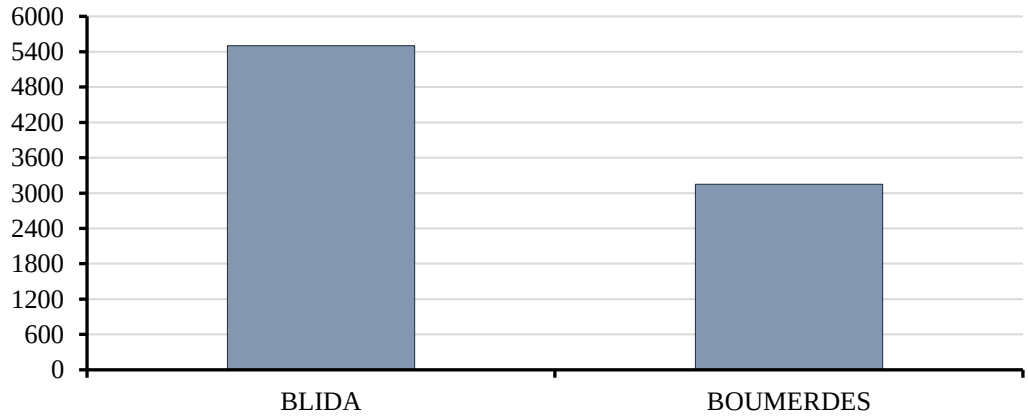

Figure 14. The service centers in 2013 of the second peripheral crown
(Source: Authors)

Comparative study between the hyper-center and a suburban pole of the first crown, Rouiba

The comparison between two representative municipalities demonstrates the dynamics of the tertiary phenomenon in its ability to make and break the very structures of the metropolitan agglomeration. Thus, the centers of gravity of the metropolis move in time and space in recent years. The first is being over-concentrated and the second is following the evolution of the tertiary sector under the influence of agglomeration.

The hyper-center identified by the municipality of Algiers center

The concentration of service activities in the central areas corresponds to a functional logic that is specific to this type of business, which is that of communication and information (information technology and communications).

The presence of corporate headquarters in the city center has a symbolic character, an attractive brand image in the urban landscape that leads to the construction of imposing buildings by their size, their solidity and their richness in addition to an architectural valorization (glass architecture).

The central space in the metropolis considered as the vital area of the metropolitan territories, the tertiary activities and especially the business services that continue to concentrate in the capital. Prefer the most central spaces but do not remain the only ones where their diffusion in the peripheral poles, like the pole of Rouiba located in its first suburban crown.

The importance of the city center is revealed by its functions as the nerve center of the metropolitan economy, still powerful and will continue to be strengthened, with the help of its strategic assets including its dynamism of the over-concentration of the tertiary sector and particularly the tertiary level.

The Rouiba pole: a receptacle for the surplus of the tertiary activities of the hyper-center and the agglomeration

This major center represented by the municipality of Rouiba encloses the most important industrial area of the metropolis. It has strategic assets for a long time. However, the recent remarkable developments are very different from those expected, in that the increase in tertiary activities instead indicates the postponement of a certain degree of decentralization-dispersal towards the near periphery than the development of business services activities. This division is expected to restructure its operations by increasing those related to the tertiary sector, at the expense of industrial events, based on the renewal of the productive industry as a secondary activity that must separate production from tertiary activities including higher services related to industrial enterprises themselves. These detached services, traditionally linked to the industry, will be able to exercise their functions freely to other companies or other applicants. This mutation transforms the simple service into a higher service that will give it the structuring role of the new tertiary sector. Aided by the availability of lands and real estate, close periphery or first crown, this new activity will increase its power to attract other dependent or complementary businesses, so it is called to structure the pole in question.

This pole is evolving, reinforces its attractiveness while beginning a new structuring of the near periphery or even the distant boundary and taking advantage of its proximity to both the metropolis and the second crown. By the parallel dispersal which works in the near periphery, the pole of Rouiba, having aptitudes to renew its space established at the beginning for the industry, to accommodate tertiary activities, which for a good part, are usually intended for the metropolises' centers, are located in the periphery. The hegemony and delay of the industry's recovery create this situation of "palliation" or "substitute".

CONCLUSION

The analysis of changes in the economic structure under the influence of urbanization-globalization has shown that the new structure, which has been organized into three major classical

sectors, is reorganized around seven industries where the tertiary sector has become unrivalled. This sector thanks to the rise of the services became the central structuring, not only of the economy itself and especially of the territorial structuring, of the Algiers metropolis. From the center/periphery, it is transforming into a polycentric structure where the first crown wins at the expense of the agglomeration and its hyper center (municipality of Algiers center). Developments have confirmed through the analysis of this phenomenon in the city of Algiers the primary hypothesis that revolves around this issue. This metropolis, touched by this phenomenon has arrived at a situation where the degree of impact has transformed the internal structure of the economic organization itself and its spatial structure (Mérenne-Schoumaker, 1991). The vast tertiarization process has been very influential, despite its importance already acquired in the previous centralized system; its impacts have introduced the new economy (Polèse & Coffey, 1984).

The recent evolution of the tertiary sector is a turning point for the geography of the metropolitan area, and the new services have contributed to a beginning of change, thanks to the availability of real estate and land in the first and second crown of the Algiers metropolitan territory. Thus, it becomes an element of territorial discrimination in the same way as other structuring equipment, such as railway stations, airports and motorway links.

For our comparative study, the example of hyper-center confirms a specific over concentration but its weight has been reduced compared to the expanding evolution of the new tertiary and its higher services including business services thanks to the availability of real estate in the outskirts of Metropolis.

The example of the pole of the near periphery (first crown), for lack of synergy, because the actual situation of the industrial activity, called to transform and develop in the new capitalism has changed little because of the weak part of the partnership to renew itself according to the planned directives.

Note that the availability of real estate has instead served as a receptacle for the surplus of the hyper-center, not regarding new services but rare conventional services

As for the centers discriminated by their position in the agglomeration of Algiers and the centers of concentration of new services caused by economic dynamism in the metropolitan areas of the inner suburban were more valued by the new tertiary and its particular functions.

Therefore, at the end of this research, the impact of the globalization urbanization is particular and is still in its start because of the peculiarities related to the conjuncture of the country. However: land and real estate have somehow determined the new structuring of the metropolitan territory. This mechanism tends to reinforce the process of spatial selectivity and from there to make and break the organization of the metropolis territories.

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MORPHO-PEDOLOGY VARIATIONS IN A PRE-SAHARAN REGION CASE ZIBAN SOILS

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Abstract: During this study, we tried to highlight the main lines of the spatial evolution of the morpho-pedological characters of certain soils, on a sequence established from the geomorphological map in the region. Biskra is an Oasis located in the North-Eastern Sahara of Algeria. After a long prospection, we have established two sequences of soils which have different morphological characteristics. These variations are mainly due to the geomorphological position of the terrain and the favorable hydrological aspect in the first sequence to the formation of gypsum soils compared to the second.

Key words: Saharan soils, gypsum, morpho-pedology, salinity, groundwater

* * * * * *

INTRODUCTION

In arid regions, rainfall, low and occasional, induces a markedly deficient climatic drainage for most of the year. Flows, superficial (oueds, backwaters) or hypodermic, are most often temporary. They reach areas of concentration which are the privileged places of saline manifestations in water and soil.

The processes of valorization of the grounds used, do not take into account all the factors (climatic, edaphic, hydrological etc.) which ensure and perpetuate this production. On the other hand,

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developing the land means above all taking into account all the factors cited above in order to assess the current capacities and meet the maximum requirements for increasing the intrinsic quality of the land and ensuring, in a sustainable manner, a yield qualitative and quantitative (Benadji, 1998).

In the same perspective, for us pedologists, it is essential to remember that the genetic characterization of soils in the Saharan environment requires knowledge of the geomorphological context in which these soils are located. It is also established that we cannot explain in an isolated way, according to the only vertical migration of the matter and only of the interdependencies with what surrounds it. The notion of topo-sequence, resulting solely from topographical considerations, is insufficient because it could lead to a comparison of soils of different ages (Boumaraf, Saadi, & Marre, 2016). Thus, a new morpho-pedological approach to soils is adopted by Bétard in 2006, (Bétard & Bourgeon, 2009) to create a new approach to land evaluation in the Saharan region of Ziban one of the most productive agricultural with 4.3 million date palm trees (Faci & Benziouche, 2021), in association with greenhouse cultivation (Ouendeno, Daoudi, & Colin, 2015).

MATERIAL AND METHODS

Geography of the Ziban region

Biskra region is located in southeastern Algeria at 425 Km of the capital (Algiers) (Figure 1). It is bounded in the north by the Saharan Atlas, which represents a SW – NE directional relief. It extends to the Chott Melghir area in the southeast and to the Eastern erg in the southwest. Biskra region constitutes a transition zone between two different morpho-structural domains, the folded domains in the north and the flat and desert expanses of the Sahara in the south.

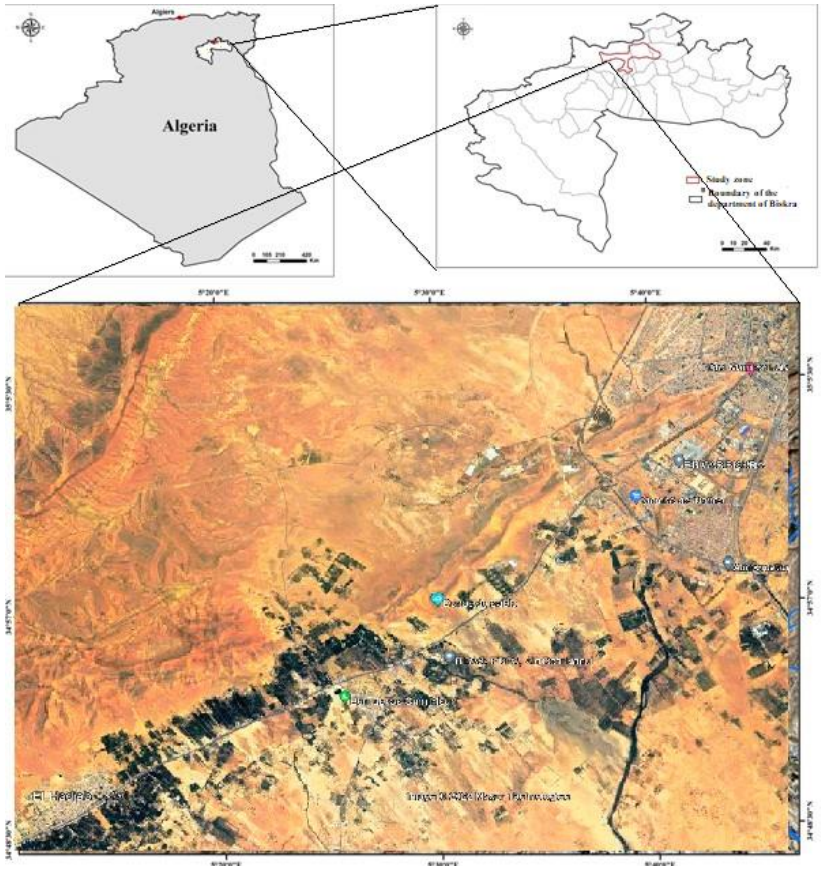

Figure 1. Geographical location of the study region (Boudhibi, 2021)

Geology and hydrogeology of the Ziban region

The Biskra region is part of the transition between the folded Atlas domain of the North (Saharan Atlas), and the flat and desert expanses of the Sahara. The latter characterized in particular by the very flat regions corresponding to the great western and eastern Erg, to the plateau of Mzab, Tadmait, Tinrheret as well as to the relatively depressed region of Gourara, Touat, Tridklet, south-Tihert (Boumaraf, Bensaid, & Marre, 2014b). The northern part of the region is in the form of a chain, roughly,oriented North-East - South-West of the Jura type and to the south, the Saharan plain is presented by a whole series of erosion glaze shaped by runoff and where oases are located (figure 2) (Chebbah, 2007). The region is characterized by sedimentary terrains ranging from the Barremian at the base to the calcaro-gypsum Quaternary with sandy and clayey alluvium, while the Tertiary is formed by sandstone beds, sandy clays and carbonate formations (Abdennour, et al., 2021). It is an environment very marked by mechanical and water erosion. The hydrographic network is dense. The Biskra region has several aquifer reservoirs that belong to the Quaternary, Miopliocene, Lower Eocene and Upper Senonian (Maastrichtian) and Albian (Bouziane & Labadi, 2009).

The quaternary water table: It is located in alluvial accumulations and is characterized by very salty water. It has a great influence on the pedogenetic process of the southern piedmont, particularly in the formation of gypsum accumulations.

The Mio-Pliocene sand aquifer: This aquifer consists essentially of an alternation of sands, gravels and clays. It is heavily exploited, especially in the Biskra area, by a very large number of boreholes intended mainly for the irrigation of agricultural land.

The Eocene and Senonian limestone water table: The reservoir of this aquifer consists essentially of limestone. Its depth varies from approximately 150 to 400 m. The waters have an alkaline sulphate and alkaline-earth facies

The CI Continental Intercalary aquifer The Albian aquifer: It is made up of sandstone and clay. The waters are variously deep according to the Atlas flexure (1500 to 2500 m) and very hot (60°C). They are also the least salty.

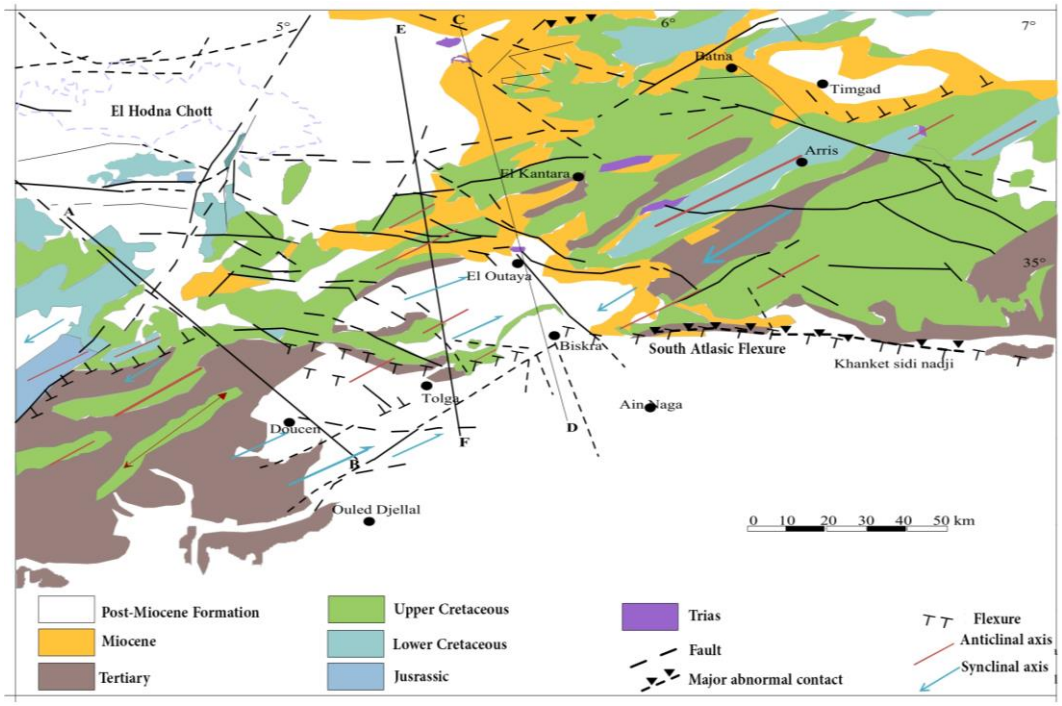

Figure 2. Tectonic sketch (Extracted from the hydrogeological map of Biskra (Boudhibi, 2021))

Climate of the Ziban region

The observation of relative to the ombrothermic diagram; shows that the climate of the region of Biskra is characterized by a single dry season extending throughout the year (Figure 2). This is one of the parameters for the climate of arid zones, in addition to the high evaporation and irregularity in the rainfall regime. 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 (Saadi, Debabech, & Traore, 2021).

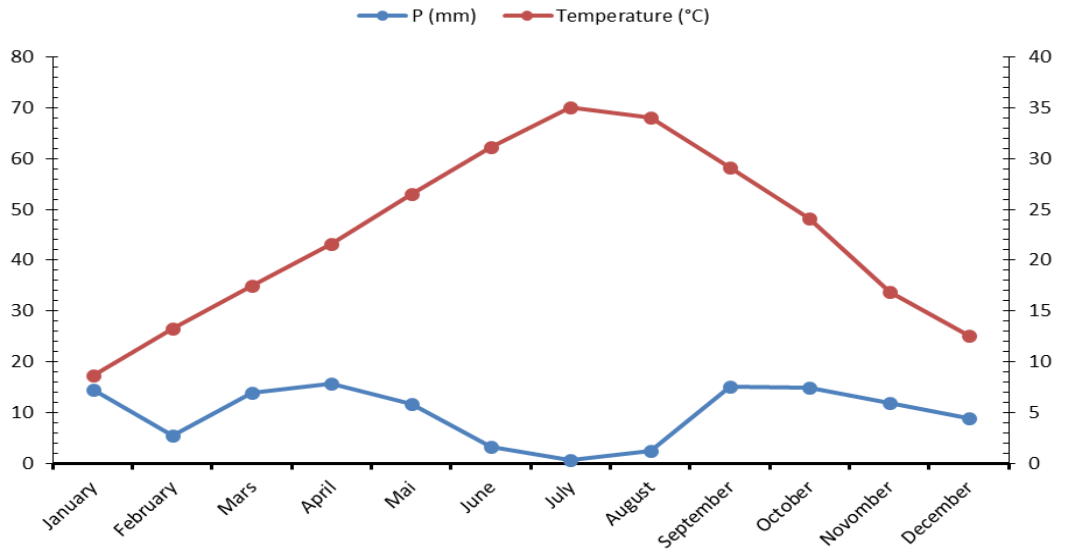

Figure 3. Ombrothermic diagram of Biskra region (period of 2000-2018) (ONMT, 2020)

GEOMORPHOLOGICAL MAPPING

The prospecting methods

After a general reconnaissance of the Biskra Valley, using basic documents (topographic, geological map and aerial images), it was in the southern part that we focused the field surveys, because it offered the bottom of the Chott Oumach, many forms of landscapes that contemplate a distribution of varied and multiple soil types (Boumaraf, Saadi, & Marre, 2016).

The geomorphological study is based on systematic mapping (Gueremy & Marre, 1996; Marre, 2007; Boumaraf, Bensaid, & Marre, 2014; Boumaraf, Saadi, & Marre, 2016). It made it possible to show the existence of two series of geomorphological levels:

- The first starts from level zero the bottom of the Chott Oumache at the Ziban Mountains (Benadji, 1998) with five morpho-pedological levels;
- The second begins from Jebel Delouate to Jebel Bourhzel with four distinct levels defining the southern and northern limit of the Faidjet El Hammam valley located northwest of the city of Biskra which has dug on the anticline since the Miocene (Figure 3).

SEQUENCE A

The bottom of the sebkha of oumache the lower level A0

This level corresponds to the current settling pit with pseudogley soils. Characteristic of the covered white salant, with an absolute absence of vegetation, it offers a remarkably flat topography (altitude-20 to 45 m). Its is characterized by a carpet of white salt crystals, of different types (sulfate and chloride). In certain areas, the surface consistency becomes a viscous and crispy crust (Figure 4).

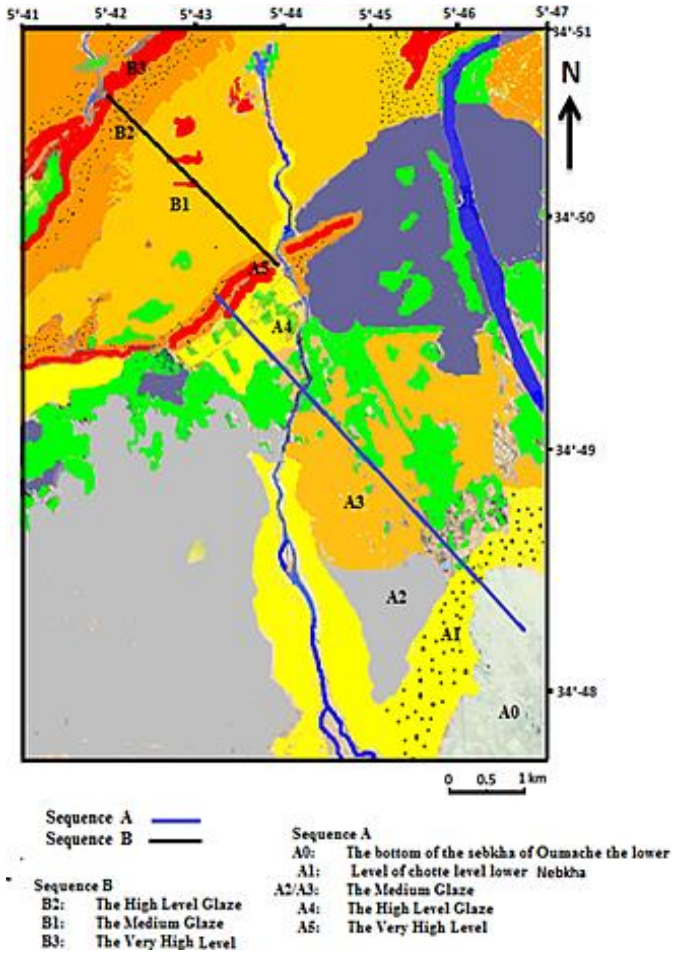

Figure 4. Morpho-pedological map of the study area

Figure 5. Gypsum crust surmounted by a veil of sand. The OumachSebkha (Laouar, 2022)

Level of chotte level lower A1

It is remarkable by a passage to a higher threshold, with a transition that is sometimes not very visible, an extremely short concavity, and where the density of halophilic plants in the form of nebkha become more numerous. It is located in a silt saturated with salts, and which marks the passage to the chott. It is characterized by silty-sandy soils sometimes dune it is a fringe of the sebkha.

The Medium Glaze A2

The surface of this level has a greater area than that of the neighboring levels. This level appears a few meters equipped with the previous one. It is presented as a glacis with a greater extension towards the southwest, with a very slight slope. It is characterized by soils with gypsum accumulation, characterized by crusts and encrustations of gypsum at varying depths. Invaded by the nebkas, there are favorable conditions for their formation due to their proximity to groundwater (the water table) (Mostephaoui, Saker, & Bensaid, 2013) which is too salty and loaded with sulphates (Table 1). This sheet varies between 0.80M and 1.5M depending on its piezometric position and the season. These chemical characteristics, particularly its content of soluble salts, are accentuated largely due to irrigation and the excessive use of chemical fertilizers. The drainage water from the palm groves upstream and occasional floods are the principal sources of water table maintenance (Abdelhafid, Rechachi, & Halitim, 2019).

Table 1. Analytical results of groundwater In the Oumache Region

Prof M	CE dS/C	PH	Cl-- PPM	So4-- PPM	HCo3 PPM	Na+ PPM	K+ PPM	Mg++ PPM	Ca++ PPM	Σ- / Σ+	ES g/l	SAR	Cl-- / So4--
>1.5	47.8	8.2	626.2	142.4	6.5	466.13	33.2	109.19	184.6	0.97	37.2	4.51	4.39

The Medium Glaze A3

This level appears to the northwest of the Oumache depression, towards the Aurès Mountains and the plain of the Faidjet El Hammam valley. It is characterized by alluvial-colluvial clay-silty soils with high total limestone content (from 30% to 45%). These are unstructured soils with a very diffuse transition between the underground horizons. Located on the foothills of the Aurès mountain range, our landscape is presented as an accumulation of glaçi entangled with the last level with pronounced erosion escarpments, sometimes giving rise to moors degraded in its upper part by more active watercourses. The surface appearance of this level presents characters of vertisms with very characteristic shrinkage slots.

The High Level A4 Glaze

It is an erosion glaze defined by certain inclined surfaces and others very sandy. The presence of sands on this level is due to the dominant wind current in this region and which blows from the Nod West to the South East. This flow of sands and gypseous dusts existed several times during the Upper Pleistocene and the Holocene. It is materialized by veneers of dunes and more or less indurated gypsum accumulations on the side of the Ziban reliefs. Deposits from arid periods alternate with deposits from wet periods (paleosols, alluvium) (Figure 5).

A variable slope of 5% to 15% for the swallow with a reduced spatial extension, very variable compared to the previous level. The piedmont becomes slightly concave giving the appearance of a perched glacier. Hydrographic network and more pronounced downstream by ravines 20 to 40 cm deep, more pronounced downstream. On the surface, breccia is very regularly observed, probably developed on Miopliocene materials (Ballais, 2010).

The Very High Level A5

This level is represented by an immense glacier dominating the northern part of sequence A defined by the mount of Jebel Delouate by a drop of several tens of meters. These formations are

upper crusts (figure 6) made up of crumbly clods and nodules stuck to a harder layer of gypso-limestone. At its base, a consolidated marly substrate. The vitreous structure in crusts and encrustations marries the topography. Observed on surface debris in holes of varying sizes. Covered with a veil of sandy and loose cover composed of xerophytes rarely reaching 50 cm. This level bears some traces of flow reduced to a few tens of centimeters of hack.

Figure 6. Gypsum crust surmounted by a veil of sand (Laouar, 2022)

SEQUENCE B

This sequence begins from the mount of DJebel Delouate described in the previous section A5 towards the mount of Jebel Bourehezal which delimits the valley of Faidjet El Hammame (Figure 7).

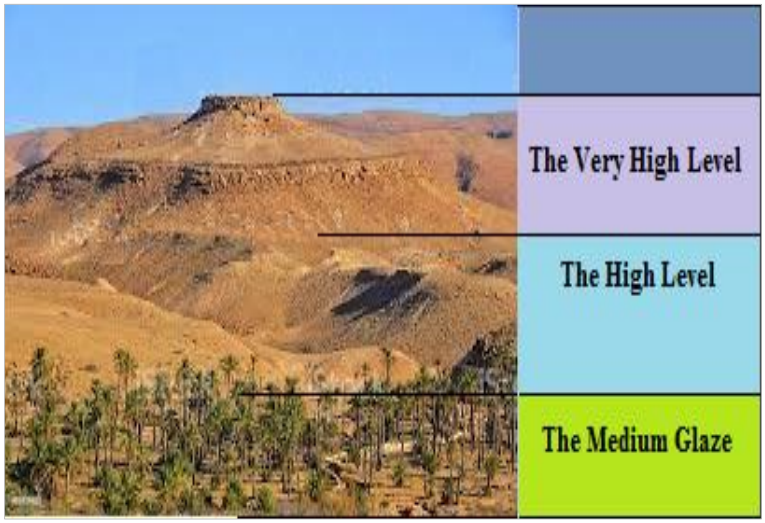

Figure 7. The variation in glaze levels observed in the Biskra region

The High B2 Level

This level is presented at the same time by Djebel Delouate in the south and Djebel Bourehezal in the north with altitudes between 200 and 250 meters the first and from the Upper

Cretaceous: represented by crystalline and dolomitic limestones in very thick layers, marly and gypsum lagoon intercalations many in the west.

The second that of Jebel Bourehezal is from the Lower Cenomanian: Its power is 300 to 400 m of gray or white limestone regularly alternating with greyish, sometimes gypsum marls.

The Medium Glaze B1

They appear as slightly inclined surfaces with a slope generally at 3%. One observes there in a very regular way exclusively colluvial deposits represented by clays; gypsum in thick layers, anhydrites and dolomitic limestones. In the form of breccias from the Villafranchiene period developed on large-scale Mio-Pliocen gypsum fluvio-lacustrine materials. Residual reliefs which are observed especially in the northern region, from the geological point of view they are relic formations of the Cenomanian and the ancient Quaternary.

These reliefs appear in the landscape as witness mounds characterized by the presence of gypsum encrustations on the surface (associated with the Marls) and marly gypsum at their base. These formations are more or less tabular and generally sandy. The slope of the land is generally steep (3-7%) with often undulating micro-relief undergoing more or less active erosion sometimes giving bad land to the north.

The Very High Level B3

This level is represented by a huge glaze, dominating the northern part of the Valley by a steep of several tens of meters. These formations are top crusts (Figure 7) and consist of crumblyclumps and glued nodules layer harder gypso-limestone. At its base, a consolidated marl substrate. The scabbing and crusting, glassy structure marry topography. Observed on the surface of debris from breccias of varying sizes. They are covered with a veil of sandy cover and loose wind input. This landscape is also characterized by sparse xerophytic plants rarely reaching 50 cm. This level bears some traces of flow reduced to a few tens of centimetres hack.

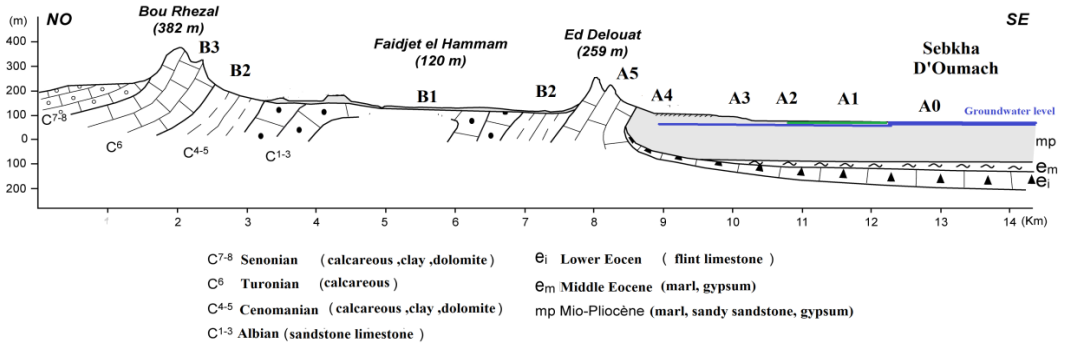

Figure 8. The spatial distribution of morpho-pedological units in the Biskra region

CONCLUSION

All the factors that preside over the formation and evolution of soils induce a double differentiation in the vertical organization of the profiles and in their lateral distribution. By analyzing the variations of the analytical and morphological results obtained from the sebkha of Oumach towards the upper level of Jebel Delouat, and from the towards Djeble Boughezal, it clearly appears to us that the landscape of the Biskra region is part of a region that evolves as part of the endorheic system.

The evolution of the landscape of this region depends for the structural part on the conditions defined by the lithology and the tectonics and also on the systems of erosion subjected to paleoclimatic aspects inherited from the Quaternary, of which the crusts are the testimonies in the first section.

the series of soils located on the sequence going from the Djebel Bourehezal to the depression of Oumache, the sulphated layers, contribute to the accumulations of gypsum in the form of cuirasses and encrustations. This sequence is largely subject to the progressive accumulation of sulphates in the colluvial material, this is the domain of gyso-morphy. This precipitation results from the upward movements of the saline solutions of the water table very close to the surface (Bouselsal & Hakim, 2022). This aquifer is fed by rainfall, floods, diffuse flows, drainage water from agricultural activities in this region.

In addition, on the northwest slope of the Ziban valley, precisely on the southern slope, of the Aurès anticlines (figure 8) a series of soils are distinguished by finer accumulations of clayey silt from alluvium and colluvium and gypsum rates are much lower, in the absence of shallow aquifer dynamics.

The alternation of wet and dry recent Quaternary climatic phases operated in this region, allowed the construction by mechanical erosion observed through surfaces interrupted by incisions and embankments. And similarly also on the second section of the northern flank of Djebel Bourehezal at Djebel Delouate sequence B. The soils formed on sequence B and that located to the North East of sequence A define similar morphological properties on the structural and textural level and do not offer their own pedogenetic evolutionary characteristics observed on sequence A where the formation of soils with gypsum accumulation is characteristic.

Aknowlegments

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ANALYSIS OF HUNTERS' RETURN IN THREE MAJOR BUSHMEAT DEPOTS, IN SOUTH-WEST NIGERIA

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Abstract: Submissions of game harvested by hunters per expedition to bushmeat landing depots in Southwestern Nigeria were studied for one year. Three established bushmeat landing depots were purposively selected for the study. Olomore and Kila in Ogun State and

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Odo Ona in Oyo State. The three were so selected because of their distribution along almost the same line of geographical placement on a line with Kila falling in between the other two on a line. Hunters' return of harvested game after overnight hunting to the three locations on weekly basis was identified and counted for a year. Twenty-one (21) species of Vertebrates in the class Mammalia, reptiles and birds were returned to the three bushmeat depots by hunters during the study. Location-wise, Olomore had the highest return (1,457) and the least was returned to Kila (987) both in Ogun State. Species-wise, *Thryonomys swinderianus* (Grasscutter) had the highest population of 2,383 animals with a mean value of 794.3 ± 180.58, followed by *Cephalophus maxwelli* (duiker) with a mean value of 184.0 ± 32.51. The least hunters' returns were *Bitis gabonica* (Black cobra) and *Perodicticus potto* (Bosmans potto) with a mean value of 0.33 ± 0.58 and 0.67 ± 1.15 respectively.

Key words: Nigeria, bushmeat, trade, hunters' return, season, depots

* * * * * *

INTRODUCTION

In many areas of Central and West Africa, the appetite for bushmeat is so insatiable that hunting levels are thought to be unsustainable for even the faster breeding and relatively common species, such as the smaller duikers (Martins, 1983). Standards for bushmeat processing and marketing vary from one area to another (Ntiamoa-Baidu, 1998; Adefalu, Olabanji, Bhadmus, Ibrahim-Olesin, & Kareem, 2021).

On the other hand, the rules are so strict that it is almost impossible to meet the conditions without huge capital investment in abattoirs and cold storage facilities, while on the other hand, there are no rules or standards and the quality of bushmeat offered for sale in the markets varies widely as indicated by (Mendelson, Cowlishaw, & Rowcliffe, 2003; Cowlishaw, Mendelson, & Rowcliffe, 2005).

Bushmeat is eaten as fresh meat, smoked, salted or sun-dried. Smoking is a widespread form of preservation and smoked bushmeat is available in the urban market in most African countries. The protein content of wild meat often 20-25% by weight is comparable to and sometimes higher than that of meat from domestic animals (FAO, 1989; FAO, 1992; Olawepo, Tunde, Malik, & Daudu, 2021). For people in many tropical countries, wildlife killed for consumption is a principal supplemental source of dietary protein (Bennet, 2006; Tătar, et al., 2021).

Wild animals eaten vary from rodents, reptiles, monkeys, and a whole range of investment species including snails, beetles and also termites. Rodents are particularly important in terms of the range of species and numbers taken in many parts of Africa because they are not subject to hunting restrictions in many countries and their high reproductive capacity makes them relatively more abundant (Ntiamoa-Baidu, 1998; Muntele, 2022). Factors that determine species that are sold or consumed include the size of the animal, cultural inhibition as well as personal or public appeal and demand. This rate of harvest, combined with habitat loss and alteration, has led to very severe population declines (Begon, Mortimer, & Thompson, 1996); if this trend is unchecked, extinction is likely (Bowen-Jones & Pendry, 1999; Babalola, 2023).

Hunting is the practice of pursuing and harvesting wild games for food, recreation, trade or resources. It is also known as regulated and legal hunting when the law is observed and poaching when the killing and trapping of animals is contrary to the law (Wikipedia Encyclopedia, Post Offices - with a map of LGA, Ogun State Census: NIPOST, 2009a). Hunting and gathering of wildlife have always been and continue to be an important aspect of life in rural African societies (Ntiamoa-Baidu, 1997; Ibiso, Akani, Nioking, & Glorious, 2021). This is so because the importance of bushmeat to local communities cannot be ignored. Other authors (Lahm, 1996) described how villagers in Gabon have become more dependent on bushmeat because of permanent settlement along roads, replacement of traditional weapons, abandonment of traditional beliefs and participation in a cash economy.

METHODOLOGY

Study Area

Three bushmeat landing depots in Oyo and Ogun State were purposively selected for the study because of the numbers and volume of bushmeats that are being processed daily as hunters return to these locations. They are the Olomore bushmeat centre (Olomore) and Kila bushmeat centre (Kila) in Ogun State (Figure 1).

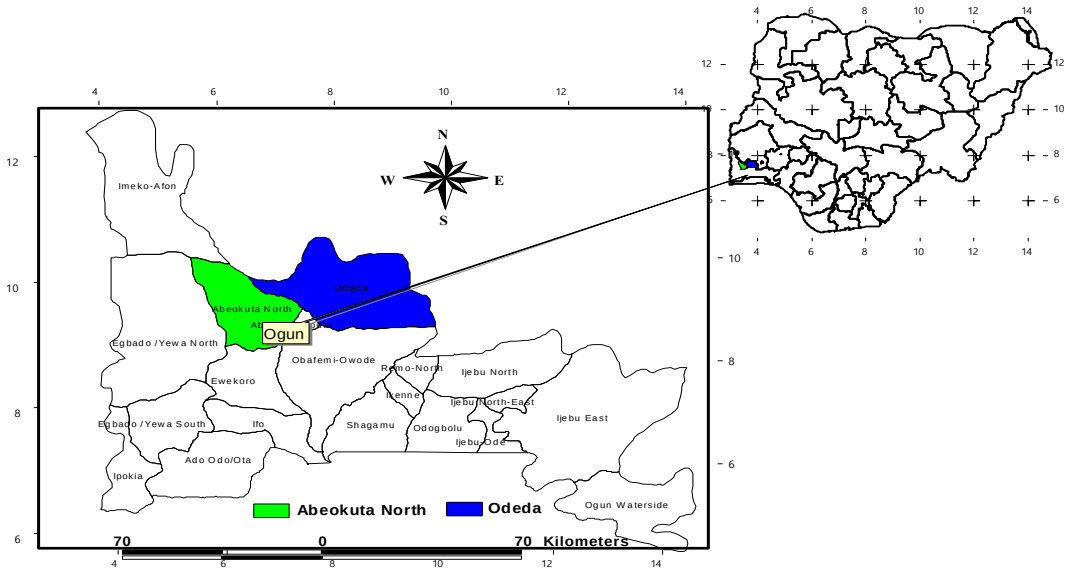

Figure 1. Map of Ogun State showing Abeokuta North and Odeda Local Government area where Olomore and Kila bushmeat depots are located. Inset is the map of Nigeria depicting the location of Ogun State (Data source: (Wikipedia Encyclopedia, 2009a))

Data collection

These depots were routinely visited from Monday to Saturday in two-cycle of Monday to Wednesday and Thursday to Saturday respectively for one year. Each visit lasted for 6 hours between 08.00 hours to 14.00 hours. Data were collected through on-site observation at those centres where hunters deposit their games for sale. Each animal brought to the depots during the visiting hours was identified and classified by its sex and age categories. Thorough visual observation of the external reproductive organs of the animals was used to ascertain the age class. Information was collected from each depot on weekly basis for a year period during which the study lasted. Weekly records of hunters' returns were pooled and sorted on a species basis per depot. All the species encountered within the study areas were categorized using descriptive statistics based on species, sex, and age. Each species returned was ranked with the frequency of killing and analyzed descriptively, and with a one-way analysis of variance as inferential statistics using SPSS software.

RESULT

Hunters return during the Wet Season in the three bushmeat depot

A total of twenty (20) species of bushmeat were returned to the three depots surveyed in this study during the wet season. This gave a cumulative figure of 2,110 wild games which comprises Grasscutter (*Thryonomys swinderianus)* as the one with the highest total persecuted population (1439) with an average of 479.67 ± 81.53. This was followed by Maxwell Duiker (*Cephalophus maxwelli)* (302) with an average population of 100.67 ± 13.04, Hare (*Lepus capensis)* (87) with an average population of 29.00 ± 2.65, while Black Cobra (*Naja melanoleuca)* was the least persecuted and returned to the depots by hunters during the wet season (Table 1).

Table 1. The population of Animal Species returned to the three depots during Wet Season
(Data source: Field Survey Calculations)

Animal	Olomore	Kila	Odo Ona	Total	Mean ± SE
Black Cobra	1	0	0	1	0.33 ± 0.33
Bushbuck	3	2	7	12	4.00 ± 1.53
Bush fowl	2	3	4	9	3.00 ± 0.58
Civet cat	5	2	5	12	4.00 ± 1.00
Crocodile	2	3	2	7	2.33 ± 0.33
Duiker	122	77	103	302	100.67 ± 13.04
Gabon viper	1	1	2	4	1.33 ± 0.33
Genet cat	11	6	9	26	8.67 ± 1.45
Giant rat	8	13	16	37	12.33 ± 2.33
Grasscutter	639	370	430	1439	479.67 ± 81.53
Ground squirrel	10	6	7	23	7.67 ± 1.20
Guinea fowl	1	4	4	9	3.00 ± 1.00
Hare	33	24	30	87	29.00 ± 2.65
Mona monkey	1	0	1	2	0.67 ± 0.33
Monitor lizard	16	9	11	36	12.00 ± 2.08
Pangolin	22	13	24	59	19.67 ± 3.38
Porcupine	8	8	3	19	6.33 ± 1.67
Python	3	1	8	12	4.00 ± 2.08
Shortnose Crocodile	4	1	4	9	3.00 ± 1.00
Tree hyrax	2	0	3	5	1.67 ± 0.88
Total	**894**	**543**	**673**	**2110**	**703.33 ± 102.45**

The trend follows the same pattern in the dry season, Twenty species were equally returned to the three depots, with Grasscutter (314.67 ± 23.92) and Maxwell duiker (83.33 ± 6.01) being the first and second highest returned games, while other species of Snakes (Gabon Viper) and Mona monkey were the least persecuted (0.33 ± 0.33 each) and returned animals to these Centres during the dry season (Table 2).

Table 2. The population of Animal Species returned to bushmeat depots during the Dry Season
(Data source: Field Survey Calculation)

Name of Animals	Scientific Name	Olomore	Kila	Odo Ona	Total	Mean ± SE
Bosman potto	*Perodicticus potto*	2	0	0	2	0.67 ± 0.67
Bushbuck	*Tragelaphus scriptus*	3	0	0	3	1.00 ± 1.00
Bush fowl	*Francolinus bicalcaratus*	3	2	0	5	1.67 ± 0.88
Civet cat	*Viverra civette*	10	2	5	17	5.67 ± 2.33
Crocodile	*Crocodilus niloticus*	0	1	2	3	1.00 ± 0.58
Duiker	*Cephalophus maxwelli*	95	75	80	250	83.33 ± 6.01
Gabon viper	*Bitis gabonica*	0	0	1	1	0.33 ± 0.33
Genet cat	*Genetta pardina*	5	5	3	13	4.33 ± 0.67
Giant rat	*Cricetomys gambianus*	12	7	6	25	8.33 ± 1.86
Grasscutter	*Thryonomys swinderianus*	362	297	285	944	314.67 ± 23.92
Ground squirrel	*Xerus erythropus*	3	3	6	12	4.00 ± 1.00
Guinea fowl	*Numidia meleagris*	2	3	1	6	2.00 ± 0.58
Hare	*Lepus capensis*	28	25	24	77	25.67 ± 1.20
Mona monkey	*Cercopithecus mona*	1	0	0	1	0.33 ± 0.33
Monitor lizard	*Varanus niloticus*	18	6	16	40	13.33 ± 3.71
Pangolin	*Manis tricuspis*	14	12	19	45	15.00 ± 2.08
Porcupine	*Hystrix cristata*	0	3	7	10	3.33 ± 2.03
Python	*Python sebae*	2	1	3	6	2.00 ± 0.58
Shortnose crocodile	*Osteolamus tetraspis*	2	2	2	6	2.00 ± 0.00
Tree hyrax	*Dendrohyrax dorsalis*	1	0	2	3	1.00 ± 0.58
Total		**563**	**444**	**462**	**1469**	**489.67 ± 37.03**

The quantity of bushmeat returned to various depots seasonally indicated that populations of the persecuted games were higher during the wet season (2,110) than in the dry season (1,469). In both seasons, Olomore had the highest return (894; 563), followed by Odo Ona Kekere (673; 462) and the least was returned to Kila (563; 444) for wet and dry seasons respectively (Tables 1, 2). Annually, twenty-one (21) species of vertebrates were deposited in the three bushmeat depots by the hunters in both States. The grasscutter was still the highest annual persecuted and returned game, followed by Maxwell duiker while Black Cobra, Gabon Viper and Mona Monkey were the least.

Monthly returns of Animals to the three depots

Seasonally, it was discovered that Olomore had the highest population of wild animals returned (563) during the dry season followed by Odo Ona (462) while the least population of animals were returned to Kila (444), thus a total of 1,469 animals were returned in the dry season. However, within the months of the dry season, the three locations recorded the highest return of Games in November; Olomore (183) Odo Ona (138) and Kila (117) each. The least return in the three landing depots during the months of the Dry season was in January with Olomore (47), Odo Ona and Kila returning 39 games respectively, but within the months that fall into the wet season, records of the highest monthly return vary. For instance, Olomore recorded the highest return (212) in May, While Odo Ona was in June (128) and Kila in September (100). Coincidentally, the least return in the three locations during the wet season was in July, though the same figure was also recorded in March at Olomore. Cumulatively, the highest population of bushmeat were returned to the three locations in November (438). This was followed by June (384) while January (144) had the least returned during the period of study. The highest monthly population of bushmeat was returned to Olomore in May (212) while the least was returned in January (47). However, Odo Ona depots recorded their highest monthly return in June (128) and least return in January (58). Kila also had its highest return in November (138) and least return in January (39) respectively (Table 3).

Table 3. Monthly Return of bushmeat by hunters to the three Depots in Oyo and Ogun State
(Data source: Field Survey Calculations)

Month	Olomore	Kila	Odo Ona	Total	Mean ± SE
January	47	39	58	144	48.00 ± 5.51
February	110	110	98	318	106.00 ± 4.00
March	86	72	85	243	81.00 ± 4.51
April	112	74	114	300	100.00 ± 13.01
May	212	82	87	381	127.00 ± 42.52
June	186	70	128	384	128.00 ± 33.49
July	86	60	75	221	73.67 ± 7.54
August	112	85	89	286	95.33 ± 8.41
September	100	100	95	295	98.33 ± 1.67
October	92	78	96	266	88.67 ± 5.46
November	183	138	117	438	146.00 ± 19.47
December	131	79	93	303	101.00 ± 15.53
Total	**1457**	**987**	**1135**	**3579**	**1193.00 ± 138.74**

Note: Months that appear in bold prints are those that fall within the wet season.

Distribution of Individual Animal species in each location

Twenty-one (21) species of Vertebrates in the class, Mammalia; Reptiles and Birds were returned to the three bushmeat depots by hunters. Location-wise, Olomore had the highest return (1,457) and the least was returned to Kila (987) both in Ogun State. Species-wise, *Thryonomys swinderianus* (Grasscutter) had the highest population of 2,383 animals with a mean value of 794.3 ± 180.58, followed by *Cephalophus maxwelli* (duiker) with a mean value of 184.0 ± 32.51. The least hunters' returns were *Bitis gabonica* (Black cobra) *and Perodicticus potto* (Bosmans

potto) with their mean values of 0.33 ± 0.58 and 0.67 ± 1.15 respectively. The bushmeat centre with the highest number of Grasscutter of 1001 out of 2383 and Maxwell duiker with 217 out of 552 hunters' return was Olomoore while the remaining two locations shared the rest. The least animal species returned was the Black cobra (1) in the Olomoore centre (Table 4).

Table 4. Number of animal species returned in the three centres during the study period
(Data source: Field Survey Calculatuion)

Common Name	Scientific Name	Olomore	Kila	Odo Ona	Total	Mean ± SE
Black cobra	*Naja melanoleuca*	1	0	0	1	0.33 ± 0.33
Bosman potto	*Perodicticus potto*	2	0	0	2	0.67 ± 0.67
Bushbuck	*Tragelaphus sylvaticus*	6	2	7	15	5.00 ± 1.53
Bush fowl	*Francolinus bicalcaratus*	5	5	4	14	4.67 ± 0.33
Civet cat	*Viverra civetta*	15	4	10	29	9.67 ± 3.18
Crocodile	*Crocodilus niloticus*	2	4	4	10	3.33 ± 0.67
Duiker	*Cephalophus maxwelli*	217	152	183	552	184.0 ± 18.77
Gabon viper	*Bitis gabonica*	1	1	3	5	1.67 ± 0.67
Genet cat	*Genetta pardina*	16	11	12	39	13.00 ± 1.53
Giant rat	*Cricetomys gambianus*	20	20	22	62	20.67 ± 0.67
Grasscutter	*Thryonomys swinderianus*	1001	667	715	2383	794.3 ± 104.26
Ground squirrel	*Xerus erythropus*	13	9	13	35	11.67 ± 1.33
Guinea fowl	*Numida meleagris*	3	7	5	15	5.00 ± 1.15
Hare	*Lepus capensis*	61	49	54	164	54.67 ± 3.48
Monitor lizard	*Varanus niloticus*	34	15	26	75	25.00 ± 5.51
Mona monkey	*Cercopithecus mona*	2	0	1	3	1.00 ± 0.58
Pangolin	*Manis triscupis*	36	25	43	104	34.67 ± 5.24
Porcupine	*Hystrix cristata*	8	11	10	29	9.67 ± 0.88
Python	*Python sebae*	5	2	12	19	6.33 ± 2.96
Shortnose crocodile	*Osteolamus tetraspis*	6	3	6	15	5.00 ± 1.00
Tree hyrax	*Dendrohyrax dorsalis*	3	0	5	8	2.67 ± 1.45
Total		**1457**	**987**	**1135**	**3579**	**1193.00 ± 138.74**

Sex Structure of Hunters' Returns in the study areas

Hunters' return in the three study locations revealed that a total of 3,579 individual species were deposited out of which 1,866 were male animals with the distribution as follows 761, 521 and 584 in Olomore, Kila and Odo Ona respectively. Female animals 1,713 were deposited to the locations out of which Olomoore had 696, Odo Ona Kekere had 551 and Kila had at least 466 female animals. The t-test analysis for sex structure of return in different locations showed that the differences are significant at $p<0.01$ for Olomore (112.88), Kila (92.5), Odo Ona (100.9) and figures with different superscripts along the row and column are significantly different $p<0.01$ from male and female returned hunters' returns (Table 5).

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Table 5. Sex Structure of Hunters' Return in the Study Areas
(Data source: Field Survey Calculations)

Sex	Olomoore	Kila	Odo Ona	Total
Male	761^{a}	521^{c}	584^{e}	1866 (52.1)
Female	696^{b}	466^{d}	551^{f}	1713 (47.9)
t-value	112.88	92.59	100.9	
Total	**1457**	**987**	**1135**	**3579**

Note: $p< 0.01$ sexes

Age Distribution of Hunters' Returns in the Study Locations

Age distribution of game returned by hunters in the different locations indicated that adults were supplied most in all the locations followed by subadults and the least are juveniles. Though

Olomoore had the highest sub-adult returned (254) the highest percentage of sub-adults returned is in Kila (19.0%). Analysis of the variance of the age structure of bushmeat returned in different locations showed that the differences are significant ($p<0.05$). This was confirmed by Levene's test for homogeneity of variance p (probability) as 0.04. But Turkey's pairwise comparison of age structure among locations showed that there were no significant differences ($p>0.05$) in their structure (Table 6).

Table 6. Age class distribution of game returned by hunters in the Study Location for one year
(Data source: Field Survey Calculations)

Age	Olomoore	Mean ± SE	Kila	Mean ± SE	Odo Ona	Mean ± SE	Total
Adult	1139	22.78 ± 1.38	768	15.36 ± 0.83	903	18.06 ± 0.93	2809
Sub-adult	253	5.06 ± 0.43	188	3.76 ± 0.27	192	3.84 ± 0.27	634
Juvenile	65	1.30 ± 0.22	31	0.62 ± 0.10	40	0.8 ± 0.14	136
Total	**1457**	**29.14 ± 1.77**	**987**	**19.74 ± 0.87**	**1135**	**22.70 ± 1.08**	**3579**

The taxonomic details and IUCN status of wildlife species returned to the three locations are presented in Table 7.

Table 7. Taxonomic details and IUCN status of wildlife species returned to the three locations
(Data source: Field Survey Calculations)

S/N	Common Name	Scientific name	Order	Family	Total
1	Black cobra*	*Naja melanoleuca*	Elapidae	Reptile	1
2	Bosmans potto**	*Perodicticus potto*	Lorisidae	Mammal	2
3	Bushbuck	*Tragelaphus sylvaticus*	Trangelaphidae	Mammal	15
4	Bush fowl	*Francolinus bicalcaratus*	Phasianidae	Birds	14
5	Crocodile*	*Crocodilus niloticus*	Crocodylus	Reptile	29
6	Civet cat*	*Viverra civetta*	Viverridae	Mammal	10
7	Duiker	*Cephalophus maxwelli*	Cephalophinae	Mammal	552
8	Gabon viper*	*Bitis gabonica*	Viperidae	Reptile	5
9	Genet cat*	*Genetta pardina*	Viverridae	Mammal	39
10	Giant rat	*Cricetomys gambianus*	Cricetidae	Mammal	62
11	Grasscutter	*Thryonomys swinderianus*	Thryonomidae	Mammal	2383
12	Ground squirrel	*Xerus erythropus*	Sciuridae	Mammal	35
13	Guinea fowl	*Numidia meleagris*	Phasianidae	Birds	15
14	Hare	*Lepus capensis*	Leporidae	Mammal	164
15	Monitor lizard*	*Varanus niloticus*	Varanidae	Reptile	76
16	Mona monkey*	*Cercopithecus mona*	Cercopithecidae	Mammal	3
17	Pangolin**	*Manis tricuspis*	Manidae	Mammal	104
18	Porcupine*	*Hystrix cristata*	Hystricidae	Mammal	29
19	Python**	*Python sebae*	Boidae	Reptile	18
20	Shortnose crocodile*	*Osteolamus tetraspis*	Crocodylidae	Reptile	6
21	Tree hyrax*	*Dendrohyrax dorsalis*	Procaviidae	Mammal	5

Note: ** critically endangered, * endangered

DISCUSSION

One year's study of hunter's efforts at harvesting and submission of wild game at the bushmeat depots in Ogun and Oyo States revealed that more games are usually harvested during the wet season cumulatively. This was confirmed in the works of (Bowen-Jones & Pendry, 1999; Hofmann, Ellenberg, & Roth, 1999; Lindsey, et al., 2013; Calvert, Alisauskas, & White, 2017; Amusa, Azeez, & Olabode, 2021), contrary to the thinking that the harvest of bushmeat is better and easier in the dry season, attract more hunters who are less busy with farm work during the dry

season to engage in a hunting expedition, but it shows that more animals were harvested during the wet season. To buttress the earlier assertion, the total return in the three locations in November, which is the peak of the dry season portrays the highest record. But looking at the three locations differently, the months of May, November and June had the highest in Olomore, Kila and Odo Ona respectively, meaning that two of the three locations had their highest monthly return during the wet season.

The least populations of animals were returned to Kila at the end of both seasons. This may be as a result of the location being on the road between Ogun and Oyo State or probably because the hunters that are closer to these areas are mostly not full-time practitioners (Barrett & Arcese, 1998) but are mainly farmers who see hunting as a pastime or perhaps (Oso & Babalola, 2021), the other two locations in Olomore and Odo Ona have established bushmeat markets where hunters all around the two States have identified as major landing depots for their wares.

A trend of supplies was noticed in the populations of Hunters' return both seasonally and on monthly basis in each location. In the months that fell within the dry season, the three locations experienced the least supplies of the game in January and the highest in November, while in the months that fall within the wet season, the least supplies are in July and the highest was in May, September and June in Olomore, Kila and Odo Ona respectively. What this explained was the effects of seasonality and homogeneity of hunting sociology in the area (De Merode, Homewood, & Cowlishaw, 2004; Calvert, Alisauskas, & White, 2017; Akinsorotan, Olaniyi, Oguntuase, & Raheem, 2020). It goes to show that the hunters in this area had the same knowledge of when to hunt. It also depicts that weather conditions and the vegetation structure per location are important pointers to the determinations of catch per unit effort of the hunter. The little variation in ecological parameters per location may be the determinant of the changes in times of bountiful harvest and return per location in the wet season. This in agreement with various observations (Fimbel, Curran, & Usongo, 2000) (Adebowale, Oduntan, Adegbenjo, & Akinbode, 2021) can be explained to be a result of the differences in vegetation and other ecological parameters of different locations which goes to determine the quantity and types of wildlife that inhabit each location. For instance, the majority of hunting sites in Ogun State are in the derived savanna and an ecotone of the Southern Guinea Savanna while that of Oyo State are either in the secondary rain forest or derived savanna while Kila falls within the transition zones of the two.

The roles of weather and climate as a determinant of the volume of the harvest were also shown by the least returned game population per location in the dry season, where the month of January recorded the least game population returned in the three centers. This is probably because January usually has the highest number of days with a full moon in the night as postulated by (Fa, Currie, & Meeuwig, 2003; Bogerson, 2016) which thus makes hunting laborious and less rewarding. Moreover, most games returned to the depots are harvested overnight, thereby the reason for the low population of hunters' returns in January.

Sexual structures of Hunters' return to the study locations indicated that males are numerically as well as significantly ($p<0.01$) higher than females, though the populations and the sex ratios are directly proportional to the total populations of the game return to each center. The percentage ratio of males to females is almost equal in all locations. This is probably a reflection of the natural sex ratio of wildlife in the area and by extension in the wild. The reverse would have been healthier to guarantee population growth as suggested by Ntiamo Baidu (1998) and (Maisels, Keming, Kemei, & Toh, 2001) in the case of Montane forest, but hunting without restriction especially in a free area like the study locations will always present a situation as in this study. Strictly speaking, this structure may not be too bad since the persecuted sex (Males) are more than the females that are needed for population growth. In terms of age structures, it was also shown in this study that juveniles and sub-adults are rarely persecuted. An indication that the population are spared to renew itself within a very short time. This was what other researchers also suggested as a focus for discussion and training for the hunters (Onadeko & Amubode, 1998; Kates & Parris, 2003; Layade, Layade, Owoeye, Adenika, & Oyediji, 2021).

CONCLUSION

In both season and year-round, Grasscutter was the most persecuted game, followed by Maxwell duiker, Hare and Pangolin in the three locations sampled. Out of the 21 species of games returned to the depots during the 12 months of study, these four species jointly constitute not less than 80% of supplies to each location during the period. What this shows is that these groups of animals are the main species that are commonly available and are facing hunters' persecution in their ranges in the two States. The remaining 17 species which constitute about 20% are rarely persecuted since they are not easily encountered within their ranges. The availability of this group goes to confirm the status of quite a lot of them as stated by the International Union for Conservation of Nature and Natural Resources (IUCN). One that needs attention and deserves the attention of regulators and wildlife managers is the attitude and persecution level of Pangolins whose status both locally and internationally calls for total preservation but are highly persecuted in the three sampled locations. In the endangered species act as well as the Red lists of IUCN, Pangolin belongs to Schedule I of the list and is also described by IUCN as a critically endangered species whose population are currently threatened with extinction. But these species are being traded freely and openly in the three bushmeat depots sampled, this calls to question the activities and actions of the agencies saddled with the responsibilities of enforcing those laws and conventions. Open displays of the returned endangered species and processing of same for the pots is a clear indication that if the laws exist, their enforcement is zero on any scale of performance in these States and by extension Nigeria.

In a bid to regulate the bushmeat trade and make it sustainable thereby ensuring the conservation of wildlife species in and around the area and beyond, the following activities are hereby encouraged. Bushmeat sellers and hunters need to come together as a formal body recognized, registered and licensed for proper guidance and monitoring by the State actors. This if done will give credence and emphasis to the recommendation of (Baptist & Mensah, 1986). The trade, albeit legalized but should be restricted to those animals that are not of conservation concern as suggested by (Falconer, 1992). Wildlife officers in the State need to be empowered to enforce the laws even in free areas to monitor sales and harvesting of games with safe status. Both hunters and sellers as well as all other stakeholders need to be trained on sustainable harvesting and trade in bushmeat and economic venture.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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GROUNDWATER OVEREXPLOITATION OF THE CONTINENTAL INTERCALACRY AQUIFER. A CASE STUDY FROM GHARDAIA, ALGERIA

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Abstract: Since the late 1999, extensive groundwater extraction within the Sahara aquifer system has been investigated. In this study we analyze the overexploitation of the thermal groundwater stored in the Continental Intercalary aquifer in the Algerian province of Ghardaia. The Saharan aquifer system is recognized by a large number of over 8800 boreholes and springs, on which 3500 operate the Continental Intercalary series and 5300 operate the Terminal complex. This work describes the groundwater order problem of overexploitation and the flows that exploit this hydrothermal system to be identified and analyzed. We have negative impacts on groundwater in that region due to the practice of certain activities which directly affect the quantity causing the water level of the aquifer to be lowered. Using theoretical context, water quality status can be assessed and recommendations suggested. Results show that we have 387.86 million m^3/yr of flow today which is determined 30 m drawdowns. Measures need to be taken until the effects of the appeal become irreversible and the legal system instruments need practical applicability to prevent this context from extending to other areas.

Key words: Algeria, continental intercalary, drawdown, groundwater, piezometric level

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INTRODUCTION

In Algeria, due to its rarity and interruption of its natural cycle, water occupies a crucial role in economic development, especially for the areas getting closer to the desert, such as the Ghardaia province (86,000 km^2 wide, South of Algeria, located in the northern parts of the Sahara Desert). Agricultural production over the last 50 years and population growth in the Ghardaia province resulted in considerable water demand. Groundwater is the primary source of water supply for several cities, such as Ghardaia City and Sebseb, contributing more than 70 per cent to the water needs of more than 96,000 residents. When groundwater extraction exceeds groundwater recharge in extensive areas over a long period of time such as Ghardaia province, depletion of groundwater may occur (Wada, van Beek, & Bierkens, 2012). The term overexploitation occurs when extraction exceeds both the natural and induces long-term aquifer recharge (Pophar, Lamsoge, Katpatal, & Nawale, 2014). Some widely known examples of researches on groundwater depletion are US High Plains and Central Valley (Scanlon, et al., 2012), North China Plain (Jiang, et al., 2020; Kinzelbach, Wang, Li, Wang, & Li, 2021; Feng, et al., 2022; Zhou, Dai, Wei, & Luo, 2023), southern Europe (Herandez-Mora, Martinez, & Llmas, 2007; Kallioras, Pliakas, & Diamantis, 2010) and Algeria (Amroune, Mihoub, Guastaldi, & Urena-Nieto, 2020; Dekakra, Menani, & Khedidja, 2022).

Ghardaia province is masked by the strong early Quaternary erosion of the river which cut the flat-topped buttes and shaped valleys in its southern part. Two aquifers exist in this region, the Continental Intercalary, and the Terminal complex. Continental intercalary midsole series combines Lower Jurassic and Lower Cretaceous terms. Terminal complex ranges from the Upper Cretaceous to the Paleocene, Eocene, and Miocene, the carbonate formation period. However, due to over-exploitation by unregulated pumping, the piezometric level is gradually lowering (Amroune, Boudoukha, Boumezbeur, Benaabidate, & Guastaldi, 2017). The condition of degradation and decline of water supplies is not only limited to Ghardaia province, but it's present also in Saudi Arabia and the Gulf States (Mihoub, 2017).

The nomenclature of boreholes and the study of water volumes are taken from the Continental Intercalary deep aquifer, since the extensive extraction of groundwater supplies has greatly affected this aquifer's hydrodynamic functioning. As a result, flow extracted from the Saharan aquifer decreased significantly. The problem is much more pronounced in the world where climate changes have led to a rise in water demand for multiple uses. Groundwater overexploitation is a relatively typical problem in semi-arid, arid or Saharan climate regions as recorded in numerous studies (Changming, Yu, & Kendy, 2001; Salameh, 2008; Pophar, Lamsoge, Katpatal, & Nawale, 2014; Amroune, Boudoukha, Boumezbeur, Benaabidate, & Guastaldi, 2017; Gonzalez, Carreon, Franceschini, Cerca, & Teatini, 2018).

The cumulative pumping rate was quantified at 387.86 million m^3 per year, while the total recharge is zero, in an area where people believes that water is a inexhaustible resource in such aquifers (Mihoub, 2017). This means in not renewable underground water the medium rate of aquifer recharge is very weak, but on the other hand with very important complete reservations (several km^3 often). Then, such a overexploitation consists in a sort of a working of underground water of mining type, when means are not renewed, that implicates a reduction of reservations (Custodio & Llmas, 1976; Columbus, 1992; Margat, 1992). The consequences of this problem, among others, could be at different levels:

Environment: water quality change, due to physico-chemical imbalances caused by excessive drainage of aquifers;

Economic: higher operating costs, for water level depth increasing; drop loss, by wells being dry or producing very low; need to carry water from a distant location.

MATERIALS AND METHODS

Study area

The Ghardaia province extends across the northern part of the Sahara basin. This is bordered by the Grand Erg Occidental to the west, the Grand Erg Oriental to the east, the

Timimoun depression to the south and the Saharan Atlas to the north (Figure 1). It is characterized by an arid climate type, with minimum and maximum air temperatures varying during the summer and winter months from 14°C to 47°C and from 2°C to 37°C respectively. The area is distinguished by 68 mm of annual rainfall on average (Mihoub, 2017). On the other hand, mean annual evapotranspiration, as estimated by empirical formulae such as Thornthwaite, Turc, and Penman, ranges from 2000 to 2800 mm per year (ANRH, 2006).

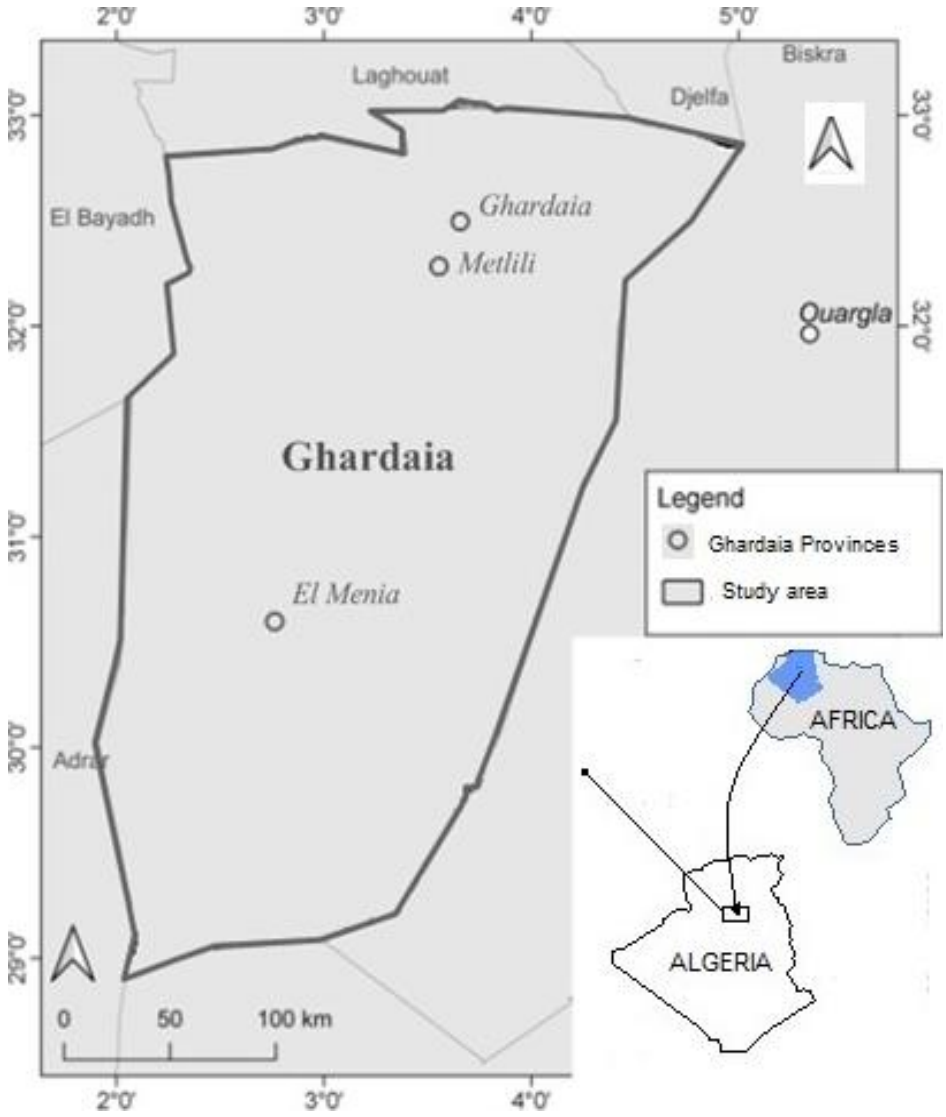

Figure 1. Geographical location of the study area

The extensive drainage network consists of a few ephemeral flows, locally called wadis, which collect surface runoff from the Saharan Atlas to the Timimoun and Oued Mya continental depressions (Mihoub, 2017). The study area pediments, which generally encompass loamy soils rich enough in organic matter, involve eolic or river soils and form the arable land of traditional oases. The plant cover in the oasis consists of almost intact date palm forests (*Phoenix dactylifera L.*), organized into various gardens separated by walls of palm trees.

Geological setting

Ghardaia province presents a succession of geological formations, from the Cenomanian to the Continental Miocene-Pliocene. The Carbonate and Marly Upper Cretaceous formation is gradually thickening and deeping eastward, and is covered by more recent layers of Tertiary period, in particular of Miocene-Pliocene (Mihoub, 2017). The quaternary corresponds to the alluvial recovery sediments (Figure 2).

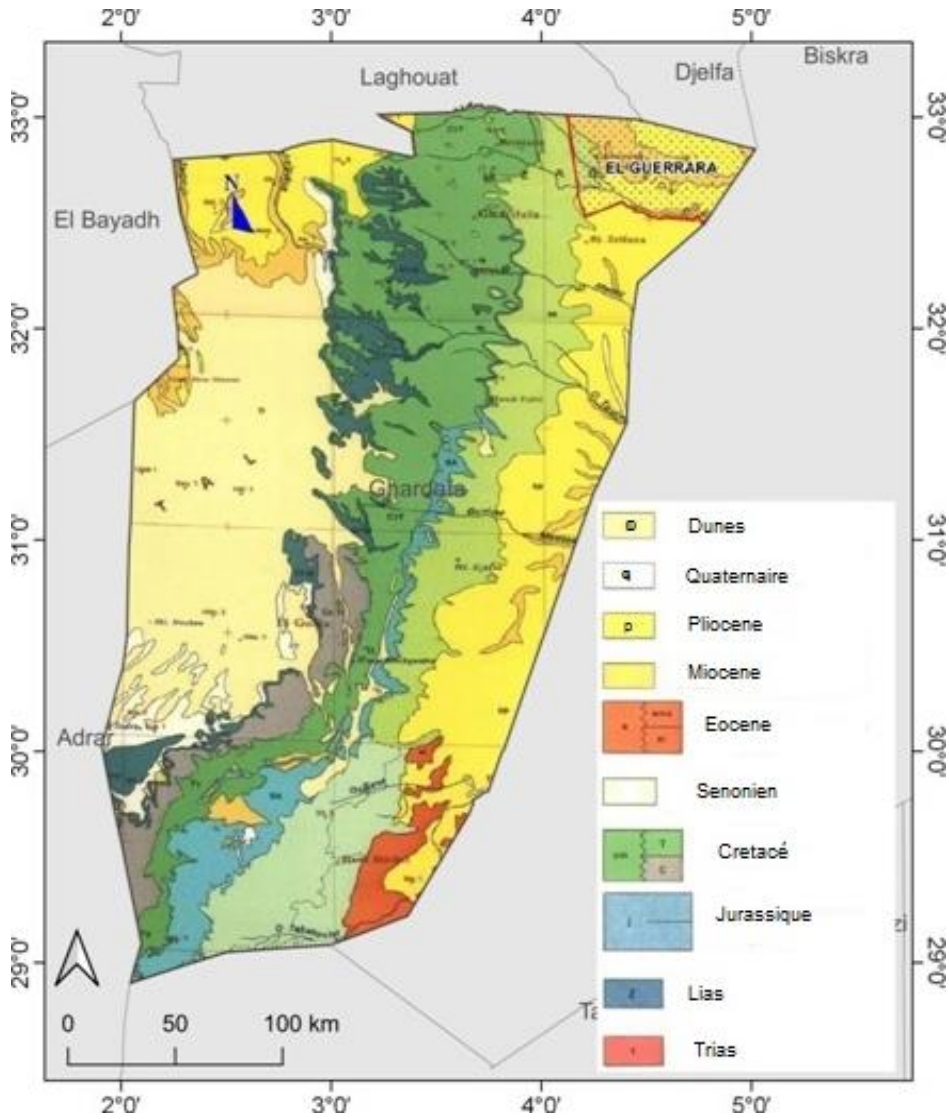

Figure 2. Geological map of the study area; SASS

The geology study also revealed the presence of large-depth formations (3,641–3,732 m) that can present significant geothermal potential. Hence, lithological observation enables the continental clay formations of the Lower Cretaceous to be defined (Neocomian, Barremian and Albian). This geological data will be associated with the thermal data and used to create digital models for understanding positive and negative thermal anomalies and their spatial behaviors.

Hydrogeological conditions

From a hydrogeological point of view, the three different aquifer systems being used are as follows (Figure 3):

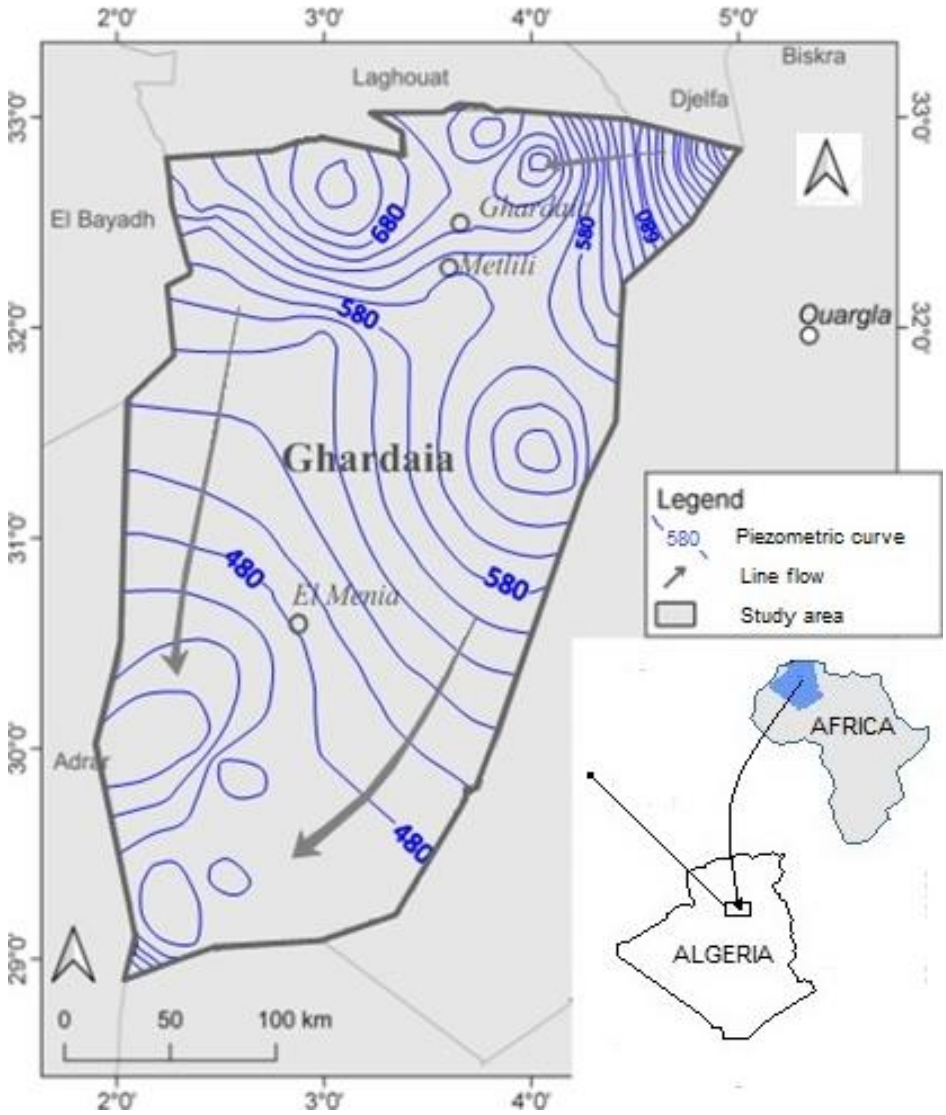

Figure 3. Hydrogeological cross-section of the Saharan basin

At the base, the Continental Intercalary aquifer (CI) is confined deep into the Lower Cretaceous formations. It is found in a complex sequence of Mesozoic age clastic sediments with a significant lateral variability in thickness and lithology. Its depth reaches 500 m locally (Bel & Demargne, 1966). The flow rates of the study region's boreholes range from 100 to 200 l/s.

The middle aquifer is composed by very heterogeneous formations of the Terminal Complex (TC). It represents the permeable Senonian limestone bases, as well as the Mio-Pliocene clay sands and sandstones. This aquifer has a depth of between 100 and 600 m and averages 300 m. It is contained within the boundaries of the region studied (Bel & Demargne, 1966; Bel & Cuche, 1970; Bel, Cuche, Schoute, & Lefort, 1970; UNESCO, 1972). The direction of flow of the aquifer as

established on the scale of the entire study area (UNESCO, 1972; OSS, 2002) shows that the main flow proceeds from the north-west (recharge zone: Saharan Atlas) towards the south-east (discharge zone: Zelfana, El Guerrara and El Golia) (Figure 3). Mio-Pliocene formations on the surface contain the phreatic waters. It consists mainly of medium pink sand, rounded to subangular, passing locally to poorly consolidated white sandstone and white calcareous levels. It is exploited through more than a thousand wells dug by farmers. This aquifer's mean permeability is approximately 10^{-4} m/s (Guendouz, Moulla, & Reghis, 1993). Estimations of its horizontal transmissivity and storage coefficient were 10^{-2} m^2/s and 2.10^{-1} m^2/s respectively (Lavassor, 1978).

RESULTS AND DISCUSSIONS

Nomenclature of flows extracted from water points

The nomenclature referred to 565 boreholes exploited by CI aquifer, 426 of which are in operation providing a flow of approximately 387.86 Hm^3/year and 92 functional drilling capable of generating a volume of 85.65 million m^3 in addition, an inventory of illegal boring for their potential sealing was also taken out in the area of El Menia and Hassi el Fahel in the south of Ghardaia. The area has experienced a rapid change in the number of boreholes falling off the Continental Intercalary (Figure 4).

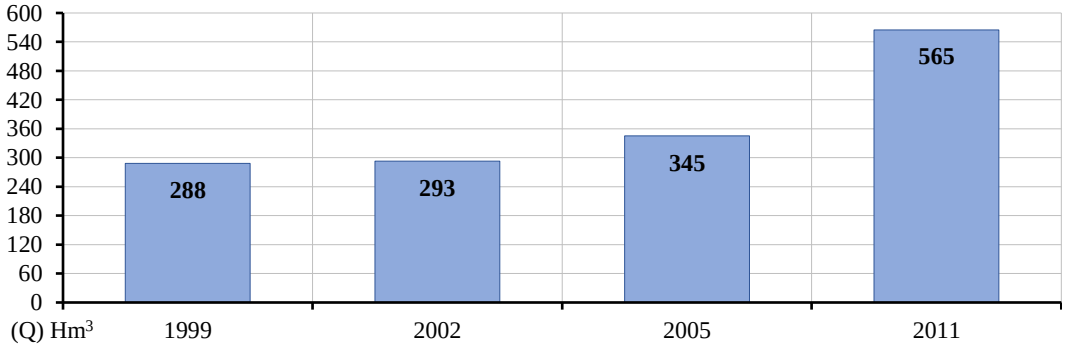

Figure 4. Mobilized flows in the period 1999 to 2011 (Mihoub, 2017)

This change is mainly due to the introduction of programs for agricultural growing in the territory (Figure 5), as well as to meet the increasing population's water needs. Table 1 and Table 2 show the CI operating volumes for the main three users in the main localities of the area (AEP: drinking water supply; IRR: irrigation and AEI: industrial water supply).

Table 1. Number of boreholes, exploitation volumes, water destinations
Data source: (Mihoub, 2017)

Municipality	Total	Exploited	No Exploited	Average flow (l/s)	Extracted volume (hm^3/year)	Depth (m)	Destination
Bounoura	18	13	3	30^p	7.73	500	AEP+IRR+ AEI
El Atteuf	21	16	3	25^p	6.70	500	AEP + IRR
Ghardaia	41	27	7	30^p	14.90	500	AEP+IRR+ AEI
Daya bendahoua	20	9	8	20^p	2.48	500	AEP + IRR
Berriane	22	12	6	30^p	7.59	500	AEP+IRR+ AEI
Metlili	39	25	12	80^a	13.42	1000	AEP + IRR
Sebseb	14	10	4	60^a	4.00	450	AEP + IRR
Mansourah	21	16	5	45^p	13.23	450	AEP + IRR
Hassi F'hel	40	33	6	$20\text{-}70^{a+p}$	59.47	250	AEP+IRR+ AEI
El Meniaa HG	262	209	34	30^p	178.07	500	AEP+IRR+ AEI

Guerrara	43	36	4	35[p]	49.06	450	AEP + IRR
Zelfana	24	20	0	80[a]	31.22	1000	AEP+IRR+ AEI
Total	**565**	**426**	**92**	-	**387,86**	-	-

Note: [p]: Pumping; [a]: Artesian, IRR: Irrigation, AEP: Drinking water supply, AEI: Industrial water supply

Table 2. Number of boreholes, exploitation volumes, water destinations
Data source: (Mihoub, 2017)

Municipality	Boreholes		IRR Drilling		AEI Drilling		Total of drilling	Volumes extracted (m^3/year)
	Number of boreholes	Q (hm^3/an)	Number of boreholes	Q (hm^3/an)	Number of boreholes	Q (hm^3/an)		
Bounoura	7	5.09	3	1.33	2	1.31	17	7.73
El Atteuf	8	2.45	6	1.26	2	0.51	21	6.70
Ghardaia	22	13.97	3	0.63	2	0.30	42	14.90
Daya bendahoua	4	1.30	4	1.02	1	0.16	20	2.48
Berriane	7	5.55	5	2.04	0	0.00	22	7.59
Metlili	11	7.27	10	4.03	1	0.26	39	13.42
Sebseb	1	0.79	7	3.41	0	0.00	14	4.00
Mansourah	2	1.05	11	10.10	0	0.00	21	13.23
Hassi F'hel	4	4.42	29	53.16	0	0.00	40	59.47
El Meniaa HG	18	10.30	184	163.88	5	3.13	262	178.07
Guerrara	7	6.53	26	40.98	0	0.00	43	49.06
Zelfana	5	10.00	11	20.18	4	1.04	24	31.22
Totals	99	68,71	299	302,02	17	6,71	565	387,86(*)

Note: *Not including the volume of illicit boring (116 boring) in the valley of El Menia, which total a volume of water extracted 19,30 m^3/ year, which is 0,612 m^3 /s (Mihoub, 2017)

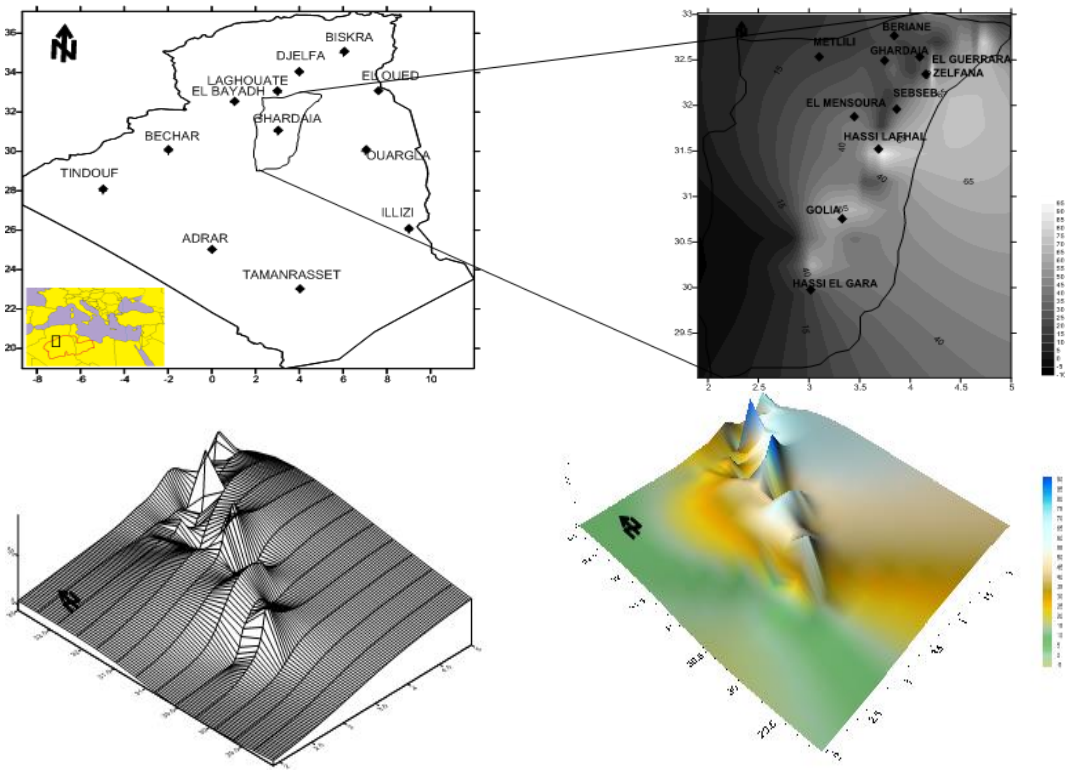

Figure 5. Flows extracted ($l.s^{1-}$)

In this time (1999–2005–2011), the volumes exploited for the 3 applications AEP, IRR and AEI exceeded 179 million m^3/year in 1999 to 214 million m^3/year in 2005, compared to 388 million m^3/year in 2011 (Figure 6).

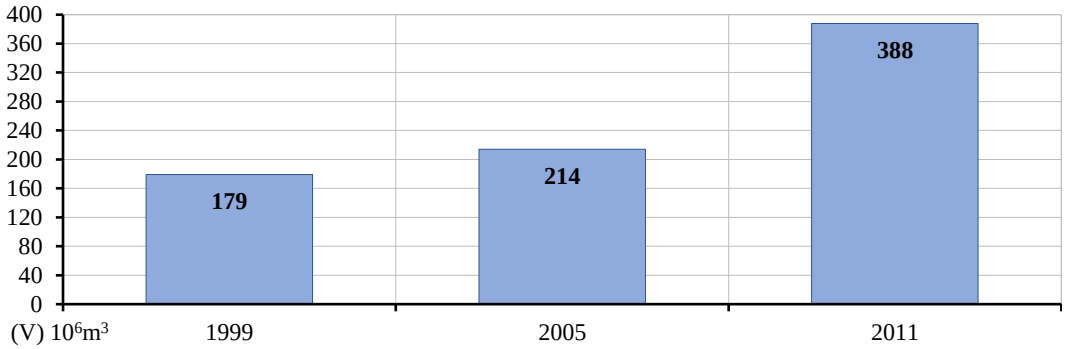

Figure 6. Evolution of the volumes of water taken out of the aquifer during the period (1999-2005-2011)

299 boreholes are intended for agricultural use on the 426 drilling operated throughout the territory. This means that the total volume of water in the agricultural sector is 302 million m^3/year of total mobilized water (Figure 7).

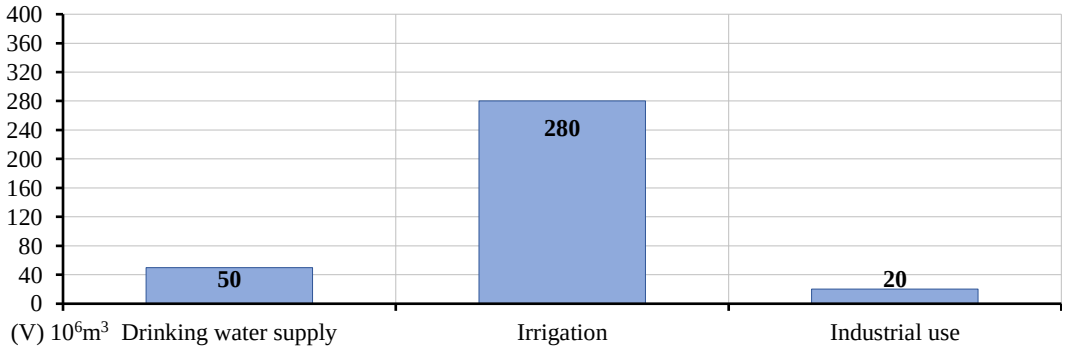

Figure 7. Volumes of water elevated by uses

The entire debit side collected by the CI is 387, 86 million m^3/year (Figure 8), which is 12, 30 m^3/s by 426 exploited boring.

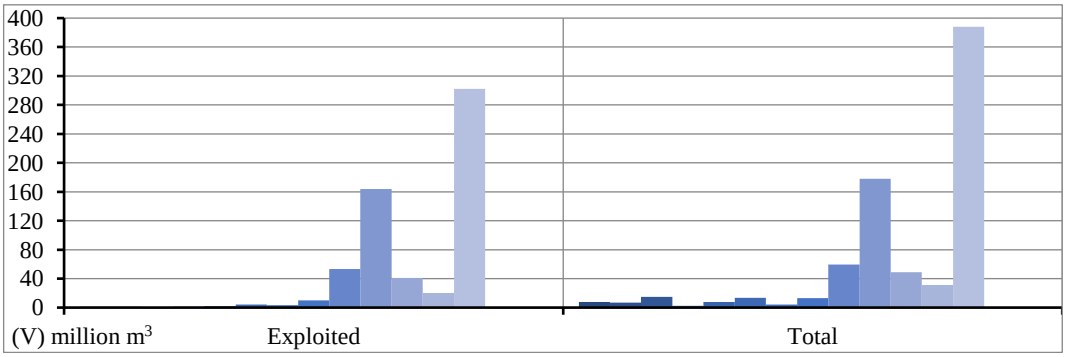

Figure 8. Exploited and total water

Such overuse most frequently causes long-term transient hydrodynamic conditions and disrupts the hydraulic interconnection between aquifer systems. It can contribute to adverse changes in water quality. Overexploitation just meets the required reload. It cannot even cause an immediate decrease in the hydraulic head because the relation in the water-bearing adjacent enables the requirement to be fulfilled (Andres & Egger, 1985).

Illegal boreholes problems

The plain is relatively urbanised and irrigated for agriculture purposes by means of very poor quality water, mainly coming from 500 m depth (Figure 9); it has decreased stagnant or local levels.

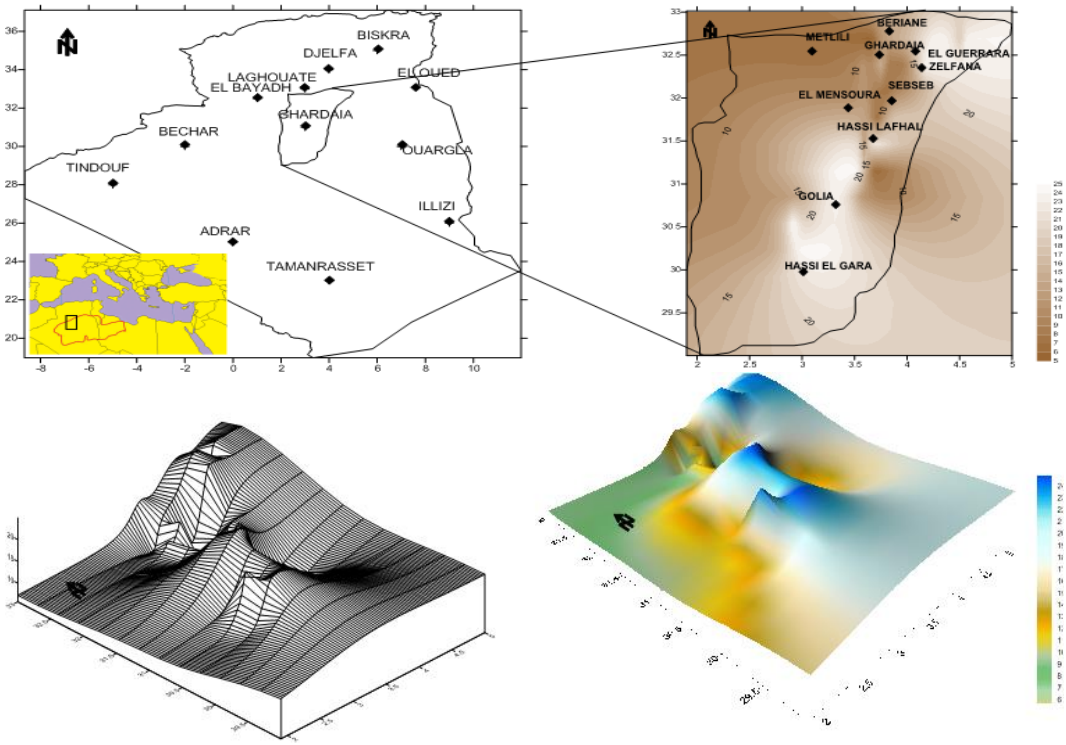

Figure 9. Frequency pumping time (l/day)

The El Meniaa valley has experienced a significant proliferation of illegal boreholes these last years, drilled by percussion, with an average depth of 75 m, touching the upper part of CI. The area has more than 116 illegal wells, with an average pace of up to 12 l/s of artesian discharge at Hassi el Gara. The 116 illegal drillings totaled a volume of extracted water of 19.30 million m^3/year, or 0,612 m^3/s, representing 24% of the total output of authorized Ghardaia boreholes.

Drawdowns at the CI

In the Ghardaia region, drawdowns of around 15 m have been recorded (Figure 10). Further south, at Ouargla, the drop is 66 m and it is 46 m at Hassi Messaoud and 10 m at El Golea (OSS, 2002).

Subsequently, all the hydrogeological synthesis and fundamental data relating to the CI were enriched and supplemented by important studies and in particular the simulation models developed during the last 30 years. Finally, it should be remembered that Besbes and Zammouri (1988) and Zammouri (1990) provided a first comprehensive modeling of the Saharan Continental Intercalary, at the Algerian-Tunisian-Libyan scale.

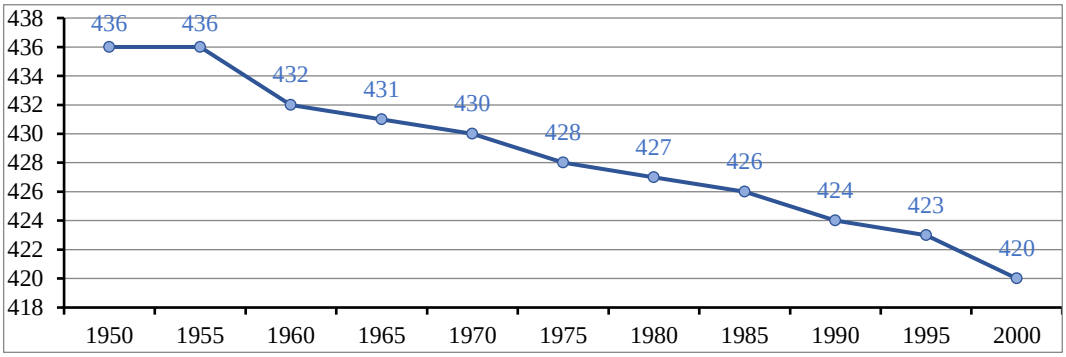

Figure 10. General evolution of piezometric level at CI in Ghardaia from 1950 to 2000

This simulation constitutes the critical guideline (OSS, 2002). The drawdowns are determined by utilizing the piezometric amounts restored by the system in 2000 (Figure 11).

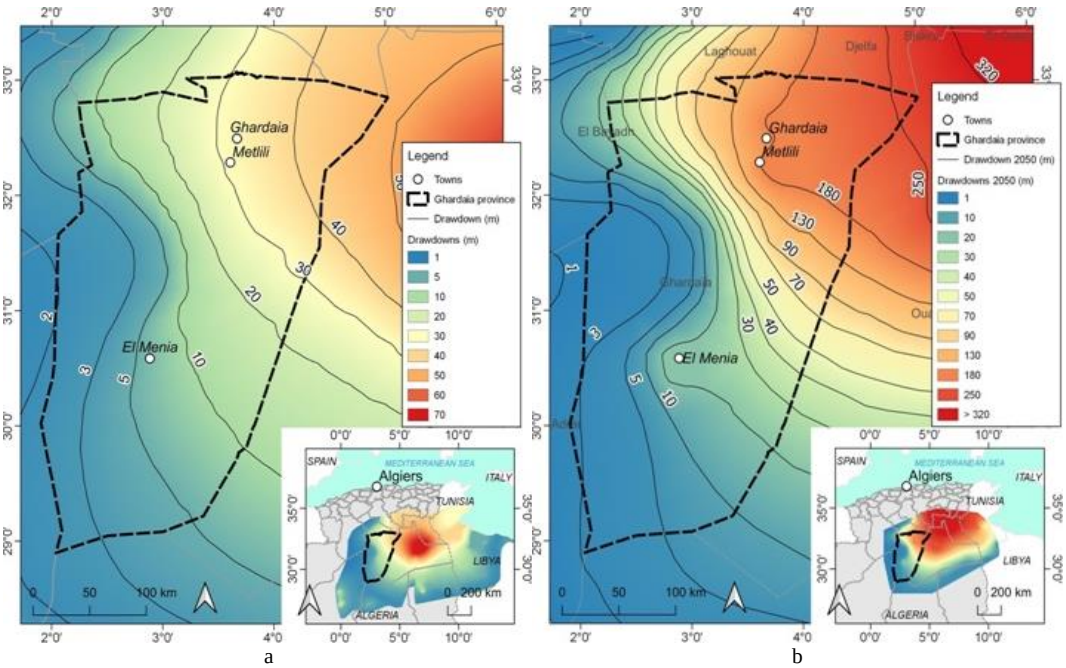

Figure 11. Drawdowns at the Continental Intercalary; 11a: 2000 to 2050 and 11b: in 2050

The simple continuation of current withdrawals is expected to lead to major drawbacks more than 40 m (measured by 2000 water levels) by 2050 across the Algerian Lower Sahara.

CI Water chemistry

A hydrochemical survey was carried out during the year 2011 to demonstrate the degradation of chemical quality due to overexploitation of CI aquifer. This study showed two very distinct facies.

As shown in Figure 12, the CI waters in the northern part of the area are characterized by a calcium sulfate chemical facies (PT01). They are from sulfated to sodium chlorides (PT03, PT04) in the southern part with a SO_4/Cl ratio indicating an enrichment of chloride to the east (PT19). Water becomes more salty in high-exploitation households (PT13, PT23). This salinity rise was

most likely caused by mixing with deeper and saltier levels. The salinity is of evaporative non-marine origin. But it remains to examine the sources of dissolved NaCl (Figure 12).

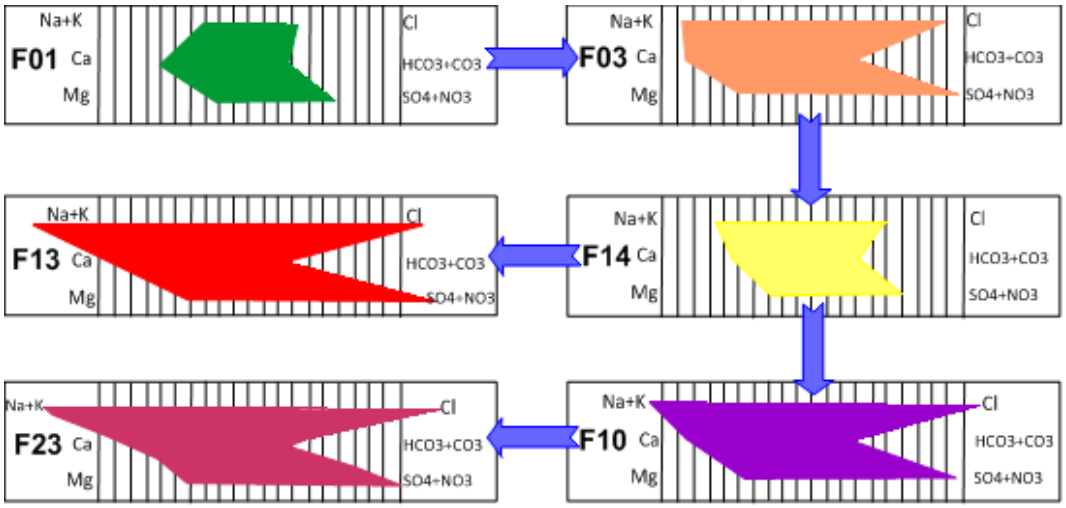

Figure 12. Evolution of the CI hydrochemistry
Source: (Hakimi, Orban, Chettih, & Brouyerre, 2019)

With regard to the salinity of the CI waters at Ghardaia, we note that 80% of water points have a salinity of less than 2 g/l; and 92%lower than 3 g/l salinity.

The waters towards the north of the area produce salinities below 1 g/l. (Hakimi, Orban, Deschamps, & Brouyere, 2021). This is not the case in the southern portion, where the salinities oscillate between 2 and 4 g/l. The salinity of 39% of water points varies from 2 to 3 g/l (Hakimi, Orban, Chettih, & Brouyerre, 2019)

CONCLUSION

The groundwater coming from CI aquifer is of considerable importance for central Algeria's Saharan oases, which share this resource used for drinking and irrigation purposes sharing it with other North African countries. However, this precious resource is threatened by the effects of increased overexploitation and flood irrigation activities, and can be seriously stressed if not properly controlled, as already witnessed by decreasing water levels and deterioration of water quality. This study indicated that overexploitation is really huge and influences the characteristics of groundwater flow and quality, which consequently affects the possibility of properly using it as a resource.

The amount derived from these illegal boreholes mainly involves two municipalities' total production, i.e. the cities of Ghardaia and Sebseb. The overexploitation impacts and human activities have had the following consequences:

Artesian's absence in some areas, and a large decline in pumping fields.

Furthermore, toxic irrigation has affected water quality by encouraging saltwater contamination of the water table.

The key effect of the extraction of non-renewed aquifers is the steady reduction of hydrostatic pressure and thus the water level, which has led to significant consequences.

Deepening of water levels in oasis, palm groves and crop areas.

Drainage of draining galleries, reduction of flow rates up to drying up of springs.

Reduction in water levels at the drilling head in places where the water table is deep in the captive aquifer, with a gradual drop in the Artesian level requiring deeper and deeper pumping, accompanied by a fall in the soil due to hydrostatic pressure that has become lower.

Aknowlegments

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