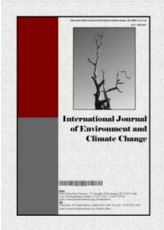

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Simulation of the Water Demand in 2050 in the Lobo Watershed in Nibéhibé (Central-Western Cote d'Ivoire): Application of the WEAP Model

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Authors' contributions

This work was carried out in collaboration among all authors. Author TFF designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors KWAB and KTJJ managed the analyses of the study. Authors YAB and DA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Due to climate change, which has caused the scarcity of rainfall and the depletion of water resources in recent decades, Côte d'Ivoire has embarked on a planning program for the integrated management of its water resources. The present study is carried out on the Lobo watershed in Nibéhibé, located in the western part of Côte d'Ivoire (between 6°17' and 6°44' W longitude and between 6°46' and 7°41' N latitude). Indeed, the multisectoral use, the impact of climate, the demographic growth on water resources as well as the uncoordinated management lead to a crucial water shortage in the basin. The objective of this study is to propose optimization scenarios for the use of water resources for planning and sustainable management. To this end, field surveys were carried out among the state structures and the populations of the basin to acquire the socio-economic data necessary for the simulation of future water demand. The product of the specific consumptions by the levels of activities allowed to estimate the needs by sectors of activities (water supply, agriculture, and breeding) and consequently the global needs of the basin in 2021. The

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Water Evaluation And Planning (WEAP) model, which is a water resources management tool, was used to simulate the future water demand of the basin under different scenarios. The results show that the water demand for 2021 is 30 180 588 m^3. The water demands by 2050 under the reference, low population growth rate, high population growth rate, improved standard of living and climate change scenarios are 83,700,000 m^3; 57,700,000 m^3; 114,100,000 m^3; 107,600,000 m^3 and 114,100,000 m^3 respectively. As a result, the unsatisfied water demands for the same scenarios are 23,700,000 m^3; 10,700,000 m^3; 38,600,000 m^3; 34,300,000 m^3 and 38,600,000 m^3 respectively. The reduction of these unsatisfied demands for the well-being of the basin populations requires the implementation of planning and integrated management systems of the basin water resources through optimization scenarios.

Keywords: Watershed; integrated management; Lobo; water resources; WEAP; Cote d'Ivoire.

1. INTRODUCTION

Water is a limited natural resource, necessary for life and socio-economic development [1]. Despite the relative abundance of water resources in West Africa compared to the rest of the continent, it is faced with a weakening of ecosystems due to demographic pressure and the general decline in rainfall in the 1970s and 1980s [2]. Indeed, the impacts of climate variations over the last thirty years are alarming in terms of water resources, especially since the results of studies conducted on climate fluctuations show that rainfall has declined by 10% to 30% depending on the climatic zone [3]. This situation has resulted in a decrease in the average flow of major rivers by 20% to 60% since the 1970s, reducing the surface area of the main natural wetlands [4]. With population growth, rapid urbanization and climate change, water is under pressure in terms of quality and quantity [5]. In order to manage or prevent crises related to access to water, political authorities have for some years been taking action to provide specific responses to the water issue. One of these solutions is Integrated Water Resources Management (IWRM). This is a very important strategic framework in the coupled process of achieving the Millennium Development Goals (MDGs) and the sustainable development strategy as advocated at the World Summit on Sustainable Development (WSSD) in Johannesburg in 2002 [6]. The humid tropical countries, although possessing an enormous water potential (artificial lakes, rivers, lagoons, etc.) are facing crises of accessibility to water, such is the case of Côte d'Ivoire. Indeed, in several Ivorian regions, conflicts between the various users related to access to water can be observed. According to [7], IWRM appears to be an approach that can prevent this type of conflict. To be implemented, this approach must be supported by management tools and analysis of current data and forecasts. In Côte d'Ivoire, studies conducted in the different basins (Comoé, Bandama, N'zi, N'zo) have also shown a decrease in water resources, both surface and groundwater [8,9]. Thus, we realize that water resources are not infinite in the face of climate change. It is necessary to evaluate the available water resource in order to optimize its management to meet the needs of all users. The Lobo River watershed in Nibéhibé was chosen as the framework for this work. Indeed, this basin is a region of coffee and cocoa production. These crops, which require a considerable amount of labor, have attracted many people from the Ivorian savannahs and neighboring countries [10]. The population of the basin was estimated at 1,103,059 inhabitants in 2014 [11] or a density of 160 inhabitants per km^2. According to the general census of population and housing, this population has increased to 1,329,069 inhabitants in 2021 [12] or a density of 192 inhabitants per km^2. Consequently, the water needs of the populations are gradually increasing and water resources will be increasingly solicited. In addition, water management at the basin level is characterized by sectoral management. Generally speaking, each water use sector (agriculture, drinking water supply, pastoral hydraulics, etc.) mobilizes the quantities it needs to satisfy its requirements, without concern for the needs of other sectors or the long-term survival of ecosystems. Thus, sectoral water management, rapid population growth and the effects of climate change are affecting the availability of water resources. These various phenomena are leading to increased water scarcity in the basin and the destruction of vital ecosystems. The objective of this study is to propose optimization scenarios for the use of water resources for planning and sustainable management using the Water Evaluation and Planning (WEAP) model.

2. MATERIALS AND METHODS

2.1 Study Area

The Lobo watershed has an area of 6,923 km^2 and is located in central-western Côte d'Ivoire between 6°17' and 6°44' W longitude and between 6°46' and 7°41' N latitude (Fig. 1). It drains an area of 7,000 km² with an outlet at Nibéhibé. This watershed has a catchment area that is not circumscribed within a single administrative entity. Most of the basin covers the departments of Daloa, Issia, Vavoua, and Zoukougbeu. The Lobo river has its source at an altitude of 400 m south of Séguéla and flows into the Sassandra river not far from the locality of Loboville. The town of Daloa represents the economic pole of the region. The Lobo River rises at an altitude of 400 m south of Séguéla and flows into the Sassandra River not far from the town of Loboville [13].

From 788,526 to 1,329,069 inhabitants [12]. This represents an annual growth rate of approximately 3.1% and a density of 192 inhabitants per square kilometer. Economic activities are quite diversified; however, agriculture remains the main income generating activity practiced by the majority of the population. The agricultural dynamic is based essentially on perennial cash crops (coffee, cocoa, rubber, oil palm), food crops and market gardening. The agricultural system, which was initially extensive, is now evolving towards a much more intensive agriculture due to the scarcity of cultivable land. Livestock breeding is a secondary activity in the region.

2.2 Sampling Methods

The choice of localities to be surveyed was defined using the reasoned choice method and proportional calculation. This technique is based on three (3) determining factors which are: 1) the estimated prevalence of the variables studied (access to drinking water); 2) the 95% confidence level and 3) the acceptable margin of error of 5%.

The population of the basin is changing rapidly. Between 1998 and 2021, the population increased

On this basis, the sample size was determined according to equation (1) [14,15] :

$$N = \frac{T^2 * P(1-P)}{M^2} \quad \text{(Eq.1)}$$

Where,

N = Required sample size;
T = 95% confidence level (standard value of 1.96);
P = Proportion of households in the surveyed basin with access to safe drinking water (25% according to the [11]);
M = Margin of error at 5% (standard value of 0.05).

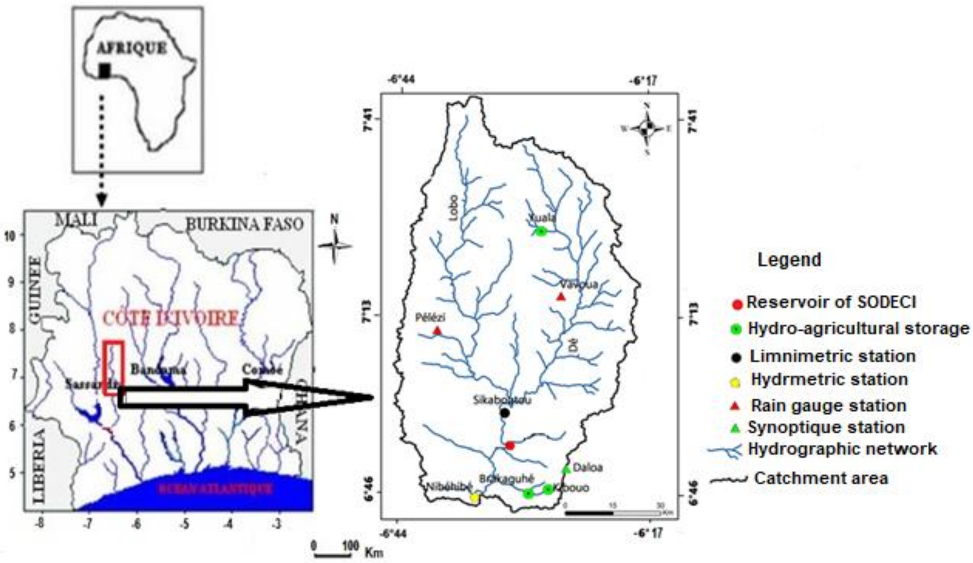

Fig. 1. Location map of the Lobo watershed in Nibéhibé

The need to set a minimum sample size in advance is related to the need to have a margin of error determined at a certain confidence level [16]. Thus, a total of 384 households in 30 locations in the watershed were selected for the questionnaire survey.

2.3 Field Survey

The objective of the field survey was to identify the various water users as well as their needs and sources of supply. The interview guides were directed towards the state structures involved in the field of water resources for the acquisition of socio-economic data. These included the Water Distribution Company in Côte d'Ivoire (SODECI) in the Daloa region, the National Office for the Development of Rice (NODR) and the Territorial Direction of Hydraulics (TDH). These surveys took place from March 25 to April 14, 2019 and were distributed over 30 localities in the watershed that met the criteria of accessibility and homogeneous spatial distribution (Fig. 2).

A Garmin GPS was used to geolocate the positions of the different localities, demand sites and water supply sites of the different users. A digital camera was used to take pictures. Also, a questionnaire relating to the various uses was addressed to the users of water.

2.4 Data Processing

The processing of the different data collected through our questionnaire and guide required the use of Excel spreadsheet, ArcGIS and WEAP software. Indeed, the socio-economic and statistical data were processed by the Excel spreadsheet to estimate the current water needs of the different users. The ArcGis software was used to facilitate the processing of shapefiles containing the boundaries of the Lobo watershed in order to extract the study area and the different localities. It was also used to produce the various thematic maps. The WEAP software was used to simulate the water needs of the different users for the year 2050 and also to plan the water resources of the basin.

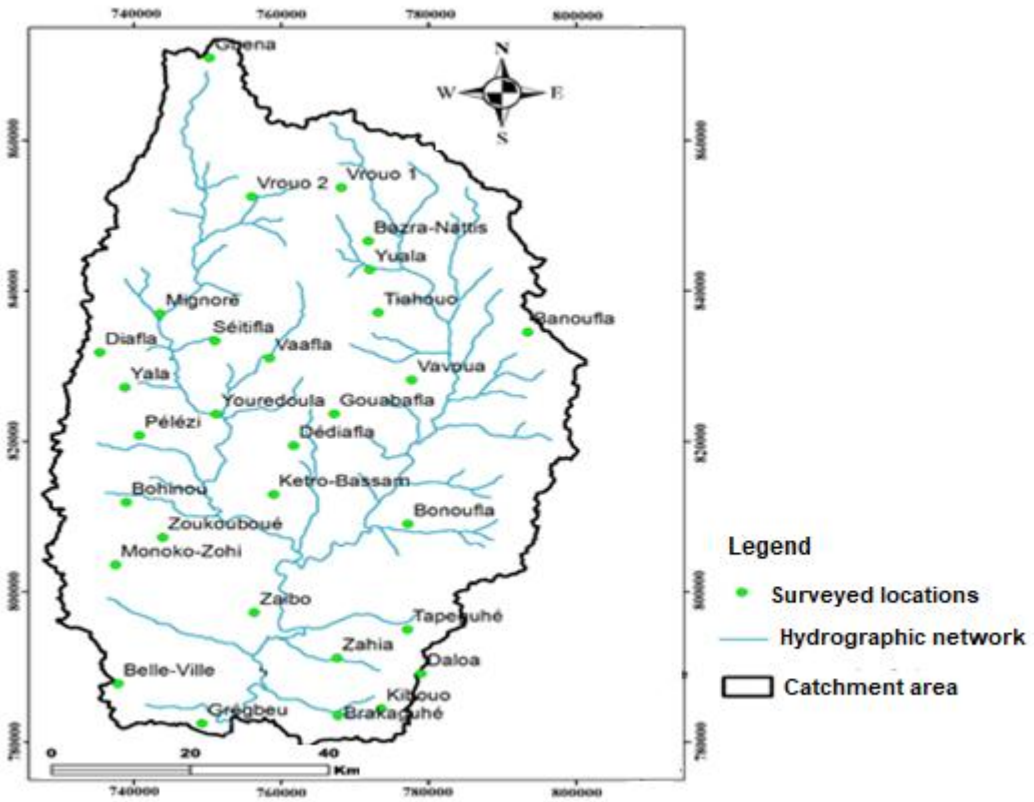

Fig. 2. Map of surveyed areas

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Estimation of water needs of different users

The water resource is used by both consumptive users (water supply, agriculture and livestock) and non-consumptive users (cultural uses and Bozo fishermen).

For the estimation of the water needs, we have taken into account the consuming users because these are the actors who act on the availability of the water resource. It is therefore essential to know the needs of these users for a better management of the water resource.

3.1.1.1 Drinking water supply needs in the Lobo watershed in Nibéhibé

Table 1 presents the drinking water needs of the populations of the Lobo watershed in Nibéhibé. The total daily needs for drinking water are estimated at 54,227 m^3 with an estimated need of 39,932 m^3 for urban areas and 14,295 m^3 for rural areas. The total annual requirement for the basin is estimated at 19,792,493 m^3 with a requirement of 14,574,861 m^3 for urban areas and 5,217,632 m^3 for rural areas. The high needs of urban areas are related to the specific consumption in urban areas (65l/hbt/d) against 20l/hbt/d in rural areas.

3.1.1.2 Water needs for agriculture in the Lobo watershed in Nibéhibé

The water needs for agriculture are estimated at 9,000,000 m^3/year and depend on the total irrigated agricultural area (450 ha) as well as the specific consumption (20,000 m^3/ha/year). Table 2 presents the annual water needs for agriculture in the Lobo watershed at Nibéhibé.

3.1.1.3 Pastoral water requirements in the Lobo to Nibéhibé watershed

Table 3 presents the water requirements for livestock in the Lobo watershed at Nibéhibé. The water requirement for cattle is the most important with 925,275 m^3/year. This is followed by the water needs of sheep (203,305 m^3/year), goats (124,556.25 m^3/year), poultry (83,767.5 m^3/year) and pigs (51,191.25 m^3/year). These needs are higher, especially since the number of livestock and specific consumption are high.

Table 1. Need for drinking water supply (DWS)

	Urban areas		Rural areas
Daily needs (m3/d)	39 932		14 295
Daily total (m^3/d)		**54 227**	
Annual needs (m^3/year)	14 574 861		5 217 632
Annual total (m^3/year)		**19 792 493**	

Table 2. Water needs for agriculture

Total area (ha)	450
Specific consumption (m^3/ha/year)	20 000
Agricultural needs (m^3/year)	9 000 000

Table 3. Water requirement for livestock

Livestock	Number	Specific consumption (m^3/year)	Consumption (m^3/year)
Cattle	101 400	9,125	925 275
Sheep	111 400	1,825	203 305
Goats	68 250	1,825	124 556,25
Pigs	18 700	2,7375	51 191,25
Chicken	2 295 000	0,0365	83 767,5
Total	2 594 750		1 388 095

3.1.2 Simulation of water demand in the basin for the year 2050

3.1.2.1 Cartographic presentation of the model

The watershed map model created with WEAP is shown in Fig. 3. The WEAP project thus developed includes the following objects:

- A river (Lobo) (in dark blue) and its tributary (Dé) (in light blue) whose flow is simulated by the WEAP model;
- Thirteen demand sites (the red dots) representing the different water uses;
- Thirteen transmission links (green arrows) allowing water transits from sources to demand sites;
- Thirteen return flow links (the red arrows) due to the consumption of water at the demand sites which is not entire and part of which returns to the river;
- Four reservoirs represented by the green triangles supplying agricultural sites (Yuala, Kibouo, Brakaguhé) and the drinking water supply of the city of Daloa;
- Five groundwater catchment points represented by green squares supplying the departments of Daloa, Vavoua and Zoukougbeu.

The simulation of the water demand allows to know the water needs of the different users represented by the different sites of demands and grouped through three (3) types of uses, namely water supply, agriculture and breeding. This simulation has been made for the period 2021-2050 according to different scenarios.

3.1.2.2 Reference scenario

➢ *Water demand*

In the Lobo to Nibéhibé watershed, water demand is currently estimated at 30,180,588 m^3. The water demands for drinking water supply, agriculture and livestock are estimated at 19,792,493 m^3, 9,000,000 m^3 and 1,388,095 m^3 respectively. The demand for water for drinking water amounts to 65.58% of total water demand. Then, the agricultural sector representing 29.82% and the livestock sector with a demand of 4.6% of total water demand. By 2050, the total water demand of the basin will be estimated at 83,700,000 m^3 with a water demand of 47,900,000 m^3, 33,100,000 m^3 and 2,700,000 m^3 respectively for drinking water supply, agriculture and livestock. These water demands for drinking water supply, agriculture and livestock will represent 57.1%, 39.45% and 3.45% of the total water demand respectively (Fig. 4).

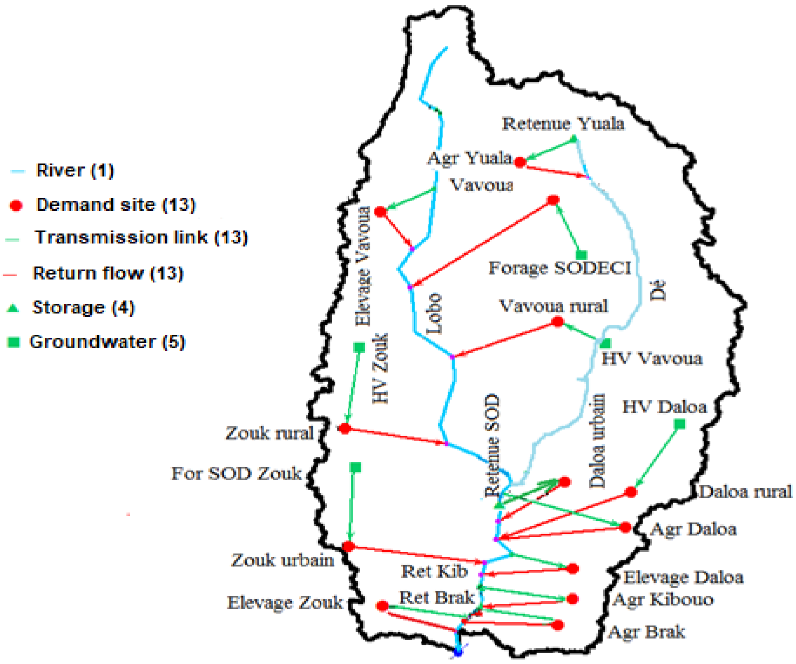

Fig. 3. Schematic representation of the Lobo watershed at Nibéhibé using the WEAP model

In the Lobo to Nibéhibé watershed, drinking water supply uses the largest share of the total water demand, followed by the agricultural and livestock sectors.

➢ *Unsatisfied water demand*

Unsatisfied water demand (UWD) represents the water shortages experienced in the basin. This current unmet water demand is estimated at 4,500,000 m^3. Unsatisfied water demand is found in the water supply sector, particularly in the rural areas of Daloa (1,800,000 m^3), Vavoua (100,000 m^3) and Zoukougbeu (500,000 m^3). It is also observed in the urban areas of Vavoua (1,600,000 m^3) and Zoukougbeu (500,000 m^3). By 2050, the UWD will be estimated at 23,700,000 m^3. It will be 5,000,000 m^3; 6,100,000 m^3 and 1,500,000 m^3 respectively in the rural areas of Daloa, Vavoua and Zoukougbeu. This unmet water demand will amount to 7,600,000 m^3 in the urban area of Vavoua (Fig. 5). In the agro-pastoral sector, unmet water demand will be nil because existing water resources are able to meet these uses.

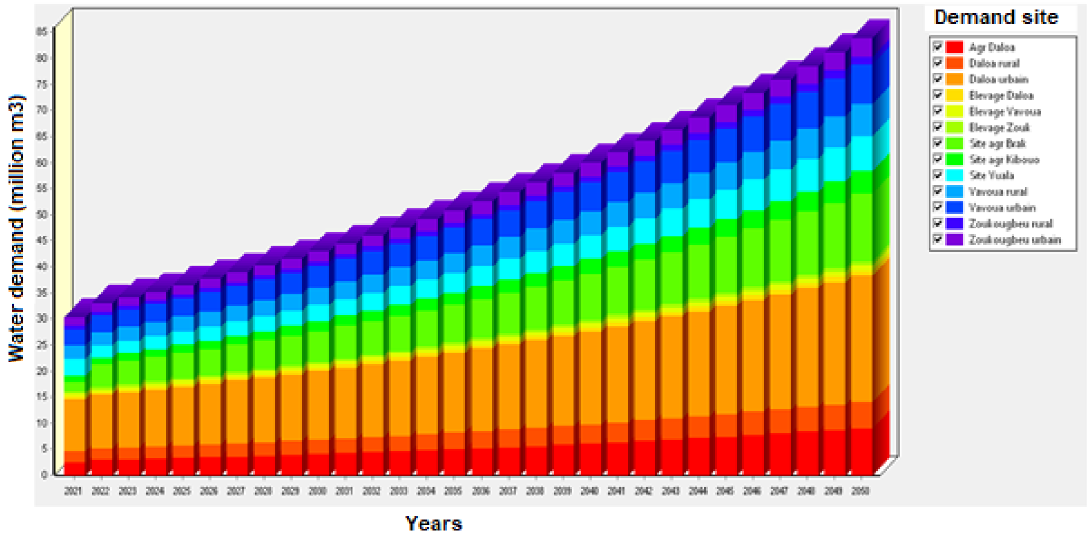

Fig. 4. Simulation of water demand for the 2021-2050 horizon according to the reference scenario

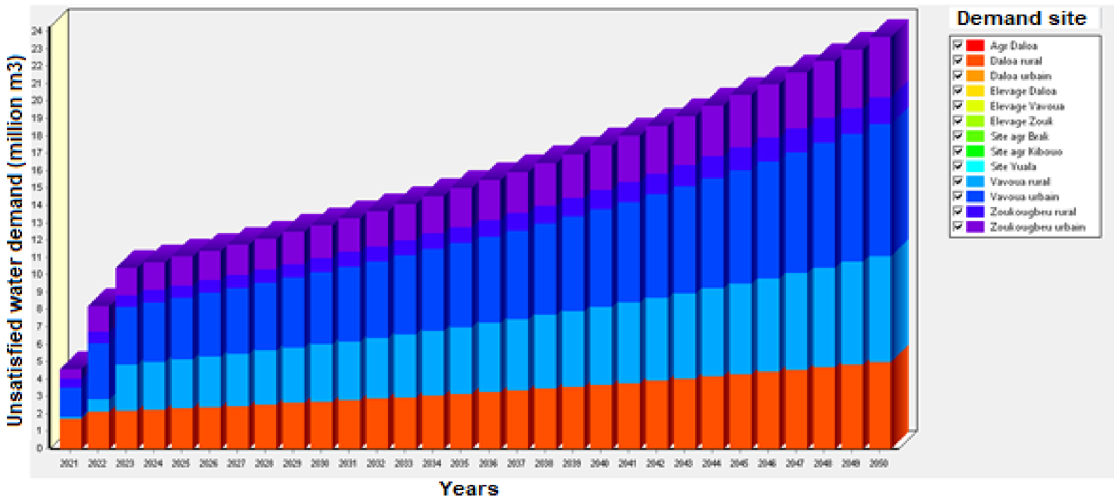

Fig. 5. Simulation of unsatisfied water demand by 2021-2030 under the reference scenario

3.1.2.3 Low Population Growth Scenario

The simulation of water demand under the low population growth rate scenario simulates the impact of the lowest growth rate (0.33%) observed in the Lobo to Nibéhibé watershed on water resources.

➢ *Water demand*

Current water demand in the basin under the low population growth scenario is estimated at 30,180,588 m^3. Water demand in 2050 will be 57,700,000 m^3. Compared to the water demand in the baseline scenario, a 31.23% decrease in water demand will be experienced under the low population growth scenario (Fig. 6).

➢ *Unsatisfied water demand*

The unsatisfied water demand by 2021-2050 under the low population growth scenario ranges from 4,500,000 to 10,700,000 m^3. Unmet water demand is found exclusively in the water supply sector. Indeed, the rural areas of Daloa, Vavoua and Zoukougbeu have unmet water demands of 1,800,000 m^3; 100,000 m^3 and 500,000 m^3 respectively. The urban areas of Vavoua and Zoukougbeu have unmet demands of 1,600,000 m^3 and 500,000 m^3 respectively. On the other hand, the urban area of Daloa has a satisfied demand. By 2050, unsatisfied water demand will amount to 10,700,000 m^3, a decrease of 54.85% compared to the baseline scenario (Fig. 7).

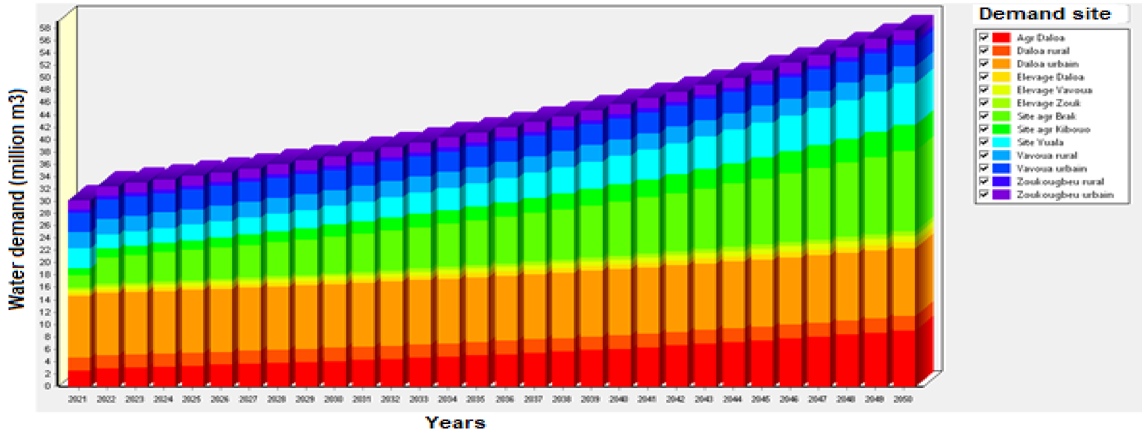

Fig. 6. Simulation of water demand by 2021-2050 under the low population growth scenario

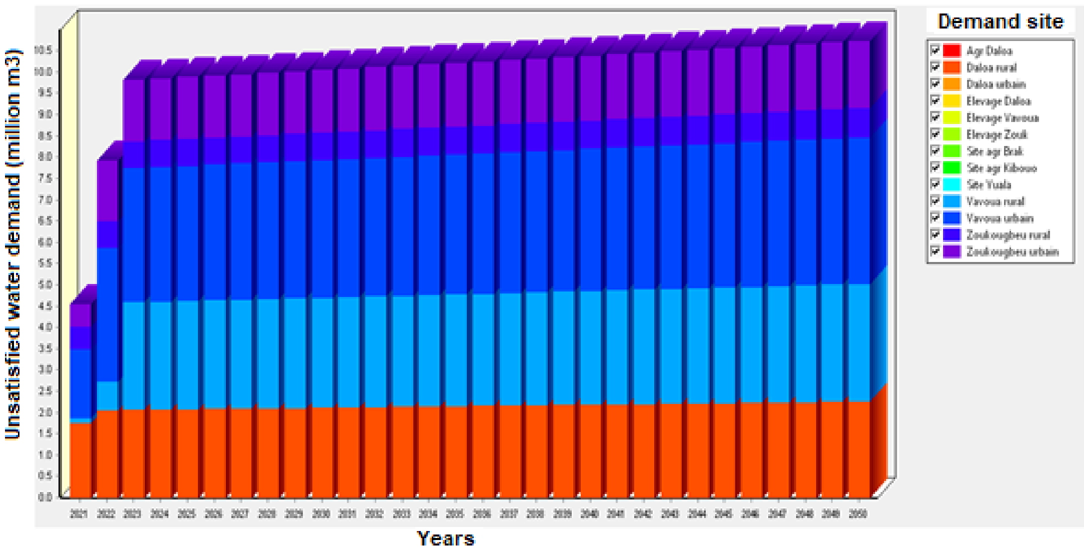

Fig. 7. Simulation of unsatisfied water demand by 2021-2050 under the low population growth scenario

3.1.2.4 High Population Growth Scenario

The simulation of water demand according to the high population growth scenario simulates the impact of the highest growth rate (4.85%) observed in the Lobo to Nibéhibé watershed on water resources.

➢ *Water Demand*

Current water demand in the basin under the high population growth scenario is estimated at 30,180,588 m^3. Water demand in 2050 will be 114,100,000 m^3. Compared to the water demand in the baseline scenario, there will be a 36% increase in water demand under the high population growth scenario (Fig. 8).

➢ *Unsatisfied water demand*

The unsatisfied water demand by 2021-2050 under the high population growth scenario ranges from 4,500,000 to 38,600,000 m^3. The unmet water demand is only found in the water supply sector. By 2050, the rural areas of Daloa, Vavoua and Zoukougbeu will have unmet water demands of 8,200,000 m^3; 9,900,000 m^3 and 2,500,000 m^3 respectively. As for the urban areas of Vavoua and Zoukougbeu, they will be 12,400,000 and 5,600,000 m^3 respectively. On the other hand, the urban area of Daloa will have its demand met. Unsatisfied water demand will be estimated at 38,600,000 m^3, an increase of 62.86% compared to the baseline scenario (Fig. 9).

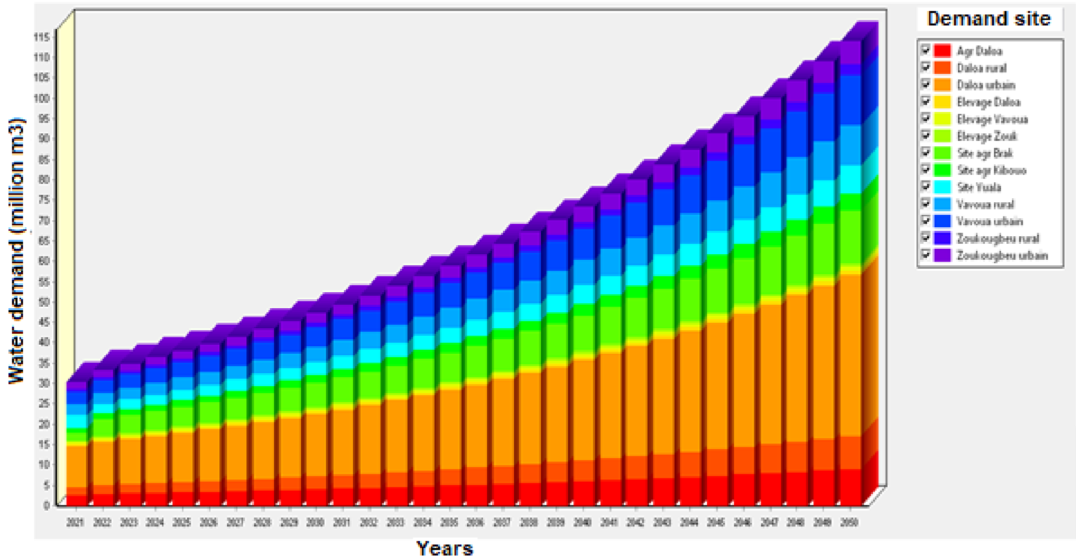

Fig. 8. Simulation of water demand by 2021-2050 under the high population growth scenario

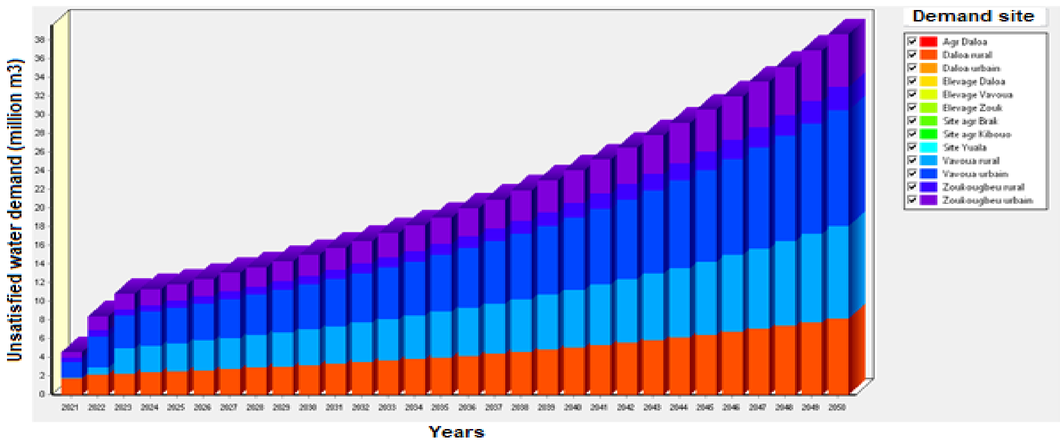

Fig. 9. Simulation of unsatisfied water demand by 2021-2050 under the high population growth scenario

3.1.2.5 Standard of living improvement scenario

The simulation of water demand according to the scenario relating to the improvement of the standard of living makes it possible to simulate the impact of the increase in specific consumption of the urban (100 l/hbt/d) and rural (25 l/hbt/d) populations on water resources.

➢ *Water demand*

Water demand by 2021-2050 under the improved standard of living scenario increases from 30,180,588 to 107,600,000 m^3. By 2050 the water demand of this scenario will increase by 28.25% compared to the reference scenario. This water demand for water supply will be 71,800,000 m^3 and will be estimated at 35,800,000 m^3 for agro-pastoral uses (Fig. 10).

➢ *Unsatisfied water demand*

The unsatisfied water demand over the period 2021-2050 under this scenario increases from 4,500,000 to 34,300,000 m^3. By 2050, unmet water demand will increase by 44.72% compared to the baseline scenario. This unmet water demand will affect the water supply sector throughout the simulation period, except for the urban area of Daloa, which will experience an unmet water demand of 500,000 m^3 in 2041. These unsatisfied water demands will be zero in the agropastoral sector except for the agricultural site of Daloa where unsatisfied water demands will occur during the year 2041 (Fig. 11).

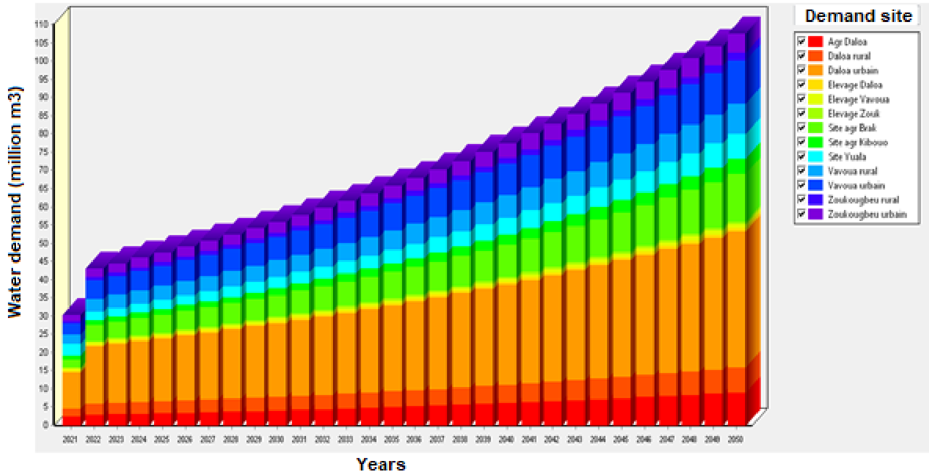

Fig. 10. Simulation of water demand to 2021-2050 under the improved living standards scenario

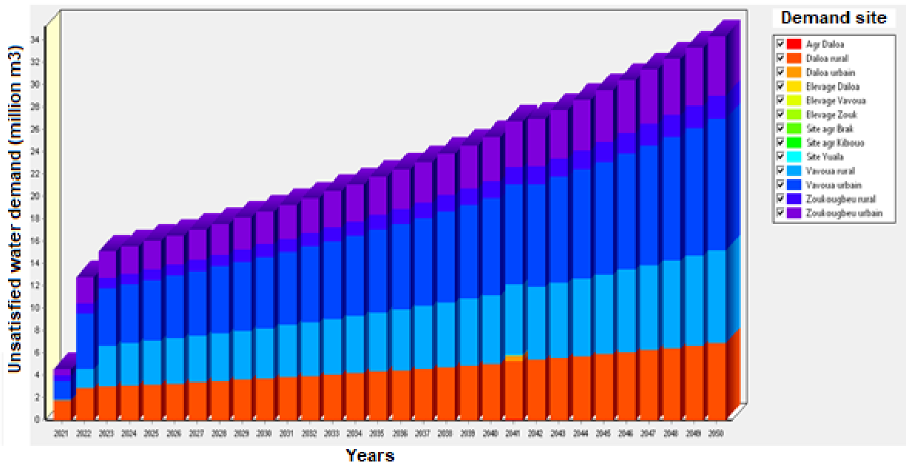

Fig. 11. Simulation of unsatisfied water demand by 2021-2050 under the improved living standards scenario

3.1.2.6 Climate Change Scenario

The water year method allows for variations in climate data (rainfall and temperature) to be taken into account in the WEAP model. This involves integrating simulated flows with climate data from the CCLM4-8-17 model into the WEAP model. This scenario makes it possible to evaluate the impact of climate variability on water resources.

➢ *Water demand*

Water demand over the period 2021-2050 under the climate change scenario ranges from 30,180,000 to 114,100,000 m^3 (Fig. 12). Current water demand is highest in the urban areas of Daloa and Vavoua with demands of 10,000,000 and 3,100,000 m^3 respectively. Similarly, the demand for water is high in the rural area of Vavoua and on the agricultural site of Yuala, with demands of 2,500,000 and 3,300,000 m^3 respectively. By 2050, these water demands will reach 39,500,000 ; 12,400,000 and 9,900,000 m^3 respectively for the urban areas of Daloa and Vavoua and for the rural area of Vavoua. The water demands will be 13,000,000 and 6,800,000 m^3 respectively for the agricultural sites of Brakaguhé and Yuala.

➢ *Unsatisfied water demand*

Unsatisfied water demands are currently estimated at 4,500,000 m^3 and will reach 38,600,000 m^3 by 2050. Regardless of the effects of climate change, agropastoral uses will be satisfied throughout the simulation period (2021-2050), except for the Daloa agricultural site. Indeed, this site will have an unsatisfied water demand estimated at 100,000 m^3 in 2048. As for water supply, the rural area of Daloa and the urban area of Vavoua currently have unmet demand of 2,200,000 and 3,300,000 m^3 respectively. By 2050, these unmet water demands will be 8,200,000 m^3; 9,900,000 m^3, 12,400,000 m^3 and 5,600,000 m^3 respectively for the rural areas of Daloa and Vavoua, and for the urban areas of Vavoua and Zoukougbeu. This unmet water demand will be 400,000 m^3 in the year 2048 for the urban area of Daloa (Fig. 13).

The objective of this work is to propose water resource management alternatives for a rational, equitable and sustainable use. Thus, after estimating the water demands and highlighting the unmet water demands of the use sectors, it is important to propose optimization scenarios for a better management of water resources. These different scenarios will make it possible to reduce as much as possible or to meet the unmet water demands for the well-being of the different users. The scenarios of high population growth and climate change are used to evaluate the evolution of unmet demand. Indeed, the unmet water demands of these two scenarios are the most important. Thus, meeting their unmet water demands would be equivalent to meeting the unmet demands of all scenarios.

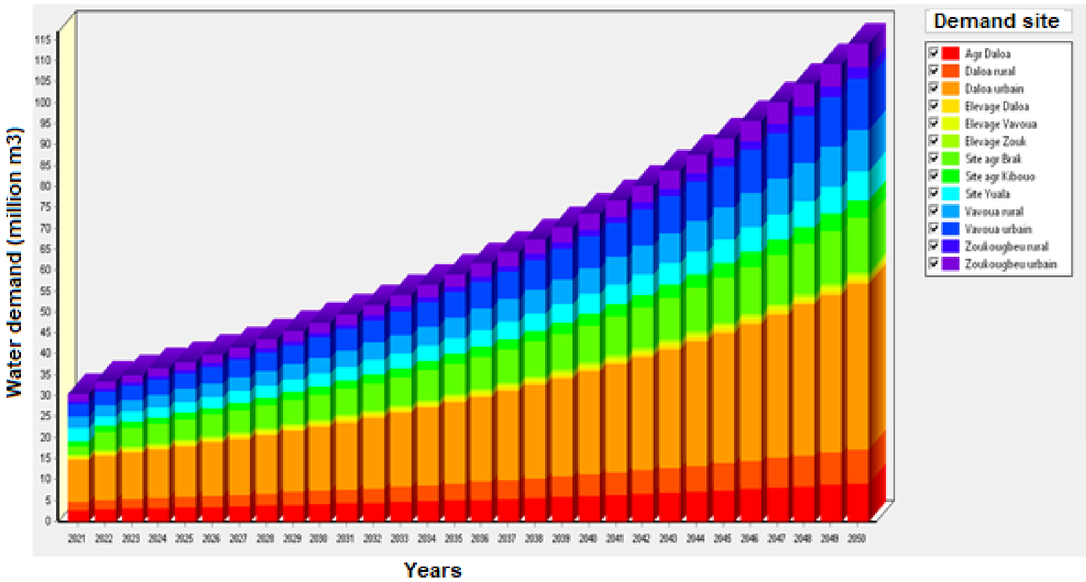

Fig. 12. Simulation of water demand to 2021-2050 under the climate change scenario

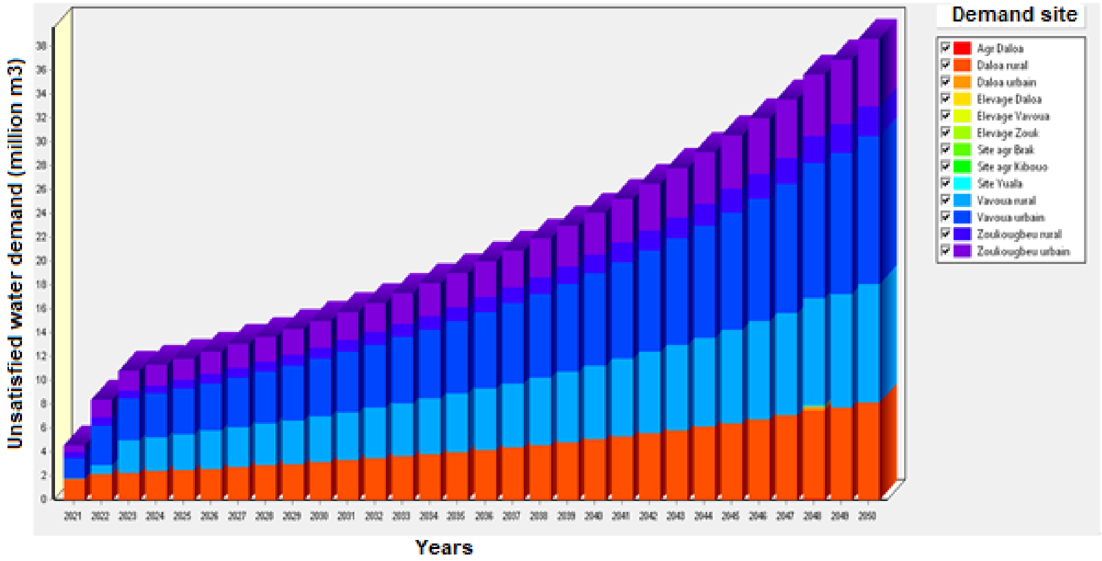

Fig. 13. Simulation of unsatisfied water demand by 2021-2050 under the climate change scenario

3.1.2.7 Optimization scenarios

3.1.2.7.1 Scenario for the use of new water sources

Fig. 14 shows the effect of using new water supplies in the rural areas of Daloa, Vavoua and Zoukougbeu, and the urban areas of Vavoua and Zoukougbeu under the high population growth scenario. Indeed, the supply of 180 m3/h of water to each of these areas would meet the unsatisfied water demands over the entire simulation period.

In the climate change scenario, in addition to the above areas, the urban area and the agricultural site of Daloa will have unmet water demands of 400,000 and 100,000 m^3 respectively in the year 2048. Thus, the supply of a volume of water of 180 m^3/h in each zone would meet the unmet water demands (Fig. 15).

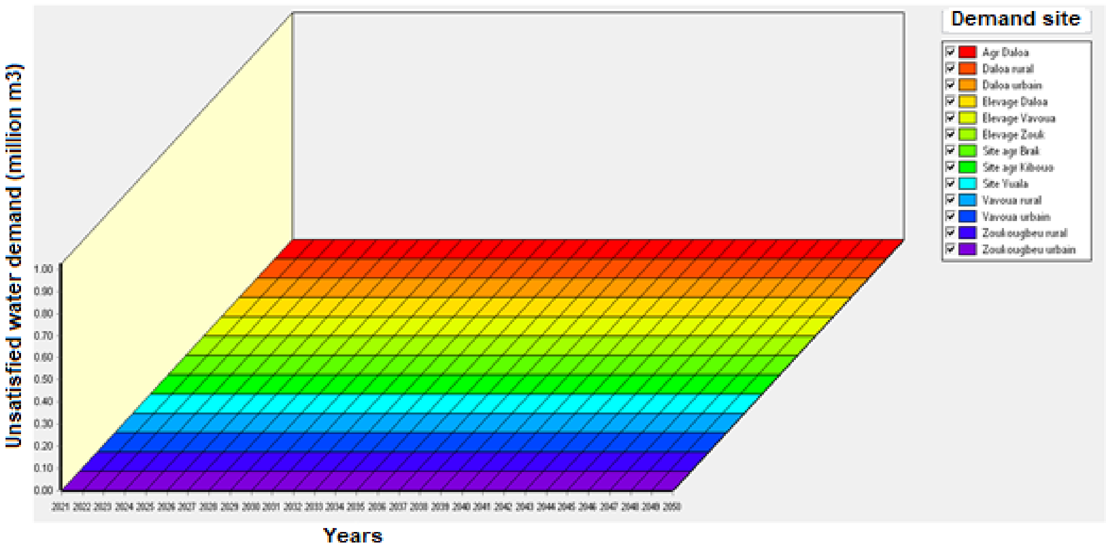

Fig. 14. Scenario of using new sources of supply on unsatisfied water demand under high population growth rate

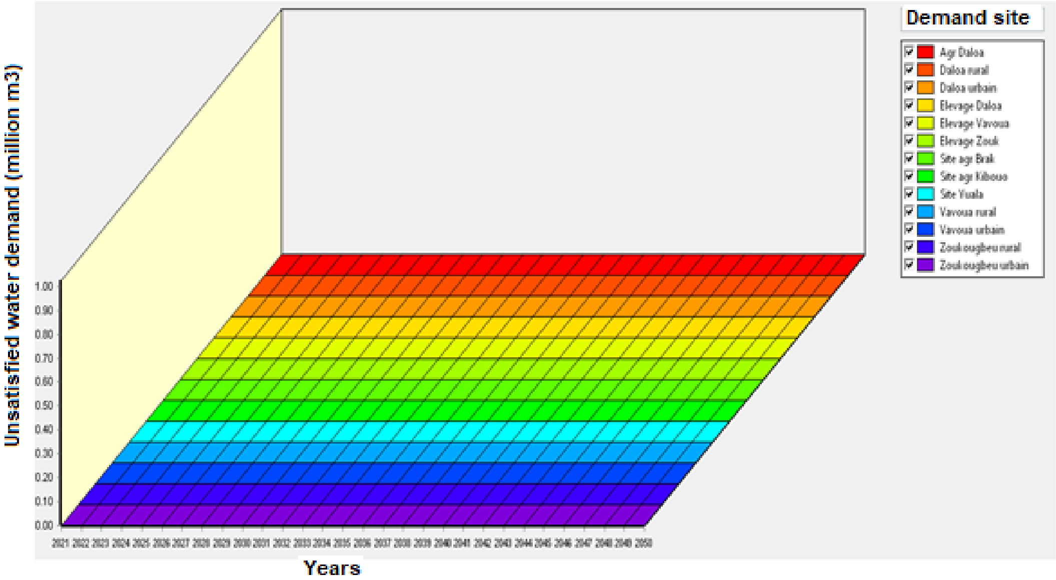

Fig. 15. Alternative supply scenario on unsatisfied water demand under climate change

3.1.2.7.2 Agricultural Gate Management Scenario

In this scenario, the amount of water to be supplied to the agricultural surfaces is regulated according to the phenological stage of the rice. The aim is to provide the right amount of water to the agricultural areas at specific times to avoid wastage. Thus, it appears that under the effects of climate change, the unmet water demand observed on the Daloa agricultural site (100,000 m^3) in the year 2048 will be met (Fig. 16).

3.1.2.7.3 Scenario for increasing water supply to the urban area of Daloa

In the context of climate change, by applying this scenario, the unsatisfied water demand observed in the urban area of Daloa (400,000 m^3) in the year 2048 will be met as well as over the entire simulation period (Fig. 17). In fact, an additional drinking water supply of 360 m^3/hr will be granted to this site in order to fill the entire deficit. Thus, the unsatisfied water demand reflected in the water shortage regularly observed in the city of Daloa will be met.

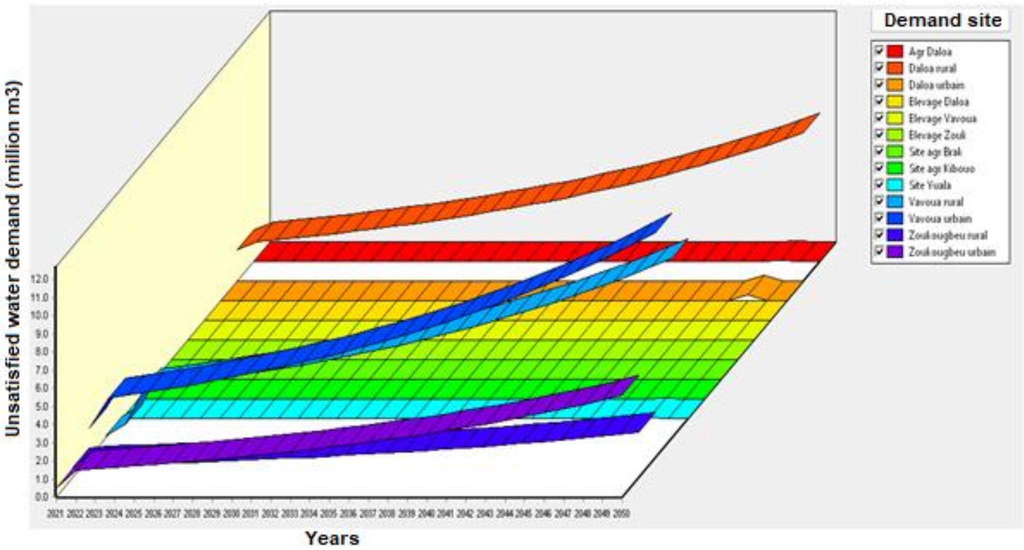

Fig. 16. Scenario of gate management on unsatisfied water demand under climate change

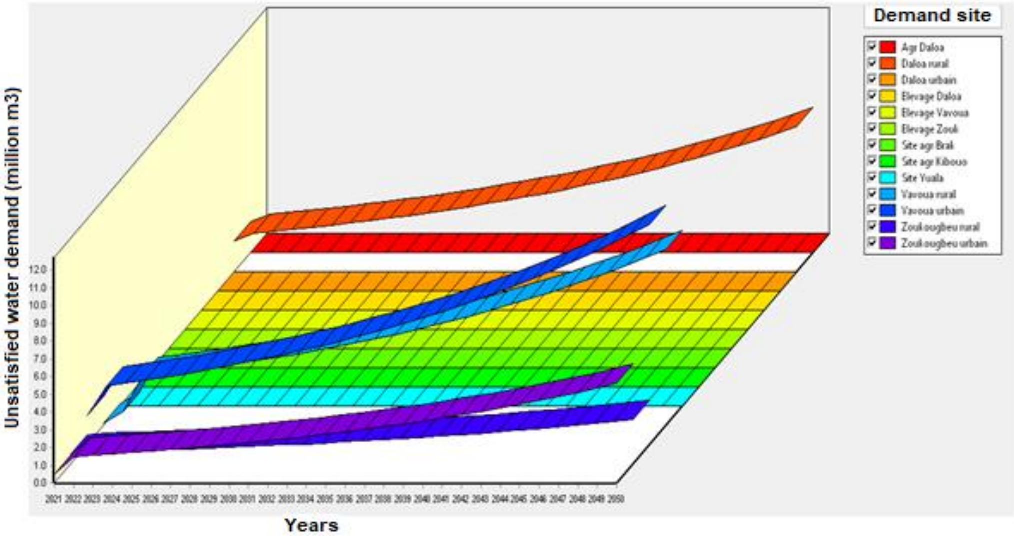

Fig. 17. Increased water supply in the urban area of Daloa on unsatisfied water demand based on climate change

3.2 Discussion

3.2.1 Estimation of water needs of different users

The use of water resources is divided between drinking water supply, agriculture and livestock. Thus the estimate for drinking water supply is 14,574,861 m^3 for urban areas and 5,217,632 m^3 for rural areas, making a total of 19,792,493 m^3 for the year 2021. The high value for urban areas could be due to the specific consumption in urban areas. This finding is similar to those made by [6, 17] for the urban centers of Odienné and Bondoukou respectively. Water demand is higher in urban areas than in rural areas, although rural areas are highly populated. This result is due to the choice of specific consumption set according to the environment. Indeed, many works related to the estimation of water demand [18, 19] have shown that there is a great variability in theoretical standards. As can be seen, its theoretical character is therefore extremely variable according to the type of habitat (collective or individual) and according to the standard of living. The estimates for agricultural and pastoral uses are respectively 9,000,000 m^3 and 1,388,095 m^3, i.e. a total of 10,388,095 m^3 for the year 2021. These different values depend on the irrigated rice-growing areas and the number of livestock. In the Lobo watershed in Loboville, [13] obtained a value of 42,589,231 m^3 for agropastoral uses. These high values are due to the large surface area of the basin with large irrigated rice-growing areas and the high number of livestock.

3.2.2 Simulation of water demand in the basin for the year 2050

The water requirements obtained for the reference, low and high population growth rate, improved standard of living and climate change scenarios by 2050 are 83,700,000 m^3, 57,700,000 m^3; 114,100,000 m^3; 107,600,000 m^3 and 114,100,000 m^3 respectively. The application of the WEAP model to the Lobo watershed in Nibéhibé revealed an increasing need for water regardless of the type of scenario used over the entire simulation period (2021 - 2050). This growth is due to the increase in activity levels (population, agricultural areas and livestock numbers) in urban and rural areas, on agricultural and livestock sites. These results are confirmed by those of [20, 21] by applying the same model respectively to the Lokoho (North-East of Madagascar) and Haut Bandama basins in Côte d'Ivoire. According to these authors, the larger the population, the greater the water needs of the region in the years to come. Population growth is one of the main causes of the evolution of water demand over time [22, 23]. Thus, the evolution over time of the water demands observed in the basin is linked to the importance of their increasing level of activity during the simulation period. As for the unmet demands for the same scenarios by 2050, they are respectively 23,700,000 m^3 ; 10,700,000 m^3 ; 38,600,000 m^3 ; 34,300,000 m^3 and 38,600,000 m^3. The unsatisfied water demands evolve in the same direction as the water demands. Indeed, whatever the type of use and the type of scenario considered, the demand for water is far from being satisfied because the resources only partially cover the demand for water. The deficits observed in the satisfaction of drinking water needs have various origins: the availability of the resource, the insufficiency of investments and withdrawals from the resource. This is justified by the Unsatisfied Demand (UD) recorded during the whole simulation period with the WEAP model in the different scenarios created. Thus, on the domestic and agro-pastoral sites, the increasingly increasing Unsatisfied Demand observed are related to the flow constraint that should be progressively readapted to the increasing needs of the populations and agro-pastoral uses. According to [24], unmet water demand is rarely zero under growth and climate variability. To this effect, demand sites could be partially satisfied or not regardless of the scenario used. Thus, this unsatisfied demand for water at domestic sites is one of the causes that directs the populations of the basin to seek other water points such as springs and traditional wells to satisfy their primary needs. It is from this perspective that [25] suggests that the preservation of water resources such as springs and their development could be a potential source of water supply for the populations of Haut Sassandra. For better management of water resources, optimization scenarios have been put in place to meet all unsatisfied water demands. The scenario of using new water supplies in the rural areas of Daloa, Vavoua and Zoukougbeu and the urban areas of Vavoua and Zoukougbeu under the high population growth scenario was applied. Indeed, the supply of 180 m^3/h of water to each of the areas would meet the unmet water demands over the entire simulation period. By applying the scenario related to the use of new water supply sources, [26] in the Sourou watershed in Burkina Faso managed to fill the Unsatisfied Demand of all sites until 2043. The Unsatisfied Demand after 2043 is due to the effects of climate change that were accentuated after that year impacting water resources. In addition, the scenario relating to the management of the gates of the agricultural surfaces would make it possible to fill the unmet water demand on the agricultural site of Daloa (100,000 m^3) during the year 2048 through the regulation of the quantity of water to be brought to this site. This regulation of the quantity of water to be supplied would avoid water losses that constitute possible wastage. As for the scenario relating to the increase in water supply to the urban area of Daloa, this site has been granted an additional drinking water supply of 360 m^3/h to make up for the entire deficit. Indeed, in a context of climate change, the application of this scenario would allow the Unsatisfied Demand observed in the urban area of Daloa (400,000 m^3) to be filled in the year 2048. Thus, the unmet water demand reflected in the water shortage regularly observed in the city of Daloa will be met. The application of all these optimization scenarios would allow the unmet water demands of all users to be met over the entire simulation period.

4. CONCLUSION

This study allowed us to estimate the current water demand of the different users in the basin (drinking water supply, agriculture and livestock), to simulate the future water demand and to propose optimization scenarios for the use of water resources for planning and sustainable management. Thus the estimate for drinking water supply is 14,574,861 m^3 for urban areas and 5,217,632 m^3 for rural areas, making a total of 19,792,493 m^3 for the year 2021. The estimate for agropastoral uses for the year 2021 is 10,388,095 m^3. The application of the WEAP model has revealed increasingly growing water needs regardless of the type of scenario used over the entire simulation period (2021 -2050) with a strong demand for drinking water supply. The unmet water demands by 2050 for the reference, low and high population growth, improved standard of living and climate change scenarios are 23,700,000 m^3; 10,700,000 m^3; 38,600,000 m^3; 34,300,000 m^3 and 38,600,000 m^3 respectively. The sustainable management of water resources in this watershed requires optimization scenarios such as the use of new water supply sources, the management of valves on agricultural land and the increase in water supply to the urban area of Daloa. In addition, the establishment of water point management committees and a framework for consultation with the various users could help reduce unmet water demands and thus improve the living conditions of the population.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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