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Using "Water Evaluation and Planning" (WEAP) Model to Simulate Water Demand in Lobo Watershed (Central-Western Cote d'Ivoire)

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Abstract

Climate change continues to pose a threat to the sustainability of water resources while, water need is increasing. In spite of the efforts made by the state authorities to build water infrastructure, a large majority of the population is not having access to drinking water. In this study, Water Evaluation and Planning (WEAP) model was used to model the current situation of water supply and demands, to create scenarios for future water demands and supply. The results show that, in contrast to the livestock sector, which has a zero DNS, huge deficits are observed in reference scenario. These unsatisfied demands (DNS) are dominated by deficits in rice irrigation. The analysis of the evolution of demand according to the growth scenarios has shown that the deficits already observed in the reference scenario will reach 100.45 × 10^6 m^3 in 2040. To mitigate the effects of such deficits, water management optimization measures have been proposed. Strengthening the water supply to urban centers from the creation of dams could considerably reduce the observed deficits. These results are an important decision support tool for sustainable water resource management in the Lobo watershed. However, these strategies to improve access to water depend on the government's political will on water and economic opportunities.

Keywords

WEAP, IWRM, Request Site, Water Resources, Unsatisfied Demand, Côte d'Ivoire

1. Introduction

Water is a limited and vulnerable resource, essential for life, socio-economic development and the environment. In some regions, its scarcity and critical deficits always allow the coverage and satisfaction of needs; they are sometimes the causes of conflicts [1] [2] [3]. Indeed, the unequal distribution throughout the world of this fragile resource combined with the decline in rainfall and the progressive degradation of environmental components are factors that contribute to the increasing scarcity of this natural resource for which there is an ever more pressing demand [4]-[9]. This issue remains even more worrying, because according to FAO [10], climate variability and extremes are among the key factors of the recent increase in world hunger. Thus, the sustainability of water resources has become, for several decades, a priority issue of interest in sustainable development policies at both national and international levels. Though Côte d'Ivoire, has an enormous water potential (rainfall inputs, artificial lakes, rivers, lagoons, etc.), the country is facing an acute drinking water supply crisis. These problems are linked, to the uncoordinated and management of the resource, the lack of a policy for maintaining the quality level of drinking and irrigation water and the policy for safeguarding water resources for future generations [11] [12]. Given the complex and multi-use nature of water resources, one-dimensional and fragmented approaches to water resource management have reached their limits [13]. Hence, the interest in developing integrated management approaches that consider the watershed as a relevant management unit. Evaluation and allocation of water resources require knowledge of the available resources and the needs of those who use them. Agriculture, drinking water and animal husbandry are the main user sectors of the basin's water resources. In recent years, water pressure has become very high and the efficient and rational managements of water resources to be distributed among those different sectors of activity are urgently required. Surface water, treated by Côte d'Ivoire's Water Distribution Company (SODECI), is used to supply the populations from the main towns (Daloa, Issia and Vavoua) with water. Unfortunately, the number of subscribers is growing every year and the high demand for water cannot be fully met. In addition, the intensification of agriculture through the massive use of chemical inputs, associated with the development of invasive aquatic plants, is causing the silting up of water bodies [14]. Very few studies have addressed the analysis of the availability of water resources in the near future and their management strategies. The objective of this study is to analyze the current situation of the resource and its capacity to meet the demand for water by 2016-2040 horizons. The methodological approach adopted is based on the simulation of water demand in the basin using the WEAP22 model with different growth and management scenarios to analyze the adequacy between the availability of the resource and the capacity of meeting the needs of the population.

2. Materials and Methods

2.1. Study Area

Lobo River is one of the main tributaries on the left bank of Sassandra River. It is located between Longitude 6˚05' and 6˚55' West and between Latitude 6˚02' and 7˚55' North with an area of 12,722 km^2 and flows in a North-South direction. Its hydrographic basin is not circumscribed within a single administrative entity: most of the basin covers the departments of Daloa, Issia, Vavoua, and Zoukougbeu; the extreme North belongs to the department of Séguéla while in the South it overflows into the department of Soubré (**Figure 1**). Relief of the watershed is composed of plains and low plateaus of altitudes varying between 160 m and 480 m occupied by dense humid semi-deciduous forest. This forest heritage has progressively deteriorated over the last few years. In the basin, the degraded forest has become more and more the dominant element of this vegetation marked by agricultural exploitation with a landscape where crops and fallow land alternate [15]. Geological formations of the watershed are dominated by three geological entities, namely granite, which occupies most of the basin, and shale and flysch, which are found in some places [16]. These geological formations are covered by predominantly moderate desaturated ferralitic soils consisting of sands and clays.

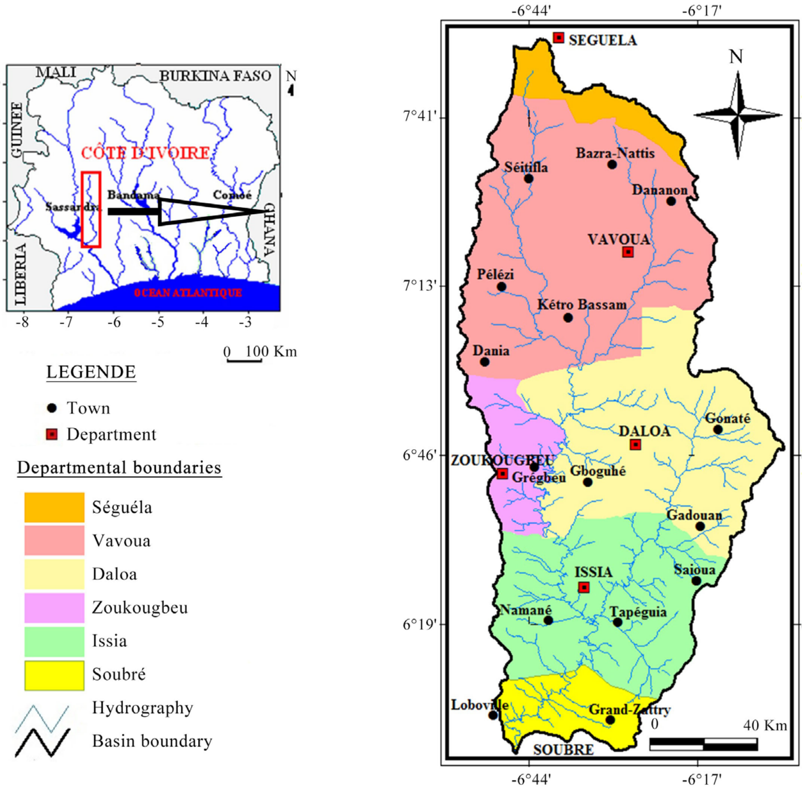


Figure 1. Presentation of Lobo watershed.

Climate of the basin is of the equatorial type of attenuated transition. It is characterized by a rainy season from April to October and a dry season from November to March (**Figure 2**). The average annual rainfall is 1248 mm at the Daloa station over the period 1990-2015. The months of February and March are the hottest months of the year with temperatures around 28˚C. The lowest average temperatures (24.8˚C) are observed in July and August.

Hydrological regime of the Lobo River is unimodal. Period of lowest waters is observed during the first months of the year (January and February). During the year, maximum monthly flow occurs in October (**Figure 3**). Average monthly interannual mean modulus is estimated at 44.17 m^3/s period between 1990 and 2015.

Drinking water supply of the basin's populations is ensured by both surface and ground water. The supply of towns and large villages is ensured by the water supply systems of the Water Distribution Company of Côte d'Ivoire (SODECI) and by village water system for the other localities. Irrigated agriculture has been practiced since 1970; in addition to irrigation, there are also pastoral uses [17]. Population of the basin is estimated at 1,430,960 inhabitants in 2014; a density of 112 inhabitants per square kilometer. It's essentially rural; in fact, 74% of population lives in rural areas whereas 26% are in urban areas [18].

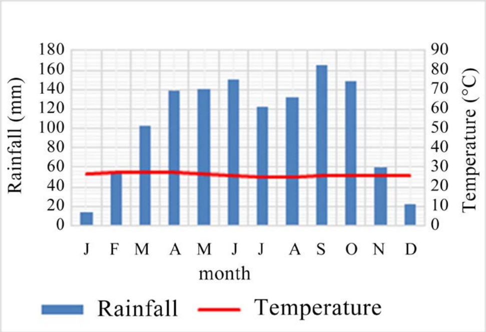


Figure 2. Umbro-thermal diagram of the Daloa station (1990-2015).

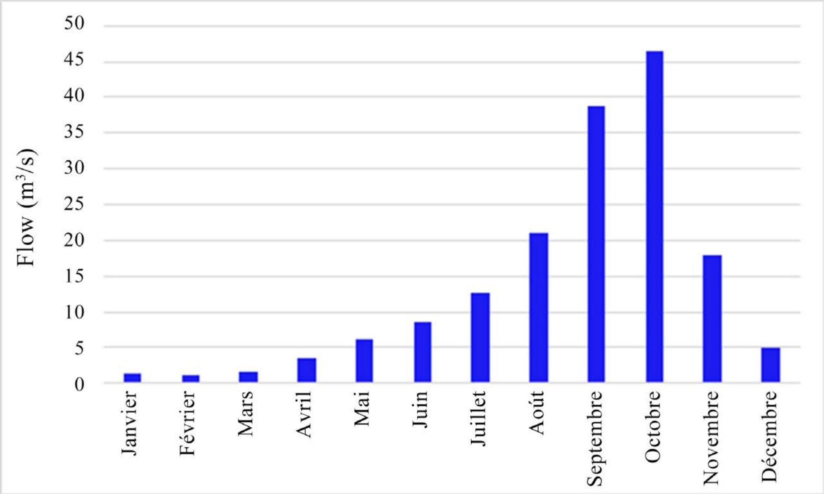


Figure 3. Seasonal variation of flows at the Nibéhibé station (1991-2015).

2.2. Data Collection

Data used are composed of climatic, flow and socio-economic data. Climatic data were provided by the Airport and Meteorological Operating and Development Company (SODEXAM). They consist of a series of rainfall and monthly temperatures available period between 1943 and 2015. Flow data come from the Directorate of Standards, Regulations and Quality (DNRQ), a structure under the supervision of the General Directorate of Human Hydraulic Infrastructures (DGIHH). These are the average monthly flows measured at the Nibéhibé station over the period 1961-2015. The socio-economic data include the number of people living in the basin, number of subscribers and volumes of water produced by the Water Distribution Company of Côte d'Ivoire (SODECI), areas of irrigated rice, number of livestock and their specific needs in 2015. These data were obtained from national data collection agencies and documentary sources [12]. The characteristics of the demand sites are recorded in **Table 1**.

3. Methodology

WEAP model is a decision support system developed by the Stockholm Environment Institute (SEI). It is a model for the simulation and management of watersheds and aquifers [19]. It is distinguished by its integrated approach, allowing the simulation of natural components (hydrological inputs, evaporation, and runoff) and anthropogenic components (dam, pumping station, agricultural development…). It is based on a representation of the hydrological system under the form of a network where nodes (watersheds, demand sites, different sources of supply) are linked by transmission links, return links or by water flow processes (runoff or infiltration). Each demand site is assigned a level of priority and a possible source of supply, thus allowing a wide variety in the management of the demand for water resources from the chosen water policy. Simulation of water demand using the WEAP model is done in several steps that are widely described in the work of references [19]-[25]. A synthesis of these steps is shown in **Figure 4**.

3.1. System Configuration

System configuration (**Figure 5**) consists of defining the spatial boundaries, system components and simulation period. Water demand sites (the demand for drinking water supply to the basin's populations, water demand for agriculture (irrigated rice areas) and water demand for livestock are supplied by Lobo River. **Table 2** provides an overview of the demand site codes used for system configuration. Water supply is provided by the Lobo River and groundwater through boreholes equipped with human-powered pumps. Resources are allocated on the basis of the priorities accorded to the different uses. In Côte d'Ivoire, major orientations of national water policy [12] stipulate that: "In the development and use of water resources, priority must be given to the satisfaction of basic needs and the protection of ecosystems". Taking into account these provisions, the following priorities were considered: Drinking water supply: priority 1; Rice irrigation: priority 2; Livestock: priority 3.

Table 1. Characteristics of demand sites.

Uses	community	Demand sites	level of activity	specific consumption	variation in specific consumption
Drinking water supply	Urban	Daloa	323,334 habitants	32.5 m^3/pers/an	proportional to the number of days in the month
		Vavoua	48,982 habitants	11.68 m^3/pers/an	
		Issia	106,298 habitants	22.99 m^3/pers/an	
		Zoukougbeu	10,812 habitants	6.20 m^3/pers/an	
	Rural	Daloa	416,249 habitants	9125 m^3/pers/an	
		Vavoua	303,602 habitants		
		Issia	222,184 habitants		
		Séguéla	20,352 habitants		
		Zuénoula	17,760 habitants		
		Bouaflé	15,413 habitants		
		Soubré	16,6792 habitants		
Agriculture		Irrigation rice	1773 hectares	10,000 m^3/ha	November 0%, Dec 0%, January 0%, February 0%, March 0%, April 0%, May 0%, June 37%, July 33%, August 18%, September 6%, October 3.67%
Livestock		UBT	136,040	14.6 m^3	proportional to the number of days in the month
		Porcines	15,841	2.65	
		chickens	1,643,360	0.036	

Table 2. Codification of water demand sites.

Type of demand	Demand sites	Sites code
Drinking Water Demand (DWD)	Daloa municipality	DLA URB
	Issia municipality	ISSIA URB
	Vavoua municipality	VAV URB
	Zoukougbeu municipality	ZKGEU URB
	Daloa (rural)	DALOA RUR
	Issia	ISSIA RUR
	Vavoua	VAV_RUR
	Bouaflé	BFLE_RUR
	Séguéla	SEGUELA_RUR
	Soubré	SOUBRE RUR
	Zoukougbeu	ZKGEU RUR
	Zuénoula	ZUENOULA_RUR
Agricultural Demand	Rice growing	Irr_LOBO
Demand in breeding	Breeding	Breeding_ LOBO

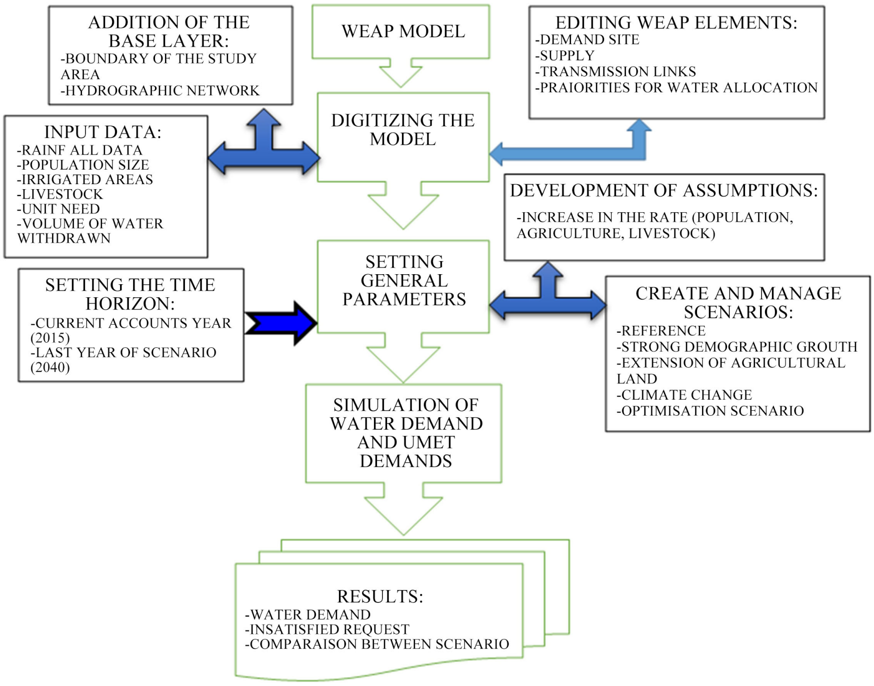


Figure 4. Modeling steps under WEAP.

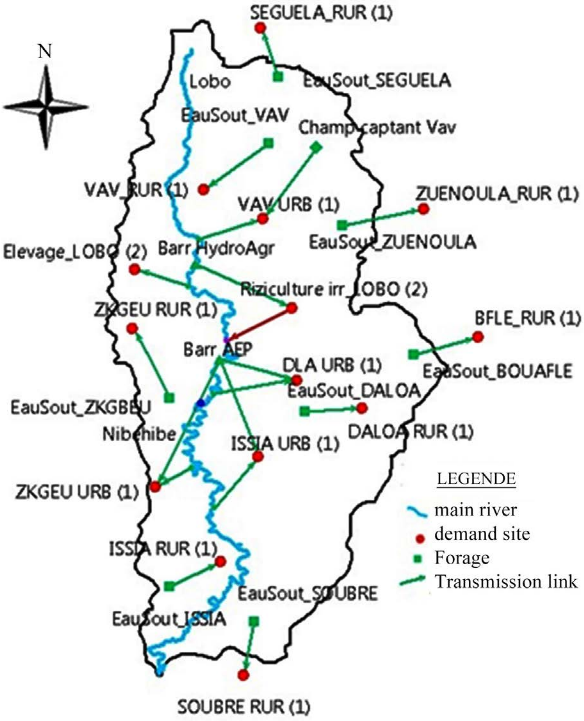


Figure 5. Schematic representation of the project "WEAP Lobo".

3.2. Elaboration of Water Demand Forecasting Hypotheses

Forecasting assumptions estimate future demands were considered for water and rebalancing the system adapted to its new situation. Year 2040 has been chosen as the forecast date in accordance with objectives set by national water policy in

Côte d'Ivoire, which aims at creating a future in 2040 in which potential of water resources would be exploited in order to stimulate and strengthen economic development and social welfare [12]. Algorithm for forecasting different water needs is as follows:

3.2.1. Forecasting the Demand for Drinking Water

Demand for water for domestic use (population need) is based on the rate of population growth. This hypothesis analyzes evolution of water needs with a gross annual population growth rate estimated at 3.7% in 2014 [18]. Water demand in 2016 and for future years is estimated by the formula in Equation (1):

$$D_i = Cs \times N \tag{1}$$

D_i : Water requirements for year i (m^3/year)
Cs : Specific consumption (l/hbt/day)
N: Size of the population

3.2.2. Forecasts at the Level of Agriculture

Irrigated agriculture still occupies a secondary place in Ivorian agriculture, despite the existence of important potentialities constituted by the lowlands and irrigable plains. In Lobo watershed, rice is the main irrigated crop [14].

Gross water requirements for rice cultivation are estimated at 10,000 m^3/ha. Water requirements for irrigation in the coming years are calculated by equation (2):

$$D_i = D_0 \left(1 + \Psi\right)^n \tag{2}$$

D_i : Water requirements for the year i (m^3/an)
D_0 : Water needs in 2015 (m^3/year)
Ψ : Annual growth rate (%)
n: Deadline (year)

3.2.3. Forecasting Water Demand for Animal Husbandry

Poverty Reduction Strategy Paper [26] spelled out priority given by Government to agricultural issues, particularly the use of livestock to strengthen the national economy and combat poverty. In this context, a Livestock Recovery Plan for Côte d'Ivoire (PRECI 2012-2020) was adopted in June 2012. The actions of PRECI from 2015 to 2020 was to focus on increasing production and improve the coverage needs of the population leading to the reduction of imports of animal products. The objective to reach in 2020 is to cover more than 60% of national needs in animal proteins. To reach this objective, water requirements for livestock are assumed to grow at an average annual rate of 3% [27].

3.3. Description of Water Demand Simulation Scenarios

3.3.1. Reference Scenario

Role of scenario called "Reference Scenario" is to project water demand different use sectors as described in the current state (2015) over the entire study period (2016-2040). This scenario has been developed to serve as a basis of comparison for other scenarios that will be created by simulating possible changes that could affect water demand sites.

3.3.2. Growth Scenarios

Growth scenarios are composed of scenarios "High population growth" and "Extension of irrigated areas". The "High population growth" scenario, is to evaluate and compare satisfaction of water needs if the population growth rate increases from 3.7% (2015) to 5.0% (2016-2040). The scenario "Extension of irrigated areas" analyzes the satisfaction of water needs for agriculture if irrigated areas expand at a growth rate of 4% over the period (2016-2040).

3.3.3. Scenario: "Climate Change"

This scenario is developed to analyze the impacts of climate change on the river's ability to meet water demands. Therefore, climate outputs (rainfall and temperature) from RegCM3 regional climate model under scenario A1B were used to simulate river flows at Nibéhibé station over period 2016-2040.

Methodological approach of flow simulation from outputs of the RegCM3 model is described in Yao' work [9]. Calculated flows were imported into WEAP model through the ReadfromFile [28]. Combined effects of climate change and growth scenarios were also analyzed in a scenario called "SC and climate change" to evaluate their impact on satisfaction of water needs.

3.3.4 Scenarios for Optimizing Water Management

If water needs are not covered, exploration of optimization scenarios will be necessary to ensure sustainable management of resource. This can be done through actions to raise awareness among stakeholders on good water use practices, maintenance of hydro-agricultural structures, use of new sources of supply, or adoption of new agricultural techniques.

In these scenarios, we propose to provide solutions to reduce water deficits observed in satisfaction of demands. To this end, scenario "Reinforcement of water supply" aims at strengthening drinking water supply in urban centers from a water supply dam, with additional flow of 2250 m^3/h for cities of Daloa and Issia. For Vavoua, we propose to mobilize groundwater from a catchment field composed of several boreholes for an average flow rate of 55 m^3/h [29]. Gravity irrigation is irrigation technique practiced in Lobo watershed. Scenario "Improvement of irrigation technologies" refers to implementation of techniques that reduce water consumption. Annual water consumption is reduced from 10,000 m^3/ha to 7500 m^3/ha over the period 2016-2040 [30].

4. Results

4.1. Evolution of Water Demand in Lobo Watershed at Horizon 2040

4.1.1. Urban Demand

In reference scenario, water demand at urban sites is estimated at 14.09×10^6 m^3 in 2016 (**Figure 6(a)**). Over time, this demand will steadily reach 33.7×10^6 m^3

in 2040 compared to 46 × 10⁶ m³ in “high population growth” scenario (**Figure 6(b)**). In both cases, total urban demand will increase by more than 100% of initial demand. Comparison of demand between urban sites shows that this demand is largely dominated by the needs of the city of Daloa. Indeed, demand from Daloa site is estimated at 10.5 × 10⁶ m³ in 2016 representing 76.6% of urban demand.

4.1.2. Rural Demand

In rural areas, water demand is estimated at 11.57 × 10⁶ m³ in 2016 (**Figure 7(a)**). In urban areas, water needs will gradually increase in the coming years. In 2040, this demand could reach 27.7 × 10⁶ m³ in reference scenario and 37.8 × 10⁶ m³ in case of high population growth (**Figure 7(b)**). Highest rural demand is observed at Daloa RUR (34%) and Vavoua RUR (25%).

4.1.3. Agropastoral Demand

In reference scenario, the agropastoral demand varies from 20.16 × 10⁶ m³ in 2016 to 31 × 10⁶ m³ in 2040; an increase of 60% of initial demand (**Figure 8(a)**).

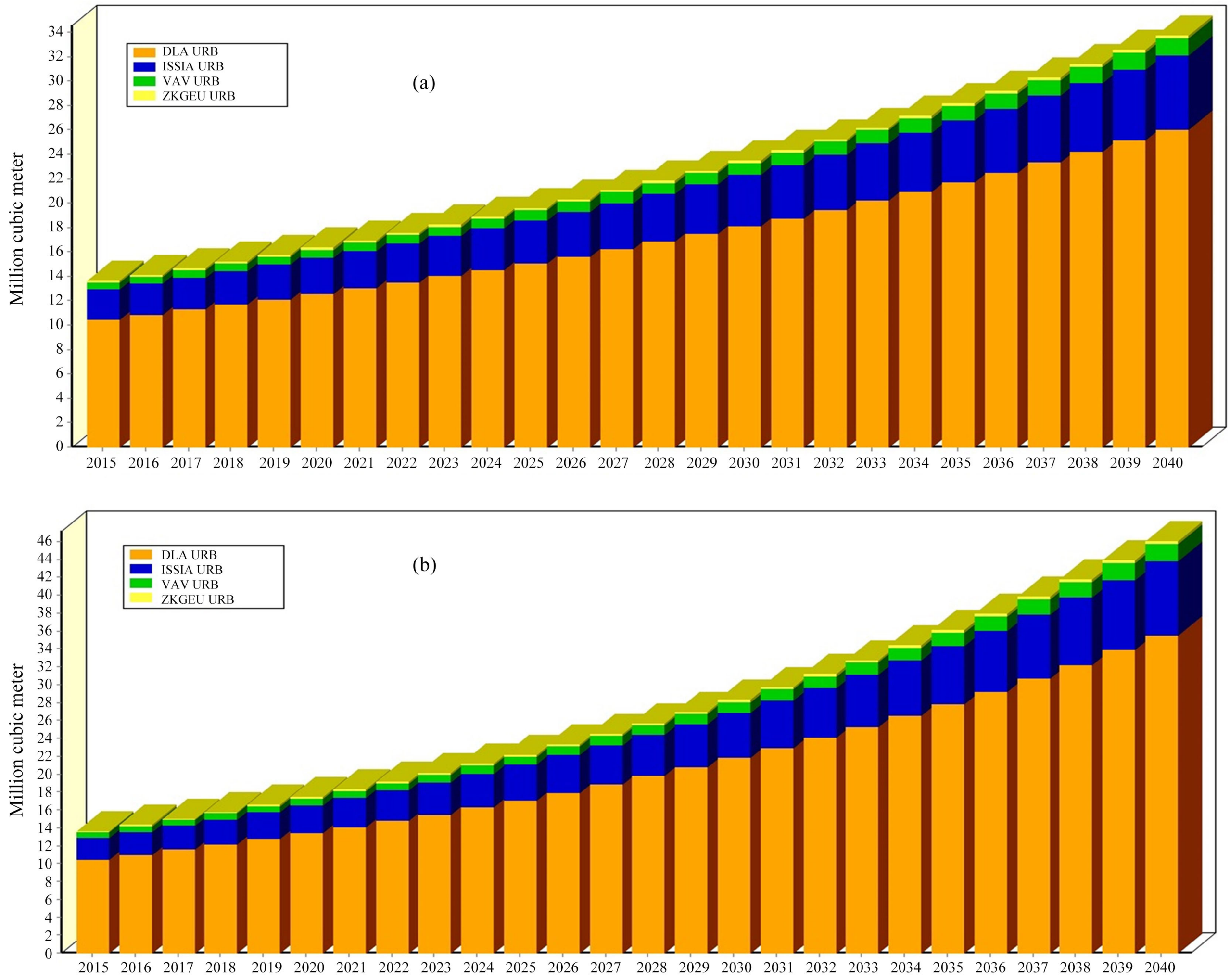


Figure 6. Evolution of domestic water demand in urban areas: (a) Reference scenario, (b) High population growth scenario.

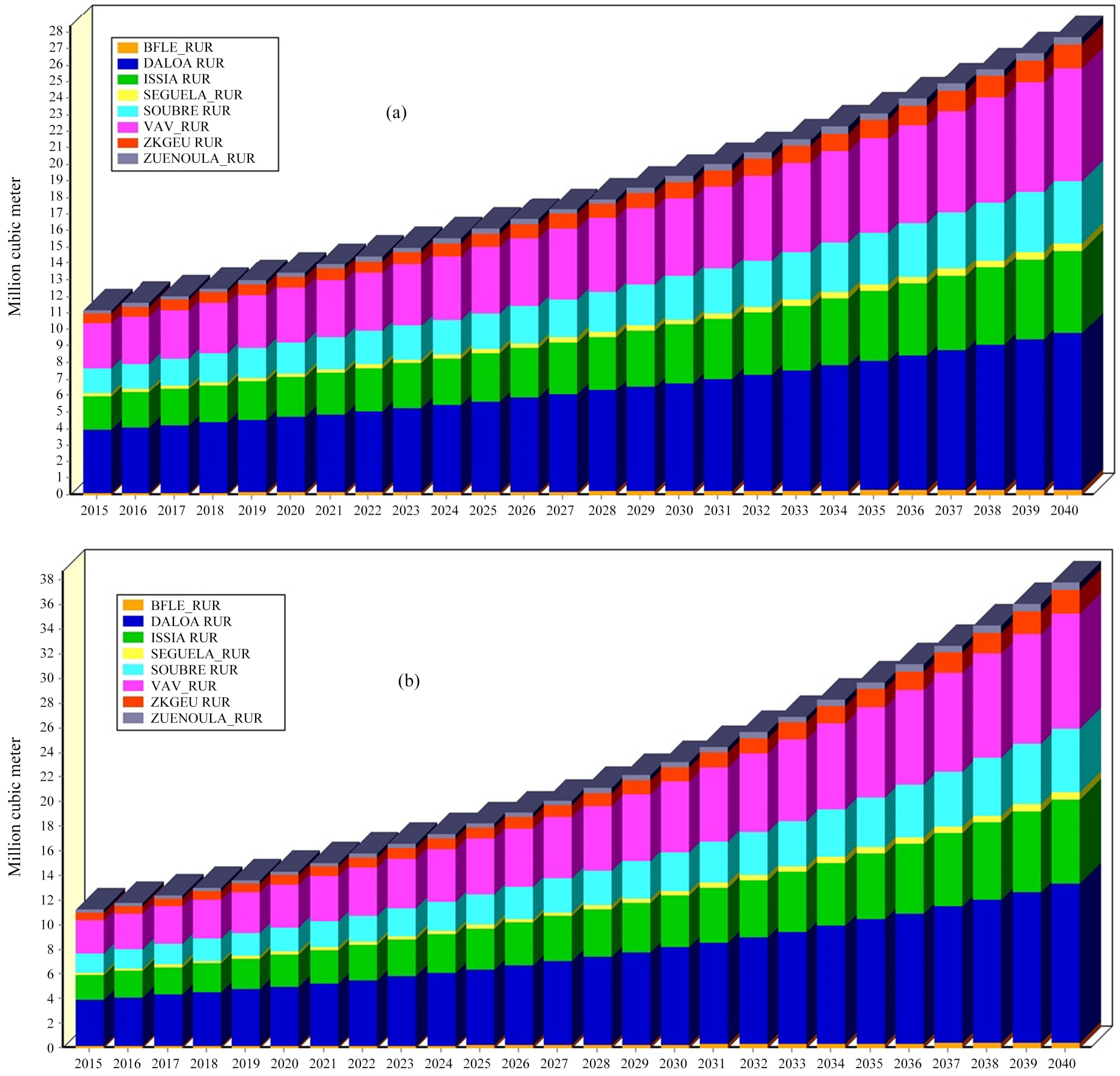


Figure 7. Evolution of domestic water demand in rural areas: (a) Reference scenario, (b) High population growth scenario.

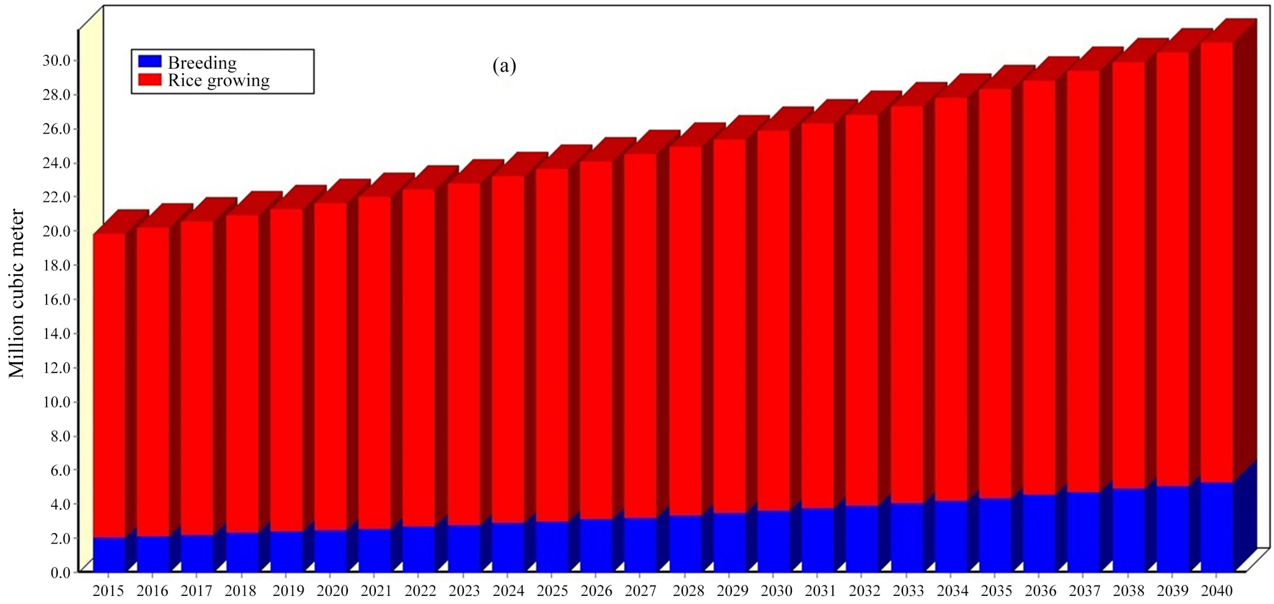
For an extension of agricultural areas, demand increases to 52.6 × 10^6 m^3 in 2040 (**Figure 8(b)**). In this scenario, increase is more than 100% of initial demand. Water requirements for breeding sector remain low over time. Rice irrigation remains the largest water consumer in this sector with 90% of agropastoral demand.

4.2. Analysis of Not Satisfied Demand

4.2.1. Comparison between Baseline and Growth Scenarios

Adequacy between volumes of water mobilized (supply) and the water needs of the sites (demand) is analyzed through Not Satisfied Demand (NSD) (**Table 3**).

Contrary to breeding sector which has a zero DNS (whatever the scenario), the results show an upward trend in DNS from 2016 to 2040. These not satisfied demands (DNS) are dominated by deficits for irrigation. Volumes of water to be mobilized to meet rice irrigation needs are estimated at 15.53 × 10^6 m^3 in 2016. In "Extension of irrigated areas" scenario, the DNS will be about 44.50 × 10^6 m^3 in 2040. For domestic demand, deficits to be met in urban areas are estimated at 30.02 × 10^6 m^3 in reference scenario and at 42.34 × 10^6 m^3 for the "high population growth" scenario (SFCD). For domestic needs in rural areas, the NSD is initially low (2016-2025) but could increase towards the end of the observation period (13.61 × 10^6 m^3 in 2040).



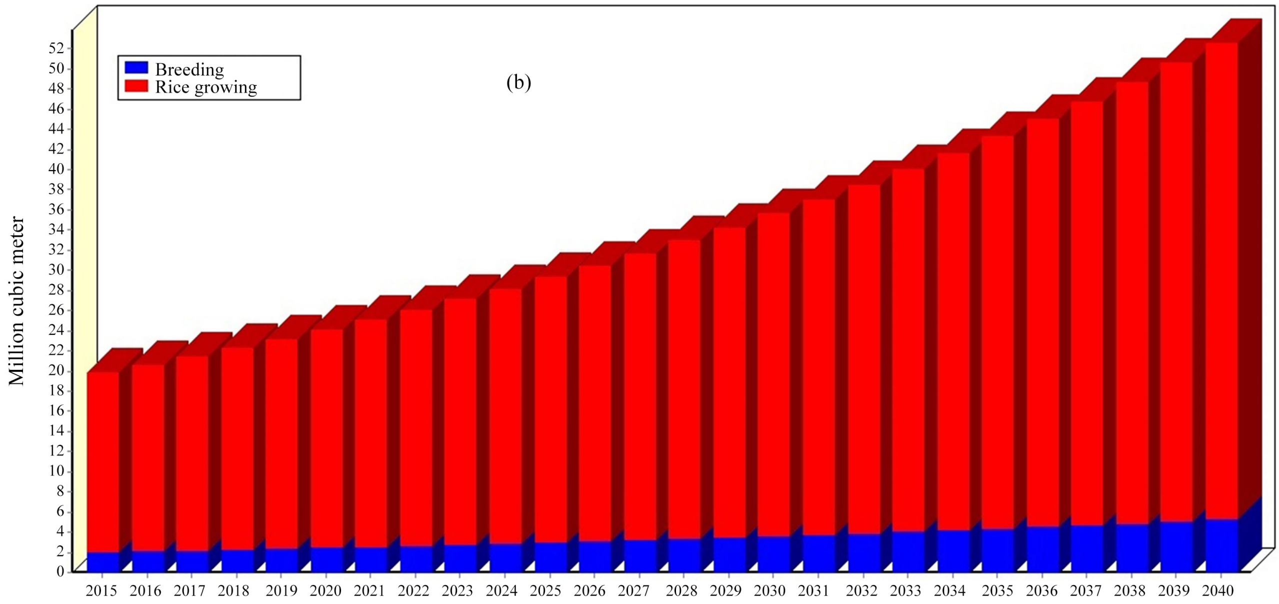


Figure 8. Evolution of agropastoral water demand: (a) Reference scenario, (b) Scenario extension of irrigated areas.

Table 3. Not Satisfied Demand (NSD) in the different water use sectors.

Types of demand	Sites	Scenarii	2016	2020	2025	2030	2035	2040
Domestic (106 m^3/year)	Urban area	SR	10.42	12.61	15.86	19.76	24.4	30.02
		SFCD	10.56	13.66	18.45	24.57	32.38	42.34
	Rural area	SR	1.11	1.97	3.24	4.77	6.6	8.79
		SFCD	1.18	2.38	4.26	6.66	9.71	13.61
Agropastoral (106 m^3/an)	Irrigation	SR	15.3	16.4	17.8	19.4	21.1	23
		SESI	15.7	18.8	23.5	29.2	36.1	44.5
	breeding	SR	0	0	0	0	0	0
		SCC	0	0	0	0	0	0
Total (106 m^3/year)		SR	26.83	30.98	36.9	43.93	52.07	61.81
		SC	27.44	34.84	46.21	60.43	78.19	100.45

SR: Reference Scenario; SFCD: High Population Growth Scenario; SESI: Scenario Extension of Irrigated Surfaces; SCC: Climate Change Scenario.

4.2.2. Analysis of NDS in the "Climate Change" Scenario

By compiling population growth plus the extension of irrigated areas plus climate change (Figure 9), it can be observed that the NDS observed in the growth scenarios (high population growth and extension of irrigated areas) will increase. NDS increases from 27.5 × 10^6 m^3 to 109.9 × 10^6 m^3 in 2040. Between 2016 and 2025, the gap between two scenarios is small (an average of 4.25 × 10^6 m^3); however, from 2026 onwards, a deficit of 25.60 × 10^6 m^3 could be highlighted between the two scenarios.

4.2.3. NSD Analysis in Optimization Scenarios

Results of the "strengthening water supply" scenario show that increasing water supply could significantly fill the gaps identified in growth scenarios (Figure 10(a)). From 2016 to 2031, NSD will be zero for all sites, with the exception of Vavoua, where some more or less negligible deficits (3.6 to 417.8 thousand m^3) may still be observed. From 2032 to 2040, we could observe the appearance of some water problems, particularly at Daloa URB. These NSD vary from 0.3 to 6.7 × 10^6 m^3 in 2040. Comparison with combined effects of the growth and climate change scenarios also shows an attenuation of deficits (Figure 10(b)). However, inflows could fully meet water needs of demand sites until 2031.

Assuming reduced water consumption and losses ("improved irrigation technology" scenario), NSD are reduced but not eliminated (Figure 11). These DNS will be of order of 19 × 10^6 m^3 in 2040 compared to 23 × 10^6 m^3 in reference scenario and 44.50 × 10^6 m^3 in the "Extension of irrigated areas" scenario; a reduction of 17.39% and 56.81% respectively.

5. Discussion

This study analyzed adequacy between water supply and demand in watershed of Lobo river according to several scenarios of demand evolution. Methodology

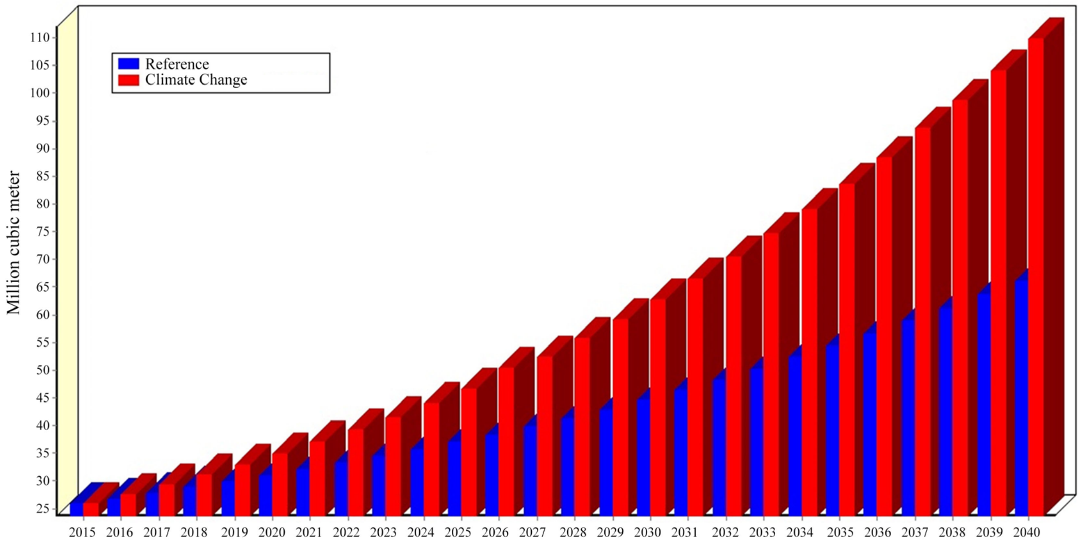


Figure 9. Evolution of not satisfied demand in the climate change scenario.

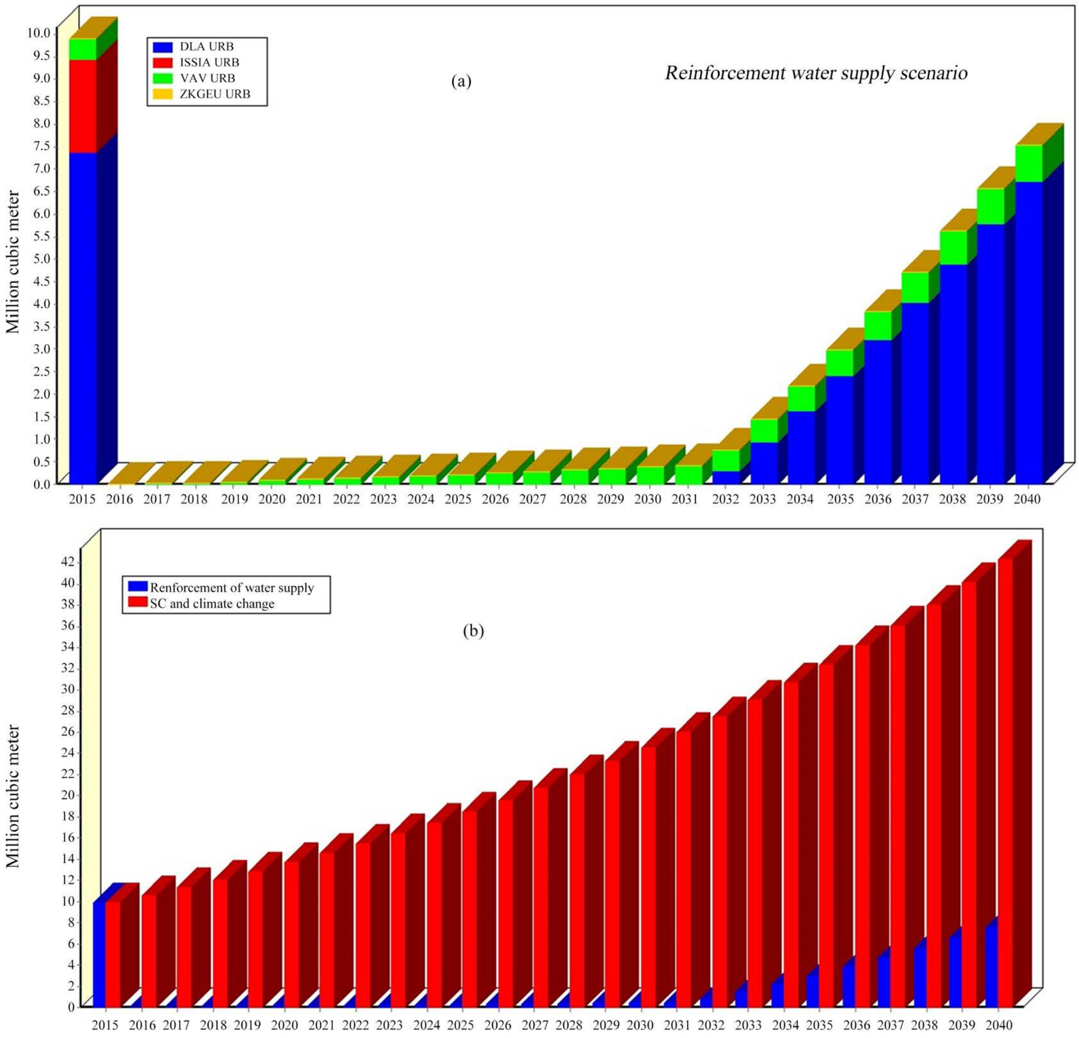


Figure 10. Evolution of non satisfied demand in the "Reinforcement water supply" scenario (a) Urban Drinking Water Demand Sites; (b) Comparative analysis.

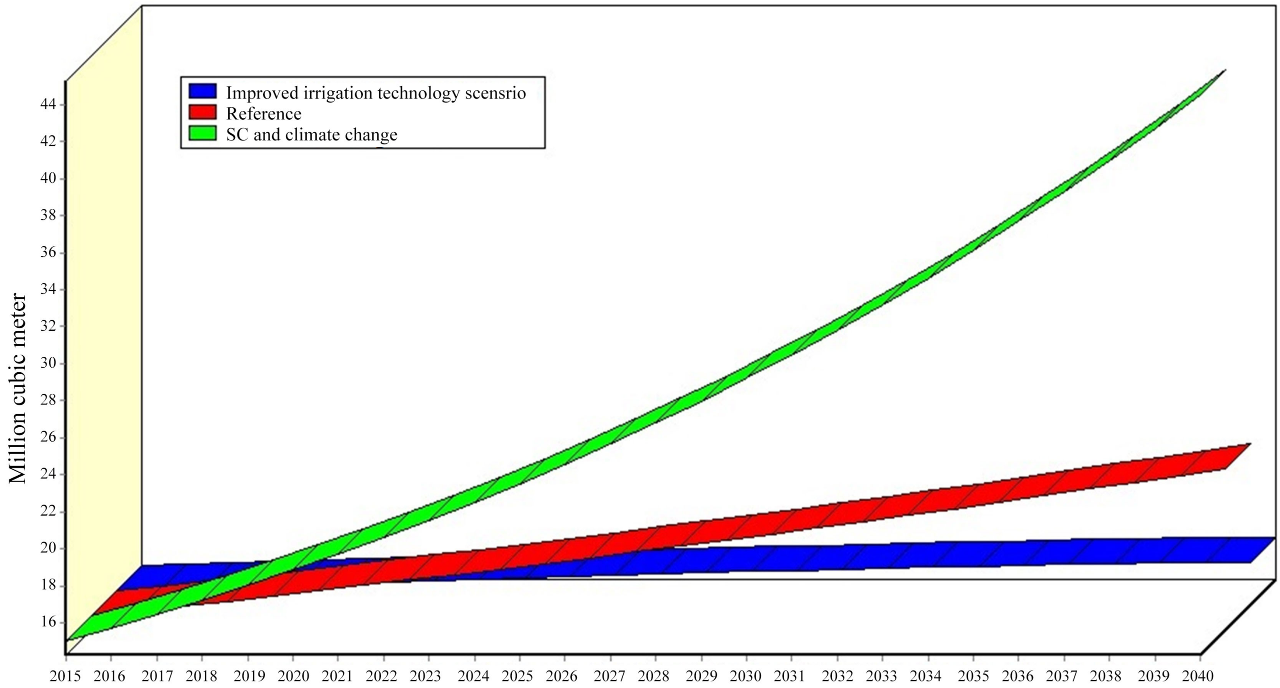


Figure 11. Evolution of not satisfied demand in the scenario "Improvement of irrigation technologies".

consisted in simulating water demand according to a reference scenario to understand current water supply system and users' needs in study area. Then, level of satisfaction of needs according to the development alternatives was assessed. Subsequently, water management optimization scenarios were analyzed to reduce non satisfied water demands.

In reference scenario, overall water demand in Lobo watershed is estimated at 45.8×10^6 m^3 in 2016, with a higher demand for rice irrigation (44% of total demand). By 2040, this demand will be around 92.4×10^6 m^3, an increase of more than 100% of initial demand. All sectors of water use (domestic, agropastoral) are concerned by this increase. For domestic uses, demand would reach 61.4×10^6 m^3 in 2040. Agropastoral demand is estimated at 31×10^6 m^3 in 2040. However, the smallest share is for breeding (5.30×10^6 m^3 in 2040). In general, water resources mobilized in the watershed do not cover these demands. In 2040, NSD in growth scenarios could reach 42.34×10^6 m^3 for domestic use, 44.50×10^6 m^3 for irrigation. NSD observed shows that there is enormous pressure on the current water supply system. These results highlight the fact that simulated growth factors (population growth and new land irrigation) exert a very significant potential future pressure on current system as reported in a similar study on Marahoue watershed in Côte d'Ivoire [31]. Our results could be justified by instability of the resource and insufficient investment for extension of water network. This observation was also raised by [32] who showed that the drinking water deficit still persists in major Ivorian cities, notwithstanding all the actions undertaken by authorities in Côte d'Ivoire. This situation is exacerbated by reduced rainfall observed in West Africa and Côte d'Ivoire. Current studies have shown that the decline in rainfall that began in the early 1970s is continuing [7] [15] [33] [34] [35]. Its effects led not only to a reduction in the operating flow rates of the hydraulic structures but also to a drying up of certain boreholes [36]. In addition to impacts of lower rainfall, it should be noted that after several years of service, dam reservoirs are subject to combined actions of silting and eutrophication phenomena [32]. Simulation according to the climate change scenario showed a similar evolution of NSD observed in reference scenario with exception of years 2026 and 2037. These results could be justified by the fact that the climatic conditions as simulated by RegCM3 model would be close to those observed in current account (2015). Although most climate models predict a decrease in precipitation, at local level, the work has shown that by 2025 horizon, the flow trend in some watersheds will increase [37] [38].

Analysis of the combined effect of growth scenarios and climate change has shown that it would be possible to observe NSD over the period 2016-2040. Thus, to mitigate the effects of water deficits, strengthening water supply from dams and groundwater mobilization is a significant contribution to meeting needs. Results of this scenario showed a cancellation of NSD of all request sites over period 2016-2031. After this period, there is a reappearance of DNS between 2032 and 2040, particularly at the Daloa URB site. Scenario "Improvement of irrigation technologies" proposed to reduce NSD at agriculture level could contribute to reduce deficits but not to cancel them completely. Indeed, works by authors [39] and [25] have shown that it is difficult to cancel NSD especially in the context of rapid population growth and climate change. Projections made it possible to give some orders of magnitude of needs to be met by 2040 in Lobo watershed. Limitations of applying the WEAP model to a watershed were discussed by [40].

6. Conclusion

Objective of this study was to analyze the adequacy between water supply and demand in Lobo watershed from several scenarios of demand evolution. To do so, this study used WEAP model to analyze availability of this resource for the 2016-2040 horizon. Results show that the overall water demand of basin is estimated at 45.80×10^6 m^3 in 2016, with a higher demand for rice irrigation (44% of total demand) and for drinking water supply to urban centers (30.8% of total demand). In general, water resources mobilized in the basin don't cover these demands. Not satisfied demand is estimated at 26.83 million m^3 in 2016, with dominance for urban drinking water supply and rice irrigation. Analysis of evolution of demand according to scenarios has shown that deficits already observed in reference scenario will increase to reach 100.45 million m^3 in 2040. In the "climate change" scenario, non satisfied water demands are observed to be roughly equal to non satisfied demands of the reference scenario. To mitigate effects of these deficits, water management optimization scenarios have been analyzed. Strengthening water supply to urban sites from creation of dams could considerably reduce deficits observed in growth scenarios; with some problems at the level of Daloa URB site after the year 2031. Assuming reduction in water consumption and losses for irrigation, this would help reduce DNS without cancelling them. These results represent an important decision support tool for sustainable water resource management in Lobo watershed. However, these strategies to improve access to water depend on government political will for water and economic opportunities.

Author Contributions

A. B. Yao analyzed the data and wrote the manuscript; O. M. J. Mangoua and S. G. Eblin assisted in the preparation of the manuscript and reviewed the document; A. Kane and B. T. A. Goula supervised the study.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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