Analysis of the factors that influences pastoral resources dynamic in the Zou waterdhed at dome Outlet (Benin)

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Abstract. Livestock the main economic sector in West Africa is threatened in the Zou Watershed at the Domé outlet (BVZD) by climatic changes, land degradation and agricultural's growing pressure expansion due to demographic growth. The aim of this study is to analyze the factors that influences pastoral resources dynamics in the basin. This study relies on 30 years climatic's data (1991–2020), Sentinel-2 satellite images from 2016 and 2020 and demographic data from INStaD. Indices such as the Vegetation Condition Index (VCI) and the Standardized Precipitation Index (SPI) were used to characterize droughts and climate conditions. The results show significant precipitation variability, with an increase in severe droughts between 2016 and 2020. In January 2016, 29.2% of the BVZD area was affected by severe drought, compared to 36.84% in January 2020. Moreover, areas without drought decreased from 8.63% in January 2016 to 7.78% in 2020. Demographic's growth in the basin, which increased from 576,727 inhabitants in 1992 to 1,367,389 in 2020 increased a pressure on pastoral carrying capacity and accelerating ecosystem degradation. This study highlights the urgency of sustainable strategies to protect livestock in the face of climate and demographic challenges in Zou Watershed.

Keywords: pastoral resources, climate variability, drought, watershed, Benin.

1 Introduction

Livestock plays an important role in the global economy, representing approximately 44% of the agricultural GDP in several areas. It is important in West Africa, where the cattle is estimated at 64.8 millions heads [1]. In Benin, especially in the northern regions, this activity relies on the exploitation of fallows and savannas in the Sudano-Sahelian zone [2]. However, pasture quality and water availability have diminished, exacerbated by climate change. Agricultural expansion, driven by population growth contributes to the reduction of grazing areas, accelerating ecosystem degradation, marked by the decline of vegetation [3] ; [4]. In the Zou watershed at the Domé outlet (BVZD), anthropogenic and climatic pressures are

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affecting pastoral resources. This study aims to analyze the factors that influences pastoral resources dynamics in the basin. The BVZD is located in central-western of Benin, between the departments of Collines and Zou. It lie between 1° 37'23" and 2° 27'30" East longitude, and between 6°54'48" and 8°34'23" North latitude (refer to Fig. 1), covering an area of approximately 8,767 km², representing 7.64% of the national territory.

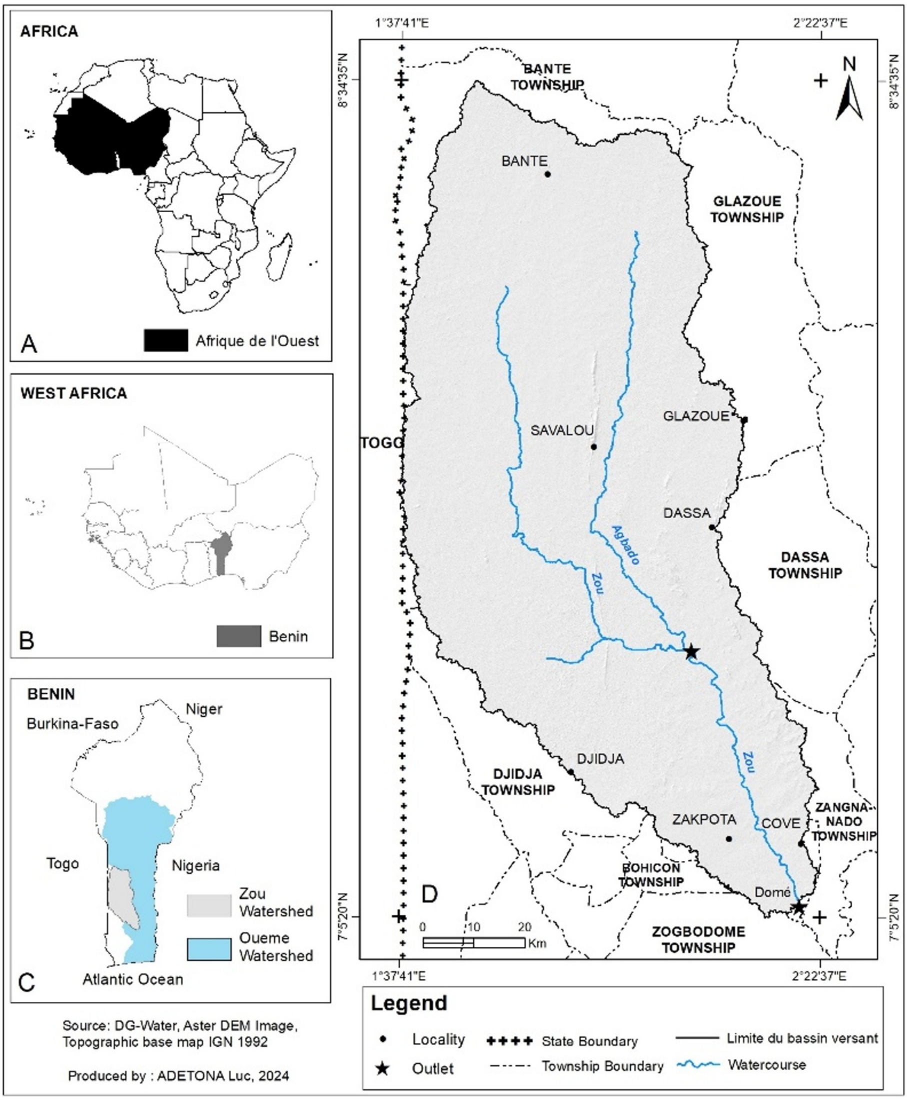

Fig. 1. Geographical location of the Zou watershed at the Domé outlet

2 Materials and Methods

2.1 Climatic and Satellite Data Used

The climatic data used for this study are the rainfall data obtained from the NASA website : https://power.larc.nasa.gov/data-access-viewer/. They cover a 30-years from 1991 to 2020 to establish climate normals [5]. Sentinel-2 imagery from 2016 and 2020, obtained from http://earthexplore.usgs.gov/ with a resolution of 10 meters for January and February, was used to calculate vegetation condition indices. Population data for the 9 townships within the watershed for 1992, 2002, 2013, and projected for 2020, were obtained from INStaD Benin.

2.2 Methods

The collected data were processed using ArcGIS 10.2 software and Excel spreadsheets. The factors that influences pastoral resources avaibility were analyzed through the calculation of several parameters and indices: population growth in the basin, vegetation condition index, and the standardized precipitation index.

2.2.1 *Mean Deviation Index (Em) and Precipitation Deficit Index (PDI)*

The Mean Deviation Index (Em) and the Precipitation Deficit Index (PDI) quantify the deviations between annual precipitation and the average over a given period, thereby identifying wet years (positive index) and dry years (negative index). These indices are used to visualize long-term climatic trends and assess precipitation fluctuations in the basin.

$$E_m = P_i - P_m \text{ et } PDI\ (\%) = \left(\frac{P_i - P_m}{P_m}\right) \times 100$$

2.2.2 *Vegetation Condition Index (VCI)*

The VCI characterizes vegetation moisture conditions [6] by comparing the effects of climatic variability on vegetation, based on the minimum and maximum value of the vegetation index (NDVI) [7] ; [8]. It is calculated as a percentage from NDVI data using the formula :

$$VCI = \frac{(NDVI - NDVI_{min})}{(NDVI_{max} + NDVI_{min})} \times 100$$

with NDVI representing the NDVI values for the studied years, $NDVI_{min}$: as the minimum value for the studied period, and $NDVI_{max}$: as the maximum value for the studied period. The Standardized Precipitation Index (SPI), developed by [9], was used to validate the vegetation condition index. This index allows for the analysis of wet and dry periods [10] and is calculated over 6 to 24 months to characterize hydrological drought [5] in the basin. The SPI is calculated using the following formula :

$$SPI = \frac{P_i - P_m}{\sigma}$$

3 Results and Discussion

3.1 Factors Influencing Pastoral Resources Dynamic in the BVZD

Climatic variability and demographic pressure are the primary factors influencing the availability of pastoral resources. These findings are consistent with those of [11], who also highlighted the relationship between these factors and the pastoral resources dynamic in several African areas.

3.1.1 Analysis of Climatic Variability in the BVZD

Climatic variability characterized by fluctuations in precipitation (refer to Fig. 2 and 3) and temperatures between 1991 and 2020, affects vegetation conditions and water availability, which are essential for grazing.

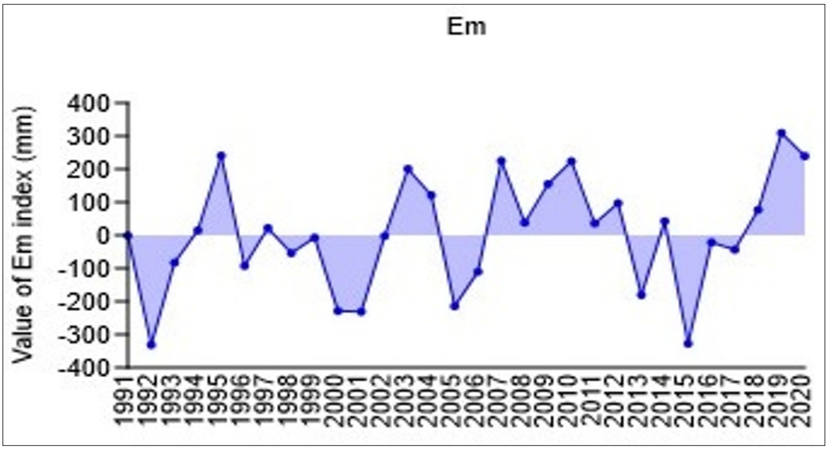

Fig. 2. Mean Deviation Index (Em).

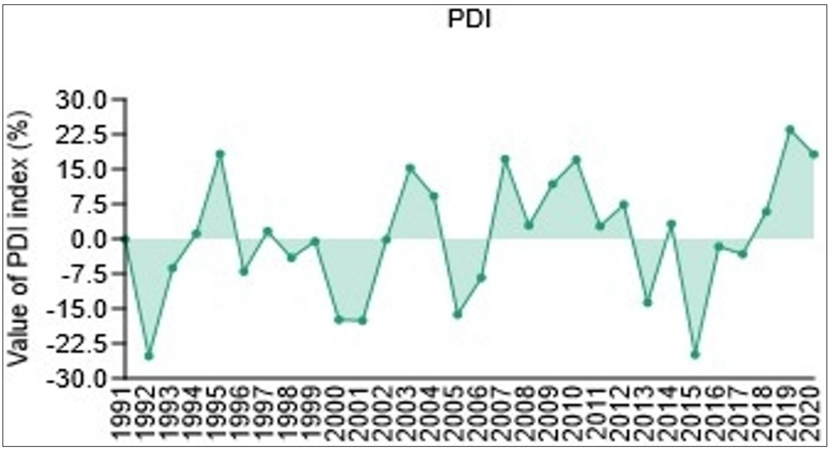

Fig. 3. Precipitation Deficit Index (PDI).

Significant precipitation peaks were observed in 14 years, with values exceeding 200 mm above the average, while 16 years experienced deficits of up to -300 mm, as corroborated by the Precipitation Deficit Index. Pronounced fluctuations, with deviations up to 25%, lead to reductions in biomass during deficit periods and flood risks during excess rainfall, thus affecting pasture availability. Fig. 4 show the evolution of the Vegetation Condition Index (VCI) for January and February in 2016 and 2020.

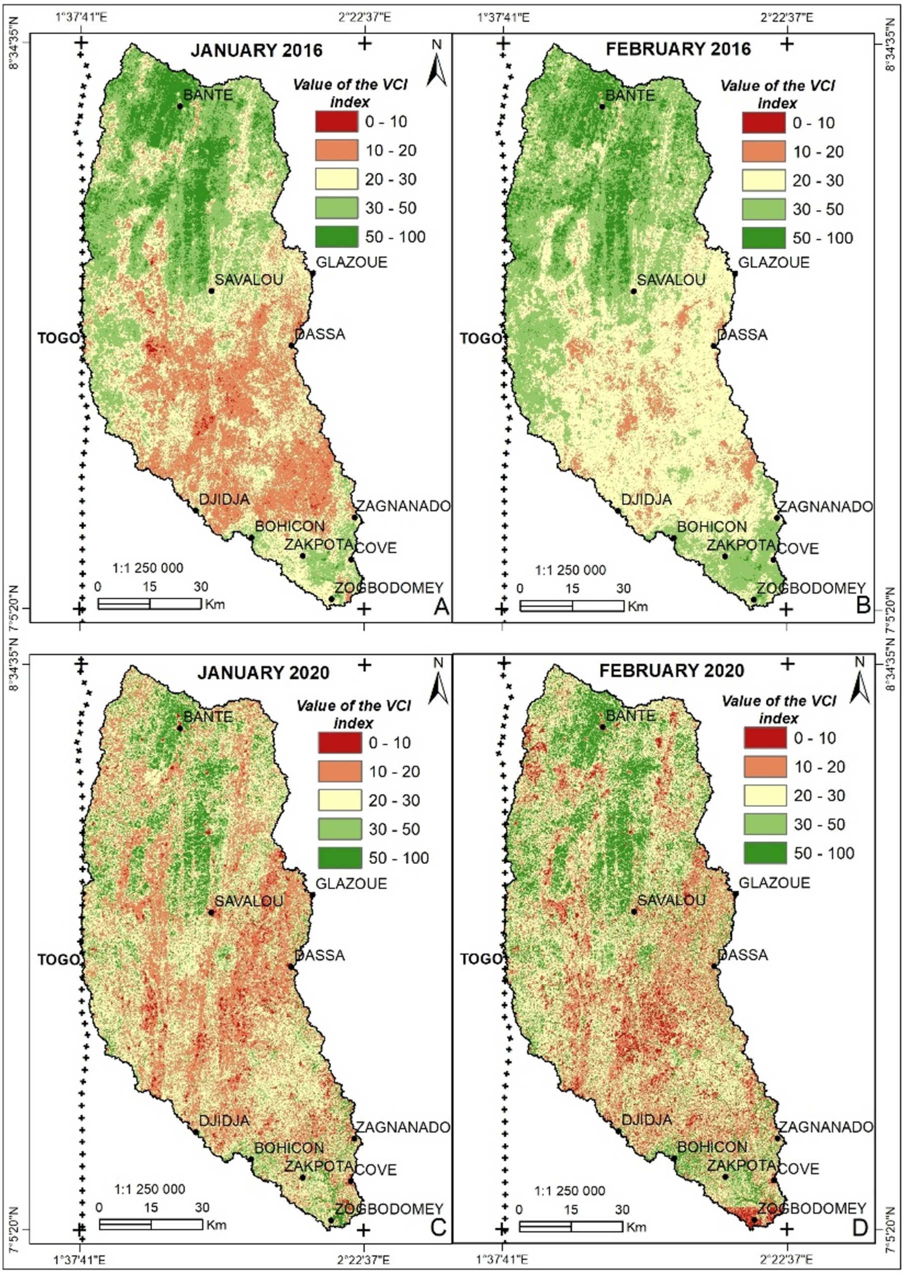

Fig. 4. Spatiotemporal Variation of the Vegetation Condition Index between 2016 and 2020.

The physiognomic analysis of figure 4 reveals a significant variation in vegetation condition between January and February 2016 and 2020, with a partial improvement in 2016 and an exacerbation of drought in 2020, particularly in the central and southern parts of the basin. Table 1 show the distribution of areas as a percentage according to VCI index classes for January and February in 2016 and 2020. These data allow for a comparison of drought conditions in the basin, distinguishing between different categories of drought, ranging from "extremely severe drought" to no drought.

Table 1. Area occuped by indice VCI class

VCI Index Classes	Area in %			
	JAN 2016	FEV 2016	JAN 2020	FEV 2020
Extremely Severe Drought (0-10)	0,78	0,01	3,57	6,77
Severe Drought (10 -20)	29,20	8,52	36,84	27,12
Moderate Drought (20-30)	32,66	45,26	38,72	38,49
Very Low Drought (30-50)	28,72	37,13	13,09	13,82
No Drought (50-100)	8,63	9,09	7,78	13,80

In January 2016, 32.66% of the basin area experienced moderate drought, 29.20% severe drought, and only 0.78% extremely severe drought, while 8.63% of the area had good vegetation's condition. In February 2016, conditions improved with a decrease in extremely severe and severe droughts, although moderate drought increased to 45.26%. In January 2020, the situation worsened with an increase in areas affected by extremely severe and severe droughts and decrease in areas with no drought. In February 2020, although severe drought slightly decreased, extremely severe drought increased, and the proportion of areas unaffected by drought remained lower than in 2016. This indicates an intensification of dry conditions, highlighting a progressive degradation of water and vegetation conditions. The standardized precipitation index for January and February reveals moderate drought (1.0 to -1.49) affecting the entire basin area. According to this index, the basin was dominated by moderate drought in January, persisting into February with slight improvement. These results underscore the direct impact of reducing precipitation on hydrological conditions and water resources, thus affecting vegetation. This allows livestock herders to migrate to the southern part of the basin due to the large areas of wetland.

3.1.2 *Analysis of Population Growth in the BVZD*

The BVZD had a total population of 576,727 according to the 1992 General Census of Population and Housing, which increased to 799,613 in 2002, representing an increase of 222,886 peoples over 10 years. Similarly, the population grew to 1,114,503 in 2013, an increase of 314,890 peoples from the 2002 census. The projection made with the 2013 population data more than doubled by 2020, reaching 1,367,389, compared to the 1992 population (refer to Fig. 5).

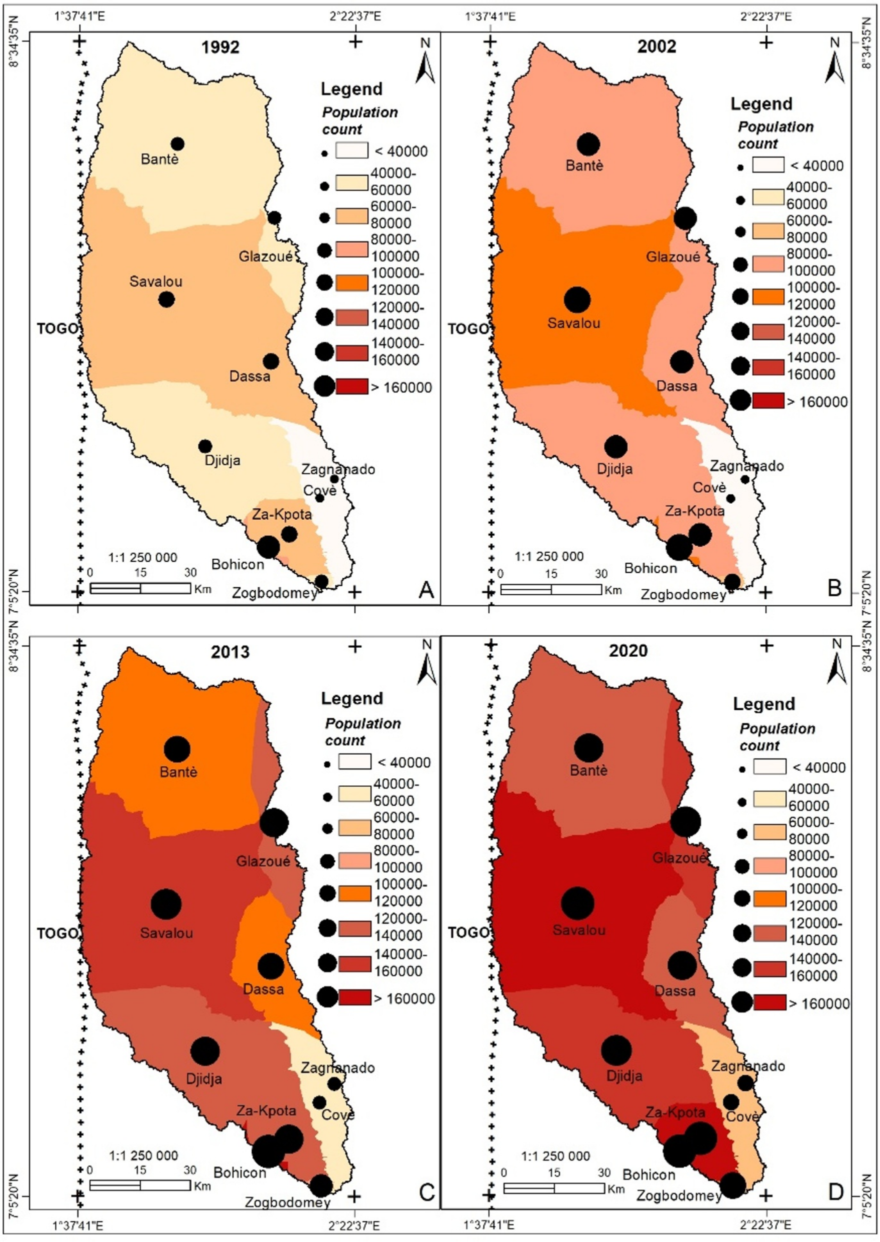

Fig. 5. Population Growth in the BVZD from 1992 to 2020

Bohicon and Savalou townships experience significant expansion, are seeing their rural lands progressively converted to meet the residential and agricultural needs of a growing population. Significantly it reduces the available land for pastoral activities, forcing livestock herders to seek more distant grazing areas. Conversely, rural and less populated townships such as Djidja, Zogbodomey, and Za-Kpota, which are favored by livestock herders, are also experiencing population growth, potentially accelerating the conversion of land for agriculture. With the increase in agricultural population, grazing lands are increasingly competing with lands for intensive agriculture, leading to a reduction in grazing areas. This directly impacts pastoral carrying capacity.

4 Conclusion

This study examines climatic variability impact and demographic pressure on pastoral resources in the Zou watershed. The results reveal a decrease in precipitation and an intensification of droughts, which have reduced the availability of pastures and water resources between 2016 and 2020. Concurrently, population growth increases pressure on land, promoting agriculture at the expense of livestock. This situation threatens the sustainability of pastoral practices, necessitating climate resilience measures and integrated land management to preserve pastoral resources. Given the results and methodology used, several avenues for further research are possible to strengthen the sustainable management of pastoral resources in the basin, including predictive modeling of futurs scenarios.

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Author contribution
The research project was a collaborative effort among seven authors, each contributing distinct expertise. Luc Adetona played a central role, overseeing conceptualization, data management, methodology development, and investigation. Bio Orou Kpera provided expertise in formal analysis and also contributed to the initial writing and preparation stages. Norbert Agoïnon offered critical supervision and validation, ensuring the project's integrity and direction. The revision process benefited from the combined efforts of Norbert Agoïnon, Jean Bosco Kpatindé Vodounou, Imorou Ouorou Barre Fousseni, and José Edgard Gnele, who refined and enhanced the manuscript. This structured collaboration highlights the team’s commitment to a rigorous and high-quality research process.

Ethics approval and consent to participate
Not applicable.

Consent for publication
All authors have agreed to publish this article.

Competing interests
The authors declare that they have no competing interests.

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