Journal of Wildlife

GIS Based Approach for Analysis of Habitat Suitability and wildlife conservation for African Buffaloes (Syncerus caffer) at Dhati Welel National Park, Ethiopia

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Research Article

Open Access &

Peer-Reviewed Article

DOI: 10.14302/issn.2997-2248.jwl-23-4539

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Keywords:
African Buffalo, GIS, Habitat Suitability Analysis, Wildlife conservation.

Received: March 27, 2023

Accepted: September 19, 2023

Published: October 19, 2023

Academic Editor:

Andreia Manuela Garcês, University of Trás-os-Montes and Alto Douro.

Citation:

Tekalign Ketema Bahiru (2023) GIS Based Approach for Analysis of Habitat Suitability and wildlife conservation for African Buffaloes (Syncerus caffer) at Dhati Welel National Park, Ethiopia. Journal of Wildlife - 1(2):1-11.https://doi.org/10.14302/issn.2997-2248.jwl-23-4539

Abstract

Wildlife management is a crucial issue to maintain the sustainability of an ecosystem whereas habitat suitability analysis is very important for better conservation and management of species like the African Buffalo. Therefore, the effort of this study was to analyze habitat suitability for African Buffalo (*Syncerus caffer*) by employing GIS at Dhati Welel National Park, Ethiopia. The study employed five datasets include: land use land cover (LULC), elevation, slope, settlements, and rivers. In this study, the Analytic Hierarchy Process (AHP) and weight overlay analysis methods were applied using IDRISI 17 and ArcGIS 10.5 software. Each dataset was integrated using GIS and AHP to rate the individual classes of each factor and weigh the influence of one factor against the other, to determine the weighted contribution of importance to the habitat suitability. As result, the consistency ratio was 0.03 and found with acceptable limits. Then, the weighted overlay tool was applied to calculate the final habitat suitability map of the African Buffalo based on the influence value. The result indicates, 35.3 % (362.7 km^2) of the study area was optimal for the African Buffalo habitat. Therefore, according to the results of the finding more areas of Dhati Welel National Park are suitable for the African Buffalo habitat based on the factors employed in this study. So that, this indicates the area is important for conservation from habitat loss and fragmentation.

Introduction

Wildlife management is an issue of global importance where habitat suitability mapping is essential for better management and conservation (31, 32, 33). It is not only the preservation of wildlife species, but it also involves the management of a complete ecosystem (18, 29). Moreover, it attempts to balance the needs of wildlife with the needs of people using the best available science. Wildlife management includes gamekeeping, wildlife conservation, and pest control (16).

Habitat loss, fragmentation, and degradation pose direct threats to wildlife species worldwide that are driven by human population growth, unsustainable consumption of natural resources, and policies that do not fully value biodiversity

(4, 5). Habitat destruction is widely accepted as the leading cause of wildlife extinction rates in recent decades (23). Furthermore, fragmentation and habitat loss, due to anthropogenic pressures are one of the major challenges to conservation (3) and are considered a major threat to the viability and status of populations, species, and ecosystems around the world (30, 11).

Habitat destruction and fragmentation are the most critical threats to biodiversity and ecosystems throughout the world (6). It affects the survival of wildlife populations by reducing the number of available habitats, reducing habitat quality, and creating edge effects (13). Habitat loss has pervasive and disruptive impacts on biodiversity and its magnitude of ecological impacts can be exacerbated by habitat fragmentation (14, 2).

In Ethiopia, The expansion of agricultural practices, settlement in and around the Sanctuary, and increasing pressure from human and livestock populations are major threats to several protected areas (21). Moreover, the Lack of proper management is a problem that is threatening the quality and quantity of wild biodiversity in Ethiopia (13).

In Dhati Welel National Park, habitat loss and fragmentation is rapid and pose a severe threat to the survival of most wildlife species (19). It has been under increasing pressure from the rapidly growing human population agricultural land expansion, and the increment of livestock number (19). Encroachment from the surrounding communities is currently among the major problems the park is facing.

The African buffalo is a large sub-Saharan African bovine that is found throughout most of sub-Sahara Africa including Ethiopia. Presently their distribution is considerably reduced and in many areas largely limited to reserves. Their habitat is fragmented in many areas by human activity and their numbers have been hugely reduced (1).

The Dhati Welel National Park contains *Syncerus caffer caffer* species. According to Dhati Welel National Park the population of buffalo is affected by habitat fragmentation combined with a continuing decline in the numbers of mature individuals. A Continuous loss of habitat due to subsistence agriculture expansion represents a major threat to species.

Therefore, GIS is an excellent tool for identifying areas of conservation significance and assessing the habitat potential sites (20). It enables wildlife distributions, movements, and habitat use patterns and processes to be mapped and analyzed, which can provide valuable information for the development of management strategies (15, 24). The use of GIS for mapping, monitoring, analyzing, and modeling habitats of wildlife populations has become increasingly widespread (8). Therefore, this study was aimed at utilizing the GIS methods for analyzing the suitable habitat sites for African buffaloes in Dhati Welel National Park.

Materials and Methods

Description of Study Area

The study was conducted in Dhati Welel National Park, Oromia National Regional State, Western Ethiopia. The area is located between 34° 36’ 0’’ to 35° 2’ 30’’ E longitude and between 9° 6’ 0’’ to 9° 30’ 0” N latitude. The area is located in six districts including Gawo Kebe, Jimma Horro, and Gidami which are found in Kellem Wollega, Zone, and Begi, Kondala, and Babbo Gambel are found in West Wollega Zone. The Park contains the most important wetland ecosystem in the western part of Ethiopia located in the upper basin of the Blue Nile, and approximately covers 1035km^2 area in size. Figure 1.

Figure 1. African Buffaloes in Dhati Welel National Park

The most common resources of the park are; the wetland biodiversity including; wetlands dependent and wetlands associated birds, the extraordinary richness of Mega-fauna such as the African Buffalo, and Hippopotamus (*Hippopotamus amphibius*), and ample fish fauna. Vegetation consists of various floral species including wetland-dependent and wetland-associated plants, and a vegetation type known Sudan-Guinea savanna biome. The study area classified into four habitat types: Wetland, woodland, riverine forest and Savanna grass land. The Park shares the northwestern portion of the southwestern tropical forest part of the country and receives over 1,350mm average annual rainfall. As indicated in Rabira (2019) the area is relatively hot with mean maximum and minimum temperature ranging between 29^0C and 27^0C and between 15^0C and 17^0C respectively.

Datasets and GIS mapping

The data used for the habitat suitability analysis includes satellite imagery of Landsat 8, Shuttle Radar Topography Mission (SRTM) with 20m resolution (elevation and slope), toposheet (rivers), and settlements. For data preparation, organization, data analysis, and output generation, hardware and software were used. Softwares used for data processing and preparation are ArcGIS 10.5, and ERDAS IMAGINE 2015. To analyze the habitat suitability of Buffaloes in Dhati Welel National Park, the Literature Review and Expert Opinion Habitat Suitability Model were applied. Besides the discussion with Dhati Welel National Park members, published and unpublished materials were reviewed for the convenience of the study. Generally, in the process of habitat suitability analysis for Buffaloes, five factors including LULC, elevation, slope, river, rainfall, and settlement were used.

The study employed LULC interpretation and classification of the study area as one factor. As a result, Landsat 8 OLI images of resolution 30m of the year 2019 were used by downloading from the United States Geological Survey websites. Then image geometric correction and stacking layer of each band

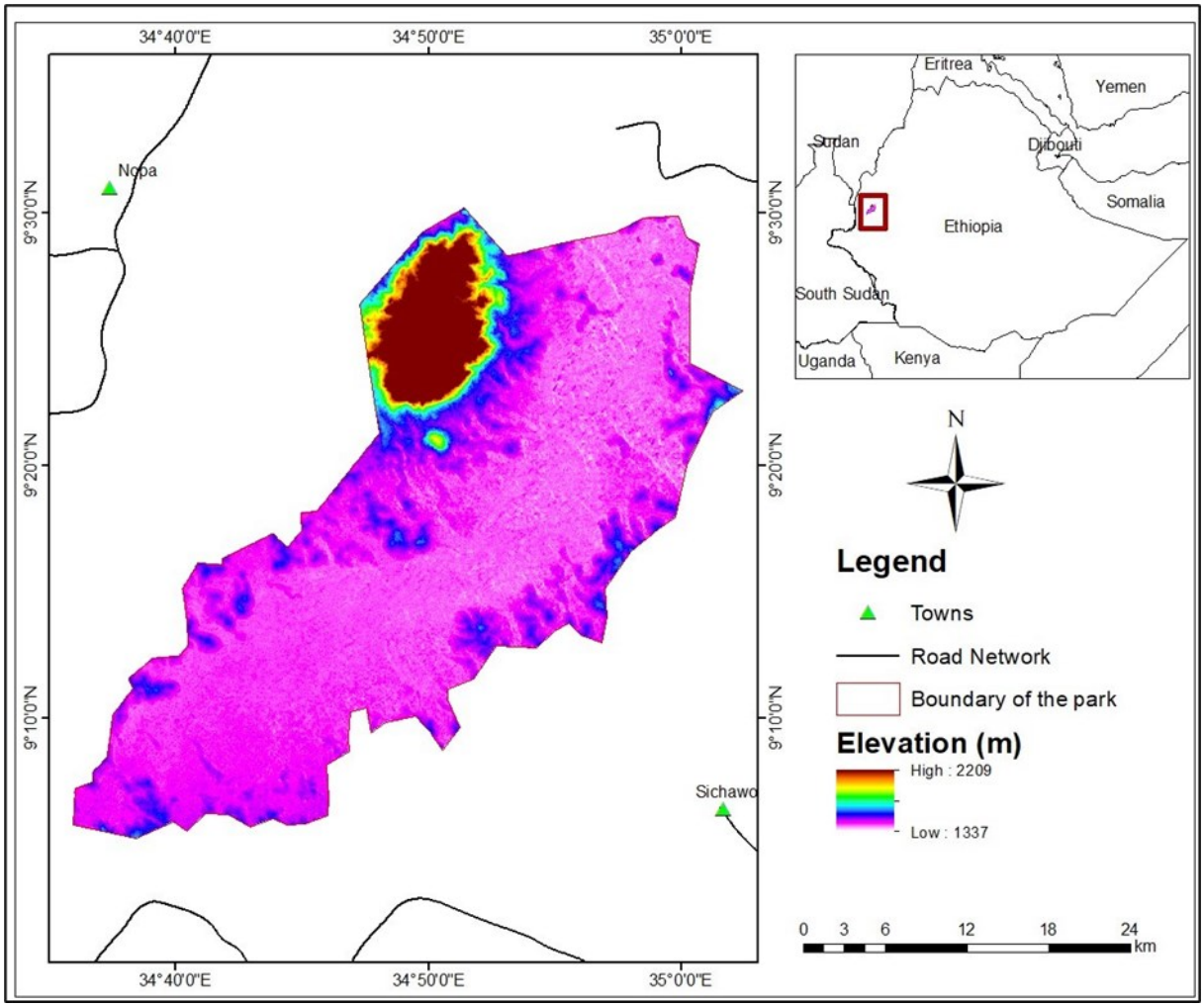

Figure 2. Map of Dhati Welel National Park

were conducted subsequently by using ERDAS IMAGINE 2015 software. Following that, the mosaicking of two scenes was made in order to clip the images of the study area. Supervised classification was performed to classify the LULC of the Dhati Welel National Park. After that Accuracy assessment of the classified image was done by field observation and data was collected using handheld GPS apparatus from sample areas to match the classified image with ground features. Finally, the classified LULC image was crosschecked by overlaying it with Google Earth Image using ERDAS IMAGINE 2015 software. Settlement and river were digitized from the toposheets collected from the Ethiopian Mapping Agency and using ArcGIS 10.5 software proximity computation was performed and analyzed. The Elevation and Slope of the study area were generated from SRTM-30 meter resolution that was downloaded from the United States Geological Survey websites and analyzed using ArcGIS 10.5 software. Figure 2

After each variable converted from vector to raster (rasterization process) continuing through the performing of their analysis, reclassification was performed based on an attribute value that has been specified through ArcGIS software. A pairwise comparison method in the context of the Analytic Hierarchy process was used for the evaluation of the factors. Each assigned weight for the factors was based on a multi-criterion evaluation Analytical Hierarchy Process. The Analytic Hierarchy process uses a nine-point measurement scale i.e. 1 – Equal importance, 3 – Moderate importance, 5 – Strong

importance, 7 – Very strong importance, and 9 – Extreme importance. The other values of 2, 4, 6, and 8 constitute intermediate values between two adjacent values.

The Weighted Overlay tool applies one of the most used approaches for overlay analysis to solve multicriteria problems such as suitability models. Each factor in the weighted overlay analysis may not be equal in importance. Weighted overlay analysis was computed using the Influence value assigned to each factor based on their significance in deciding habitat suitability for African Buffaloes.

Results and Discussion

All factors used in the study were geo-referenced, loaded into the Geodatabase, converted into raster format, and reclassified according to their suitability classes in the ArcGIS environment. After the reclassification process, the suitability classes were identified for each factor. The factor maps were reclassified based on suitability classification standards i.e. highly suitable, suitable, moderately suitable, and unsuitable. In this regard, highly suitable, suitable, and moderately suitable, are areas that in general called habitat-suitable ranges for African Buffaloes. Whereas unsuitable was an area that is not suitable for Buffaloes.

Based on literature reviews and information gathered through interviews on each factor, the following habitat suitability levels were identified for Buffaloes Table 1.

Table 1. Weighted suitability analysis.

S/N	**Factors**	**The level of suitability classes and Ranks** Where 1. Unsuitable, 2: Moderately Suitable, 3: Suitable, and 4: Highly suitable		**Influence (%)**	**Sources**
1	LULC (Type)	Agricultural lands=1 Shrub land=3	Forests land= 2 Water bodies / Wetlands = 4	35.3	(Parihar et al., 1986; Estes, 1991)
2	Slope (%)	>26.7=1 5.0-13.7 =3	13.7-26.7 =2 <5.0=4	12.3	Pokhrel et al. (2019)
3	Proximity to Set-tlement (km)	<6=1 9-12=3	6-9=2 >12=4	7.3	(Treves et al., 2006)
4	Proximity to River (m)	>700=1 2100-4400=3	4400-7000 =2 <2100 =4	26.8	(Parihar et al., 1986)
5	Elevation (m)	>1790=1 1420-1562 =3	1562-1790 =2 <1420 =4	18.4	(Lamsal et al., 2016)

LULC of the study area was one of the criteria used to select habitat sites for Buffaloes. The LULC was reclassified according to its suitability for Buffaloes habitats. Depending on the literature reviews and information gathered from the Park, the weight has been assigned for each LULC type. Wetlands are highly suitable and Water bodies are a life requirement for any species of wildlife including Buffaloes. Buffaloes live in swamps, floodplains, mopane grasslands, and the forests of the major mountains of Africa (17, 17, 9). It prefers a habitat with dense covers such as reeds and thickets (12), and also be found in open woodland. Buffaloes require water daily so they depend on perennial sources of water.

According to Lamsal (2016), the Suitable habitats of Buffaloes are extended to in lower elevations. They are found in dense lowland forests, lowland rainforests, montane forests and grasslands, Acacia grasslands, plains, and semi-arid bushland (22). The highest Buffaloes population densities are found in the wetland part of the Park which is a lower elevation of the study area. Figure 3

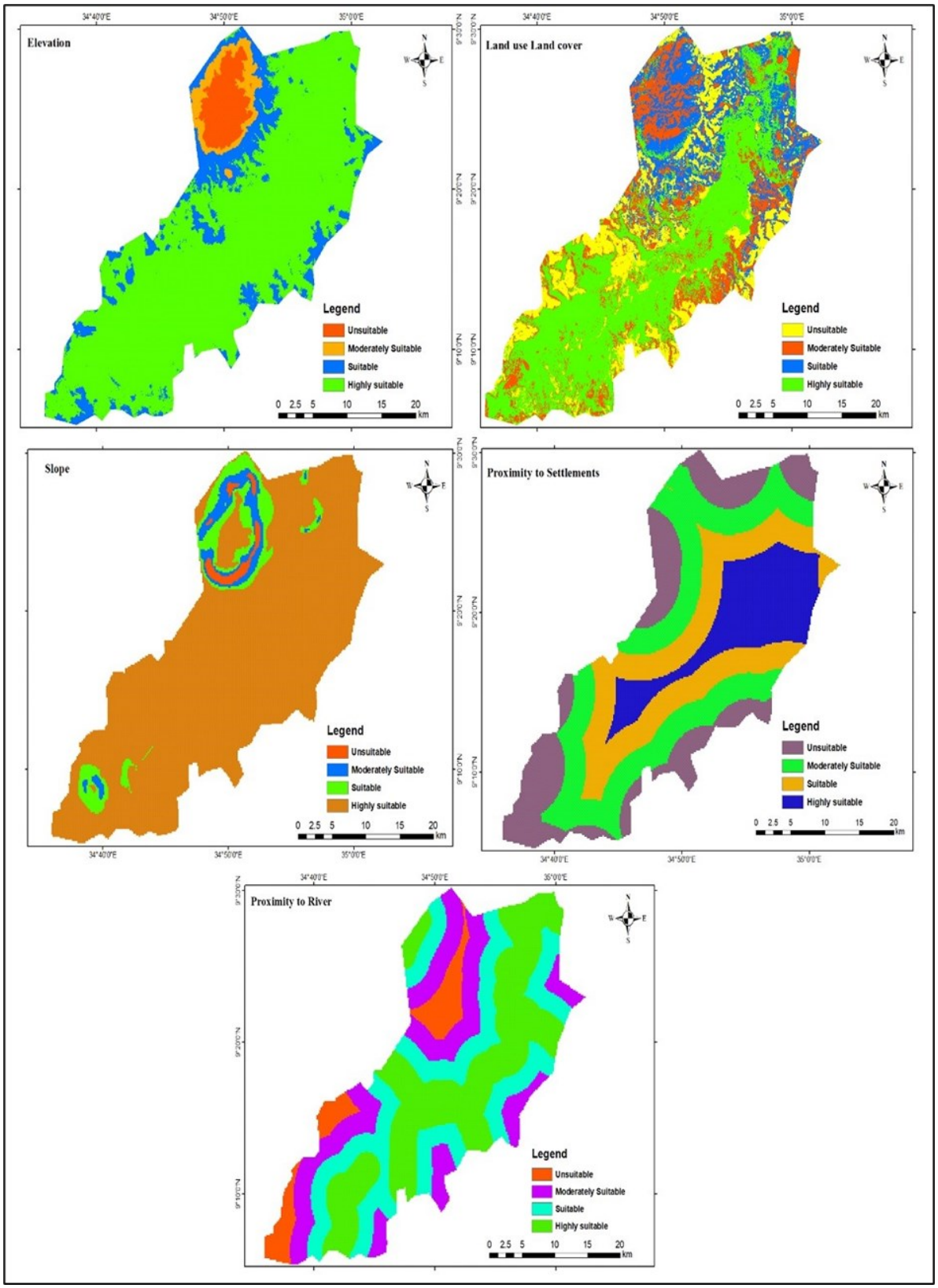

Figure 3. Factor suitability Maps

According to Pokhrel et al. (27), the suitable habitat for Buffaloes on the slope point of view is along with flat or gently sloping areas. Therefore, Buffaloes prefer a gentle slope rather than a steep slope from the slope gradient perspective. As a result, Slope has been identified as an important factor for Buffaloes. Gentler slopes are more preferable and energy savers during grazing rather than the steepest slope.

Water is one of the life-supporting systems that allows all living things to survive on the surface of the earth (Sinha and Kaushik, 2010). It's a crucial life requirement for every species and the suitable habitat for Buffaloes is near the rivers. Buffaloes show a preference for riverine habitats, especially in the dry season. They prefer close proximity of less than 1 km to water and are only found within 20 km of water (35). Therefore, suitable habitat for the Buffaloes species is recommended if water is available within a 20km radius. As result, the area found within a 1km distance to the river is termed as a suitable region for Buffalo's habitat.

Human interference is one of the most problems that disturb the conditions of wildlife including Buffaloes (10, 34). In and around Dhati Welel National Park, settlements are increased in all areas of the park including the remote and inhospitable areas. As a result, the habitats are more profoundly modified by the human population. Buffaloes are not suitable for living with the closest human settlements. A Settlement with agriculture overwhelmed a large area of woodlands around the wetlands of the park which was the part of former ranges for Buffalo, and therefore, forced Buffaloes to a swampy plain.

The reclassified layers were combined in order to select suitable habitat sites for Buffaloes in the study area. All factors cannot have equal preferences as a result; weighting was used to express the importance or preference of each factor relative to another factor. Accordingly, five factors were standardized and computed by using IDRISI 17 software to produce their weights.

Table 2. Weights of the factors using pairwise comparison matrices

Factors	LULC.	River	Elevation	Slope	Settlement	Weight	Weight (%)
LULC.	1					0.35	35.3
River	1/2	1				0.27	26.8
Elevation	1/3	1/2	1			0.18	18.4
Slope	1/3	1/3	½	1		0.12	12.3
Settlement	1/5	1/5	1/3	1/3	1	0.07	7.3
Totals						1.00	100

Consequently, the weighted overlay tool in the ArcGIS spatial analyst extension was used to combine all factors according to their rank and weight that has been computed from the pairwise comparison matrix to select the intended outcomes for the suitable habitat of Buffaloes in the study area. Table 2

As it is shown on the above map (Figure 4), the area indicated by dark blue and light blue colors are suitable and highly suitable for the habitats of Buffaloes. These areas are found around the central and wetland-dominated portion of the National Park. The remaining area shown on the map in red and black color represents the area moderately suitable and unsuitable for Buffaloes habitat respectively. From the total area of the park, 35.4% (362.7km^2), and 44.1% (452.8km^2) found as highly suitable and suitable for Buffaloes habitats respectively. These areas fulfill the optimal requirement for habitats based on the

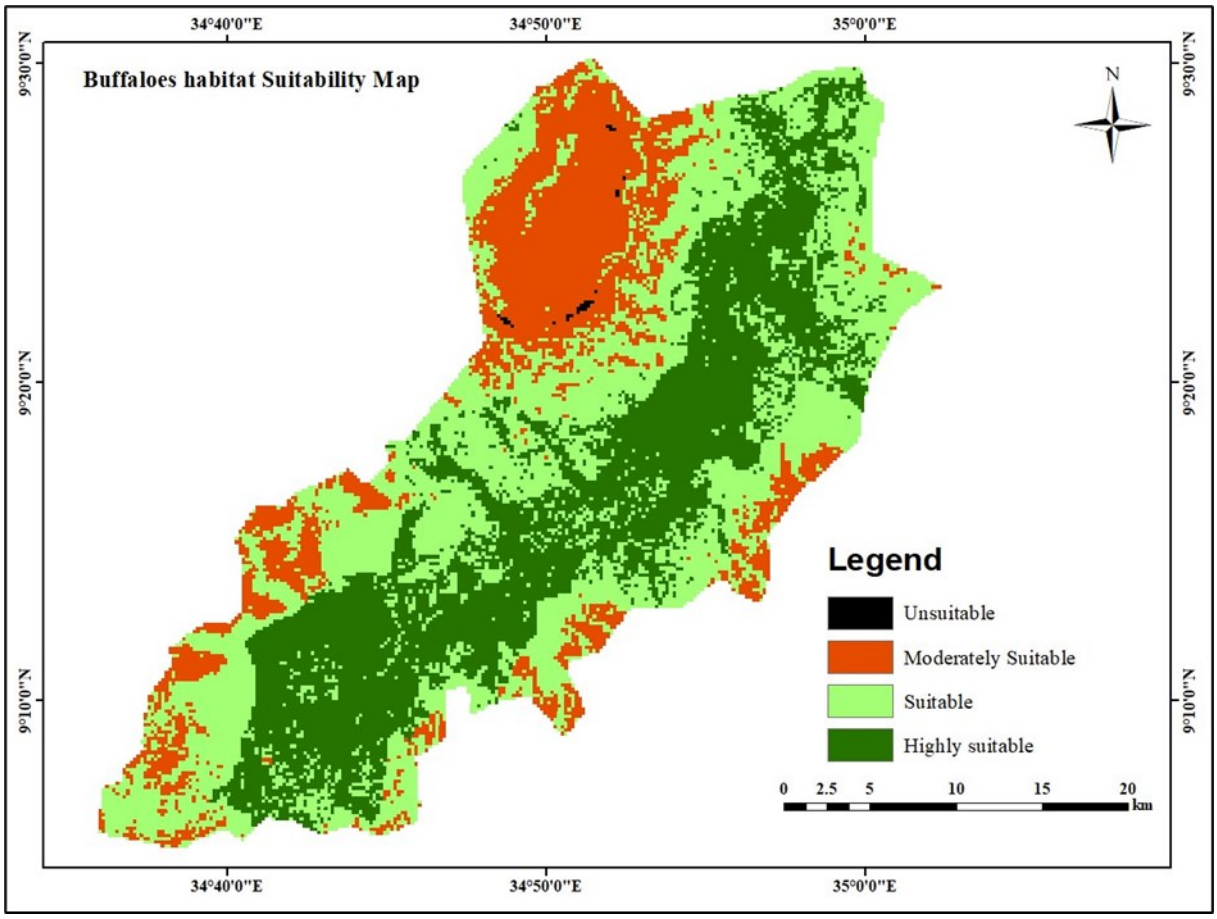

Figure 4. Buffaloes habitat Suitability Map

factors analyzed in the study. The remaining 20.4% (209.3km^2), and 0.1% (1.1km^2) of the study area were found as moderately suitable and unsuitable for the habitat of Buffaloes respectively. These were areas occupied by anthropogenic activities and known by habitat fragmentation in the park.

Conclusion

Dhati Welel National Park is one of the protected areas in western Ethiopia with large areas of wetland habitats and it supports several species like African buffalo. The intention of this study was to analyze habitat suitability for African Buffaloes by employing GIS at Dhati Welel National Park. In this study, five environmental factors were used to generate a suitable habitat map of the study area including elevation, slope, LULC, rivers, and settlements. A GIS-based method was employed to identify suitable habitat sites. The findings of this study have shown that the central parts of the Park were found more suitable for African Buffaloes due to the existence of important environmental factors that are the necessary conditions for their living. The peripheries of the Park were found to be unsuitable for Buffaloes habitat due to the presence of settlements, which pose anthropogenic pressure. Generally, the findings of this study have shown that 35.4% (362.7 km^2) area of the park is the optimal habitat zone for African Buffaloes. The habitat suitability maps produced in the study can be used as a tool for wildlife conservation and management programs.

Funding

This research received no external funding.

Data availability statement

The authors will provide the data used for habitat suitability analysis of African Buffaloes that supported the results presented in the paper. Additionally, data that support the findings and maps that have resulted from this study will be made available on request from the corresponding author.

Disclosure statement

There is no conflict of interest regarding this study.

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