Identification of Areas for Sustainable Settlements in Highly Conflicted Protected Areas Using ArcGIS Spatial Analyst: A Case of Chobe District, Botswana

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Abstract

The increasing human settlements around protected areas is a significant cause of the shrinking size of conservation areas globally. This is an alarming situation, especially in countries where protected areas significantly contribute to the National economy. The use of new tools to solve Land use conflicts that exist around protected areas is needed. This study employed the weighted overlay analysis using ecological, social and economic factors to model suitability for developing settlements in Chobe District, an international tourist destination in Northern Botswana, using ArcGIS spatial analyst. The majority of the land (83.4%) in Chobe is not suitable for settlement, while suitable areas that could for settlement remain relatively small (0.3% of the land). This study suggests that more land for settling the increasing population be created out of Chobe District to avoid encroachment on the conservation areas. The study demonstrated that ArcGIS spatial analyst model builder could be integrated into the land resource planning process of protected areas, making it a handy tool for the analysis and the identification of ecological, economic and social factors, thus establishing an excellent area for further research, especially for sustainable management of protected areas.

Keywords: protected areas, ArcGis spatial analysis, land conflicts, land suitability, settlements

1. Introduction

The consensus between the increasing population in protected areas and the need for conservation remains a challenge for policymakers and practitioners. In recent decades, there has been a rise in reports of encroachment on protected areas globally fuelled by increasing human pressure (Geldmann, Manica, Burgess, Coad, & Balmford, 2019; Mannetti, 2017; Murti, 2019; UNEP-WCMC, IUCN & NGS, 2019; Watson, Becker, Milanzi, & Nyirenda, 2015). Although these areas are critical species conservation areas, some of the ecosystem services and benefits derived from these areas, primarily through tourism, have attracted people to seek residence in these areas. The increase in human pressure in such protected areas, especially in Sub-Saharan Africa, has caused several changes in the ecosystem, including changing flow regime, habitat fragmentation, increased competition for habitats due to expansion of livestock and uncontrolled hunting practices (J. Mbaiwa, 2011; J. E. Mbaiwa & Stronza, 2010; Moswete, Thapa, & Child, 2012). The effect of these changes is evident in some protected areas; for instance, in the Maasai Mara, Kenya, the numbers of impala (*Aepyceros melampus*), warthog *(Phacochoerus aethiopicus)*, giraffe (*Giraffa camelopardalis*) and hartebeest (*Alcelaphus bucelaphus*) have been reported to have declined by more than 70% over the last few decades (Pinnock, 2011).

Over time, people living around and within protected areas tend to derive economic costs and benefits from the areas creating a significant impact on their livelihoods and everyday social relations such as; who within a family lives where, how and why intra-household exchanges occur, and what forms of control individuals have over their own lives (Gupta, 2015). Such complex social, economic and ecological interactions have resulted in conflicts in cases of conflicting interests (Campbell, 1996; von der Dunk, Grêt-Regamey, Dalang, & Hersperger, 2011). Though often not clearly understood, the complexity of such interrelationships is critical when dealing with land-use conflicts. It seems like conflict is an inevitable part of regional planning processes, especially when the planning involves meeting several incompatible community demands and, if handled constructively, could

function as an engine for community development.

Several other protected areas are facing the impact of human-wildlife conflict in Africa (Stone, 2013). As governments continue to debate the dangers and merits of biodiversity conservation for human communities, attention must be paid to these changes in the fabric of everyday life for those who live near, and in some cases far, from protected areas. The level of complexity of the environmental, social, economic factors and the number of stakeholders involved in a given system influence the feasibility of solving land-use conflicts (Rodríguez, 2017). West, Igoe, & Brockington. (2006) reiterate that cases of practitioners disregarding and being ignorant of the social dynamics of areas prioritised for conservation have increased land use conflict and injustices. Therefore, concentration should be on how protected areas have affected spatial distribution in demographics instead of the impact caused by the conflicts since competition for land among various land uses increases, the frequency of land-use conflicts (Ma et al., 2020).

According to Alexander, Ramotadima, & Sanderson (2018), the demand for land access around resource-rich areas is growing, influencing wildlife conservation and community livelihoods. The projected increase in population may further aggravate the situation and increase demand for land and land resources due to the varying needs of the new population. Therefore, when planning settlement of populations in protected areas, there is a need to understand under what circumstances and what spatial patterns protected areas might influence the settlement of people (Igoe, Brockington, Randall, & Scholfield, 2008). Areas with the urban-rural interface are expected to experience higher conflict occurrences since these areas are exposed and particularly vulnerable to the influx of population and economic activity and infrastructural development (Halseth, Reimer, Manson, & Markey, 2009; Nabielek, Kronberger-Nabielek, & Hamers, 2013). The change in the social structure that arises while creating new settlement areas may lead to land use conflicts, hardship, and social injustices that likely hinder human livelihood and development.

However, creating more land for settlement should sustain economic activities that contribute to the national economy. The integration of different tools in solving such conflicts is critical to achieving sustainable management of conservation areas. This study, therefore, aimed at using an integrated spatial analysis to identify new settlement areas around a protected area to reduce the increasing land-use conflicts in Chobe District, Botswana. The study intended to integrate the interests of different relevant sectors using a sustainable environment point of view (Izakovičová, Miklós, & Miklósová, 2018). Noteworthy, the potential to diversify the activities within the Chobe district lies in the effectiveness of land allocation for settlement. The need for effective land allocation requires a systematic allocation of land to cater for the increased population. The objectives of this study were; to determine the contribution of different factors to conflict-free and sustainable land use and to identify suitable areas for conflict-free settlements within the Chobe district using ArcGis spatial analyst.

2. Materials and Methods

2.1 Description of the Study Area

2.1.1 Location of the Study Area

The Chobe District of north-western Botswana (Figure 1) is semi-arid dryland supporting a diverse collection of wildlife species and habitats of ecumenical conservation significance, known for its largest elephant population in Africa (Junker, 2008; Stokke & Toit, 2014). The region receives an annual rainfall of about 550mm. It means monthly temperatures range between 17^0c and 29^0c and is characterised by highly variable rainfall, with nearly the entire annual rainfall budget concentrated during the November—March wet season, followed by a general absence of precipitation from April-October. The favourable climate of the area supports a wide variety of land uses, including agriculture, settlements, tourism. Chobe district is the only area in Botswana that can support rain-fed agriculture despite limitations due to wildlife conflicts. The Chobe District also has a permanent surface water supply from the Chobe River and its surrounding wetlands. The area is part of a transboundary watershed, the Chobe River Basin, considered a core component of the Kavango-Zambezi (KAZA) Trans-frontier Conservation Area, shared by Angola Botswana, Namibia, Zambia, and Zimbabwe.
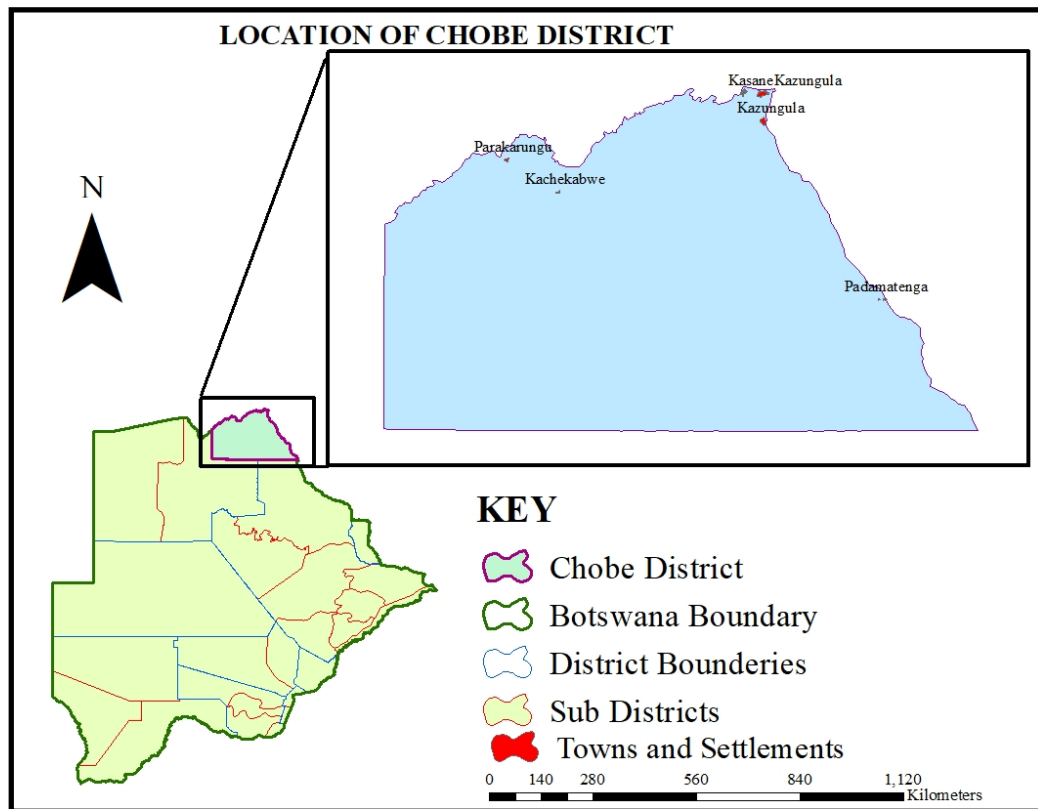
Figure 1. Location of Chobe District

2.1.2 Land Use and Land-Use Conflicts

The Chobe District has become an internationally renowned area due to its large wildlife that attracts many tourists throughout the year. Tourism in Botswana has contributed over 13.1% to the national GDP and 8.9% to total employment. Although Chobe District is one of the smallest districts in the country, it is endowed with its natural resources, including the Chobe River, forests, and several wildlife species. Over 80% of the district is for conservation, and only 20% is devoted to human settlement, industrial development and social amenities (Figure 3). Several factors have influenced population growth in the areas, including the availability of productive soils, rains, government policies, and the increasing tourism potential. Chobe district population increased in previous decades and may reach 32,154 people by 2026 (Figure 2). The majority of this population (39%) lives in Kasane town (Gupta, 2015). Many people are moving into the district to take advantage of the tourism potential and jobs created by the hotels and camping sites within the area. The exponential increase in population over the years has led to an increase in human pressure on the available natural resources in the district, creating the need to intensify conservation and protection of these natural resources and the environment from being degraded and negatively impacted by the increasing human population and settlement (Gupta, 2015). Besides, according to (Gwebu, 2004), local migration is a common practice among the country's population used as an adaptive strategy to the harsh conditions; this could exacerbate the situation.

The majority of Chobe District is part of the conservation area predominantly inhabited by free-range wildlife. Human settlements in the district have been negatively affected by growth and human livelihood because of the conflicts with wildlife (Fox, 2016; Gupta, 2015; Nijhawan, 2008; van der Sluis et al., 2017). There are several land-use conflicts in the area, with the central conflict being the human-wildlife conflicts. The rise in conflicts is due to the increasing encroachment on conservation land by the increasing population, shrinking carnivore and herbivore habitats and feeding zones. Although the area has potential for crop and livestock production, agricultural production is limited in most areas (van der Sluis et al., 2017). Cases of crop destruction and livestock predation have been reported, mainly from villages living around the Game reserve. Additionally, the local population living within the area predominantly depends on subsistence livestock, crop production and gathering, the creation of restrictions to safari hunting within the Game reserve, which has created more land-use conflicts (J. E. Mbaiwa, 2018). Although hunting greatly influences wildlife numbers, dealing with a change in the

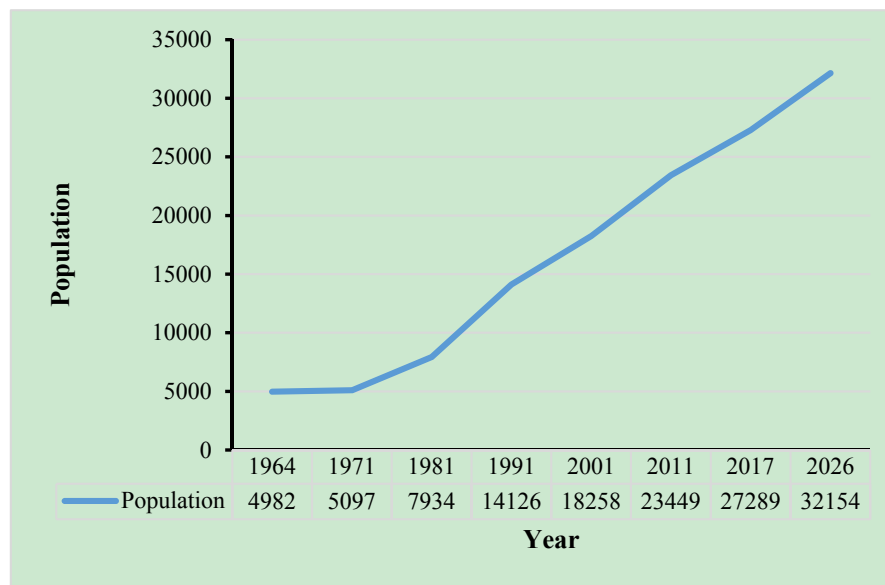community's way of life is seemingly a complex process.

Figure 2. Chobe District population 1964-2017 and projection for 2026 (Statistics Botswana, 2015)
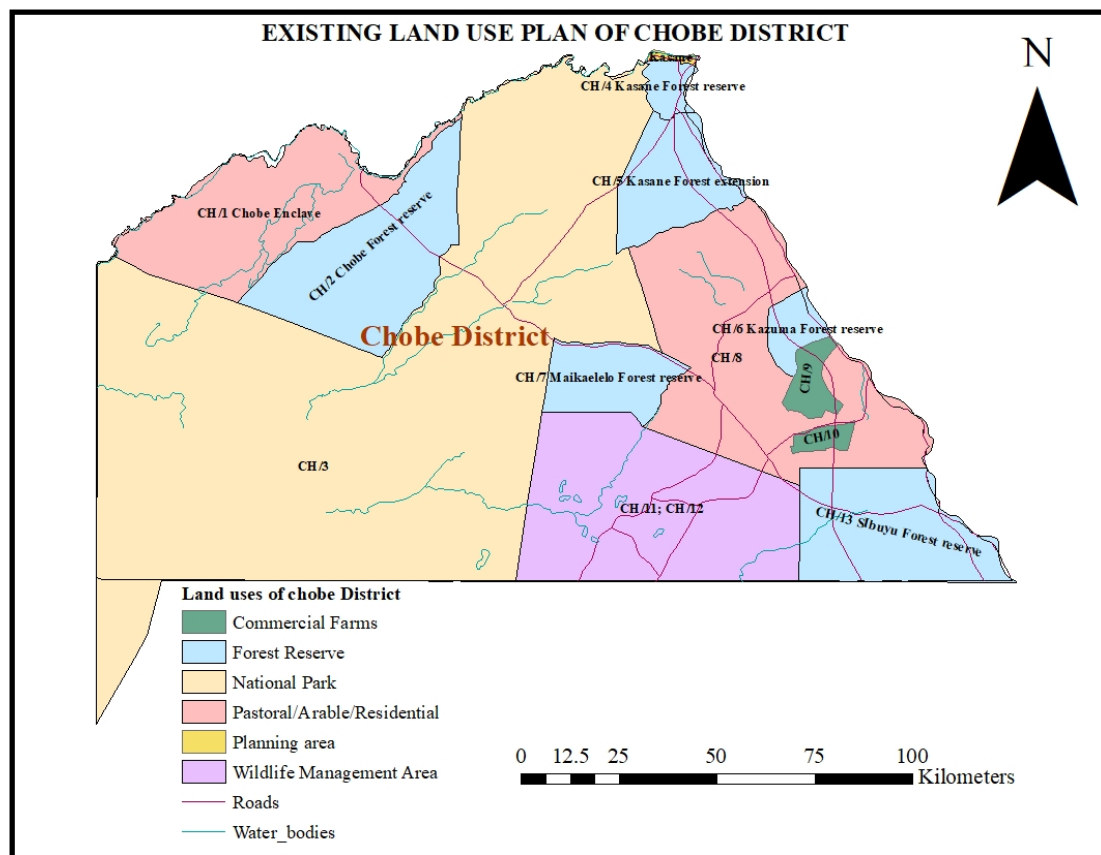

Figure 3. Chobe District current land use plan

A complex human-wildlife interaction characterises Chobe District, and the negative perceptions of the native people could have fuelled an increase in poaching, habitat destruction encroaching into the conservation area, which has negative impacts (Graham, Beckerman, & Thirgood, 2005; Romañach, Lindsey, & Woodroffe, 2011). According to Jackson, Mosojane, Ferreira, & van Aarde. (2008); Madden, (2004) and Nyhus, 2016), human-

wildlife interactions lead to negative impacts on life and property, economic activities, health, food, and safety when viewed from the human perspective concerning human livelihoods and property. Jackson et al. (2008), Rodríguez (2017), in their studies, also found that the interaction of humans and wildlife and the level of conflict in Chobe District varied according to the spatiotemporal distribution of the species as well as the spatial and temporal scales (seasons). Human-wildlife conflict is often negatively viewed for human life without considering the impact on wildlife (N. Peterson, Birckhead, Leong, M. Peterson, & T. Peterson, 2010; Soulsbury & White, 2015). However, such interaction can be managed through several copying strategies to ensure the coexistence of both humans and wildlife for environmental protection, social equity and sustainable development (Adams, 2006; Digun-Aweto & Van Der Merwe, 2020).

The creation of Safari, hotels, camping sites and other tourism-related services, primarily in the Chobe Enclave area (CH1), has also sparked several conflicts hindering livelihoods within the area (Kemmonye, 2009). There are increasing conflicts between lodge and hotel owners and the nearby local community of the villages. Such conflicts have risen from the hunting lifestyle of the natives. Hunting activities disrupt the comfort and peace of the visitors to the lodges and hotels in the enclave area. The increasing population within the enclave would lead to a business loss for lodge and hotel owners combined with the decline in the number of animals available for viewing by the tourists. As the population in the area increases, identifying new areas for settlement would ensure sustainable settlements with peaceful human-wildlife conflict. Besides, the increased settlement in the Kasane Forest reserve has caused significant environmental issues arising from waste generation by the community and mining of construction materials from within the forest reserve.

2.2 Assessment Criteria

A review of the literature and several recommendations set forth by previous studies was conducted to assess all aspects of human settlement development. Factors considered included social, economic and ecological factors that would influence potential settlement areas. Therefore, the following factors were used as the evaluation factors for the sustainable and conflict-free settlement areas; availability of Tourism sites, elevation, soils, protected areas (Forest reserves and National Park, hydrology (Rivers), towns and existing settlements and roads. The description of the different indicators used in this study is indicated below (Table 1).

Table 1. Description of indicators of development of settlements in Chobe District

Indicators	Description
Distance to protected areas	Protected areas occupy the most significant part of the district's total land area. The area includes the Chobe National Park (CNP), six protected forest reserves and extensions (Kazuma, Maikaelelo, Sibuyu, Chobe, Kasane Forest Reserve, and the Kasane Forest Reserve Extension). The distance from these protected areas was calculated for each pixel. Human settlements near protected areas have reported higher human-wildlife conflicts compared to those leaving farther away. This study considered a 15km buffer zone from protected areas as recommended by van der Sluis et al. (2017).
Distance to tourism sites	The criterion computed the distance to various tourism sites such as lodges, camping sites. Settlements nearer to tourism sites face higher land-use conflicts due to hunting activities.
Distance to the river	Many herbivores, elephants, in particular, concentrate their browsing activities within relative proximity to the Chobe River due to the availability of high-quality forage enabled by fertile alluvial soils, making areas around rivers highly utilised, especially in dry seasons and harsh environments (Fox, 2016; Mosugelo, Moe, Ringrose, & Nellemann, 2002; Wiegand, Saltz, & Ward, 2006). The criteria preferred areas away from the rivers for developing settlements to avoid human-wildlife conflicts. The map was processed to contain information on the distance from the rivers for each pixel.
Soils	Chobe District has the highest potential for rain-fed agriculture in Botswana, enhanced by relatively high rainfall amounts and Vertisols in some parts of the district. The criteria defined the different soils into agriculturally productive and unproductive soils. The criteria avoided productive agricultural soils for human settlement.
Elevation	The criterion mapped the elevation of the land. Areas with low elevation negatively contribute to human settlements' suitability due to high incidences of flooding during the heavy rainy period.
Distance to existing towns and settlements	The town of Kasane is the regional government seat and, together with Kazungula, are the most extensive urban settlements in the district. The map pixels were processed to contain information about the distance to the existing towns and settlements. Those sites nearer to existing settlements are preferred so as the new settlements benefit from the existing social services like hospitals, water connection, sewerage services and reduce costs for establishing new ones. The criteria considered an existing settlement in Chobe District.
Land use	This criterion considered land allocated for various uses according to the existing land use plan such as industrial development, waste management, mining sites. Some land uses such as industries could provide jobs and diversify the economy, while closer damping sites facilitate the settlement's safe and sustainable waste management.
Distance to roads	Roads facilitate economic development; the criteria considered the existing road network of the area. Those sites that are nearer to roads contribute in a positive way to the development of human settlements. Information on the distance from the existing road network was processed and added to the pixels of the map.
Distance to schools	The criterion considered the distance from the existing schools calculated and added to the map pixels. New settlements near existing schools prevent further government expenditure on new ones, reducing the strain on already limited education funding. The possibility of other social factors like health and recreation being provided by the private sector, unlike education, makes the distance to schools a critical criterion in establishing new settlements. Additionally, other social factors are available in locations with existing settlements and towns.

2.3 Determination of Criteria Weights for Contributing Factors

Weights for the Factors were used to establish the relative contribution of each factor concerning the evaluation criteria set by assessing its performance in achieving the objective (Ferretti & Pomarico, 2013). The Super Decision Tool software applied the pairwise comparison method to obtain the weights (Creative Decisions Foundation, 2019). The pairwise comparison of the model elements was divided into two levels: the comparison between clusters that are more general and strategic and the comparison between nodes that are more specific and detailed for each of the specific indicators considered. The relative importance or preference of indicators was rated on a scale of 1–9 points relative to the other. Table 2 shows the final weights and relative contribution of the indicator factors resulting from the pairwise comparison matrix.

2.4 Data Source and Spatial Analysis

Data for this study were obtained from different sources. Administrative boundary, rivers, roads and elevation shapefiles were acquired online from Diva GIS (DIVA-GIS, 2017), while soils and land use shapefiles were sourced from previously collected by the Botswana Department of Surveys and Mapping. Existing schools, tourism sites and settlements shapefiles were acquired from online Google earth and imported as Kmz files to ArcGis, then later converted into shapefiles with the help of conversion tools.

Figure 4 indicates a step by step process to determining suitable settlement areas. ArcGIS version 7.0 (ESRI, 2019) software was used for spatial analysis. Using the "multi-layered weighted map overlay technique" (weighted overlay), one of the spatial analysis methods within the ArcGIS spatial analyst tools, a model for identifying suitable land for the development of human settlements was built. Before the weighted overlay process, Distance to protected areas, existing settlements, tourism sites, productive soils, roads and existing schools were determined for each cell using the Euclidean distance tool.

The developed classes for all the factors except land use were then reclassified using the Reclassify tool into five classes and ranked from 1 to 5 with increasing levels of desirability. The Re-classed datasets were then used to plan the proposed location for the settlement areas, considering the factors and their weights indicating their level of influence. The weighted overlay technique combined all the factors following procedures indicated in ESRI (2010). Settlements in the protected areas and areas with water were restricted in addition to a 15km buffer zone. The most desirable areas were ranked with 5, while the least desirable areas were 1. Suitable areas ranked five were considered highly suitable, 4 for moderately suitable, 3 for marginally suitable, 2 for currently not suitable, while areas with 1 and 0 were permanently Not suitable.
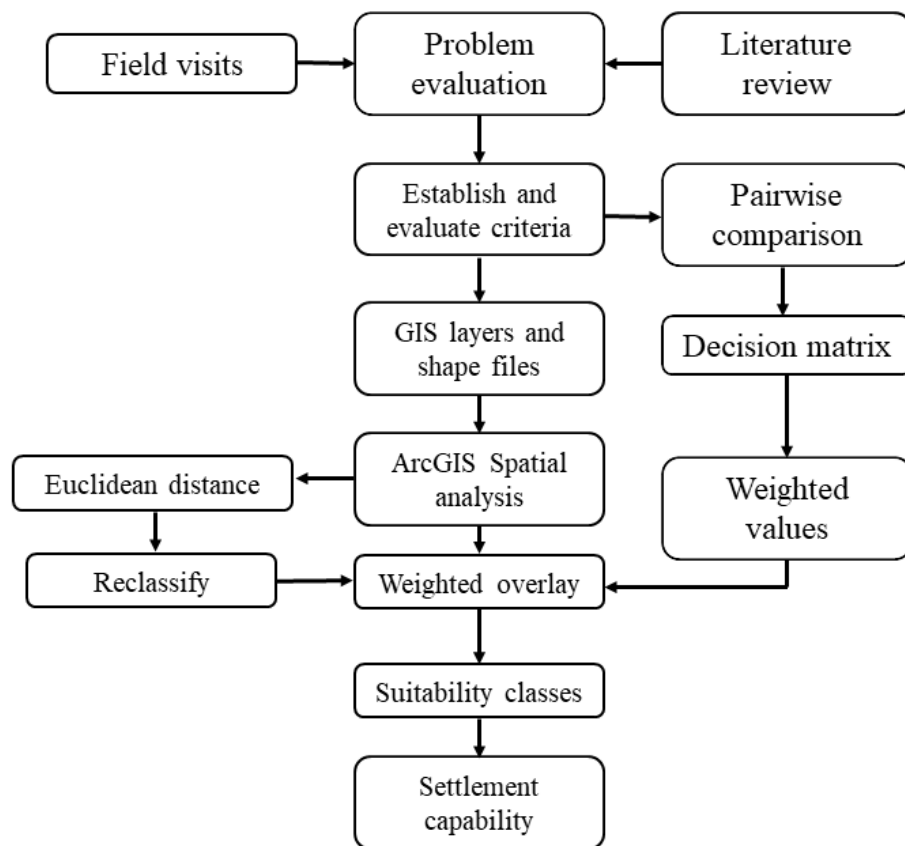
Figure 4. Research flow chart for identification of suitable settlement areas in protected areas

3. Results and Discussions

3.1 Contributing Factors to Sustainable Settlements

The management of protected areas can be complex and requires finding a balance between ecological functions, social demands and economic benefits, a situation faced by many if not all protected areas. The results of the multi-criteria procedure adopted for weighting the elements considered in the model highlighted that the essential factors in determining the suitable land for development of human settlements are the "distance to protected areas" with 33% in the "Ecological factors" cluster and the "Distance to tourism sites" with 20% in the "Economic factors" cluster (Table 1). The results also indicate that the most important social factor in determining the suitability of the land for the development of human settlements is the "distance to existing schools" (13% of importance), while the "distance to rivers" was the second most important factor (13% of importance).

3.1.1 Ecological Factors

The higher contribution (33%) by protected areas is because the most significant part of Chobe district is under protected areas (Figure 6c). A 15km buffer area was left around the protected areas as suggested by (van der Sluis et al., 2017). This study prioritised safeguarding protected areas since protected and conservation areas remain the only sustainable option for biodiversity conservation. Even though access to land within or around protected areas might be detrimental or beneficial (Joppa, Loarie, & Pimm, 2009), it is not clear how much new settlement and developments in protected areas could alter the existing systems and habitats. These results suggest the need to consider protected areas during the planning process highly. Also, the fact that the government of Botswana is promoting local tourism within the area (J. E. Mbaiwa, 2018) has led to the increasing recognition of Chobe District as a tourism destination for tourists all year round.

Results from the reclassification analysis indicated that the influence of distance from protected areas leaves over

81.6% of the area permanently not suitable for settlements (Table 3). Only 0.5% of the area, farther away from protected areas, could be highly suitable. Additionally, other factors such as distance from productive agricultural soils, elevation, land use and distance to rivers were also analysed and found to have 12% Influence for distance from rivers, 5% for elevation, land use and distance from productive soils (Table 2). Due to rivers ' closeness, a significantly higher (52%) proportion of the area was found permanently unsuitable. This study suggested avoiding areas closer to the river to prevent conflict for water with wildlife that tends to itinerate areas around water sources, especially during dry periods.

Table 2. Indicators and criteria weights

Goal	Clusters	Indicators	Weight	% weight
	Ecological Factors	Distance to protected areas	0.163	33
		Distance to Rivers	0.061	12
		Elevation	0.024	5
Development of sustainable conflict-free settlements		Soils	0.027	5
		Land use	0.025	5
	Economic Factors	Distance to exiting towns and settlements	0.014	3
		Distance to tourism sites	0.106	21
		Distance to Roads	0.013	3
	Social factors	Distance to schools	0.066	13

3.1.2 Economic Factors and Social Factors

Areas farther away from tourism sites such as hotels, campsites were given higher priority compared to areas closer to tourism sites (Figure 6b). Only 3.2% of the area could be highly Suitable for settlements, while the majority, 33% of the area, was unsuitable (Table 3). Restricting such areas could prevent the increasing conflicts between owners of tourism sites and their surrounding communities and ensure the peaceful stay of tourists. Higher priority was given to areas closer to schools to avoid higher government expenditure in establishing new educational institutions and roads for new settlements (Figure 5b), roads (Figure 5c) and existing settlements (Figure 5d). A significantly larger area (60.8%) closer to existing roads was more suitable than only 17.9% for existing settlements and 19.4% for existing schools (Table 3).
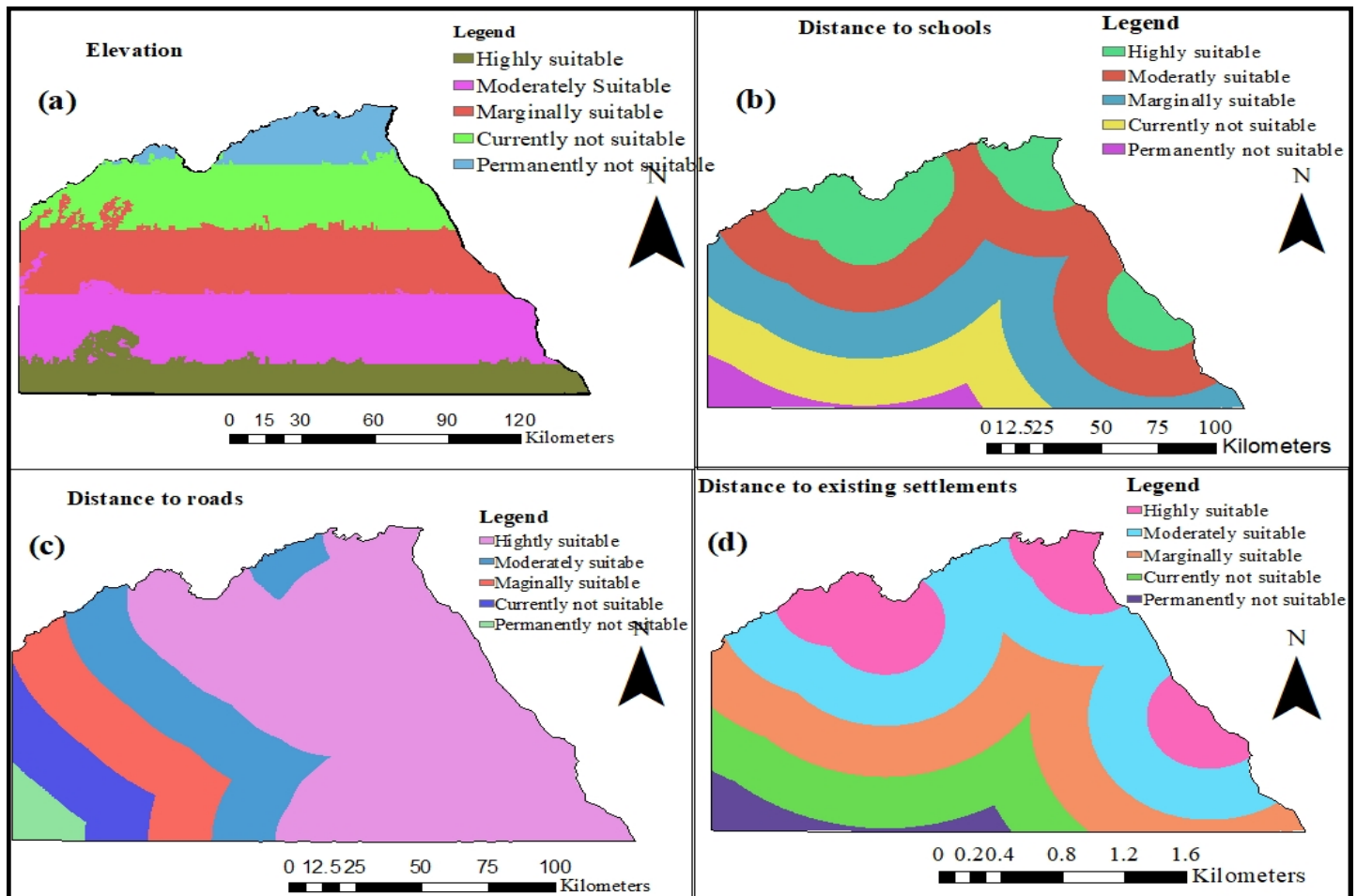
Figure 5. Standardized criteria maps for the different factors

3.2 Suitability for Settlements

By overlaying the layers for the different feature classes from the reclassification process, the results indicated that land restricted for protected areas and buffer zones was unsuitable for developing settlements (Figure 5 and 6). From the suitability map (Figure 7), much of the study area is Unsuitable for the development of settlements; however, significant portions of land were suitable for settlements. Additionally, a significantly smaller land area was highly suitable (0.3%) for settlements while Moderately (9.6%) and Marginally suitable land was significantly larger (6.8%) (Table 3).

These results suggest that the Chobe district could better be reserved as a conservation area to prevent land-use conflicts from increasing settlements in the area. Although protected areas such as Chobe attract several activities, their effectiveness in contributing toward the protection and conservation of biodiversity is critical (Joppa et al., 2009). Hypothetically, the development of settlements around protected areas comes with developing infrastructures such as industries for employment, roads and other goods and services for human survival. Developing such infrastructure would attract larger human settlements to benefit from the urban centres that may arise. The urban area would compromise the existence of protected areas and their contribution to ecosystem conservation, local economy, livelihoods and their use as community tourism areas, Chobe District. Therefore, the development of settlement areas in the Chobe district would encourage population growth and accelerate the degradation of the natural landscape; the impact of protected areas conserving biodiversity and endangered species is thus compromised.
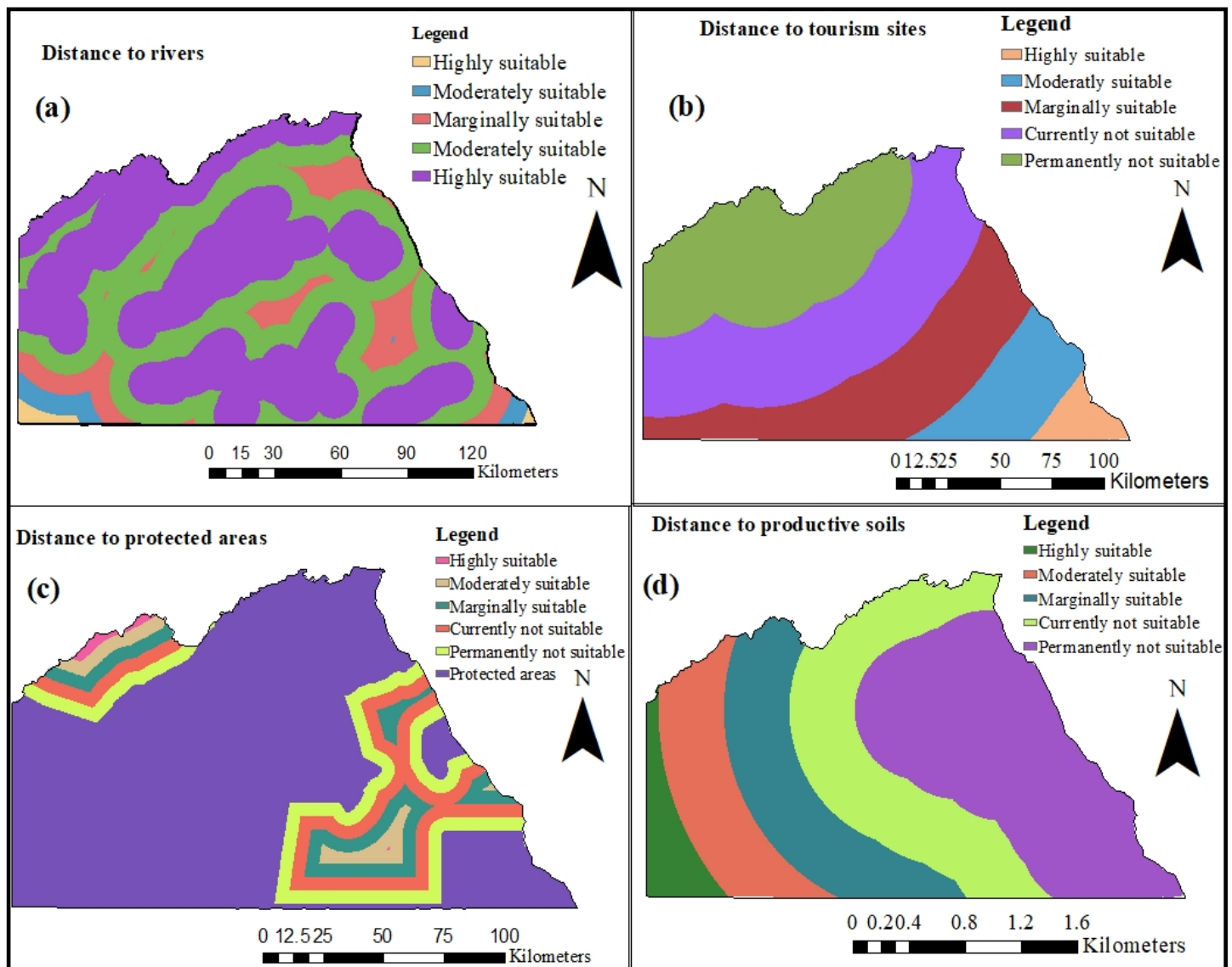
Figure 6. Standardised criteria maps for the different factors

Additionally, the Chobe District plays a critical role in achieving the sustainable development goals for the Nation through community tourism development based on the sustainable use of natural resources. The tourism activities in Chobe District have contributed to eradicating poverty through employment opportunities and economic development of the surrounding local communities (Government of Botswana, 2016). The settlements development should be such that households can meet their needs while at the same time allowing the development of economic activities that provide revenues to the national coffers. The increased revenue would foster the focus of the Chobe District development plan to secure long term sustainable utilisation and conservation of wildlife resources and management of ecosystems that support this goal.

The results indicated that most of the area classified as Highly suitable is located in the south-eastern areas of the district, while Not suitable areas occupied the majority of the areas of the district. The most significant portion of Forest reserves and National parks are in the Central and Northern sections of the district. Not suitable areas are areas occupied by Forest reserve, Chobe National Park and wildlife management areas and thus should be reserved for conservation purposes. Human settlements closer to wildlife conservation areas have reported the highest rate of land use conflict compared to areas located far from the conservation areas.

Table 3. Area (%) suitability of different influencing factors

Factors	Per cent % area				
	S1	S2	S3	N1	N2
Distance Protected areas	0.5	2.6	6.0	9.3	81.6
Distance to roads	60.8	16.8	12.2	7.6	2.6
Distance to existing settlements	17.9	34.0	26.8	17.0	4.3
Distance to productive soils	5.4	14.2	18.6	24.6	37.2
Distance to schools	19.4	31.9	26.8	17.5	4.4
Distance to tourism sites	3.2	10.8	24.5	32.9	28.7
Elevation	16.8	29.5	26.9	20.1	6.7
Distance to rivers	0.7	2.1	9.5	35.6	52.0
Overall Suitability		0.3	9.6	6.8	83.4

S1-Highly suitable, S2-moderately suitable, S3-Margianally suitable, N1- currently not suitable, N2-Permanently not suitable
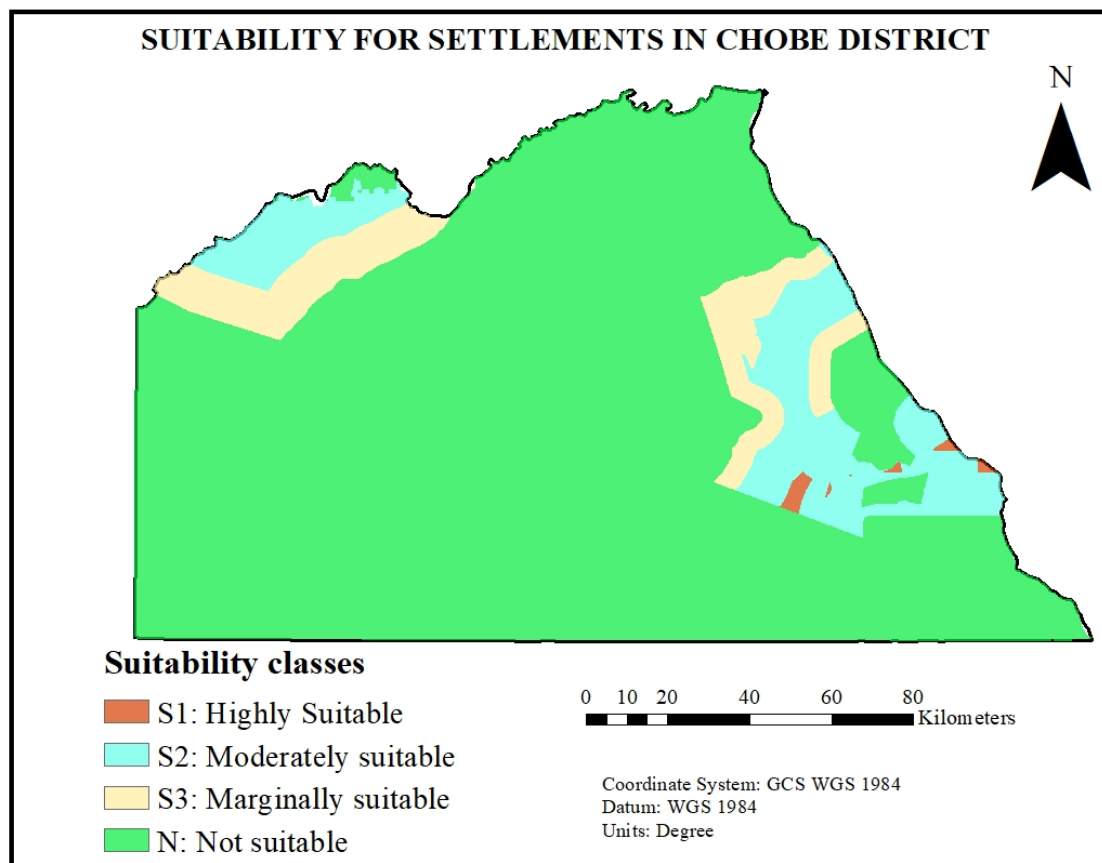

Figure 7. Chobe Land suitability map for the establishment of settlements

4. Conclusion

Whilst many studies on land conflicts and wildlife were conducted in Chobe District, further research is needed to model complex land resource situations in the district, considering the dynamics of human demographics, land use, and the limitations of the current land-use plan. This study explored ArcGIS spatial analyst application in land suitability evaluation and proved its effectiveness in identifying suitable settlements areas for the highly conflicted protected Chobe District. This study found that environmental factors significantly influence settlements'

suitability than social and economic factors. These results indicate that more land for settling the increasing population should be created out of Chobe District to avoid encroachment on the conservation areas. This study demonstrated that GIS integration in the land resource planning process is a handy tool for analysing and identifying ecological, economic and social factors, thus establishing a valuable area for further research, especially for sustainable management of protected areas.

Acknowledgement

Declaration of Interests

We declare that we have no significant competing financial, professional, or personal interests that might have influenced the performance or presentation of the work described in this manuscript

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