Open Journal of Ecology, 2018, 8, 126-145
http://www.scirp.org/journal/oje
ISSN Online: 2162-1993
ISSN Print: 2162-1985

Rangeland Condition and Herbage Utilization by Herbivores of the Kafue Flats North Bank: A Historical Perspective before the Construction of the Itezhi-Tezhi Dam, Zambia

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How to cite this paper: Chabwela, H., Chomba, C., Chimbali, D. and Malama, M. (2018) Rangeland Condition and Herbage Utilization by Herbivores of the Kafue Flats North Bank: A Historical Perspective before the Construction of the Itezhi-Tezhi Dam, Zambia. *Open Journal of Ecology*, **8**, 126-145.
https://doi.org/10.4236/oje.2018.82009

Received: December 19, 2017
Accepted: February 24, 2018
Published: February 27, 2018

Abstract

This study was carried out in Blue Lagoon National Park and the North Bank portion of the Kafue Flats Game Management Area along the Kafue River in Zambia. The aim of the study was to determine rangeland condition and utilization by wildlife as well as livestock grazing in Kafue Flats, to establish the baseline data for monitoring after the construction of the Itezhi-Tezhi dam. Line intercept method and enclosure plots were used to sample in all recognized vegetation types and basal cover and frequency measurements were taken using line intercept method while enclosure plots were used to determine rangeland utilization. Data obtained from records showed that the area had annual mean rainfall of 535 mm at Itezhi-Tezhi, but the lowest rainfall recorded was 214 mm in the 1978-1979 rainy season and the highest was 1, 184 mm in the 1975-1976 season. With regard to range condition, bare ground was highest in the Termitaria vegetation at Nakenda-Critchley (62%), Bowa (57.6%) and Muwezwa (48.45%) while basal cover was relatively high in the flood plain at Namunyona (47.8%). Litter had an almost even distribution in all vegetation types and percent standing crop biomass was relatively high in all sample plots. Rangeland utilization was relatively high around Nakenda-Chitanda (43.54%) in the flood plain and Bowa (31.42%) in the Termitaria vegetation. It was concluded that Termitaria vegetation was largely at high risk of degradation due to overgrazing. While the impact of dams, environmental flows and flood pulse are discussed, detailed research and monitoring should be introduced in addition to the promotion of management of pastures in this rangeland.

Keywords

Rangeland Assessment, Grazing, Rangeland Utilization, Wildlife, Livestock, Flood Pulse

1. Introduction

The Kafue flats are the second largest flood plain wetland in Zambia covering an area of approximately 6500 km^2 [1] [2]. Because of their location and the geomorphology of the Kafue River, this wetland has attracted considerable socio-economic developments primarily the hydropower generation development, livestock and agriculture, wildlife and fisheries conservation and human settlements [3]. For the most part, natural flood plains are ecologically among the most productive ecosystems in the world with very high biodiversity [4]. And this is because the structure of wetlands is a result of overlapping characteristics of the terrestrial and aquatic environments [5], and the hierarchical landscape which makes wetlands diverse ecosystems. As a wetland, the Kafue Flats contribute significantly not only to fisheries but also wildlife and livestock grazing. Despite their values and functions however, the Kafue flats are among the most threatened ecosystems in the world.

Among the major concerns raised were those against the construction of the Itezhi-Tezhi dam above the Kafue flats with projected potential disturbances through the interruption of the natural cycles of flood plain environmental flows. The Kafue flats ecology depends mainly on regular flood pulse within certain tolerance, and both plant and animal communities that inhabit this riverine system have evolved and adapted to this pattern of flooding regime (**Figure 1**).

The Kafue flats rely mostly on a restricted period of approximately five months annual flooding, and consequently the plant species diversity and plant growth are largely adapted to this periodic flooding. Furthermore, annual movements of wildlife, fisheries and cattle are equally influenced by this pattern of flooding sojourn [6].

Criticisms and support for large scale dam developments provided a forum of a worldwide debate primarily on the negative environmental and social-economic impacts of the dams [6] [7] [8] [9] [10]. Despite so much debate against dam development, dams have received support mainly for irrigation, hydropower generation and domestic water supply [10]. However, consideration for dam development on Kafue River began as early as 1950's, while the actual developments started about ten years later [11] [12] [13]. It is important to note that these dam developments were intended to support the expansion of copper mining industry in the North-Western part of the country [13]. The developments

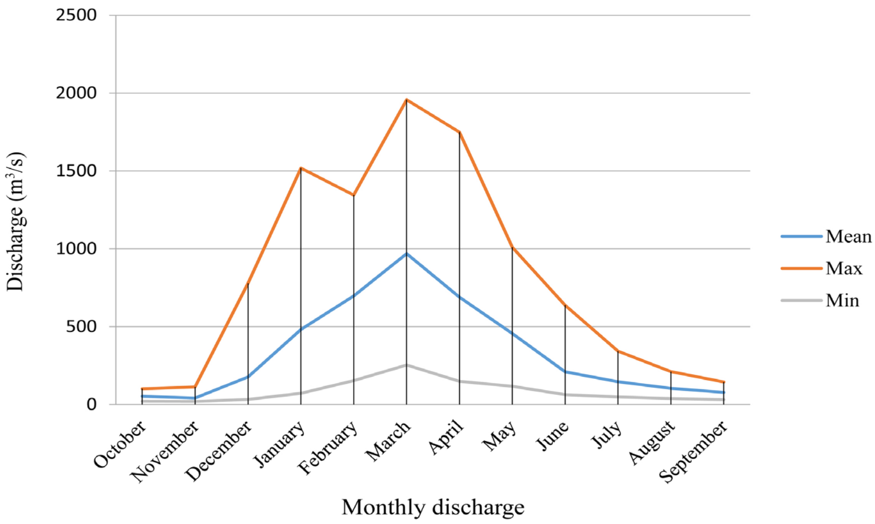

Figure 1. Kafue River hydrograph of unregulated water flows in cubic metres per second at Itetzitetzi before the construction of the dam based on JICA (1992) and ZACPLAN (1994).

were planned in five stages [13] [14], but the Itezhi-Tezhi stage was at stages II and IV [14]. The Itezhi-Tezhi dam development was meant to be a storage reservoir to provide for an additional two generation units of 150 MW each at Kafue Gorge, the upper power station. This meant it would require improving water regulation and thus could only be accomplished by building back up storage at Itezhi-Tezhi. The proposed dam was to be 65 m high with a reservoir of 5700 m^2, and the Kafue Gorge Reservoir was sufficient to ensure a firm output of more than 5000 Giga Watt (GWh) annually, to be completed by 1978.

Comprehensive studies on the environmental and social impact of the proposed impact of the dam developments were conducted by UNFAO [6] [11] [12]. These studies spelt out concerns of dams particularly the Itezhi-Tezhi dam as its effects would be considerable on the Kafue flats because of the reduced environmental water flows on the flood plain. The general predictions indicated not only reduction of environmental flows, but that the introduction of regulated water flows would have serious implications on fisheries and wildlife as well as livestock grazing [6] [11] [12]. Aware of the potential effects of Itezhi-Tezhi dam on the Kafue Flats, this study's main objective was to evaluate rangeland condition and rangeland utilization by wildlife and cattle in Blue Lagoon National Park and the north bank portion of the Kafue Flats Game Management Area. This was intended to establish baseline data for future research and monitoring of the changes in wetland health and rangeland condition as might be attributed to disturbances of Itezhi-Tezhi dam development.

2. Materials and Methods

2.1. Description of the Study Area

2.1.1. Location

The Kafue Flats are located in Southern Zambia at coordinates 15˚20'E - 15˚55'E:

5'26"28˚E, in the mid Kafue River basin (**Figure 2**). They cover an area of approximately 6500 km² of flood plain grassland from Itezhi-Tezhi dam to the Kafue Gorge, and nearly half of the area is in the north bank [1]. The Kafue Flats have been well described and documented [1] [13] as seemingly owing their origin to a buried lake, but this wetland is generally intersected by the meandering Kafue River and its variable relief presenting a complex pattern of lagoons, ox-bow lakes, abandoned river channels, marshes and levees.

2.1.2. Climate

There are three recognized seasons; 1) wet rainy season extending from November to March, 2) cool dry season from April to August, and 3) hot and dry season

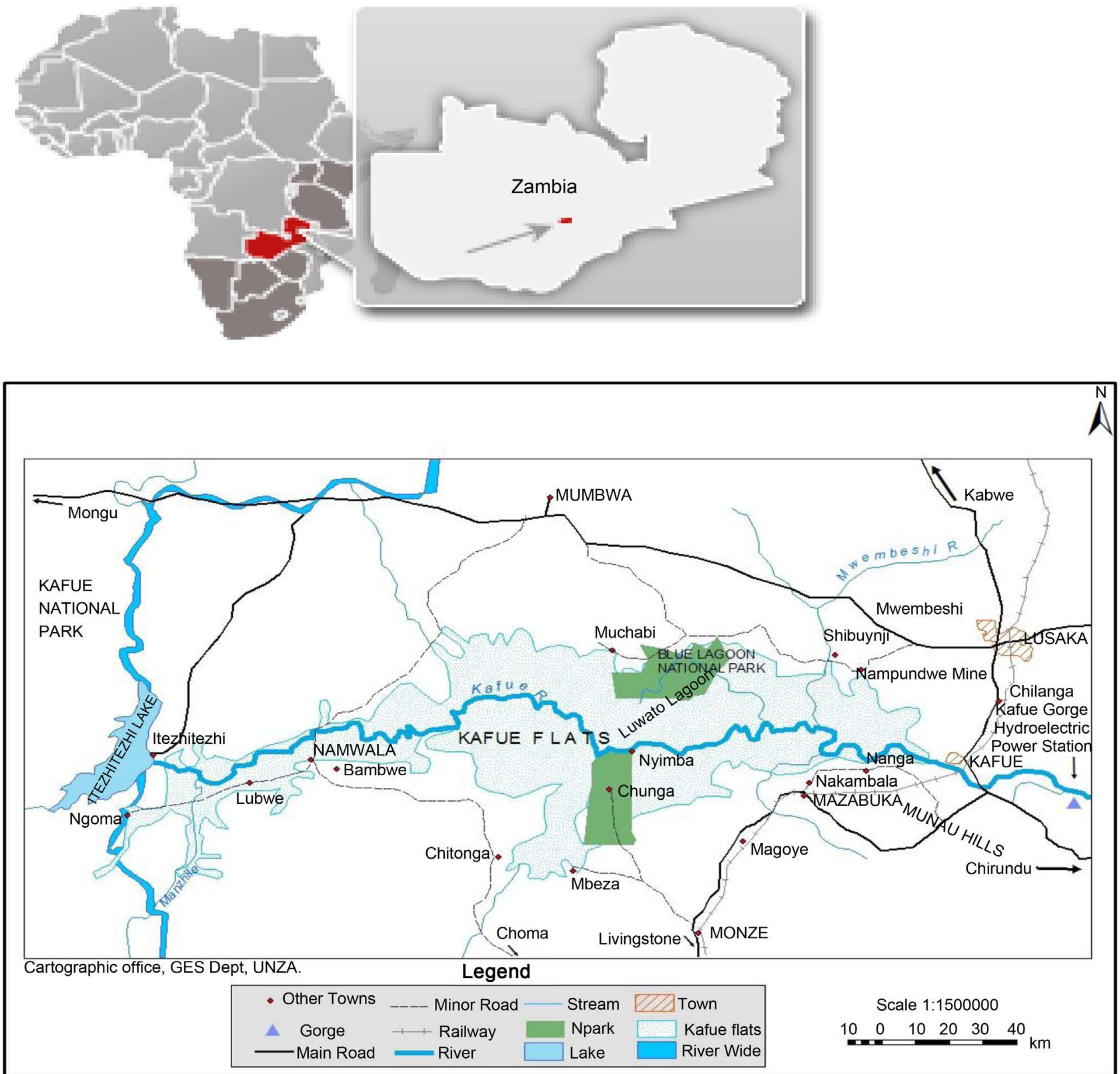

Figure 2. The location of the Kafue Flats, Zambia.

from September to October/November [12] [14]. Temperatures are quite variable with mean temperatures being 20.6˚C, while maximum temperatures may rise to 39˚C. The Kafue Flats wetland is located in the low rainfall Agro-ecological region which receives less than 800 mm of rain per year. Data source of records show that the area's mean annual rainfall is 535 mm at Itezhi-tezhi, but the lowest rainfall recorded was 214 mm in the 1978-1979 rainy season, and the highest was 1184 mm in the 1975-1976 season.

2.1.3. Drainage and Hydrology

The topography and hydrology of the Kafue River and the Kafue Flats wetland have been well documented [11] [12] [15] [16] [17]. The Kafue River extends to a total length of approximately 1577 km, rising from the North-western and Copperbelt provinces of Zambia near the border with the Democratic Republic of Congo [14]. It has a total catchment area of 154,000 km^2, which is nearly one fifth of total area of Zambia [14]. Water that feeds the Kafue Flats is a combined contribution mainly of the rainfall in the Kafue flats, inflows from the tributaries within the sub catchment and the spillover from the Kafue River [6], but much of the water import comes from the upper catchment where rainfall is fairly high and where there are a large number of tributaries [14]. Previous records show the Kafue water maximum annual yield to be approximately 9904 m^3 and as shown in **Figure 1** and **Figure 3**, the mean annual yield was estimated at 4096.56 m^3 before the construction of the dam [14] [18]. The direct contribution from the 45,526 km^2 sub-catchment of the Kafue Flats is estimated at 314 m^3 per second.

2.1.4. Vegetation

Detailed accounts of the vegetation types of Zambia are well documented [19] [20] [21] [22], and similarly wetland grasslands have been well studied in this region [20] [21] [22]. A fairly comprehensive vegetation of the Kafue Flats was

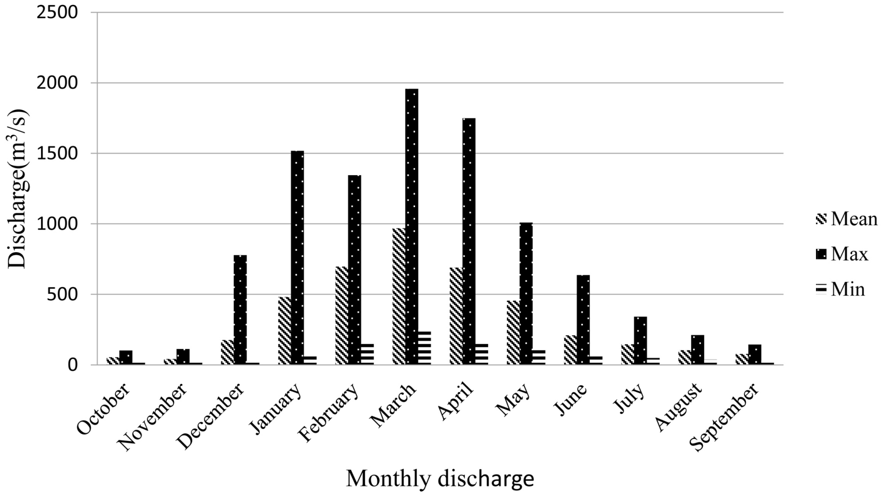

Figure 3. Kafue River annual monthly discharge for a period of over 30 years at Itetzitetzi before the construction of the dam based on ZACPLN and JICA.

also earlier described [13]. Typically, five vegetation types are broadly recognized in Kafue Flats (**Figure 4**).

The vegetation communities are described as follows:

1) *Vossia*-*Oryza* grassland: This covers much of the Kafue Flats north bank and largely consists of *Vossia cuspidata*, *Echinochloa scabra* (Lam) Roem and Schult and *Oryza longistaminata*, *Leersia hexandra*, SW, *Eleocharis fistulosa* schultes and *Cyperus esculentus*. This area is flooded annually.

2) *Setaria*-*Acroceras* grassland: This is transitional between *Vossia*-*Oryza* grassland and the *Termitaria*-wooded grassland. It is flooded annually, and it is characterized by *Setania sphacelata*, *Vetiveria nigritana*, *Acroceras macrum*, Stapf, *Panicum repens* and *Perotis patens.*

3) *Termitaria*-wooded grassland: It includes short and tall *Termitaria.* This vegetation type occupies the area immediately above the high flood level. The area is scattered mainly with short termite mounds, and it is inundated only during high floods and for a short period. Plant species common in this vegetation type include *Panicum maximum*, *Brachiaria regulosa*, *Sporobolus pyramidalis* and *Seteria Sphecelata* while woody plant species are mostly *Acacia polyacantha*, *Piliostigma thonningii*, *Albiza harveyi*, *Albigia anthelmintica*, *Capassa violacea* (*Loncocarpus capassa*), *Acacia sieberana*, *Combretum obvatum* and *Ficus sycomorus.*

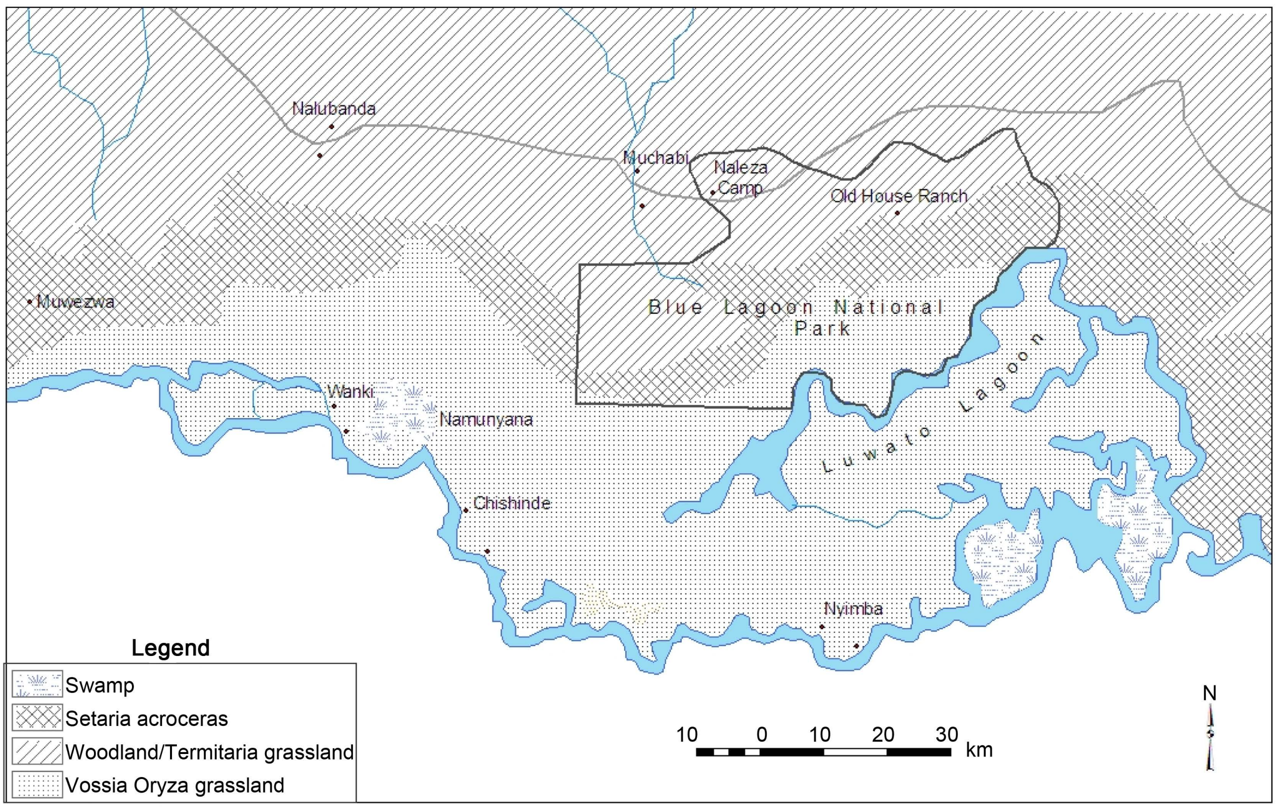

Figure 4. The general vegetation types of the Kafue Flats North Bank before the construction of the Itetzitetzi dam based on Chabwela and Siwela (1986).

4) Levees and Back Swamps: The vegetation on levees is characterized by *Sorghum verticilliflorum*, *Borassus aethiopum* and *Faidherbia albida* and grass species include *Perotis patens* and *Echinochloa pyramidalis.* Vegetation in the Back swamp is generally covered both by emergent and sub-emergent macrophytes. Typical species include *Phragmites mauritianus*, *Aeschynomene fluitans*, *Cyperus papyrus*, *Nymphaea capensis*, *Nyphoides indica*, *Typha capensis* and *Echinochloa stagnina.*

2.1.5. Wildlife and Cattle Grazing Systems

Land use of the Kafue Flats was divided into National Park and Game Management Area, land for irrigated and rain fed agriculture and human settlements respectively (**Figure 5**). Aerial surveys on the Kafue or Brown Lechwe (*Kobus leche kafuensis*) before the impoundment of the Itezhi-Tezhi dam estimated the populations to be in excess of 90,000 [23] however, the largest population occurred in the northern part of the flood plain which by 2005 accounted for 84% [23]. Wildlife species that occurred in limited numbers included the buffalo (*Syncerus caffer*), Eland (*Taurotragus oryx*), Roan Antelope (*Hippotragus equinus*) Kudu (*Tragelaphus stripsciceros*), Sitatunga (*Tragelaphus spekei*), Bush buck (*Tragelaphus scriptus*) and Hippopotamus (*Hippopotamus amphibius*). At the time, cattle population in Kafue Flats was estimated at 310,000 with highest

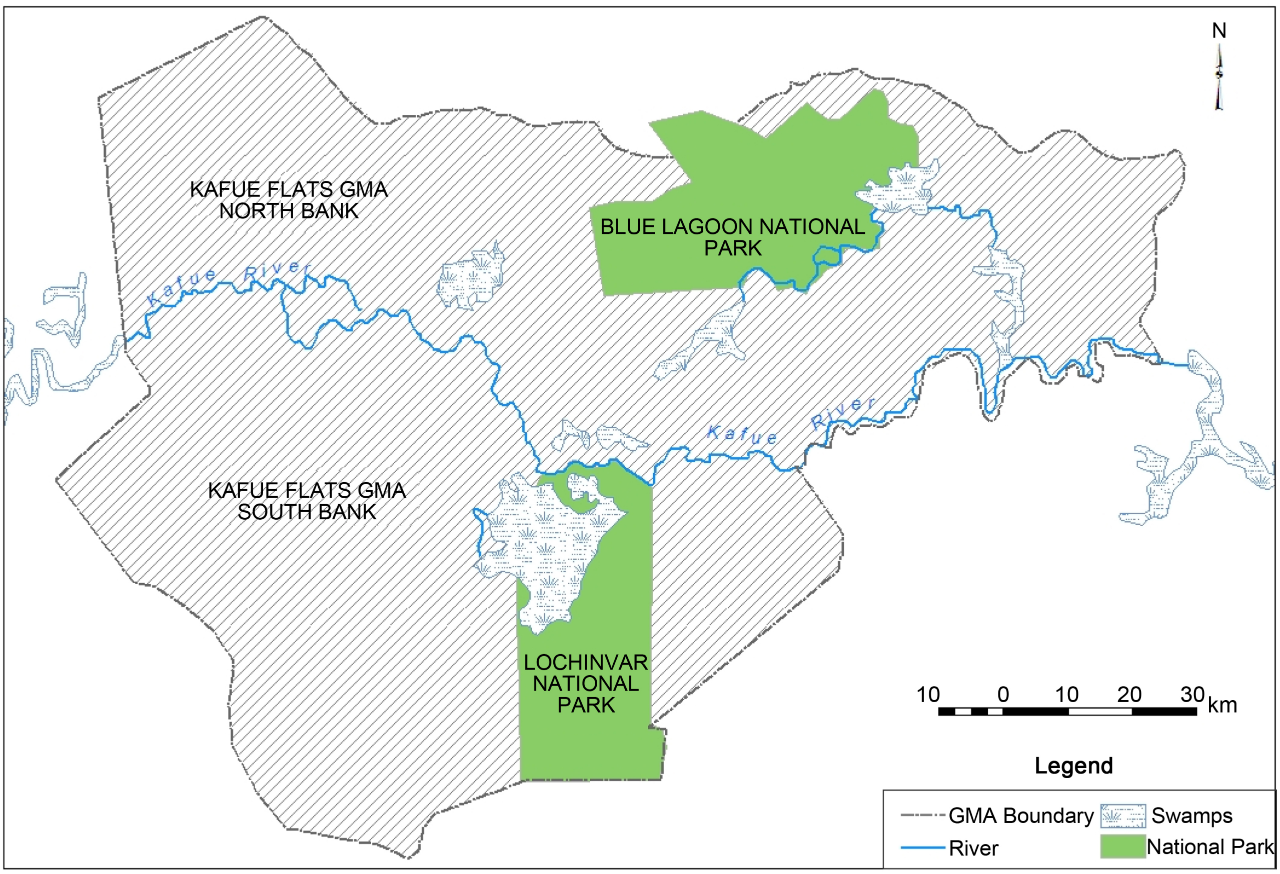

Figure 5. National parks and game management area in Kafue Flats.

numbers being in Monze and Namwala areas of the south bank. Cattle grazing period in the Kafue flats was generally between June and end of November during which the flood levels in the flood plain have receded to near the main river channel (see **Figure 1**), however, wildlife grazing pattern was dictated by flooding levels, but lechwe had complete access to most of the pastures in Kafue Flats while cattle were not allowed in the National Park (**Figure 5**).

2.1.6. Sampling Design and Data Collection

Seven locations in both Blue Lagoon National Park and Kafue flats Game Management Area were selected. We stratified the study area into the following vegetation types: *Termitaria*-Wooded grassland, *Vossia*-*Oryza* grassland and *Seraria*-*Acroceras* grassland.

1) Cover and Frequency Measurements

Seven sampling sites were systematically selected in three vegetation types in both the National Park and Game Management Area during the dry season in the last two weeks of August and first two weeks of September. We used the line-intercept method [24]. Four transects were positioned at 30 m apart in each sample site by using a 50-m steel tape, and 200 quadrats were done at each sample site. Basal cover was measured from the wire loop of 0.5 cm diameter, and if the base of the plant fell inside the loop, a hit of that plant was recorded as grass, forb, herb or shrub, otherwise the hit was recorded as bare ground, rock, or litter (dead plant material or faecal matter). Hits were expressed as a percentage of the total numbers of hits of each transect.

2) Measurements of Rangeland Utilization

In order to determine herbage utilization by wildlife, we constructed five enclosure plots of 5.0 m × 5.0 m cage each of mesh wire and all these plots were systematically located in the National Park. The enclosures were intended to protect the herbage from all forms of grazing and other animal and human activities including fire [25] [26]. Harvesting of herbaceous plants was done at the end of the growing season from end of February to mid-March, by using circular plots of 5.0 cm diameter located at 30 cm apart along a transect line inside and outside the enclosures. A total of 150 samples were collected. Herbage was clipped at the base. Samples were oven dried at 105˚C for 48 hours to remove all moisture and dry weights were recorded.

2.1.7. Data Analysis and Interpretation

Definitions of Rangeland health indicators were based on the approved classification by the Society of Rangeland Management [27] [28] [29]:

1) Bare ground (bare or bare soil): All land surface not covered by vegetation, rock, or litter as used in this document, visible biological crusts and standing dead vegetation are included in cover estimates or measurements and therefore are not bare ground (e.g., mineral soil).

2) Litter (Litter amount): The uppermost layer of organic debris on the soil surface, essentially the freshly fallen or slightly decomposed vegetal material. In

this study, it included animal faecal matter.

3) Grass: Members of the plant family Poaceae (Gramminеae) standing as annual or perennial.

4) Shrub: A plant that has persistent, woody stem(s) and a relatively low growth habit, and that generally produces several basal shoots instead of a single bole. It differs from a tree by its low stature (generally less than 5 meters, or 16 feet) and non-arborescent form.

We defined utilization as the proportion or degree of current year's forage production that is consumed or destroyed by animals (including insects) [29]. In addition, utilization also referred either to a single plant species, a group of species, or the vegetation as a whole. We determined percent utilization as the proportion or degree of the current year's forage production that is consumed or destroyed by animals (including insects) [29] and we calculated utilization as a percentage as follows [29] [30];

$$\text{Percent Utilization} = \frac{\text{Total protected weight} - \text{Total unprotected weight}}{\text{Total protected weight}} \times 100.$$

3. Results

3.1. Rangeland Condition

Results of the rangeland condition in Kafue Flats as assessed in this study are summarized in **Table 1** and **Figure 6**. The results show that short Termitaria vegetarian type recorded very high values of bare ground recorded at Nakenda Critchley (62%), Bowa (57.6%) and Muwezwa (48.45%), but bare ground values were much less in the flood plains at Nakenda Chitanda (38.7%); Shamikobo (36.6%) and Munezya (36.4%) (**Table 1** and **Figure 6**) in each sampled area. Grass basal cover in each sampled area was as follows; Namunyoma (47.8%), Munezya (42.4%) and Shamikobo (24.8) with lowest values being given in short

Table 1. The range condition of three commonly used vegetation types based on the occurrence of five condition indicators as assessed in both the national park and game management area.

Area	Sample Area	Habitat	Bare	Litter	Grass	Forb	Shrub	Total
National Park	Munezya	Flood plain	36.4	21.2	42.4	0.0	0	100
National Park	Nakenda Chitanda	Flood plain	38.7	39.9	8.6	12.9	0	100
National Park	Shamikobo	Flood plain	36.6	37.9	24.8	0.7	0	100
National Park	Bowa	Short Termitaria	57.6	27.2	12.1	3.0	0	100
National Park	Nakenda Critchley	Short Termitaria	62.0	22.0	4.0	12.0	0	100
Game Management Area	Muwezwa	Short Termitaria	48.4	36.4	6.1	9.1	0	100
Game Management Area	Namunyona	Flood plain	18.8	27.5	47.8	4.3	1.4	100

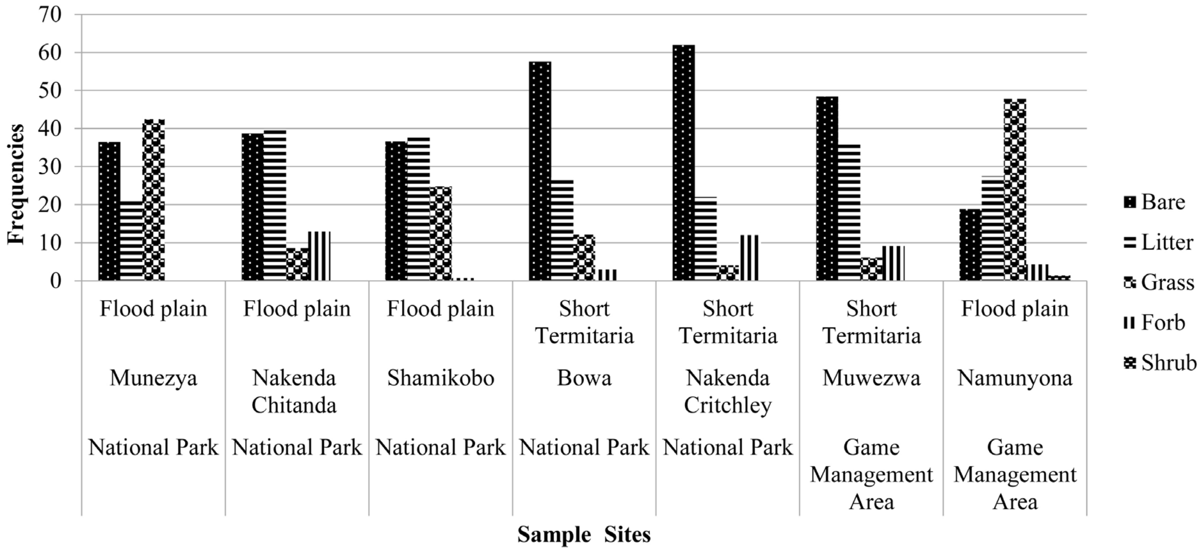

Figure 6. The range condition of three commonly used vegetation types based on the occurrence of five condition indicators as assessed in both the national park and game management area.

Termitaria at Muwezwa (6.1%) and Nakenda Critchley (4.0%). As shown in Table 1 and Figure 6, accumulation of litter appeared to be fairly high in all vegetation types and in both protected areas. However, litter was high at Nakenda Chitanda (39.9%) Shamikobo (37.9%) and Muwezwa (36.4%). Forbs were quite low in nearly all vegetation types although Nakenda Chitanda had (12.9%), and Nakenda Critchley (12.0%) and Muwezwa (9.1%). Shrub cover was only recorded in Namunyona (1.4%).

Table 2 and Figure 7 below show the results of the assessment carried out within the National Park where no cattle were allowed to graze. Based on the five rangeland condition indicators, bare ground was prominent at Nakenda Critchley (62.0%), Bowa (57.6%) and in the Short Termitaria habitat type, while grass basal cover was prominent in the flood plain at Munenzya (42.4%) and Shamikobo (24.8%). Similarly, Litter shared more importance in flood plain at Nakenda Chitanda (39.9% and Shamikobo (24.8%).

Rangeland condition indicators in both the Game Management Area and National Parks for short Terminaria vegetation type are summarized in Table 3. Bare ground was dominant in the Game Management Area in Muwezwa Short Termitaria (48.4%) while grass basal cover was highest in the flood plain at Namunyona (47.8%), but litter was relatively similar with high value in short Termitaria at Muwezwa (36.4%) and 27.5% in the flood plain (Table 3). As shown in Table 3 and Figure 7, Rangeland condition in the short Termitaria habitat was dominated by bare ground at Nakenda Critchley (62%), Bowa (52.6) and Muweza (48.4), while litter was almost evenly distributed. Both grass basal cover and forbs were in very low proportions (Table 3 and Figure 8).

3.2. Rangeland Utilization

The percent herbage standing crop biomass and percent herbage utilization are

Table 2. Range condition of three commonly used vegetation types based on the occurrence of five indicators as assessed within the national park.

AREA	Sample Area	Habitat	Bare	Litter	Grass	Forb	Shrub	Total
National Park	Munezya	Flood plain	36.4	21.2	42.4	0.0	0	100
National Park	Nakenda Chitanda	Flood plain	38.7	39.9	8.6	12.9	0	100
National Park	Shamikobo	Flood plain	36.6	37.9	24.8	0.7	0	100
National Park	Bowa	Short Termitaria	57.6	27.2	12.1	3.0	0	100
National Park	Nakenda Critchley	Short Termitaria	62.0	22.0	4.0	12.0	0	100

Table 3. The range condition short terminaria vegetation type based on the occurrence of five indicators as assessed the national park and game management area.

AREA	Sample Area	Habitat	Bare	Litter	Grass	Forb	Shrub
National Park	Bowa	Short Termitaria	57.6	27.2	12.1	3.0	0
National Park	Nakenda Critchley	Short Termitaria	62.0	22.0	4.0	12.0	0
Game Management Area	Muwezwa	Short Termitaria	48.4	36.4	6.1	9.1	0

presented in **Table 4**, **Table 5** and **Figure 9**. While values were relatively similar in percent production, Nakenda Chitanda had the highest value (71.77%) in the flood plain followed by Bowa in the Short Termitaria (65.77%, Munezya in the flood plain (61.90%) and Nakenda Critchley (59.29%). Grazing intensity or utilization of annual herbage by wildlife in both the flood plain and Short Termitaria habitats showed highest proportions in the flood plain at Nakenda Chitanda (43.54%) and Bowa (31.43%) in the Short Termitaria followed by Munezya in the flood plain (23.80%) and Nakenda Critchley (18.58%). Low consumption of herbage was recorded in the flood plain at Shamikobo (6.48%).

4. Discussion

Rangeland condition assessment is a well-established method of determining the health of pastures and the condition of soil and availability of forage for livestock and wildlife in rangelands especially in regions with limited rainfall [25] [27]. However, assessment of rangeland health remains a source of controversy despite years of practical experience and discussion. For the most part, the definition of rangeland health remains an issue of debate as it is viewed as largely qualitative and subjective in many aspects. Under the USDA and NRCS, rangeland

Table 4. Percent herbage standing crop biomass production and percent grazing intensity in each vegetation type.

Sample Area	Vegetation	Enclosure	Enclosure	Grazing intensity
Bowa	Short Termitaria	65.77	34.23	31.43
Munezya	Flood plain	61.90	38.10	23.80
Nakenda Chitanda	Flood plain	71.77	28.23	43.54
Nakenda Critchley	Short Termitaria	59.29	40.71	18.58
Shamikobo	Flood plain	53.24	46.76	6.48

Table 5. Proposed rangeland condition assessment rating score card using six rangeland condition indicators for Kafue Flats in Zambia.

Range condition indicator	76% to 100%	51% to 75%	26% to 50%	0% to 25%
Grass cover	Excellent condition	Good condition	Fair condition	Poor condition
Bare ground	Range is in very poor condition and may not recover	Range is in very poor condition but may recover	Range is at high risk	Range is in good condition and low risk
Litter amount	Range is in very poor condition and may not recover	Range is in poor condition but may recover	Range is at risk but in fair condition	Range in good condition
Forb cover	Very poor condition	Poor condition	Fair condition	Good condition
Shrub cover	Very poor condition	Very poor condition	Very poor condition	Good condition
Rock	Very poor condition	Very poor condition	Very poor condition	Fair condition

heath is defined as the degree to which the integrity of the soils, vegetation, water and air as well as the ecological process of the rangeland ecosystem are balanced and sustained [27] [31]. The use of indicators in rangeland health assessment protocol for evaluation and prediction of condition of a rangeland, has been well documented and much research has been sufficiently devoted to this subject [25] [32]. Nevertheless, limitations exist in selecting indicators, although seventeen (17) indicators are now available and commonly used [27]. These are based on plant community climax of each site. We used five (5) of these indicators in this study, and since rangeland assessment in Zambia is not well known, and in the absence of references for indicators rating, we have suggested an indicator rating system shown in Table 5. This approach entails the use of a single indicator and rated in the community climax rating system.

As revealed in our results, over 50% of the top soil in Termitaria vegetation was exposed. The amount and distribution of bare ground is one of the most

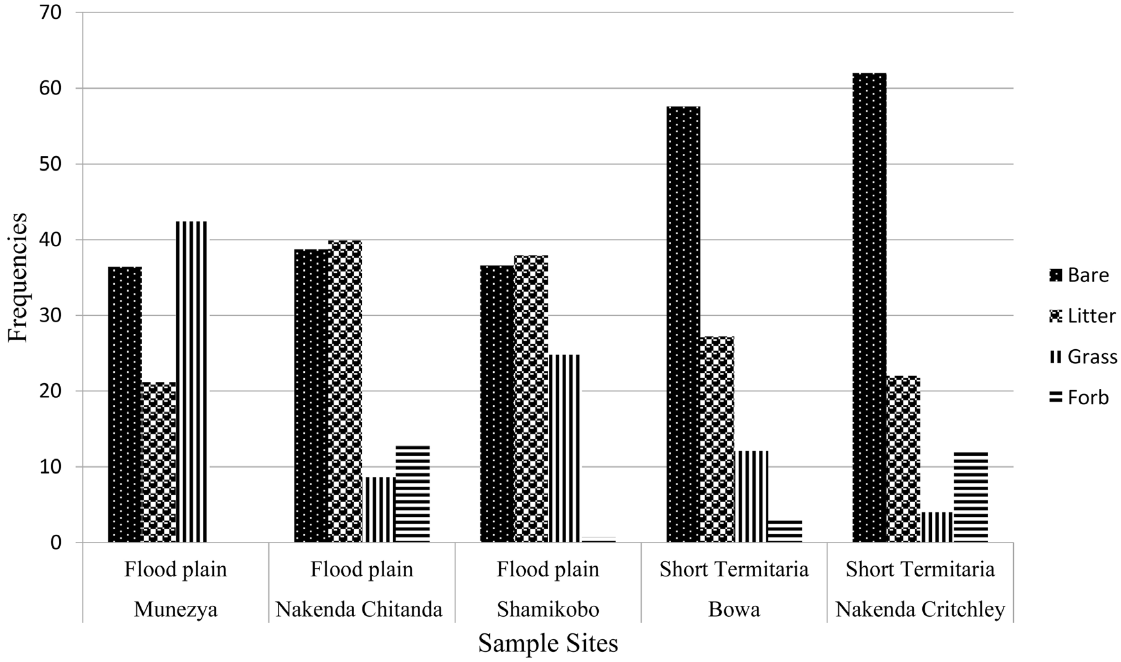

Figure 7. The range condition of three commonly used vegetation types based on the occurrence of five indicators as assessed within the national park.

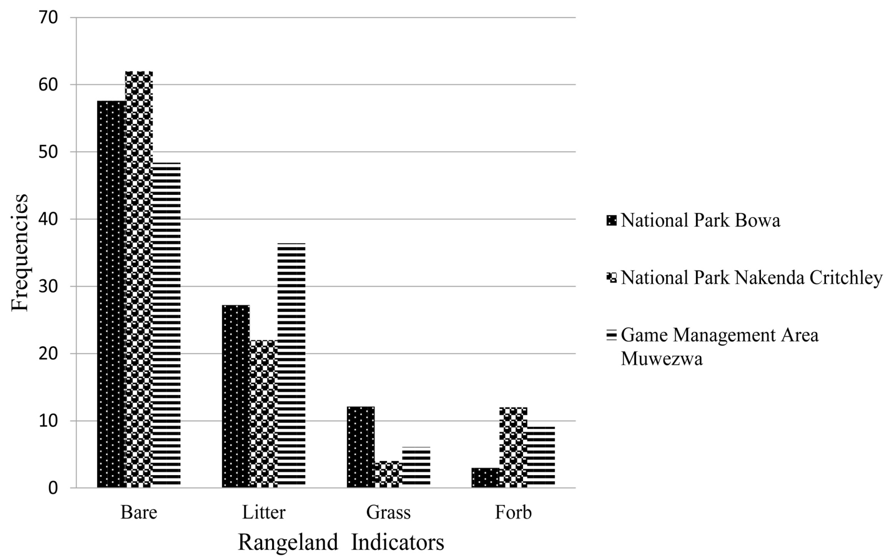

Figure 8. The range condition short termitaria vegetation type based on the occurrence of five indicators as assessed the national park and game management area.

important factors for site stability relevant to the site potential [27] and our results suggest that this vegetation type is largely susceptible to accelerated wind and water erosion. Two factors seem important to have caused this.

Firstly, Termitaria vegetation type does not regularly flood and floods may cover this area only during high flood peaks and in exceptional years, and secondly much grazing occurs in this vegetation type by large herbivores, mainly buffalo and roan antelope. Litter amount is a measure of dead plant material that

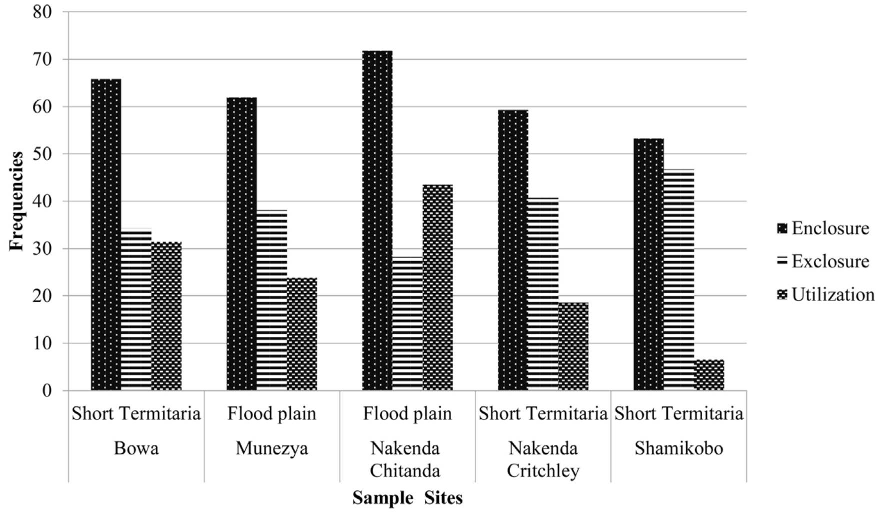

Figure 9. Percent herbage standing crop biomass production and percent grazing intensity in each vegetation type.

covers the soils and most important for decomposing and soil formation and significant for detrital food chain. The wide and even distribution of litter in all vegetation types sampled as shown in our results can only be explained by the lack of movement of litter amount in this low gradient wetland. However, this aspect requires further investigations.

Herbaceous ground cover describes the proportion of soil surface covered by grasses and forbs. These plants are most important for grazing and can either be perennial or annual and the low presence of grass cover in the area can be explained as being due to excessive grazing and that the rangeland is dominated by high presence of annual grasses which being evaders reproduce by seed and live only for one growing season.

With regard to utilization, it was evident that considerable research has been devoted to this [25], which in essence refers to the degree to which animals have consumed the annual usable forage production expressed in percentages [29]. This is important in rangeland management primarily for estimating carrying capacity and stocking rates. As our results have revealed over 40% of the herbage produced per year is consumed by wild herbivores. Whether or not this amount could be accepted as allowable use for wildlife in Kafue Flats rangeland remains largely speculative and inconclusive. We hypothesized that Kafue Flats north bank was overstocked during the period before the construction of the Itezhi-Tezhi dam. While this view may appear conjectural, various studies [33] [34] [35] have provided sufficient discussion on spatial and temporal differences in structures of wetland landscape and the impact of grazing in a rangeland. Flood patterns, plant diversity and food availability are important determinants of the distribution of animals and these require considerable empirical evidence before conclusions can be made.

The significance of these findings however, is that we now know that Kafue Flats wetland was under severe land degradation even before the construction of the Itezhi-Tezhi dam and there are several reasons and speculations which may require discussions and future research.

First, Kafue Flats as a flood plain rangeland assumes the wetland ecological character, and understanding the relationship between grazing and wetland conditions is essential for effective management of a wetland grassland [34] [36]. The data presented in this study are an important description of the Kafue Flats state before the construction of the Itezhi-Tezhi ("Meshi Teshi" as was known) dam, but full interpretation would require discussion of linkages between wetland condition and rangeland condition. Wetland condition as might apply to the Kafue Flats, refers to the health of an ecosystem that primarily supports habitats and viable native animals and plant populations similar to those present before any disturbance [37], and that it is able to return to its pre-existing condition after disturbance, whether natural or human induced and that annual flood pulse, channel forming floods, and infrequent droughts remain major driving factors in flood plain river ecosystem.

Secondly, knowledge of hydrology of the ecosystem and its processes is fundamental and critical for sustainable development, in particular, if dam development and operations are to become part of an integrated management in such sensitive ecosystems that would need environmental protection. Emerging issues on the impact of dams have been widely debated and well documented [9] [10] [38], however the main focus of concern on Kafue flats centred on limited water for the wetland and currently coupled with water regulation and altered environmental flows. The primary question is how much water is required to sustain the ecosystem in Kafue Flats wetlands? Essentially, environmental flows are understood to be the quantity, quality and timing or water flow required to sustain fresh water ecosystems and livelihood and wellbeing that depend on these ecosystem [39]. However, water requirement or ecological flow needs are levels required in a water body for flora and fauna and habitat process present within that water and its margins [40], and aware of our inability to make meaningful evaluation of environmental flow requirement, but in trying to explain and understand the hydrology of the Kafue Flats wetland, we want to propose a number of hypotheses.

We argue that Kafue Flats sub-catchment of 45,526 km^2 had much of its recharge function substantially reduced. This is because the streams within this sub-catchment are seasonal and may flow only for three to four months in a year, and in addition increasing human settlements and excessive deforestation [14] [41] have resulted in recharge function largely being dysfunctional. The relationship between water and forests has well been studied and widely discussed [41] and clearly the vegetation around the Kafue flats is an integral part of the Kafue Flats landscape. As earlier pointed out [42] forests play a significant role in the interaction between ground water of wetland ecosystem and through the recharge function as well as controlling flood flows, water quality and erosion control.

Thirdly, the use of plants to measure water requirements or wetland ecosystem condition has been an established science [39] [43]. Plant species presence and absence, plant vigour, plant diversity and invasiveness are among reliable indicators and tools in evaluating wetland condition. Similarly, plant response to altered and regulated water regimes have also been well investigated [44] [45] [46]. These tools are available for research in Kafue Flats monitoring.

Fourthly, water regime of a flood plain is its characteristic pattern of flooding, drying and water level changes and these water level changes have specific needs to ensure plant species maintenance and regeneration. The flood pulse ecology has emerged as the new science that has adequately provided explanations to such wetland processes. The basic claim of the flood pulse principle is that it refers to a river discharge, the flood, as the major force controlling biota in a river flood plain as the river and the flood conduct exchanges laterally between them [47]. Since then the principle has been well researched and discussed elsewhere [48] [49] [50]. This principle is of great interest to the Kafue Flats because of its implication on the primary production of the rangeland. The reduction on the environmental flows coupled with regulated flood pulsing through timing, duration and magnitude could have serious consequences on the annual life cycles particularly the annual grass species in this wetland [51]. However, this view would require detailed investigations and further substantiation.

Furthermore, although fires are known to be of great significance and a tool extensively used in wetland and rangeland management, their effects are not well understood. Whether or not fires cause changes in the structure of vegetation has been a subject of investigation and debate for a long time [28] [52]. Numerous and well documented studies that have been done on the effects of fires have revealed fires as an integral part of wetland and rangeland landscapes and a management tool [53] [54] [55], and that the effects of fire generally depend upon fire intensity, frequency, and time of the year [56] [57]. Although fires may remove much of the vegetation in a wetland and can change the structure and configuration of a wetland, the removal of organic soils and change in water chemistry may have a negative effect on other organisms. We believe that research on this aspect should be pursued further.

5. Conclusions and Recommendations

5.1. Conclusions

This study provides earlier information of the rangeland condition of the Kafue Flats wetland before the construction of the Itezhi-Tezhi dam. Nevertheless, its significance will depend on detailed subsequent research in the future, in particular, rangeland health and pasture dynamics, environmental and ecological flows, pulse ecology and fire ecology.

For now, it is firmly establishment that rangeland research and monitoring programmes are essential to adaptive management of vegetation dynamics.

These results have also given the picture that the rangeland in Kafue Flats north bank is largely at high risk as demonstrated by high values of bare ground of the soils and that there is high possibility of the rangeland being over grazed since the recorded 40% is unsustainable in flood pulse ecosystems.

5.2. Recommendations

1) We recommend the establishment of regular rangeland and wetland health assessment and monitoring providing for determination of causes of plant succession most likely directing change and for managers to consider repair or restoration.

2) We also propose detailed research on both wetland and rangeland health and provide answers or suggestions in view of disturbances involving multiple factors such as environmental flow, flood pulse and human impact.

References

[1] Chabwela, H.N. (1992) The Ecology and Resource Use of the Bangweulu Basin and the Kafue Flats. In: Jeffery, R.C.V., Chabwela, H.N., Howard, G. and Dugan, P.J., Eds., *Managing the Wetlands of Kafue Flats and Bangweulu Bassin*, IUCN, Gland, 11-24.

[2] Godet, F. and Pfister, S. (2007) Case Study on the Itezhi-tezhi and the Kafue Gorge Dam: The Science and Politics of International Water Management.

[3] Drjver, C.A. and Marchand, M. (1985) Taming the Floods: Environmental Aspects of Plan Development in Africa. CES State University of Leiden, Leiden.

[4] Joyce, C.B., Simpson, M. and Casanova, M. (2016) Future Wet Grasslands: Ecological Implications of Climate Change. *Ecosystem Health and Sustainability*, **2**, e01240. https://doi.org/10.1002/ehs2.1240

[5] Gordon, E. and Meentemeyer, R.K. (2006) Effects of Dam Operation and Land Use on Stream Channel Morphology and Riparian Vegetation. *Geomorphology*, **82**, 412-429. http://www.elsevier.com/locate/geomorph https://doi.org/10.1016/j.geomorph.2006.06.001

[6] Cowardin, L.M., Carter, V., Golet, F.C. and LaRoe, E.T. (1979) Classification of Wetlands and Deep-Water Habitats of the United States. U.S. Fish and Wildlife Service, FWS/OBS-79/31, Washington DC.

[7] UNFAO (1968) Wildlife, Fisheries and Livestock Production. Multipurpose Survey of the Kafue River Basin, Zambia. Vol. 5, UNFAO, Rome, 94 p.

[8] McCartney, M.P., Sullivan, C. and Acreman, M.C. (2001) Ecosystem Impacts of Large Dams, Background Paper Nr. 2 Prepared for IUCN/UNEP/WCD. International Union for Conservation of Nature and Natural Resources and the United Nations Environmental Programme.

[9] Richter, B.D., Postel, S., Revenga, C., Scudder, T., Lehner, B. and Churchill, A. (2010) The Downstream Human Consequences of Dams. *Water Alternatives*, **3**, 14-42. http://www.water-alternatives.org

[10] Wildi, W. (2010) Environmental Hazards of Dams and Reservoirs. NEAR Curriculum in Natural Environmental Science. *Terre et Environment*, **88**, 187-197.

[11] UNFAO (1968) Soil Surveys. Multipurpose Survey of the Kafue River Basin, Zambia. Vol. 2, UNFAO, Rome, 309 p.

[12] UNFAO (1968) Climatology and Hydrology Multipurpose Survey of the Kafue River Basin, Zambia. Vol. 3, UNFAO, Rome, 46 p.

[13] Chabwela, H.N. and Siwela, A. (1986) The Vegetative Structure of the Kafue Flats, North Bank, after the Construction of the Dams. In: *England EWRS/AAB Symposium on Aquatic Weeds*, Loughborough University, Loughborough, 61-72.

[14] Ellenbroek, G.A. (1987) Ecology and Productivity of an Africa Wetland System. In: *The Kafue Flats, Zambia*, Dr. W. Junk Publishers, Boston, 266 p. https://doi.org/10.1007/978-94-009-4051-2

[15] Chabwela, H.N. and Mumba, W. (1998) Integrating Water Conservation and Population Strategies on the Kafue Flats. In: de Shebinin, A. and Dompka, V., Eds., *Water & Population Dynamics: Case Studies and Policy Implications*, American Association for Advancement of Science, Washington DC, 25-48.

[16] Hedberg, O. (1971) Kafue River Hydroelectric Power Development Stage II. SWECO, Lusaka.

[17] DHV Consulting Engineers (1979) Kafue Flats Hydrological Studies. Final Report, DHV Consulting Engineers, Amersfoort, 198 p.

[18] ZACPLAN (1994) Water Resources Assessment Study: Appendices. Zambezi River System Action Plan. ZACPRO 6, ELMS/DANIDA.

[19] Trapnell, C.G. (1959) Ecological Results of Woodland Burning Experiments in Northern Rhodesian. *Journal of Ecology*, **47**, 129-168.

[20] Thompson, K. (1985) Emergent Plants of Permanent and Seasonally-Flooded Wetlands. In: Denny, P., Ed., *The Ecology and Management of African Wetland Vegetation. A Botanic Account of African Swamps and Water Bodies*, Dr. W. Junk Publishers, Boston, 1-18.

[21] Gaudet, J.J. (1992) Structure and Function of African Floodplains. *Journal of the East Africa Natural History Society and National Museum*, **82**, 1-32.

[22] Fynn, R.W.S., Murray-Hudson, M., Dhliwayo, M. and Scholte, P. (2015) African Wetlands and Their Seasonal Use by Wild and Domestic Herbivores. *Wetlands Ecology Management*, **23**, 559-581. https://doi.org/10.1007/s11273-015-9430-6

[23] Chomba, C., Nyirenda, V., Shanungu, G., Simukonda, C., Nyirenda, M.A. and Chaka, K. (2015) An Updated Population Status of the Endemic *Kafue lechwe* (*Kobus leche kafuensis*) on the Kafue Flats, Zambia, for the Period 1931-2015 Global. *Journal of Biology, Agriculture, and Health Sciences*, **4**, 154-164.

[24] Cummings, J. and Smith, D. (2000) The Line-Intercept Method: A Tool for Introductory Plant Ecology Laboratories. In: Karcher, S.J., Ed., *Tested Studies for Laboratory Teaching*, Clemson University, Clemson, Vol. 22, 234-246.

[25] Holechek, J.L., de Gomes, H. and Gait, G. (1998) Grazing Surveys: Problems, Experiences, and Ideas. *Rangelands*, **20**, 9-11.

[26] Salo, E.D., Higgins, K.F., Patton, B.D., Bakker, K., Barker, K., William, T., Kreft, B. and Paul, E. (2004) Grazing Intensity Effects on Vegetation, Livestock and Non-Game Birds in North Dakota Mixed-Grass Prairie. *Proceedings of the North American Prairie Conferences*, Madison, 8-12 August 2004, Paper 88. http://digitalcommons.unl.edu/napcproceedings/88

[27] Pellant, M., Shaver, P., Pyke, D.A. and Herrick, J.E. (2005) Interpreting Indicators of Rangeland Health, Version 4. Technical Reference 1734-6, U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, 122 p.

[28] Herrick, J.E., Van Zee, J.W., Havstad, K.M., Burkett, L.M. and Whitford, W.G. (2005) Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems Volume I: Quick Start USDA-ARS Jornada Experimental Range.

[29] Smith, L., Ruyle, G., Maynard, J., Barker, S., Meyer, W., Stewart, D., Coulloudon, B., Williams, S. and Dyess, J. (2005) Principles of Obtaining and Interpreting Utilization Data on Rangelands. College of Agriculture and Life Sciences, Arizona Cooperative Tension, The University of Arizona, Tucson.

[30] Bureau of Land Management. Interagency Technical Reference (1996) Utilization Studies and Residual Measurements. Technical Reference 1734-3 Copies Available from Bureau of Land Management National Business Center, Denver.

[31] Sheley, R.L., James, J.J., Vasquez, E.A. and Svejcar, T.J. (2011) Using Rangeland Health Assessment to Inform Successional Management. *Invasive Plant Science and Management*, **4**, 356-366. https://doi.org/10.1614/IPSM-D-10-00087.1

[32] Mitchell, J.E. (2010) Criteria and Indicators of Sustainable Rangeland Management. University of Wyoming, Laramie, Extension Publication No. SM-56, 227 p.

[33] Krausman, P.R.D., Naugle, D.E., Frisina, M.R., Northrup, R., Bleich, V.C., Block, W.M., Wallace, M.C., Wright, J.D. and Paul, R. (2009) Livestock Grazing, Wildlife Habitat, and Rangeland Values. Society for Range Management.

[34] Morris, K. and Reich, P. (2013) Understanding the Relationship between Livestock Grazing and Wetland Condition. Arthur Rylah Institute for Environmental Research Technical Report Series No. 252, Department of Environment and Primary Industry, Heidelberg, Victoria 253.

[35] USDA (2016) Grazing Management and Soil Health Keys to Better Soil, Plant, Animal, and Financial Health. Natural Resources Conservation Service.

[36] SANBI (2013) Grasslands Ecosystem Guidelines: Landscape Interpretation for Planners and Managers. South African National Biodiversity Institute, Pretoria, 139 p.

[37] Lubinski, K. (1998) Floodplain River Ecology and the Concept of River Ecological Health. Floodplain River Ecology. Ecological Status and Trends of the UMRS Division of Applied River Sciences, USGS Environmental Management Technical Center, Onalaska.

[38] Braatne, J.H., Rood, S.B., Goater, L.A. and Blair, C. (2008) Analyzing the Impacts of Dams on Riparian Ecosystems: A Review of Research Strategies and Their Relevance to the Snake River through Hells Canyon. *Environmental Management*, **41**, 267-281. https://doi.org/10.1007/s00267-007-9048-4

[39] U.S. EPA (2002) Methods for Evaluating Wetland Condition, Using Vegetation to Assess Environmental Conditions in Wetlands. Office of Water, U.S. Environmental Protection Agency, Washington DC, EPA-822-R-02-020.

[40] Acreman, M.C., Farquharson, F.A.K., McCartney, M.P., Sullivan, C., Campbell, K., Hodgson, N., Morton, H.J., Smith, D., Birley, M., Knott, D., Lazenby, J., Wingfield, E.B. and Barbier, E.B. (2000) Managed Flood Releases from Reservoirs: Issues and Guidance. Report to DFID and the World Commission on Dams, Centre for Ecology and Hydrology, Wallingford.

[41] Mumeka, A. (1986) Effect of Deforestation and Subsistence Agriculture on Runoff of the Kafue River Headwaters, Zambia. *Hydrological Sciences Journal*, **31**, 543-554. https://doi.org/10.1080/02626668609491073

[42] Chabwela, H., Chomba, C. and Thole, L. (2017) The Habitat Structure of Lukanga Ramsar Site in Central Zambia: An Understanding of Wetland Ecological Condition. *Open Journal of Ecology*, **7**, 406-432. http://www.scirp.org/journal/oje https://doi.org/10.4236/oje.2017.76029

[43] Faber-Langendoen, D., Rocchio, J., Thomas, S., Kost, M., Hedge, C., Nichols, B., Walz, K., Kittel, G., Menard, S. and Muldavin, E. (2012) Assessment of Wetland Ecosystem Condition across Landscape Regions: A Multi-Metric Approach. Part B.

Ecological Integrity Assessment Protocols for Rapid Field Methods (L2). U.S. Environmental Protection Agency Office of Research and Development, Washington DC, 111 p.

[44] Alldredgea, B. and Moore, G. (2012) Assessment of Riparian Vegetation Sensitivity to River Hydrology Downstream of a Major Texas Dam. *River Research and Applications*, **30**, 230-244.

[45] Allington, D.A. and Winemiller, K.O. (2006) Habitat Affinity, the Seasonal Flood Pulse, and Community Assembly in the Littoral Zone of a Neotropical Floodplain River. *Journal of North American Benthological Society*, **25**, 126-141. https://doi.org/10.1899/0887-3593(2006)25[126:HATSFP]2.0.CO;2

[46] Drinkard, M.K., Kershner, M.W., Romito, A., Nieset, J. and de Szalay, F.A. (2011) Responses of Plants and Invertebrate Assemblages to Water-Level Fluctuation in Headwater Wetlands. *Journal of the North American Benthological Society*, **30**, 981-996.

[47] Junk, W., Bayley, P.B. and Sparks, R.E. (1989) The Flood Pulse Concept in River-Floodplain Systems. *Canadian Journal of Fisheries and Aquatic Sciences*, **106**, 110-127. https://www.researchgate.net/publication/256981220

[48] Zalewski, M. (2006) Flood Pulses and River Ecosystem Robustness. In: Tchiguirinskaia, I., Thein, K.N.N. and Hubert, P., Eds., *Frontiers in Flood Research*, Kovacs Colloquium, UNESCO, Paris, 43.

[49] Rebelo, L.M., Senay, G.B. and McCartney, M.P. (2010) Flood Pulsing in the Sudd Wetland: Analysis of Seasonal Variations in Inundation and Evaporation in South Sudan. *Earth Interactions*, **16**, 1-19. https://doi.org/10.1175/2011EI382.1

[50] Arias, M.E., Cochrane, T.A., Norton, D., Killeen, T.J. and Kho, P. (2013) The Flood Pulse as the Underlying Driver of Vegetation in the Largest Wetland and Fishery of the Mekong Basin. *AMBIO*, **42**, 864-876. https://doi.org/10.1007/s13280-013-0424-4

[51] Benke, A.C., Chaubey, I., Ward, G.M. and Dunn, E.L. (2000) Flood Pulse Dynamics of an Unregulated River Floodplain in the Southeastern U.S. Coastal Plain. *Ecology*, **81**, 2730-2741. https://doi.org/10.1890/0012-9658(2000)081[2730:FPDOAU]2.0.CO;2

[52] Lugo, A.E. (1995) Fire and Wetland Management. In: Cerulean, S.I. and Engstrom, R.T., Eds., *Fire in Wetlands*: *A Management Perspective*, No. 19, Tall Timbers Research Station, Tallahassee, 1-9.

[53] Robertson, M.M. (1997) Prescribed Burning as a Management and Restoration Tool in Wetlands of the Upper Midwest. *Student on Line Journal*, **2**, 1-6.

[54] Mapiye, M., Mwale, N. and Chikumba, N. (2008) Fire as a Rangeland Management Tool in the Savannas of Southern Africa: A Review. *Tropical and Subtropical Agroecosystems*, **8**, 115-124.

[55] Kotze, D.C. (2013) The Effects of Fire on Wetland Structure and Functioning. *African Journal of Aquatic Science*, **38**, 237-247. https://doi.org/10.2989/16085914.2013.828008

[56] Trollope, W.S.W. and Trollope, A.L. (2004) Prescribed Burning in African Grasslands and Savannas for Wildlife Management Arid Lands Newsletter.

[57] Bixby, R.J., Cooper, S., Gresswell, R.E., Clifford, L.E.B., Dahm, N. and Dwire, K.A. (2015) Fire Effects on Aquatic Ecosystems: An Assessment of the Current State of the Science. *Freshwater Science*, **34**, 1340-1350. https://doi.org/10.1086/684073