



# Drainage Basin Anthropisation and Implication on Water Availability in the Mbum Plateau of Cameroon

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**Abstract:** The earth's ever increasing human population have bestowed varied ecological signatures replicated in spatial mutations in drainage basins and watersheds. This is evident in the Mbum Plateau as anthropogenic actions have been impacting water supply basins through land cover changes with grievous impacts on water availability and supply for utilization by the population. The aim of this study is to examine the impact of drainage basin anthropisation on water availability in the Mbum plateau. A correlational research design with mixed qualitative and quantitative research approaches is used to detect the annual rates of drainage basins changes from 1980 to 2021 and analysed at spatiotemporal scales, computed using ArcGIS 10.2. Data was collected from 230 household heads using a semi-structured questionnaire in 13 sampled villages and secondary sources from published and unpublished documents. Descriptive and inferential statistics are used for the analysis. Using the Pearson Correlation to determine the link between drainage basin anthropisation and water availability, results reveal a calculated value of -0.060, signifying a negative relationship between drainage basin anthropisation and water availability. This indicates that there has been a significant decline in water supply availability as anthropogenic activities surges in the highland area. Positive water supply implications are apparent in areas that are forested with severe decline in anthropised and degraded watersheds. The study recommends plausible watershed management options in the phase of increasing anthropogenic activities with the high use of integrated, participatory and conservation approaches in the Mbum highlands.

**Keywords:** Human Activities, Degradation, Land Uses, Water Sources, Watersheds, Mbum Plateau

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## 1. Introduction

The earth's ever increasing human population have bestowed varied signatures on landscapes replicated in spatial mutations on land cover/land use. This is symptomatic on highland ecumenes with problematic ecological traits, serving as watersheds and a source of livelihood to the population [1]. This is replicated in drainage basins and watersheds that have been modified by anthropogenic actions that impact the distribution of water resources at global, regional and local scales [2]. Over the past 50 years, man has transformed natural ecosystems more rapidly and profoundly with increasing space

occupancy in the pursuit for livelihoods opportunities. Drainage basin physiognomies of climate, vegetation, topography, geological and pedological systems are constantly being transformed by human activities. This transformation in highland areas have significantly impacted water resources negatively considering that these areas are major watersheds in the natural ecology in general and to adjacent communities in particular [3]. This is indicative of multiple land use practices like crop cultivation, cattle rearing, settlement dynamics, urbanization, and developments as cities and highways, afforestation and deforestation. Increasing anthropisation has been significantly affecting water resource availability and supply to the populations reliant thereof. This has made

highland drainage basins as symptomatic living spaces to offer rare satisfaction to rural livelihoods based on agriculture in the history of mankind [4]. This is hinge on the fact that human civilizations are dependent on the management of ecological resources which the population finds it difficult to stay aloof. Land use dynamics in drainage basins therefore have a direct link with water availability and scarcity in the terrestrial ecology [5].

More than half of the populations of the developed and developing countries depends daily on water resources from highland drainage basins and watersheds which are confronted by degradation from increasing human population actions and landscape mutations [6, 7]. This is very severe in Sub-Saharan Africa where access to land and fresh water resources are becoming crucial in most peri-urban and urban cores. Increasing human impact on drainage basins means alterations in normal water supply and availability as direct water removal (abstractions) or inputs to streams or catchments within the drainage basin are being mutilated and damaged [8]. This is common mostly in areas with increasing population, agricultural intensification and urbanisation development is concerned with direct removal of the vegetation, altering the hydrological cycle and other water supply systems. This portrays a significant positive relationship between drainage basins land cover and water discharge as anthropisation reduces ground and surface water recharge [9]. These are apparent in declining water quality and quantity which translates into the upsurge of water borne diseases, irregular flow of water, scarcity and a drop in agricultural production and livelihoods dependent on water availability. As the landscapes of drainage basins changes in response to developments, so too does water volume and quality changes. These are basis for watershed planning and management at all levels for sustainable development [10].

Cameroon has numerous drainage basins endowed with abundant fresh water resources both in quantity and quality. Despite these, most communities still suffer from water insecurity due to inappropriate management of drainage basins and water supply. Empirical evidence depicts drainage basin aerial properties to have been experiencing a drop in upland watersheds of volcanic regions between 1970 and 2006 in Cameroon. These spatio-temporal changes resulted in a fall in water yields caused by deforestation for agricultural practices and settlement expansion in forest adjacent areas [11, 12]. This is also seen in the Bamenda Highlands affected by deforestation and poor farming practices on drainage basins. These spatio-temporal changes have disrupted the regular flow of water, necessitating different adaptations response options on watershed management for quality water supply [13]. Based on seasonality, several rivers and lakes have undergone patent reductions in flow rates and surface area. This has been exacerbating spatial water scarcities in the dry season as inappropriate land uses and climate variability surges [14, 15].

In the Mbom Plateau, absence of mapping and zoning practices or land use planning around the catchment areas have bestowed illicit and ill-adapted human activities such as

poor agricultural practices, deforestation, bush fires, and the cultivation of high water consumption tree species such as Eucalyptus. As a result, sustainable drainage basin management and catchment protection are the major ecological stakes in the highland area [16]. Deforestation for agriculture is predominant in the villages of Binka, Binshua, Kungi, Konchep, Kup, Mbot, Mbipgo, Wowo, Ngarum, Taku and Talla as well as the ruralised areas of Nkambe and Ndu towns which are experiencing high encroachment of the population into the forested watersheds. Observed evidence depicts increase use of fertilizers by farmers for market gardening activities resulting in the sedimentation of stream and river valleys, destruction of riparian zones [17]. and the eutrophication of water sources [18].

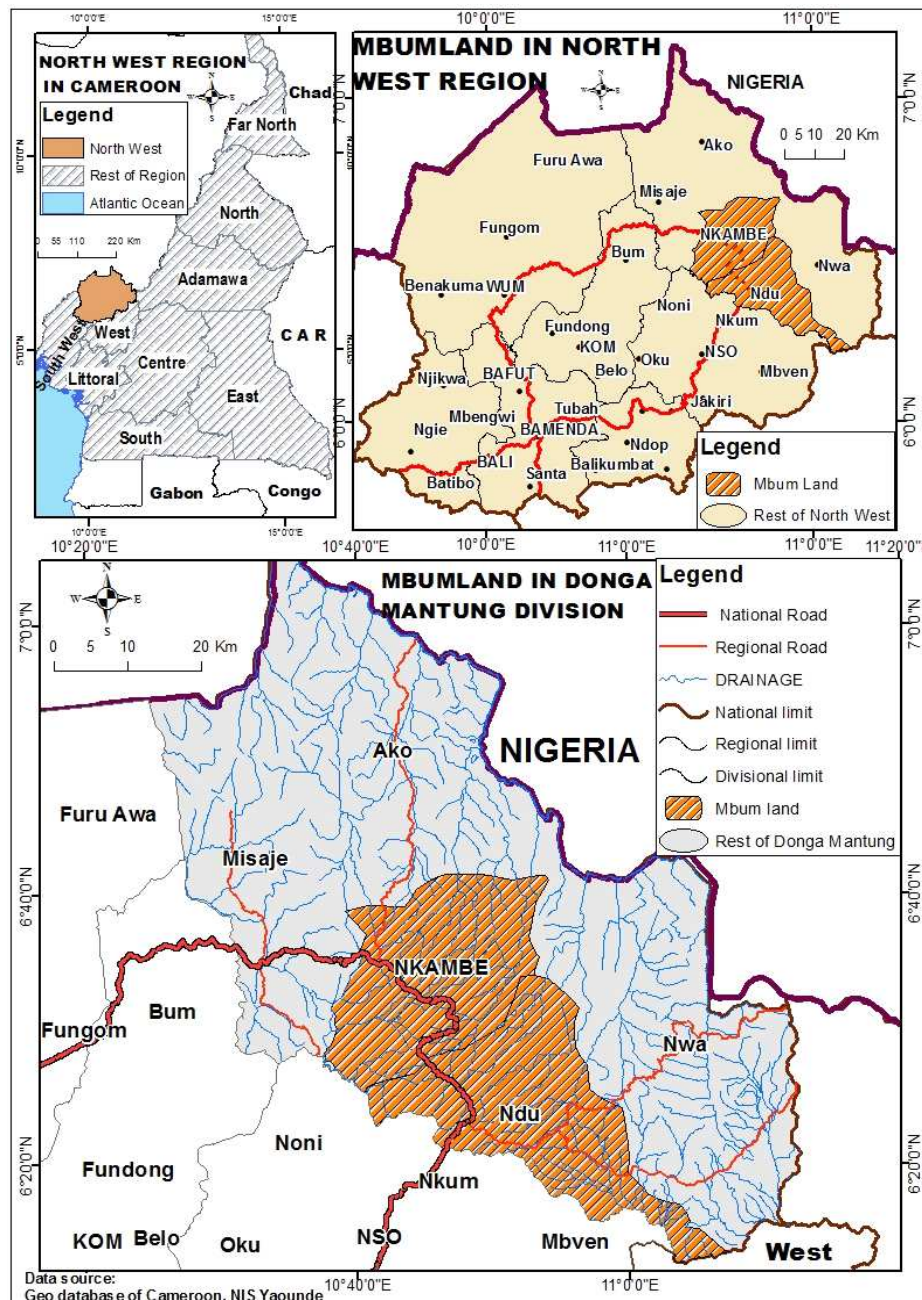
The rationale of this study is therefore to determine the relationship between drainage basin characteristics and water availability in response to increasing anthropogenic activities in the Mbom Plateau. Studies on drainage basin management in the Mbom plateau [16] show that nothing has been done with regards to increasing population and land use intensifications in drainage basins under the influence of multiple management stakeholders' activities and interests. The objective of this study is to examine the impact of drainage basin anthropisation on water availability. This is based on the premise that anthropogenic actions on drainage basins have a negative bearing on water availability in the Mbom Plateau. The period between 1980-2000 corresponds to the era of slower growth in the population with fewer stakeholders' management activities in the drainage basin. This was dominated mostly by indigenous stakeholders. From 2001-2021 there was an upsurge in population and livestock numbers and the involvement of state participation and Civil Society Organizations in the management process, thereby ushering dynamic management signatures in Plateau.

## 2. Materials and Methods

The study was carried out in Mbom Plateau of the Nkambe Highlands of Cameroon located between Latitude 6° 20' and 6° 41' North and Longitude 10°23' and 11°25' East. The area stretches from the Nkambe and Ndu districts in Northernmost part and extends down the Donga plain to the North; the Mbaw and Ndop plains to the East and South; and the Tubah and Kom mountain ranges to the West. Average height on this plateau ranges from 1400m to over 3000masl and dominated by the Njiseng-Binka peak rising to over 2222masl [19] (Figure 1).

The availability and supply of water resources in the Mbom Plateau is determined by a number of drainage basin characteristics. These are reflected in the indicators of climatic and hydrologic characteristics (Temperature, humidity, rainfall, and evaporation), relief, soils, geologic structure and vegetation. The climate determines surface and underground water recharge and consists of the Sudan tropical type characterized by a strong seasonality in which the rainy season runs from mid-March to November and the dry season from December to mid-March. Average rainfall

stands at about 1600mm per annum from June to October and the annual mean temperature is 29°C [16].



Source: Geo Database of Cameroon, NIC Yaoundé (2021).

**Figure 1.** Location of Mbum Plateau in the North west Region of Cameroon.

Ferrallitic soils are predominant and found around the mountainous parts of the Mbum Plateau where bases are migrated out of the soil by rainfall and other weathering processes. This leaves behind a high concentration of sesquioxides which may influence water availability through leaching. It is dominated by peaks with a hilly terrain having slopes ranging from 10% to 50%, thus, making the area susceptible to soil erosion which greatly affects infiltration and ground water recharge [20]. A variety of rock types have made the soil patterns on the plateau complex. The Mbum plateau is a basaltic highland with basement rocks determining slopes of

varied degrees of steepness. The rock type and topography of this plateau have greatly influenced water availability as most of the rocks are permeable, containing aquifers that store water for ground water recharge and discharge. Most of the rivers in the area take their rise from upland watersheds found in the peaks of Ntuu-Njising, Ntuu-Nyui, Mbonjong, Mbim, Kugha, Mahaa, Binshua to mention but these [18]. The highland slopes of the Mbum plateau constitute many watersheds from where catchments have been developed to provide water for the population (Table 1).

Most of these watersheds are concentrated only in areas

with height above sea level being between 700m-1800masl. This is the major reason why the drainage basin in the area has a radial drainage patterns from where rivers from the highlands take their rise and radiate towards the neighbouring lowlands. This study was carried out using a correlational research design with mixed qualitative and quantitative research approaches used to detect the annual rates of drainage basin land use and lands cover changes in the Mbum Plateau from 1980 to 2021 and analysed at spatio-temporal scales. The study was conducted in 13 sampled villages with each ward contributing a representative sample

through the use of a random sampling procedure. A semi-structured questionnaire was used for the research and a total of 230 household heads were interviewed. This was complemented by secondary data obtained from published and unpublished sources as well as laws and administrative texts. Data was analysed using inferential statistics with the Pearson Correlation to determine the relationship between anthropogenic actions on the drainage basin and water availability. Spatial Analysis were computed in ArcGIS software 10.2 for analysis of changes on land use/land cover types for the two successive periodical trends over 42 years.

**Table 1.** Watersheds in the Mbum Plateau.

Watersheds	Localities	Major Rivers and Streams	Communities Supplied
Ntuu-Njising	Binka	Maka, Machu, Nsangri	Binka, Tabenken and Binshua
Ntuu-Nyui	Taku	Langong and Njangnjo	Taku, Ngarum and Mbot
Mbonjong	Mbaa	Mabaa	Mbaa
Mbim	Mbolif	Mbi	Luh, Taku and Lasin
Kugha	Ntumbaw	Ma-Ntumbaw, Fuu and Ma-Nguu	Ntumbaw, Wowo, Njimkang
Mahaa	Nkambe	Shu-Shua	Nkambe town
Binshua	Binshua	Chahmbee	Binshua village

Source: Fieldwork (2021).

### 3. Results and Discussions

#### 3.1. Water Supply Systems in the Mbum Plateau

The entire Mbum plateau area is punctuated by streams and rivers. Most of these streams take their rise from the

mountainous part of the area and generally flowing North-East, East and South East. They are highly exploited in various villages as catchments for the community of the village. Varied water supply potentials are the basis of the availability of water for the population in the highland area (Table 2).

**Table 2.** Water Supply potentials and utilization in the Mbum Plateau.

Catchment area	Nature of water supply and availability	Availability potentials
Njap	Gravity flow	Fishing potentials, banks contain alluvial soils for agriculture
Binshua	Pumped	Drinking
Binka	Gravity flow	Agricultural potentials
Mbot	Irregular flow	Drinking and irrigation water
Bikop	Irregular flow	Irrigation water
Wat	Gravity flow	Fishing and irrigation water
Mbaa	Gravity flow	Sand and drinking
Chup	Gravity flow	Sand and drinking
Bogom	Gravity flow	Sand and irrigation water
Mayo-Binka	Gravity flow	Fishing potentials
Mbukop-Taku	Gravity flow	Irrigation water and drinking
Ntundip	Gravity flow	Irrigation water and drinking
Njitop	Seasonal flow	Irrigation water and drinking

Source: Fieldwork (2022).

Most of these rivers in the Ndu area of the Mbum Plateau take their rise from the Sinna hills in the Ndu highlands and flow through Nkot, Gom-Bom and Ngung. They empty into the River Donga (the largest river in the plateau) at Bitui. The availability in supply and potentials of these rivers are seen in the villages of Yamba, Ntundip, Luh, Ntumbaw where the population depends on these rivers for livelihoods. The main watershed in the Nkambe area of the plateau is the Mount Njising in Binka. Most of the rivers of the area take their rise from this mountain and flow to the neighbouring lowlands. These rivers follow simple river regime, experiencing a period of high waters during the wet season and a period of

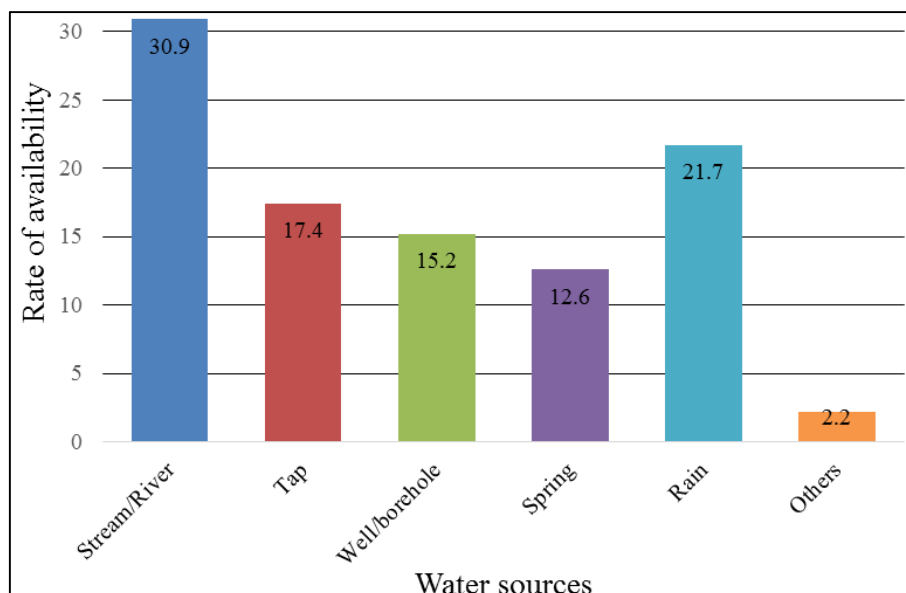
low waters in the dry period.

Some prominent rivers include: Sosifah, Marung, Ndimkfu, in Binshua; Ghongho and Chuachua in Kungi; Nsaring in Mbot; Mabah and Kungo in Binka; Tabenken. Some of the streams draining into it include: Mbingu, Chu, Ntunseh, Manji, Muntung, Maamnyie, Munkie, Marung, Wouh, Kinah, Munkie, Ntumba, Wobawoba, Changeh, Tantanrah, Marung, and Tup'Njah. This is in line with the analysis of Zhou *et al.* and Amawa [7, 16] who explained that the natural geological characteristics of the Nkambe plateau contain multiple streams and determine water flow and seasonal water availability. This study however did not consider the role of ill-adapted

reforestation from the planting of Eucalyptus trees in the plateau that also determine water availability [18]. The main river Chuachua flowing through Nkambe, Mankeng in Wat, Mamki in Nwangri and Kup, Mamki in Nwangri are suffering from the invasion of planted Eucalyptus and habitat which is closing in on the river banks [19, 18].

Water supply sources and water availability in this area are unevenly distributed over the topographic landscape. Some villages on the Mbum plateau are endowed with many water

sources while others barely manage to have a water source. Some of the sources have been harnessed in a bid to provide potable water to their inhabitants from catchments. This is consistent with the findings of Price and Jackson. [9] who posited that ground water recharge is a major determinant of variations in water sources in the Appalachians Highlands. Surface water such as springs, streams, rivers and rain water constitute the major sources (Figure 2). An estimated 82,400 persons depend on these sources for water [15].



Source: Fieldwork (2021)

**Figure 2.** Sources of Water Supply in the Mbum Plateau.

Most of the inhabitants get their water from streams and rivers (30.9%). This is accounted for by the fact that the harnessing of ground water sources for easy portability through pipe borne water is still very limited. Most of the inhabitants prefer getting water directly from the rivers and stream for their usage. This is seen in the study of Li *et al.* and Zhou *et al.* [1, 7] who considered water from rivers to be of good quality. The study explained that river water quality increases in watersheds that have not been affected by anthropogenic activities. Rain water constitutes another important source with at a comparative rate of 21.7% in the Mbum Plateau. According to the population, the rainy season

always lasts from the month of March to November. This 8 months of rainfall with 6 months of regular rainfall from April to October permits them to easily harvest the rain water for domestic and other uses. The only challenge is the dry season where by the water scarcity and crisis are always a major problem to the people. They solicit any other available source on very long distances. This is always more severe in villages with more eucalyptus trees than in areas with the natural ecosystems not anthropized [2]. The different rivers among other sources of water are exploited and used by the population for different purposes (Table 3).

**Table 3.** River exploitation and utilization options in the Mbum Plateau.

Water sources exploited	Usage
Mbi river and rain water	Cultivation of vegetables, tapped and used as portable water at Ntundip village, fishing, domestic purposes, and cattle rearing especially during the dry season
Shuashua river and rain water	Cultivation of vegetables and domestic purposes
Mambaa stream and rain water	Vegetable cultivation, drinking and general domestic purposes
Njiphaa and Yanka streams, wells and pipe borne water	Portable water source for Ndu town and the cultivation of vegetables
Fuu stream and rain water	Drinking, huckleberry cultivation, cattle rearing.
Langong spring and rain water	Drinking, cultivation of vegetables and domestic use.
Mawowo and rain water	Vegetable cultivation, drinking and general domestic purposes.
Wells at Lowland quarter in Ndu town, rain and pipe borne water	General domestic purposes
Wells at new market quarter Nkambe town, rain and pipe borne water	General domestic purposes

Source: [21].



Most of the water sources on the Mbum Plateau are utilized for domestic purposes and agriculture. Water is a domestic necessity and a source of livelihoods to the population. The economy of the area depends on rain-fed agriculture in the rainy season and irrigated farming in the dry season. It is against this background that these are the major ways in which water sources are exploited and utilised. These water sources supply water distributed to different households and institutions but the availability and access to potable water in the villages is still a nightmare. Water crisis is still a serious problem as the catchments constantly fail to adequately supply potable water to the population especially during the dry season. This is blamed on the negative practices in watersheds such as poor farming practices, deforestation and bush burning as well as ill-adapted reforestation. This corroborates the findings of Ndenecho and Nkemason [22] who concluded that upland watersheds that suffer from poor exploitation practices such as deforestation constantly suffer from water scarcity.

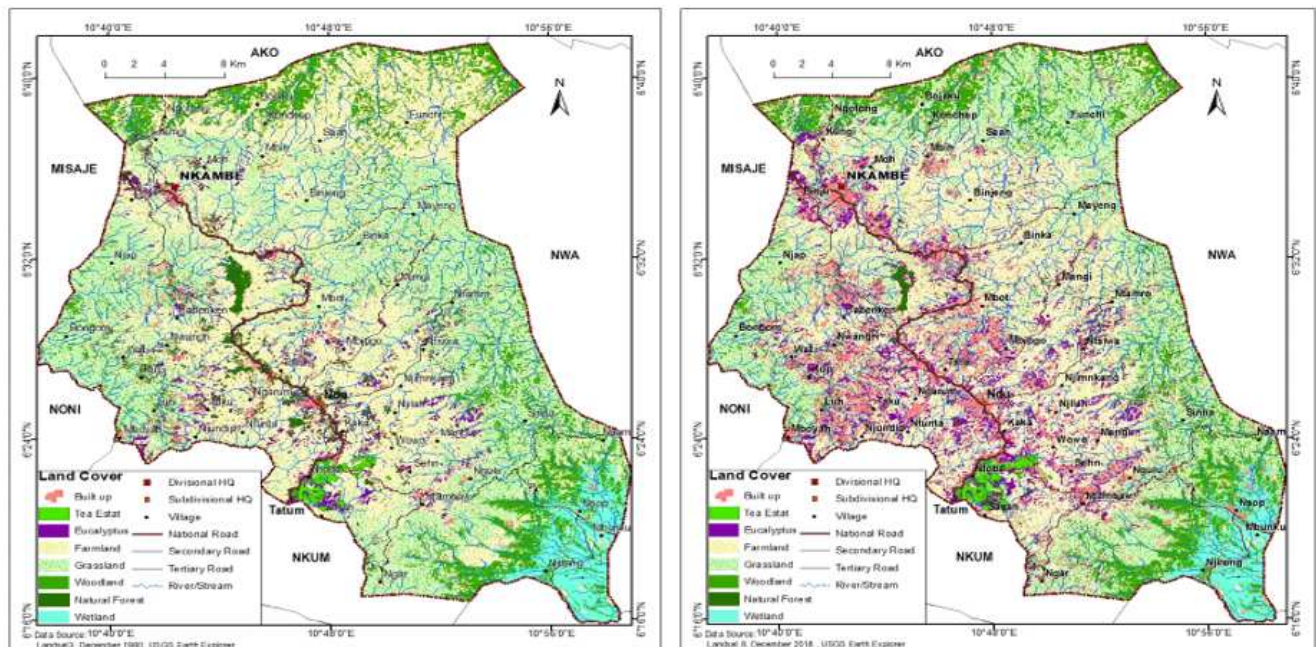
### 3.2. Anthropisation of Drainage Basins in the Mbum Plateau

The population activities on drainage basin exploitation and management has predisposed diverse signatures reflected in land uses/land cover dynamics in Mbum Plateau. The population is involved in diverse socio-economic activities which are carried out for livelihood sustenance. These activities include agriculture, housing construction, eucalyptus cultivation and animal grazing among others. These anthropogenic activities have been reflected in spatio-temporal mutations in land use/land cover from 1980 to 2021. These prominent changes affect the hydrological cycle in diverse ways with a direct bearing on water availability change and water resource utilization [18]. The trends of land cover changes in the different drainage basins are quantified based on the statistics derived from the processing of Landsat images of 1980 and 2021 (Table 4).

**Table 4.** Periodical changes in Land Use and Land Change in Mbum Plateau.

Land use	Area in 1980 (km <sup>2</sup> )	Area in 2021 (km <sup>2</sup> )	Percentage change
Settlement	36.80	78.17	112
Farm land	362.98	492.35	35.6
Grazing land	447.98	317.78	-29
Forest	143.26	114.81	-19
Eucalyptus	43.58	58.93	35
Tea estate	5.98	6.27	0.04
Wetland	64.71	42.82	33.82
Natural wood land	12.96	7.12	-45
Total	1118.25	1118.25	/

Source: Figures calculated from Landsat Image Processing 1980 and 2021.



(Source of raw images: US Geological System website at [www.usgs.com](http://www.usgs.com))

**Figure 3.** Patterns and changes in land cover for 1980 to 2021.

Considering the perceptions of the population, 95% of the people attested to the fact the human activities have been

imposing changes in the drainage basins and the watershed (Figure 3). This according to the communities have been

negatively affecting the availability of water.

Land use/land cover changes in Mbum Plateau from 1980 to 2021 (Table 2 and Figure 2) have been changing with a direct implication on water availability through their interference on the hydrologic cycle. Surface area for settlement increased from 36.80km<sup>2</sup> in 1980 to 78.17 km<sup>2</sup> in 2021 indicating a 112% increase. Farm land also increased from 362.98km<sup>2</sup> to 492.35km<sup>2</sup> revealing a 35.6% increased within 41 years. Eucalyptus increased from 43.58km<sup>2</sup> to 59.93km<sup>2</sup> representing an increase of 35%. Other land uses such as grazing land forest and natural woodland witnessed a decrease of -29%, -19 and -45% respectively. This has negatively affected water availability because a mature Eucalyptus is a water loving tree that consumes about 30liters of water per day [19, 11]. Therefore, an increase in land cover particularly from eucalyptus cover from 43.58km<sup>2</sup> to 58.93km<sup>2</sup> will obviously have a negative effect on water availability. These analyses are consistent with the findings of Valera *et al.* [17] pointing to the fact that increased human pressures on drainage landscapes modify the characteristics which in turn affect water supply timing and quantity.

### 3.3. Impact of Drainage Basin Anthropogenic Mutations on Water Availability

Drainage basin characteristics on the Mbum Plateau have conspicuously been modified by diverse human activities and land uses [2]. This has greatly influenced water availability and supply. This is seen in the dimensions of land use changes that determine surface and ground water recharge as well as supply. A large proportion of the portable water available on the Mbum Plateau comes from forested areas (watersheds). These areas are in the mountainous zones of the plateau, supplying high-quality

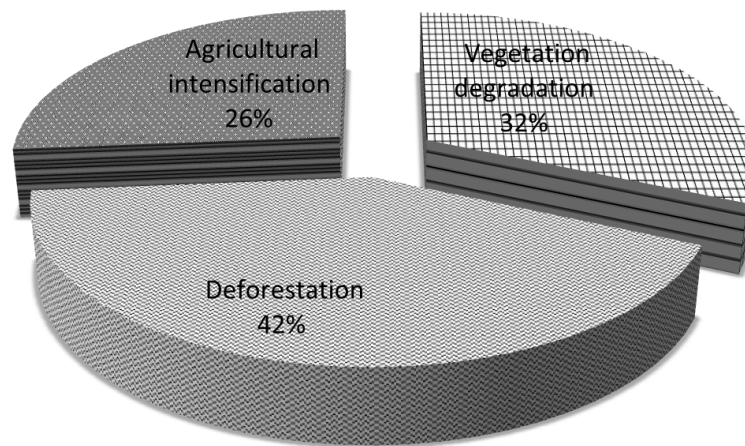
freshwater flowing downslope. The population indicated that vegetation being a major drainage basin characteristic, has an effect on water availability on the Mbum Plateau. Field surveys show that trees increase rainfall (72%), moderate temperature and increases atmospheric humidity (68%), increases the volume of water in streams (79%) and deforestation increasing soil erosion by 55%. This therefore signifies that natural vegetation contributes significantly to water availability in the Mbum Plateau. This is in line with Defra [10] who reported that the mountainous areas of East Africa with forested land covers supply water to 2.5 million residents of the Tanzanian capital, Dar es Salaam. This explains why many water catchments developed in the different forested areas with estimated amount of water supply compared to catchments in areas that have undergone vegetation loss through deforestation in the Mbum Plateau (Table 5).

The largest part of water availability and supply in Mbum Plateau comes from forested (non-anthropized) areas. On the other hand, catchments heavily deforested (degraded) have seasonal and irregular water flow. This explains why most of the villages in the area constantly suffer from problems of portable water availability. Most of it being in the dry season when these catchments experience their lowest water flows. As most of the natural forests have been cleared water scarcity is obvious. Field veracities confirmed the fact that water availability problems are more severe in the Ndu highlands than in Nkambe area. This is due to the nature of the ecological characteristics of these areas whereby the Ndu area have been severely degraded as reflected in the findings of Ndi [19]. Most of the natural forest have been cleared and replaced by Eucalyptus (ill-adapted reforestation). Considering the fact that one mature Eucalyptus tree consumes at least 30litres of water a day, the replacement of natural forest with eucalyptus serious water shortages [16].

**Table 5.** Estimated Annual Water Supply in Forested and anthropized forest Catchments of the Mbum Plateau.

Catchment Areas	Number of sacred wood		Ecological Nature	Estimated annual water capacity (M3)	Nature of water flow
	60years ago	Current number			
Njap	1	1	Forested	148.6	Gravity flow
Binshua	1	0	100% deforested	247.9	Pumped
Binka	1	1	Forested	189.7	Gravity flow
Mbot	1	0	100% deforested	66.8	Irregular
Bikop	1	0	100% deforested	83.3	Irregular
Wat	1	1	Forested	87.7	Gravity flow
Mbaa	1	1	Forested	299.9	Gravity flow
Chup	1	1	Forested	29.2	Gravity flow
Boyon	1	0	Forested	119.2	Gravity flow
Mayo-Binka	1	1	Forested	98.9	Gravity flow
Mbukop-Taku	1	1	Forested	89.3	Gravity flow
Ntundip	1	1	Forested	103	Gravity flow
Njitop	1	0	100% deforested	23.1	Seasonal
Ndu	3	0	100% deforested	99.9	Irregular
Wowo	1	1	Forested	167	Gravity flow
Kaka	1	0	100% deforested	199.8	Irregular
Ntumbaw	3	0	100% deforested	97.2	Seasonal
Mbafung	2	0	100% deforested	20.1	Irregular
Tukop	1	0	100% deforested	19.2	Irregular
Njipku	2	2	Reserved area	301	Regular
Kuya	2	0	100% deforested	22.2	Irregular
Lvu	5	0	100% deforested	23	Seasonal
Nkambe	3	0	100% deforested	25	Irregular

Source: [16]; Landsat Image Processing (2021); Field Survey 2022.



Source: Field work, 2022

**Figure 4.** Dimensions of human impact on water availability.

Since deforestation increases soil erosion, reduces infiltration, the amount of underground water also reduces thus, leading to water insufficiency. The vegetation is dominantly the tree savannah type and remnants of forest are found along river courses and wetlands. In addition to soil degradation, population increase and conflict over limited fertile farmlands as well as meteorological droughts tend to be severe on the plateau because it loses all its waters to neighbouring lowlands. All these have caused the area to have portable water stress. This implies that anthropic activities magnify changes in land cover and land use through vegetation removal. This has contributed to considerable negative impact on hydrology in terms of water quantity as a function of the dimensions of human activities on drainage basin and the incidence on the hydrologic cycle (Figure 4).

Vegetation plays an important role on water availability as it influences surface and underground water recharge.

Vegetation (grassland, natural forest and wet lands) have all witnessed negative changes from 1980 to 2021 as justified by the 42% rate of deforestation in the area (Table 2). This affects water availability in a drainage basin as it reduces water movement through the hydrologic cycle which increases the volume of streams. Vegetation degradation reduces the ability of underground water recharge and reduces the volume of water in the hydrologic cycle. Agricultural activities (26%) have been more responsible for deforestation than any other land use. Different dimension of change in agriculture from 1980 to 2021 have varied implications on water availability (Table 6). This is resonated in the findings of Nfor *et al.* [23] who indicated that environmental degradation resulting from anthropogenic actions in the Nkambe Highlands has increased the incidence of water crisis as the drainage basin characteristics-water availability link has significantly be negatively altered.

**Table 6.** Dimensions of agricultural change and implication in water availability.

Dimension of agriculture	Situation in 1980	Impact on water availability	Situation in 2022	Impact in on water availability
Market gardening	Low population involved	Less water was used for irrigation	Increase in population involved	High use of water for irrigation and stream diversion
Dynamics in farm sizes	Small farm sizes	Little encroachment into watershed	Large farm sizes	Encroachment into watersheds and reduction in underground water recharged
Motive of agriculture	Highly subsistence and small scale production	Little encroachment to watersheds	Highly commercial	Need for large farms and encroachment into watersheds

Source: Field work (2022).

These implications are felt directly on water resource utilization through agricultural activities and interference with the hydrologic cycle. There have been changes in market gardening activities from 1980 to 2022 especially in the dimensions of the farming population involved and water resource utilization through irrigation. In 1980, only a small percentage of the population was involved in market gardening especially the cultivation of huckleberry. This was predominantly carried out in villages of Ngarum, Nguu, Njipnkang in the dry season. As such few streams were diverted by the farmers to be used on these farms in the dry season especially in these villages. Market gardening

became a profitable activity especially in the towns of Ndu and Nkambe considering the decline in the coffee economy in the area [18]. This led to an encroachment of the population into hills watersheds like Kugha and Ntirtuu for commercial agriculture. This activity especially in the dry season needs the diversion of streams from the main channels for use on farms and this reduces the streams sizes and water availability in terms of volume and the downstream flow or discharged is perturbed. Changes in build-up area (urbanization and rurbanization) have been impacting water availability. According to the Nkambe Council Development Plan. [21] the built-up area increased



from 1.2% of the total surface area in 1980 to 2.6% in 2012 and approximately 4% in 2022. Changes in built-up area affected water availability in the following dimensions (Table 7).

Population increases have led to increase in built up area within the period 1980 to 2019. There are many dimensions of built up area that affect water availability according to the population.

**Table 7.** The incidence of urbanization on water availability in Mbum plateau.

Dimension of negative impact on basin hydrology	Rank
Deforestation and catchment degradation	1
Increase erosion due to increase run off and reduction in infiltration and underground water recharged	2
Morphological alteration of streams and extinction of river channels	3
River fragmentation and flow regulation in rivers	4

Source: Field work (2022).

#### 4. Relationship Between Drainage Basin Anthropisation and Water Availability

This study was based on the premise that anthropogenic actions on drainage basins have a negative bearing on water

availability in the Mbum Plateau. Based on the responses of the population. The Pearson Correlation was used based on the fact that the variables are concerned with indicators coming from a normally distributed population measured at an interval scale from the sample population (Table 8).

**Table 8.** Determining the Drainage Basin anthropisation and Water Availability link in the Mbum Plateau.

Correlations		Drainage basin anthropisation	Water availability	Sources of water
Drainage basin anthropisation	Pearson Correlation	1	.000**	-0.060
	Sig. (2-tailed)		.000	.000
	N	230	230	230
Water availability	Pearson Correlation	-0.060	1	.000**
	Sig. (2-tailed)	.000		.000
	N	230	136	136
Sources of water	Pearson Correlation	.000**	-0.060	1
	Sig. (2-tailed)	.000	.000	
	N	230	230	230

Source: Field survey (2022)

\*\* . Correlation is significant at the 0.01 level (2-tailed).

At the significant level of 0.01 for a two tailed test there is a correlation of -0.060 indicating a negative relationship between drainage basin anthropisation and water availability. This means that water supply availability on the Mbum plateau is a function of the mutations in the different drainage basins seen land use/land cover changes. This is an indication of human activities on drainage basins negatively affecting water availability and supply. These deviates from the results of Price and Jackson [9] which showed that there is a positive relationship between vegetation cover and water availability. This was based on the consideration that greater interception and evapotranspiration rates associated with forest cover increases surface water recharge, infiltration ground water recharge and base flow which increases river volumes. The negative relationship in the Mbum Plateau is therefore justified by the fact that as anthropogenic activities increase in terms of negative implications, the lower the efficiency in the supply of water to the population this is seen on reduced and irregular surface and ground water recharge.

#### 5. Conclusion and Recommendation

Drainage basin characteristics in the Mbum Plateau have

been influencing water supply availability through anthropogenic actions and related dynamic changes in land use land cover. As much as 95% of the rural and urban population of the Mbum area attests to the fact that water availability depends on these drainage basin features. The general tendency is a significant increase in vegetation degradation which directly determines surface and ground water recharge. This increasing trend is more apparent in watersheds highly colonized for agriculture and settlement expansion. These mutations have greatly ushered in remarkable negative implications on water availability. It was revealed that climate (70%) and vegetation cover (68%) being the dominant drainage basin characteristics determining water availability [24]. The dominance of climate was through the indicators of rainfall, temperature and seasonality. This is indicative of a negative correlation between drainage basin anthropisation and water availability. This means that water supply availability on the Mbum Plateau have suffered alterations imposed on the watersheds by human activities [6]. Tremendous changes exerted on the drainage basin through land cover changes from 1980 to 2021 denotes negative changes in water supply sources thereby imposing severe stress to water

resources availability for the population of the Highland area. The increasing rate of colonization of watersheds by Eucalyptus plantations and market gardening farms have led to a decline in the quantity of water supply necessitating diverse multi-stakeholder and multi-sectoral approaches to be used in the management of water supply availability for the growing population. It can be established that water supply availability does not only depend on water sources but on changes in drainage basin features resulting from anthropogenic influences. This is reflected on the increasing water scarcity and the dwindling of water resources as anthropisation increases. Water availability on drainage basins therefore have a direct link with drainage basin characteristics and anthropogenic actions on the Mbum plateau in particular and highland regions of the world in general. The study recommends plausible water supply management options in the phase of increasing anthropogenic activities with the high use of integrated, participatory and conservation approaches. This can be an ultimate measure to reversing the increasing trends of watershed degradation and imposing sustainability footprints in highland ecological areas.

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