



Tropical Montane Rain Forest Biodiversity and Environmental Sustainability in Cameroon's North Western Highlands

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Abstract: Biodiversity is our life, the reason why the year 2010 was celebrated as the international year of biodiversity. Biodiversity offers enormous opportunities for environmental sustainability and sustainable development and is the basis for essential environmental services upon which life on earth depends. Thus, its conservation and sustainable use are of critical importance as it is one critical area to achieve sustainable development. In spite of their important ecological functions as habitat for many biodiversities, tropical montane rain forests in Cameroon's North Western Highlands are threatened by over exploitation and rapid deforestation and degradation mainly as a result of human-induced developmental factors resulting to habitat destruction and loss. This study was aimed at examining the roles or potentialities of tropical montane rain forest biodiversity to environmental sustainability in Cameroon's North Western Highlands. This was accomplished through a review of published literature and field work, as well as descriptive analyses of collected data. Our results showed that the Cameroon North Western Highlands tropical montane rain forest is a habitat containing many species which makes it resilient to environmental shocks through catchment/watershed preservation, maintains food chains via energy transfer, stabilize soils from erosion, storms, flood and drought, moderate global temperatures thereby preventing global warming and provides a storehouse of genetic materials that is of enormous importance to human activity such as agriculture and medicine. The study highlights that the forest stand as a nursery and good breeding ground for multiple biological taxa that should be conserved and ensure its rational use for sustainable development through arresting the loss of biodiversity, provide funding through networking with new partners such as NGOs, charities and international companies for conservation and forgone alternatives in the various developing countries and conduction research into setting priorities for the conservation and sustainable utilisation of biodiversity in the region.

Keywords: Tropical montane rain forest, biodiversity, environmental sustainability, sustainable development, Cameroon's North Western Highlands

1. INTRODUCTION

There exists considerable diversity of montane rain forest within the tropics (Vareschi 1980; Kitayama 1995; Bruijnzeel 2001 all cited in Boehmer, 2011). The term 'montane rain forest' is often used interchangeably or as a synonym with 'cloud'; 'mountain' or 'montane' forest, which is the case in our study. Tropical Montane Rain Forest (TMRF) includes all types of rain forests in tropical mountain ranges, from naturally open upper montane rain forests at higher elevations (characterized by stunted growth, twisted trunks, and epiphytic mosses) to dense lower montane rain forests with tall trees and a closed canopy (Whitmore 1998; Foster 2001 all cited in Boehmer, 2011). TMRF are the predominating forest type in zones of maximum cloud condensation in mountain ranges of the tropics, and they frequently or permanently receive additional humidity through horizontal precipitation (direct canopy interception of cloud water, so-called cloud stripping) (Ataroff and Rada, 2000 cited in Boehmer, 2011). TMRFs typically occur between 1,500 m and 3,000m above sea level, usually within an altitude range of about 300m. It is broadly defined as "forests that are frequently covered in cloud or mist" (Hamilton, 1995 cited in Hostettler, 2002). TMRFs are the most significant places in the world as regards biological diversity, as they often display high biodiversity.

The TMRF is recognized as a biodiversity hotspot (Myers *et al.*, 2000 cited in Ledo *et al.*, 2012; Boehmer, 2011), in the likes of the eastern Andean region and the Bamenda Highlands of North Western Cameroon. As a result, TMRFs have high levels of species diversity and endemism (Lewis 1971; Gentry 1995; Kessler 2001 all cited in Boehmer, 2011; Luna-Vega *et al.*, 2001 cited in Ledo *et al.*, 2012; Peterson *et al.*, 1993; Rzedowski, 1993 all cited in Jones *et al.*, 2008). TMRFs have also been identified as one of the most biologically diverse ecosystems in the world (Gentry 1992; Hamilton *et al.*, 1994 all cited in Ledo *et al.*, 2012).

In the forward to their book “The Tropical Mountain Forest: Patterns and Process in a Biodiversity Hotspot”, Gradstein *et al.*, (2008) praised TMRFs as very rich in species, that is why they are generally considered as hotspots of biodiversity. They are also of great ecological importance as sources of water and other ecosystem services for millions of people living in the tropics. TMRFs provide important ecosystem services, such as supply, purification and retention of fresh water, regional water and air quality regulation, carbon sequestration, genetic and pharmaceutical resources, natural hazard and erosion regulation, recreation and ecotourism, etc (Boehmer, 2011). They are recognized as a reservoir of biodiversity and support life by supplying materials and energy, and absorb waste products (Daily, 1997). They also harbour highly diverse faunas with numerous co-existing animal species that are limited to certain habitat types within this zone (Boehmer, 2011).

As Hostettler (2002) highlighted, the important role of TMRF in sustaining the livelihoods of local populations by protecting watersheds and sustaining unpolluted freshwater sources has been generally recognized. For instance, they are important sources of non-timber forest products and are an essential habitat for many endemic and threatened plant and animal species. Furthermore, TMRFs make up an essential habitat for many endemic and threatened plant and animal species and provide a wide range of goods and services for local communities and strong cultural values are attached to them. They provide a unique habitat for species such as tree ferns, bromeliads and many rare and endemic orchids, as well as several important tree species.

TMRF have been identified in 736 sites in 59 countries by the World Conservation Monitoring Centre (WCMC, 1997), Hamilton *et al.* (1993) and Chaverri (2001) all cited in Hostettler, 2002) (Table 1).

Table1. Occurrence of tropical montane forest sites per region with the number of sites protected

Region	Total number of countries	Total number of montane forest	Total number of montane forest sites with protection
Asia	15	230	115
Africa	21	97	38
Mesoamerica/Caribbean	13	218	98
South America	6	160	76
Pacific/Oceania	4	31	n.a
World total	59	736	>327

Source: Aldrich *et al.*, 1997; Chaverri, 2001; Hamilton, 1993 all cited in Hostettler (2002)

Of these, 378 sites are found in Latin America and the Caribbean, mainly in Venezuela, Mexico, Ecuador and Colombia. In South East Asia and the Pacific-Oceania region, 261 sites have been identified, principally in Indonesia and Malaysia. In Africa, 97 sites have been recorded in 21 countries including Cameroon's North Western Highlands. In the 1970s, it was estimated that TMRF covered 500 000 km², a fourth of the montane and submontane forest or 11% of all tropical forests (Hostettler, 2002). A biodiversity project report by BirdLife International showed that 400 of the world's 1,200 threatened bird species are associated with TMRFs. Similarly, the WWF Global 200 Priority Ecoregions for conservation action include 90% of the TMRF sites. For instance, the resplendent quetzal (*Pharomachrus mocinno*) of Central America is now virtually restricted to a few montane forest “islands” on separate mountains. Other species such as the mountain gorilla (*Gorilla gorilla beringei*) in Central/East Africa and the spectacled bear (*Tremarctos ornatus*) in the Andes are specific to montane forest environments. They are flagship species for montane forest conservation and sustain many ecotourism ventures (Aldrich *et al.*, 2001 cited in Hostettler, 2002).

Nevertheless, there have been growing concerns on the issue of biodiversity loss in TMRFs and the need for sustainable management measures is vital to regulate the loss of Tropical Montane Rain

Forest Biodiversity (TMRFB) by governments, international and national NGOs across the globe because of the great links between TMRFB protection and environmental sustainability.

The Food and Agricultural Organization (FAO, 1993 cited in Bussmann, 2002) estimates that TMRFB comprise about 11% of the world's tropical forest resources and suffer an annual deforestation rate of about 1.1%. They generally occur on more humid mountains, and most frequently in Latin America and Southeast Asia, where mountain areas are most widespread, with outposts in tropical Africa (Stadtmiiller, 1987 cited in *Ibid*). In Africa, the TMRFB forms part of the Afrotropical forest type, which is the case with montane forests in the Bamenda Highlands region of North Western Cameroon.

Although they are important to environmental sustainability, TMRFBs are unusual and fragile habitats, being one of the least studied and least understood (Ledo *et al.*, 2012) and the most threatened (Hamilton *et al.*, 1993, Bruijnzeel and Veneklaas 1998 all cited in Jones *et al.*, 2008) terrestrial ecosystem in the world. Perched atop misty mountains, they are one of earth's most imperiled and neglected ecosystems (Peh *et al.*, 2011). They have received only marginal attention in science and society until recently, despite their ecological and economic importance as water catchments and erosion barriers (Bussmann, 2002). They are also considered to be just as highly endangered, due mainly to conversion of forests into pastures or the exploitation of high timber value species (Mosandl *et al.*, 2008 cited in Dislich *et al.*, 2009). Despite the existence of laws governing forest and biodiversity conservation in Cameroon such as Law No. 94/01 of 20 January 1994, there is still a great loss of TMRFB in the Bamenda Highlands of North Western Cameroon. The rich montane forest in this region has been reducing and disappearing rapidly over the years due to several reasons. Human activities such as agriculture, extraction of natural resources and infrastructural development as a result of population increase have been attributed as primary causes of biodiversity loss. The causes of biodiversity loss in Cameroon (the study area included) according to Nkengfack (2011) are many and diversified, including, farming systems (agriculture), shifting cultivation, lumbering, fire, land for settlement due to population growth, demand for fuelwood, mining, cattle ranching, economic crisis, poor governance, weak state institutions, lack of law enforcement, wildlife exploitation, poaching and poverty. Degradation and destruction of habitats due to anthropogenic actions are major causes of global biodiversity declines (Brooks *et al.*, 2006). Valuable forest ecosystems are now increasingly being fragmented, reduced and disturbed by human interventions (Gradstein *et al.*, 2008). They are also continually being reduced by deforestation (Lawton *et al.*, 2001). They are also facing considerable localised threats from clearance and further fragmentation, as a result of population pressure, unsustainable harvesting and poor management practices. External pressures such as mining, road building, air pollution and global warming further exacerbate the problem. Converting TMRFBs to other uses almost invariably affects water quality, and may significantly reduce water availability further downstream (Hostettler, 2002). All these results to a high rate of TMRFB loss, which have been particularly alarming over the past two decades (GFRA, 2010). Apart from human activities, other underlying causes such as weak institutions, poor governance and inadequate law enforcement also contribute substantially to biodiversity loss (EU, 2009). Despite their imperiled state, TMRFBs are vital to environmental sustainability for countries within tropical latitudes and the world over. This study was aimed at examining the roles or potentialities of TMRFBs to environmental sustainability in Cameroon's North Western Highlands.

2. MATERIALS AND METHODS

2.1. Study Area

Our study was conducted in the Bamenda Highlands in the North Western Region of Cameroon (Fig. 1), particularly in the mountain topography area of Ndu Sub-Division. Our study site (Ndu) is located between Latitudes $5^{\circ} 35' 30''$ and $6^{\circ} 40' 20''$ North of the Equator and Longitude $10^{\circ} 42' 30''$ and $10^{\circ} 02' 07''$ East of the Greenwich Meridian (Nganjo *et al.*, 2016). It is bordered to the North by Nwa Sub-Division and South-South West by Nkum Sub-Division in Bui Division. The total surface area of this sub division is 422km². It is one of the five sub divisions or administrative units of the Donga Mantung Division (North West Cameroon).

Ndu Sub-division is dominantly a plateau. It is a dissected plateau with numerous hills and mountains compose of steep slopes on the eastern portion of the area and gently slope on the central part. The

region overlooking the Mbaw plain has steep and high escarpments, which clearly separate the plain from the plateau; thus there is a plateau and a plain. Some of the outstanding hills or mountains include Mbiyeh (2,200m), Kopkah (1,916m), Wansi (1,914m) and Yamnko in Njirong, and Mbandfung (2,074m) in Ndu village. These hills provide a natural condition for dense TMRF and high biodiversity in the area.

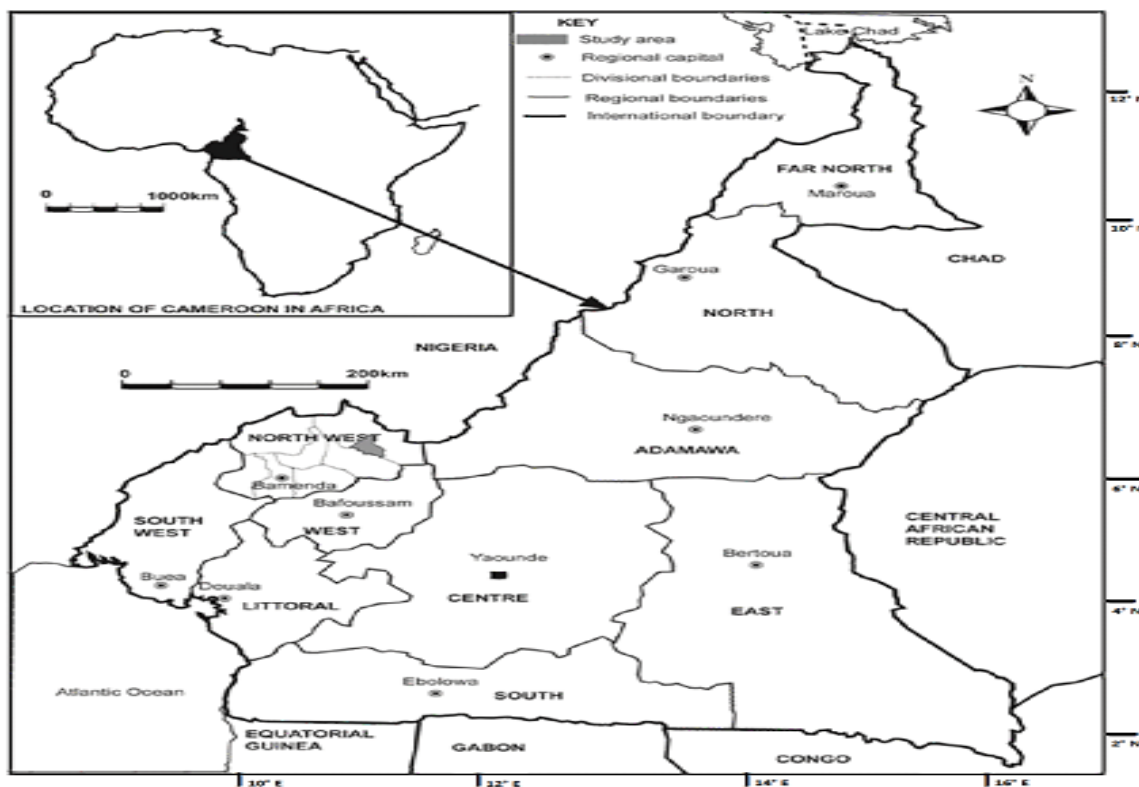


Fig1. Location of Ndu Sub-Division in the North West Region of Cameroon

Source: Adapted from the Administrative map of Cameroon, INC (1992)

2.2. Materials

On the field an inventory of fauna and floristic species (biodiversity) were carried out with the technician in charge of the Mbibi community forest using instruments quadrant, a metric tape, and camera. The three locations in this forest were identified and marked to sample tree and shrub species using the metric tape; fauna especially birds were track through eye observation, and sounds.

2.3. Methods

Complementary research approaches were carried out. These include a review of relevant literature from the analysis published sources including manuals, articles, end of year reports, journals, textbooks, institutional sources like Birdlife international and filed work. Field work was carried out to obtain primary information from the inhabitants in 17 quarters/villages in mountainous areas in Ndu Sud-Division. This was carried out from July 2011 to February 2017 during which data was collected and analyzed. Our primary sources had to do with direct field observations, distribution of questionnaires, and interviews with the various respondents (hunters, fishermen, community forest controllers, crop cultivators, traditional rulers, local council authorities, forest and agricultural technicians, etc). Our first trip to the field was for first hand observation to be familiar with all the 17 quarters/ villages of the area of study. This was from 15th to 27th July, 2011. During this period some initial oral questions were asked to create awareness and first notion of the subject matter and some preliminary notes taken. From the 14th July to 29th August, 2013 the second field work took place. The third research field work took place between 11th to 29th of February 2017, during which questionnaires (Table 2) were administered to the inhabitants.

Table 2. *Distribution of questionnaires according to quarters/villages and sample population*

Quarters/Village	Population	Questionnaires Samples	Questionnaires Analysed
Ndu	20288	30	26
Luh	3718	10	08
Mbipgo	2817	10	09
Ngarum	4581	10	07
Nvulu- Makop	1353	05	05
Njimnkang	3032	10	08
Nseh-Makop	1136	0	0
Sop	6074	10	10
Njirong	4167	10	10
Ntundip	3522	10	08
Sehn	2552	10	08
Sina	1591	05	05
Taku	4434	10	09
Talla	4382	10	08
Wowo	3967	10	10
Ntumbaw	6341	10	10
Njila	1800	00	00
Total	75 755	160	141

During these periods both the open or oral questions and questionnaires were administered as data collecting tools to some inhabitants whose activities are in direct contact with their immediate environment and particularly the forest. These were crop cultivators and livestock breeders particularly cattle rearers, agricultural and forest technicians, council administrators, local authorities both government and traditional, forest exploiters, water management boards technicians and community forest coordinators. The open and oral questions asked directly focused mostly the elders who must not necessarily know how to read or write. They were randomly sampled in different quarters of different villages of Ndu at a distance of about 200 meters to avoid the nearest neighbour influence on the answers. These questionnaires are directed to respondents who are individuals, family members, elders, Fons and Ardors as well as stakeholders of government, council and NGO departments. Direct contact through field work also enabled the snapping of photographs and collection of information on biodiversity types in the forest.

To facilitate movement and work schedule on the field, Ndu Sub-Division was partitioned into three Sections, namely, the North Western Section, made up of Talla, Ngarum, Taku, Ntundip, and Luh; the Center composed of villages like Wowo, Njila, Mbipgo and Njipnkang; and the South Eastern portion of the sub division with villages such as Njirong, Ntumbaw, Sehn, Nvulu-Makop, Nseh-Makop, Sop, and Sina. This then enabled us to established questionnaires for a given sampled population (see Table 2). The collected data was analyzed by help of descriptive statistical techniques.

3. RESULTS AND DISCUSSION

The results show that the high biodiversity of fauna and flora in the TMRF of Ndu contributes to environmental sustainability in diverse ways.

3.1. TMRF as Home of Biodiversity in Ndu

Forest, ecologically is the home for many biodiversities. Biodiversity here refers to the unique species of fauna and flora of the natural forest. The biostacy (condition of biological disruption of equilibrium) of this area is still rich in species variety. The ecological importance here is based mainly on the production of biomass, habitats of wildlife, restoration of landscape, and food chain. These elements are harmonized in these species to the forest environment. The TMRF of Ndu harbours a rich diversity of species. These species are made up of fauna and flora. The fauna species among others include mammal species, bird species, reptiles and butterfly species. The flora types include those that are exploited for medical purposes, food and construction. Some of them include mahogany, iroko, pygeum or *Prunus africana*, white wood and *njangi* (a native tree in Wimbun language).

3.1.1. TMRF in ndu Acts as Home for Mammals, Birds, Reptiles and Insects

As far as mammal species are concern, Comiskey *et al.*, (2003) estimated that about 180 mammal species are found in the Takamanda and adjacent Montane and gallery Forests of the Western Highlands, to which Ndu forms an integral part. According to samples from hunters, mountain gorillas like barboon, chimpanzee, monkeys, deer, antelope, leopard (*Panther pardu*), bush pig, and a large number of rodents are found in this locality of Cameroon but chimpanzee and leopard are all endangered species today. Table 3 below shows some of the mammals and rodents (fauna) found in the TMRF of Ndu Sub-Division.

Table 3. *Some mammals and rodents in the forests of Ndu (Cameroon)*

Vernacular Names	English Names	Scientific Names
Mandu, mbouth	Barbon (Gorilla)	<i>Gorilla gorilla</i>
Bug	Chimpanzee	<i>Pantroglodytes</i>
Nyarr	Buffalo	<i>Syncerus caffer</i>
Mbah	Leopard	<i>Panther pardus</i>
Shoop	African golden cat (bush cat)	<i>Profiles aurata</i>
Nsfuh	Yellow duiker	<i>Cephlophus silviculto</i>
Nginyang	Bush pig	<i>Potomochoerusporcus</i>
Nyanzip	Cane rat	<i>Throyonomys swinderrianus</i>
Kuptrikup	Tortoise	<i>Podica senegalensis</i>

Source: *Birdlife International (2011) and Field Work (2016/2017)*

Table 3 portrays some of the animals of rodents, mammals, and reptiles found in the TMRF of Ndu Sub-Division.

One of the seasonal hunters in the Mbaw Plain testified that there is a herd of eight buffalos and a good number of chimpanzees at Forongai. These giant mammals they said were probably trapped on their way to the great forests of Southern Cameroon by the Mapped dam, constructed to continuously feed and maintain the high level of the waters of river Sanaga for electricity generation. This dam extends to the South Eastern part of Mbaw plain. The trapped mammals then graze and take refuge in some of the forests of this area.

Of the 330 species of fauna reptiles found in Cameroon, some like crocodiles are found in all rivers flowing through the forests of Mbaw Plain (Amawa, 2009). The Ndu region as part of these areas has important species like python and viper (one short and the other long). The short viper is very dangerous because it is too poisonous. There are also chameleon species like the mountain chameleon (montium) and dwarf chameleon (rhampholeon), many in the low land forest of the Mbaw plain.

A good number of geckos, lizards like monitor lizard (yellowish and poisonous), take their shelter beneath decorticating tree barks and roots of epiphytes as well as other crevices. There are equally tortoises (*testudinidae*) and crocodiles (*crocodilidae*) in the rivers of Mirim, No-oh, Marong and Nfi of this plain. One of the fishermen interviewed admitted he had seen crocodiles and hippopotamus on several occasions during his fishing expedition. There are also large number of centipedes and millipedes.

Butterfly, another species found in the natural forests constitutes about one percent of all the named insects including those present in the forests of this study region (Comiskey *et al.*, 2003). Research which could be extended to this area reveals some interesting findings on the genetic of the polymorphic Shallow Tail represented in Cameroon by Papilio Dardanus, uncovered the Rhesus, a sort of medicine in used in human blood. This forest insect also facilitates evolution of plant herbivores interaction. To the human, butterflies and bees are agents of plants and crop pollination. Many have relatively high economic value as they are used for entertainment, decorative acts and collections (Stuart, 1986; and Dongock Nguemo *et al.*, 2012). If well exploited therefore, this insect species could make a potential biological control agent due to the high host specificity it exhibits.

Large colonies of bird species are also seen in their numbers in the TMRF of Ndu. Apart from the fact that they are used as food, these birds propagate plants, thereby multiplying the number of plant

species in the forest of Ndu. The most important of this bird precious to the natives (Wimbum people) is the Turaco bannerman. Plate 1 shows a venerated turaco bannerman in Ndu TMRF.

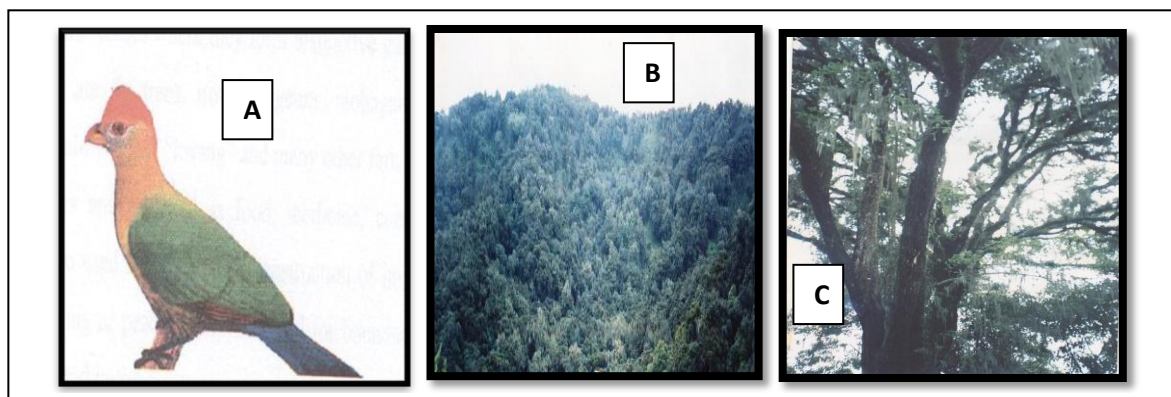


Plate1. Biodiversity of TMRF in Ndu Sud-Division. Photo A: Turaco bannerman in the kopnyu of Taku (Source: Birdlife International Office, Mile One, Bamenda, 2011). Photo B: Natural TMRF in Sop Village (Source: Photo by authors, 2014). Photo C: A *Prunus africana* (pygeum) tree in the forest of Mbakfu, Ndu (Source: Photo by authors, 2014)

Turaco bannerman is of the rare bird species very important to the people of this area. This bird distinctive red feather is worn in the hats of notables and men who have distinguished themselves in the development of their communities. It is found mainly in the Bamenda Highlands forests and that of Ndu. These birds have silky red feathers that are used to decorate men of substance in the land. The feathers of this particular bird are sorts of “medals” reserve purposely for decorating persons who have distinguish themselves in achieving something for the community. Table 4 contains names of some birds common in the TMRF of Ndu Sub-Division.

Table 4. List of some of the birds common in the tropical montane rain forests of Ndu

Vernacular names	English names	Scientific names
Nguh	Bannerman’s turaco	<i>Turaco bannerman</i>
Mfungub	Cameroon olive pigeon	<i>Columba sjostedti</i>
Pfa-ah	Bannerman’s weaver	<i>Ploceus bannerman</i>
Mutong	Cameroon blueheaded bird	<i>Cyanoitra oritis</i>
Pchacher	Little olive back	<i>Nesocharis shelleyi</i>
Mbufufub	Banded wattle eye	<i>Plastysteira laticinta</i>
Nkongsasap	Green longtail	<i>Urolais epichlora</i>
Sornisorni	Bamenda apalis	<i>Apalis Bamenda</i>

Source: Birdlife International Office, Mile One Upstation, Bamenda (2013)

Table 4 presents some of the bird species that the TMRF of Ndu is blessed with. Of this number many are endangered and others threatened like the famous Turaco bannerman. Others include eagle, kites, hawks, vultures, doves of various kinds (blue-spotted wood dove, Red eyed doves), cuckoo, owls, parrots, bee eater, kingfisher, bats, forest swallow, and wood pecker.

3.1.2. TMRF in Ndu Harbours Rich Flora Species

Another ecological importance of these forests is their richness in flora. As far as tree species are concerned, Cameroon is the most biologically rich country known to date on the African continent after the Democratic Republic of Congo. These forests encompass an intricate diverse habitat of moist, TMRF carrying over 54% of the country’s territory and Ndu council area. This diverse habitat harbours over 8260 species of vascular plants, 160 or 1.9% of which are endemic and constitute mostly Cameroon mountains or highland areas (IUCN, 2011).

The mountain forests here, though characterized by low and disjointed canopy, have large number of tree species but largely reduced because large ones are almost exterminated except forest at lower

altitudes like in the Mbaw plain of Sop and Njirong villages. Plate 1 shows a mature pygeum tree in the forest of Mbakfu in Ndu. *Prunus africana* in this area is highly threatened because it is not only exploited for medicinal uses, but also as timber and fuel wood because its charcoal glow and last longer in the fire side.

At the altitudinal limit the forest are restricted to the valley bottoms and water courses where they form distinctive gallery forest. The dominant woody species are fig trees, iroko, pygeum, mahogany, white wood, *njangi*, *wawa*, *tungmalu*, *jobe*, *kwang* and many other fern plants. These plants species are exploited for timber, food, medicine; they are also use as materials for the construction of houses, bridges, and furniture, and as winds breakers. Fig trees and “king or peace plant” are used for boundary demarcation, setting up of new markets and initiating peace.

Originally, fruit trees like lime, avocados, colanuts and oilpalm were harvested from this forest and cross breed or propagated. Like any other forest of the tropics, the forest here is still reservoir of genes for domestication of plant and animal species. Table 5 presents some of the flora species in the TMRF of Ndu.

Table 5. *Some of the flora species in the TMRF of Ndu*

Vernacular names	English names	Scientific name
Rep	Pygeum	<i>Prunus Africana</i>
Mahogany	Mahogany	<i>Khaya ivorensis</i>
Kip	Rattan	<i>Laccosperma secundeflum</i>
Iroko	Iroko	<i>Malicia excelsa</i>
Nkah	Raffia	<i>Raphia</i>
Mnteh	Palm	<i>Elaeis guineensis</i>
Tong	Voacanga	<i>Voacanga</i>
Mangoro	African mango	<i>Irvingia gabonensis</i>
Wip	Bitter leaves/Ndole	<i>Vernonia amygdalina</i>

Source: *Sub-Divisional Delegation of MINFOF, Ndu (2013)*

Table 5 presents some of the flora species in the TMRF of Ndu, with iroko, mahogany, pygeum, voacanga and wawa as some the most important tree species in the forests of this area.

3.2. TMRF in Ndu Restores the Landscape

Given that each natural ecosystem is subjected to a particular ecological condition, its presence in an area play a very important role in restoring the landscape through the following ways.

3.2.1. Natural Forests Preserve Water Catchments

The presence of the TMRF over the years greatly acted as preservation for the watershed, reservoir, aquifers (permeable rock which hold water in large quantity before allow it to pass through), irrigation, and the numerous rivers that exist in this area. The natural forests although highly deforested have for many years played a key role in maintaining these water bodies, which contribute much to the hydrological cycle.

The shades from the forests reduce direct solar rays from heating the soil and so causes it to remain moist thereby helping in the constant flow of some of the rivers. The Montane and gallery forests here are areas where the rivers take their rise before flowing to the valleys and plains. It is thanks to natural forests that Rivers like Marong, Mirim, Mbi and Nooh flow throughout the year, even though they are greatly reduced in volume during dry seasons.

Rivers Marong, Nfi and Mirim are used in the Mbaw plain for irrigational purposes for the cultivation of rice and other food crops like maize and vegetable. The numerous watersheds whose existence is thanks to the natural forest also enable pipe borne water to be connected and used for domestic purposes. Those who have no money for pipe borne water carry their water directly from the streams as well as the numerous springs available in the region. The water from rivers is also used by cattle grazers and fishermen. In fact, water is life in the whole living organisms of Ndu council area.

The only lake in the sub division, which over the years has been greatly reduced in size and volume due to over grazing around it is found in the Ntumbaw village, thanks to the presence of natural montane forest. This lake is locally called *Lip* (lake).

3.2.2. Food Chain Found in the TMRF

Food chain is a linear sequence representing the nutrition of various species from the simplest plant (producers) to the top (carnivores). Plants and animals are usually linked together in a food chain (Waugh, 1995). Plants as primary producers and animals as consumers at various levels are interconnected in their diet and in their role as sources of food in Ndu. Food chain takes place in the process of energy transferred, which is very important in maintaining life on earth. In the forest ecosystem, the first transfer of energy takes place during photosynthesis. That is, trees and flowers convert simple inorganic molecules into organic molecules by the process of photosynthesis. This is when a plant manufactures food by converting sunlight into chemical energy (Enger and Smith, 2000). Herbivorous animals or consumer utilize organic matter or the food energy in plants, which are in turn a source of energy to carnivores. The population of Ndu is not different from any other herbivores or carnivores when they obtain this form of energy transfer as a top carnivore. For example, the forests of this locality grow some type of huckleberry which is harvested by the population as food. Birds too eat these plants. This form of energy intake is called food chain. In fact, most energy intake of the inhabitants is gotten through the eating of plants and animal as food as seen on Figure 2.

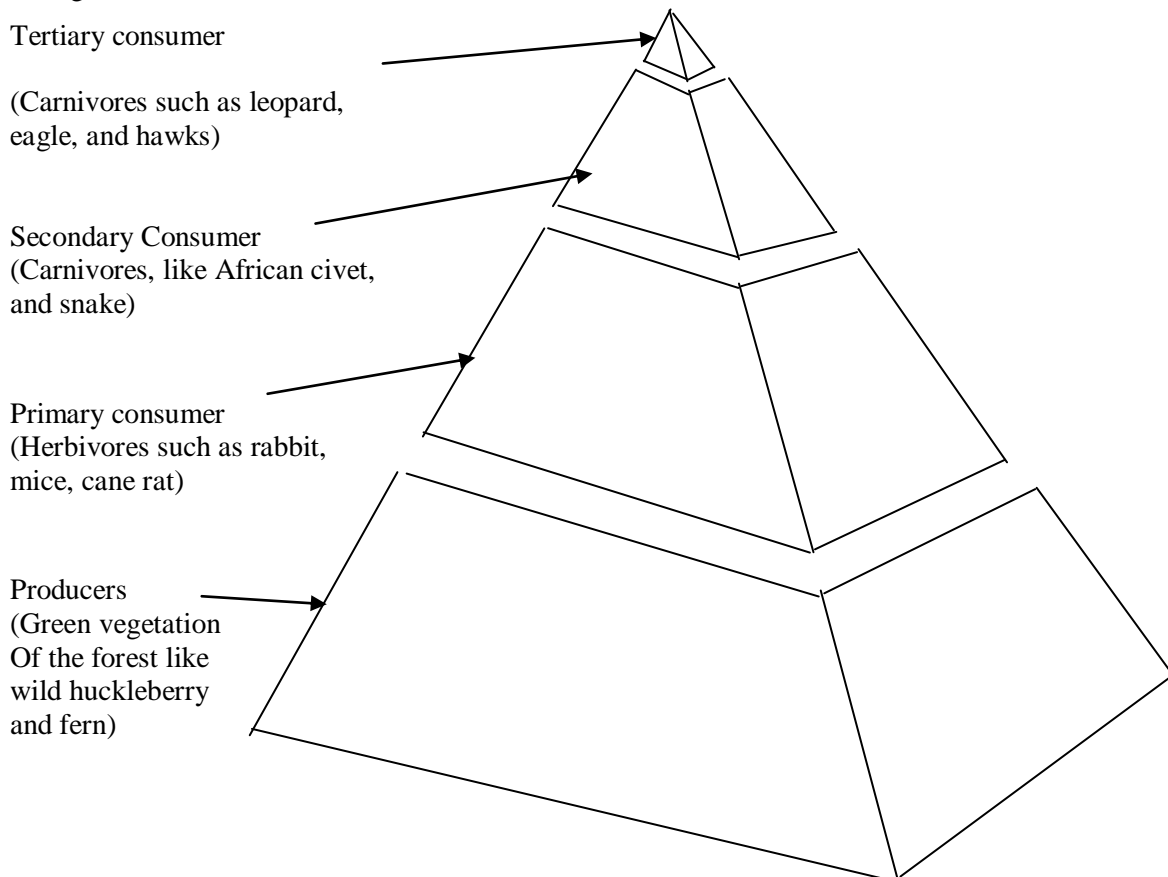


Figure2. Energy transfer through food chain in Ndu

Source: Adopted from Enger and Smith (2000) and modified by authors (2017)

This food chain on Figure 2 as a process of energy transfer in Ndu Sub-Division is seen when herbivores eat local forest lower vegetation like wild huckleberry and fern plants, then carnivores like African civet eats the herbivores which are in tend eaten by the top carnivores like leopard. For example, in the forest of Mbibi are tape worms micro-organisms that decompose the litter, lower vegetation like fern plants on which animals like rabbit feed on, and African civet which feed on rabbit is at the secondary stage of consumer. Thus the organisms of the food chain here, among

others, are fern plants and lower plants as producers, rabbit, as primary consumer and African civet as secondary consumer.

Finally, the TMRFB on the slope of Ngowar hill in Sop (Plate 1) contributes in stabilizing the soil from erosion and protects water catchments even though patches of deforestation are clearly seen. This is exactly the case of other natural montane forest in Ndu. The forests of this area even though highly deforested still seek to protect the ecological diversity from storms, floods, droughts recovery and soil erosion.

4. CONCLUSION

Even though the role of TMRFB to livelihoods of local population is well recognized, that of environmental sustainability is scant and has not been adequately addressed. Notwithstanding their very important roles in environmental sustainability, TMRFB in Ndu have been highly degraded over exploited over the years due to rapid deforestation and degradation as a result of human-induced socio-economic and developmental factors. Given the important roles or functions they play for environmental sustainability, this study champions that they should be conserved and ensure their rational use for environmental sustainability through arresting the loss of biodiversity, provide funding through networking with new partners such as NGOs, charities and international companies for conservation and forgone alternatives in the various developing countries and conduction research into setting priorities for the conservation and sustainable utilization of biodiversity in the region.

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