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ASSESSMENT OF PUBLIC ROAD CONSTRUCTION IMPACT ON PLANT SPECIES DIVERSITY IN THE CASE OF AFROALPINE HABITAT OF BALE MOUNTAINS NATIONAL PARK, SOUTH EASTERN ETHIOPIA

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Abstract

The Afroalpine of Bale Mountain National Park (BMNP) known for its biodiversity hotspot. For this purpose, 10 segments on road stretched 34 km from north to south were selected in Afroalpine section of BMNP. At each of the segments, we established two100-m transects perpendicular to the road center line, within which we sampled five macroplots from an area 400 m^2. In each macro plots, five quadrant microplots 1m × 1m in size were set up for Ground level, Herb level and shrub level plant species survey. Cover plant diversity were measured during the survey. Results indicated that forty eight plant species were recorded within the area of 100 m from the road verge and at ten (10) segments. At the different distances from the road verge and both east and north side of the road could considered. The soil cover, ground cover plant species as Alchimmella pedata and Festuca Abyssinica as well as Helichryssum splindidum from shrub species were higher compared to other species. Menhenick, Shannon and Simpson indices were higher at the distance of 0–20 m than at the distances of 40–60 m and 80–100 m. Smith-Wilson indices decreased when increasing distance to the road. These results are expected to provide critical information for decision makers and protected areas managers for managing plant species and preserving the integrity of biological communitie

This study was conducted to assess the Public Road Construction Impact on Plant Species Diversity on public road crossing the Afroalpine of BMNP

Key Words: *BMNP, Road construction, Biodiversity, plant spices, impact*

Acronyms

BMNP	Bale Mountain National Park
CRGE	Climate Resilience Green Economy
EWCA	Ethiopia wildlife conservation authority
EWCO	Ethiopian Wildlife Conservation organization
EWCP	Ethiopia Wolfe conservation program
EWNHS	Ethiopian Wildlife and Natural History Society
EWNRA	Ethiopia wetlands and Natural Resources Association
IWRM	Integrated Water Resource Management
FAO	Food and Agriculture Organization
GFC	Global Forest Coalition
GPS	Global Position System
GTP	Growth and Transformation Project
HHs	House Holds
IUCN	International Union for Conservation of Nature
MELCA	Movement for Ecological and Community Action
MWU	Madda Walabu University
PSM	Participatory Sketch Mapping
SNNPR	Southern Nations, Nationalities and Peoples Region
UTM	Universal Transvers Mercator
UN	United Nation
UNESCO	United Nation Educational Scientific and Cultural Organization
ICOET	International Conference on Ecology and Transportation
SPSS	Statistical Package for Social Sciences
ICOWET	International Conference on Wildlife Ecology and Transportation

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1. INTRODUCTION

1.1. Background of study

Trombulak and Frissell (2001) coined the term ‘hyper fragmentation’ to describe the multidimensional view of ecological fragmentation and habitat loss that emerges when the consequences of roads or any habitat alteration for terrestrial and aquatic ecosystems are considered simultaneously. Accordingly, roads of all kinds have seven general effects: mortality from road construction, mortality from collision with vehicles, modification of animal behavior, alteration of the physical environment, alteration of the chemical environment, spread of exotics, and increased use of areas by humans. Road construction kills sessile and slow-moving organisms, injures organisms adjacent to a road, and alters physical conditions beneath a road

(Harrison and Wilson 1985).

The contribution of development of infrastructure in general and construction of roads in particular to economic development is globally recognized and countries allocate huge budgets for construction, upgrading and maintenance of roads (Jackson and Scott, 1999). Roads are effective but not efficient modes of transportation due to their ecological impacts. Globally, the positive impact of infrastructure development is quite significant for the overall development of human beings. However, infrastructure development including expansion of roads is not free of adverse impacts for displacing species both rare and abundant species deteriorating ecosystem quality, pollution hydrological and erosion effects (Byron and Helen, 1999). On top of that, the impact of infrastructure development such as construction of roads on biodiversity could be quite worse if it is being applied in areas harboring unique and rich biodiversity (ICOET, 2002). Road networks calls for strategic policy interventions, spatial planning and financing infrastructure that supports road-reserve networks of native vegetation in support of biodiversity conservation and restoration of ecological resources. The harmful effects are proportion to increasing density of the roads due to increasing demand for road use *(*William, 2015).

Tropical and subtropical mountain cloud forests, one of the world's most threatened ecosystems, are being deforested at a rate greater than all other tropical forests (Laurance *et* al., 2009). A survey of participants at a recent international symposium on tropical mountains cloud forests indicated that road construction and the spread of non-native species are common threats to these ecosystems (Gieselman *et a*l, 2012) In other ecosystems it has been shown that roads can have both direct and indirect impacts on surrounding vegetation. They can be major sources of landslides and sediments and can increase forest fragmentation by creating barriers to migration and gene flow (Gieselman, 2013). In addition, the presence of roads can increase the extent of anthropogenic activities in remote areas and provide a conduit for the introduction of exotic flora and fauna. The spread of nonnative grasses and other exotics can become a serious threat to a native forest ecosystem (Laurance *et* al*.,* 2009). The adverse direct impacts of road work on biodiversity are generally easier to avoid or mitigate than the induced impacts, since direct impacts are typically more fully under the control of road construction agencies, contractors, and concessionaires. (Krebs**,** 1985). While direct impacts are normally less extensive than the more severe induced impacts, they can nonetheless be very significant for natural habitats and biodiversity. For example, in the mid-1970s, a new coastal highway connecting Barranquilla and Santa Marta was built atop a dike without adequate drainage works. This interrupted natural water flows and altered the salinity of coastal lagoons, resulting in the death of thousands of hectares of mangrove tree Among (Karani, 2008) other heavy environmental costs, the loss of these mangroves threatens the survival of various rare animals, such as the endangered Sapphire-bellied Hummingbird (*Lepidopyga lilliae*), which only occurs in mangroves along Colombia's Atlantic coast (Collar*et al.,* 1992).

Other studies also indicate that, the majority of edge-related changes in the grassland plant community occurred within 25–30 m of developed edges. In 1–3 ha patches of remnant grassland, the reduction in effective patch size for edge-sensitive species is substantial. Edge effects of this extent would influence the vegetation in at least half of small patches. While protected areas in the south Okanagan are currently much larger, mostly 100 ha (Wikeem and Wikeem, 2004), affected grassland within 28 m of the edges would still equate to at least 10% of the total area. If these edge-affected areas are degraded by pollution or replacement of native flora by weedy exotic species, then the changes in plant community could have cascading effects in other groups of organisms (Gieselman .,*e t al*, 2012).

Bale Mountains National Park is the home of diversity and endemism of flora (Hillman, 1986). However, the interruption of ecological balance resulting from road networks on biodiversity rich areas such as BMNP calls for strategic policy interventions, spatial planning and financing infrastructure that supports road-reserve networks of native vegetation in support of biodiversity conservation and restoration of ecological resources. The harmful effects are proportion to increasing density of the roads due to increasing demand for road use (Karani, 2008). In BMNP mortality is one of the primary factors that affect population size/density of a given species (Krebs**,** 1985).

Having the above reason in mind, the BMNP which is one of world's unique and biodiversity reach area is increasingly threatened by road construction including other infrastructure development which is associated with increasing demand from the people residing around the National Park. Inside the Park there are road networks developed for the public use as well as tourists. But, their impact on biodiversity (both flora and fauna) is little known or non-existing. Therefore, this particular study intends to contribute for the conservation of biodiversity in the study area through detail investigation of the existing impact of roads on the plant diversity of the area.

1.2. Statement of the problem

Environmental effects of roads include spatial and temporal dimensions and biotic and abiotic components (Karani, 2008). In addition effects can be also local (along a road segment) or extensive (related to a large road network). Beside this, direct loss of habitat and ecosystems caused by the footprint of resource roads, another spatial aspect is the "road-effect zone that can radiate out from the sides of the road and/or extend downstream where effects on aquatic conditions may be located distance from the source (Daigle, 2010). The road-effect zone also changes light conditions and disturbs soils and thus creates conditions suitable for invasive plants. Spatial effects of roads vary because species habitat requirements and ecosystem characteristics are diverse. For example, less mobile wildlife species tend to have smaller habitats whereas wide-ranging mammal and bird requirements tend to be spread across macro-environments (Daigle, 2010).

Ecological road network theory suggests that these cumulative effects may be influenced by the design and function of the network structure. Roads affect the abiotic components of landscapes including the hydrology, the mechanics of sediment and debris transport, water and air chemistry, microclimate and levels of noise, wind, and light adjacent to roadsides. The extent and intensity of the effects vary with the position of the road relative to patterns of slope, prevailing winds and surrounding land cover. Roads can increase the energy of stream systems, causing channel erosion and scouring on one hand; on the other hand, cut banks of roads near streams can cause sedimentation to occur. Either way, the presence of roads and related infrastructure has measurable effects on the morphology of stream and river channels which in turn affects the biota (Coffin, 2007).

Moreover Road construction in protected areas has great impact on biological diversity loss and challenges on natural resource conservation (Amanuel, 2015). So, the current status of protected areas should be carefully assessed and identified. In order to develop and use natural resources wisely, full attention should be paid to understanding the dilemmas that they face and identifying ways to conserve them. Basically, to improve all the problems associated with the protected area, it is important to identify factors and rates that threaten and cause of biodiversity lose. BMNP surrounded by five Woredas is being affected by rapid population growth leading to the increasing demand for transportation and construction of the road from Woreda town to different rural villages. According to Bale Mountain National Park context currently there are two main pubblick roads crossing the national park. In the northern part of the park the Asphalt road pass from Shashamane to Bale Robe elongated about 2km cross the Gaysay grassland of Bale Mountain national Park where as there are another rough public road elongated 84 km crsoss and heading from Goba town to Delomana town through Sannate plateau and Haranna forest of the Park (EWCA, 2017). However, there are ongomig road constraction plan by government outside the park through Gaba, Barbare and Dalomana Woreda which could be seen as opportunity in diverting pre constructed road impact connecting Goba to Delomena (unpublished information).

Gieselman *et al*., (20 12), have compared the impacts of dirt and paved road on plant composition. According, paved roads had the strongest influence on grassland composition, and fruit crop sites showed more edge effects than were seen at dirt roads. At paved roads, significant shifts in community structure were evidenced by the high frequency of nonlinear edge responses in plant composition, reduced cryptogam cover, the increased proportion of exotic plant species, and increased bare ground. While dirt roads showed relatively few effects on community composition, but did show a significant increase in bare ground. These results support the idea that the magnitude and frequency of effects at different edge types are predictable by the patch contrast between the developed area and the natural habitat.

In addition, Tesfaye (2016) found out that the wetland ecosystems of BMNP and their surrounding were highly deteriorating because of human induced factors such as road construction. But determining the negative impacts of public road on plant diversity in Park was not investigated so far. Therefore, the three main intentions that lead the researcher to devote on this issue are; one that the negative impacts of existing public road on the plants in BMNP is not well documented due to the little intention given regardless of the park’s uniqueness both in terms of plant and animal diversity.

1.3. Objectives of the study

1.3.1. General Objective.

The general objective of the study was to assess the impacts of public road on the plant species diversity in the case of Sannete plateau in Bale Mountains National Park, Southeastern Ethiopia This leads to plant species damage at the roadside and highly bring pollutions the affects the reproduction of the species.

1.3.2. Specific objectives

The specific objectives of this study were;

- ❖ To assess the diversity of plant species along the main road in Sannete plateau of BMNP
- ❖ To determine the impact of road on the abundance and distribution of invasive plant species These has highly negatively impact the conservation
- ❖ To recommend best and appropriate solutions to minimize the impact of existing and future roads to be constructed in BMNP for policy makers and Park authority the alternative road will be from Goba town through Berbere/Haro town then reach at Deleo Mena Woreda/Mena town.

1.4. Research questions

- What does it look like the diversity of plant species along the main road in Sannete plateau of BMNP?
- What are the plant species which are highly susceptible to road impact problems in Sannete plateau BMNP?
- What is the main invasive plant species established following the road?
- What should be recommended as a best and appropriate solutions to minimize the impact of existing and future roads to be constructed in BMNP for policy makers and Park authority? The alternative road will be from Goba town through Berbere/Haro town then reach at Deleo Mena Woreda/Mena town

1.5. Significance of the study

The Bale Mountains are part a designated International Biodiversity Hotspots and qualify for UNESCO World Heritage Site and Biosphere Reserve Listing. However, the Park has global significant and center for endemic and endangered species, the current reality on ground is challenging and Park is under serious human induced challenge as the public road construction and other infrastructure developments such as electricity ,water installation, Irrigation and etc some viable threats seen in the Park (EWCA, 2017).

The results of this study will help the park authorities to understand the impacts, the roads crossing the Park and communicate the results and concerns with the concerned bodies and apply the appropriate management actions to protect the Park's unique biodiversity. It will also help to develop the mitigation management plans that help to minimize the ecological impacts of road construction of BMNP. In addition, this study will provide valuable information on what needs to be done as a prerequisite for future infrastructure development in and around the Park. Above all the result will also provide information for further study and investigation

1.6. Scope of the study

In this study, indicative impacts of public road on vascular plant in the BMNP will be assessed through practical scientific experiment. Biological diversity challenges at the study area surely require commitment of large resources and time to generate data on each of the key natural resources. In general, the spatial boundary of the study is limited to BMNP at Afro-alpine section only. The data collected for this particular study was only targeted to analyzed and see the impact of the road on plant diversity. Accordingly, the objectives of the study could be clearly seen by the data collected and able to be justified.

1.7. Organization of the paper

This thesis consists of three chapters. The first chapter is aimed at introducing the background information of the study; that covers background information statements of the problem, objectives, research questions and scope of the study. In the second chapter the definition of terms and review of related literature are outlined. In the third chapter research methodologies are included, which cover site description, sample procedure and sample size determination research design and data sources, materials used and methods of data analysis. And the fourth chapters have the Result and discussion as well as recommendation part as it has been seen clearly in this paper.

2. LITERATURE REVIEW

2.1. Degradation of Habitats

The most direct effect of highway development on ecosystems is the destruction of a natural habitat through its “conversion” to a transportation land use or “right-of-way”. In wetland environments, road construction may require filling and draining operations that destroy wetland habitats. In aquatic environments, flow alteration (via damming or channelization) may eliminate habitat. Dredging, filling, and draining required by road construction also destroy aquatic habitat. Millions of animals are killed annually on highways. Road kills may represent a critical mortality factor for large wide-ranging species that can often avoid direct impacts of other development activities (e.g., key deer in Florida) **(**Southerland, 1994).In view of an extensive road system, abundant and rapidly growing vehicular traffic, and a literature indicating that some ecological effects of roads extend outward for >100, it seems likely that the cumulative ecological effect of the road system is considerable (Kollarou, *et al*, 2013).

2.2. Noise and other atmospheric effects

Increased noise levels are one of the most significant environmental effects of highways, and are considered a nuisance to human populations in urban and suburban areas. In the United States, the Federal Highway Act of 1970 mandated the development of standards for noise and noise abatement relative to land use. Noise abatement studies are mandatory elements of the environmental impact assessment of highway construction projects. Mitigation for noise is a substantial part of the budget of any highway construction project and often results in the design and construction of specific noise abatement structures along highways. Despite a several decades-long concern over the impact of highways on ambient noise levels, the effects of noise on populations of wildlife have not been as extensively researched. The Road Ecology Center at the University of California, Davis, recently sponsored a series of lectures in Road Ecology Center at the University of California (2005), to focus attention on the subject of the effects of noise on wildlife populations (2005), and a session of the 2005 International Conference on Ecology and Transportation (ICOET) also focused on this theme (Coffin, 2007).

The density of the road network, the volume of traffic on a roadway or road segment, the road surface, and other engineered features also affect the extent of ecological effects of a road. Many ecological effects of roads have been identified, such as loss and fragmentation of habitat; pollution of air, water, and soil; mortality of animals hit by passing vehicles; and acoustic interference caused by traffic noise. The noise of passing traffic can extend more than 4 km from a road, depending on the volume and speed of traffic and the prevailing weather conditions (Kollarou, *et al.,* 2013).

2.3. The effects of roads on biotic components of ecosystems

Roads are agents of change that have both primary, or direct effects, as well as secondary, or indirect effects on the biota. Roads affect animal and plant populations directly by entirely obliterating the ecosystems in their path. While for some species, the destruction of a small area for a roadbed may not be

Significant, for some species, particularly small animals with high levels of site fidelity, it can be ruinous. Populations of slow-moving animals and those which regularly cross roads suffer in particular from the negative effects of increased mortality due to vehicle collisions. Roads also act as conduits introducing and facilitating the spread of exotic species. The indirect effects of roads include changes or impacts that result from increased contact with humans and human land use activities (Daigle, .2010). Widespread attention continues to be drawn to the ecological effects of roads, especially as the road system continues to expand. Ecological conditions are not only affected by the construction of roads and road appurtenances but also by the traffic and by the increase in road density. Roads affect the abiotic components of landscapes including the hydrology, the mechanics of sediment and debris transport, water and air chemistry, microclimate and levels of noise, wind, and light adjacent to roadsides. Habitat fragmentation due to transport infrastructure is receiving growing concern among ecologists and civil engineers (Kollarou, *et al.,* 2013).

2.4. Road as sources of mortality and barriers to animal movement

In the United States, road kill has surpassed hunting in its effect on vertebrate mortality. (Coffin, 2007). While some species with high road kill rates e.g. House sparrow, Passer domesticus) seem unaffected by the high rate of mortality associated with roads, others are much more affected, such as the Florida panther (Felis concolor coryir), which had an annual road kill mortality rate of 10% of its population before (Spellerberg,1998).In fact road related mortality is the primary source of mortality for all of Florida's ''large, rare and endangered vertebrates,'' including panther, black bear (*Ursus americanus*), key deer (*Odocoileus virginianus clavium*) and American crocodile (*Corocodylus acutus*) (Coffin, 2007).

2.5. Roads as habitat, corridor and conduit

Areas increased invasive alien plants and animals that establish along the colonization corridors provided by roads; in addition, non-native plant species are often sown to stabilize slopes along roads; increased spread of insects and disease; increased fuel emissions (e.g., carbon dioxide) into the airs (Daigle, 2010).

Many exotic plants, which fit into the generalist category, exist disproportionately in roadside corridors. In addition to the non-native plants that are frequently used in roadside landscapes, non-native seeds and propagate are dispersed by vehicles and encounter environments in road verges where they can thrive. (Coffin, 2007).

Roadsides have abundant light, little competition for runoff water from established shrubs and trees, and are flushed with nutrients periodically as land is cleared adjacent to roads. Red imported fire ants (*Solenopsis invicta*) followed a similar trajectory (Daigle, 2010). Although it was accidentally introduced to Mobile, Alabama, in the 1930s this species spread quickly throughout the southeastern United States. It has since spread to the Florida Keys where it is threatening many rare and endangered endemic species (Coffin, 2007).

2.6. Ecological effects of road networks

While roads have many direct ecological effects on adjacent aquatic and terrestrial systems, as network structures, they also have far reached cumulative effects on landscapes which have been less well-studied. Some major effects to landscapes that directly relate to roads include the loss of habitat through the transformation of existing land covers to roads and road-induced land use and land cover change and reduced habitat quality by fragmentation and the loss of connectivity. Together they point to the larger issue of the synergistic effects of roads and road networks on ecosystems at broader scales (Roedenbeck *et al.*, 2007).

2.6.1. Landscape change and fragmentation

In tropical forested areas, econometric models of land use and land cover change have revealed important relationships between biophysical and economic variables relative to roads. Not surprisingly, in rural areas, particularly in developing countries, the presence of roads has been most strongly correlated with processes of land cover change by facilitating deforestation. The conversion of forest to agriculture is more likely to occur on lands that have higher quality soils and greater access to markets, and are not protected State Reserves. Spatial models that consider the effects of roads on deforestation processes have become much more common in recent years. A recent study examined the process of deforestation by crossing spatial analysis studies with livestock economic studies to understand the processes of land cover change in the Brazilian Amazon. However, the effect of road construction varies and depends on the type of road, the stage of economic development in the region and variably affects land owners according to their production status.

Ecological conditions are not only affected by the construction of roads and road appurtenances (bridges and culverts) but also by the traffic and, at larger scales, by the increases in road density. Through the construction of the road, the alteration of the environment is crucial. There is a primary fragmentation affecting species of flora and fauna in the area and will be noticed in the short term. The number of trees cut is very large, the excavation products are thrown on the slopes sweeping and uprooting tenths of trees and shrubs. The through cuts for culverts' placement hamper the crossing of people and bicycles, while the impacts of traffic, dust and construction machines' noise on flora and fauna are obvious. Ecosystem services are the benefits people obtain from ecosystems. They include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other non-material benefits. The existing activities in the project's area like the bee-keeping; the free grazing, hunting, forestry, and agriculture are immediately impacted. Landscape is gradually changing, altering people's habits and farmers work. The new road creates new limits for every activity. The accident risk has increased (Kollarou *et al.*, 2013).

2.6.2. Road edges and the ‘‘Road-effect zone’’

The detrimental effects of habitat fragmentation involve loss of habitat and isolation of fragments from each other. However, if community composition or environment is also altered at patch edges, such edge effects could create additional unsuitable habitat, amplifying the effects of habitat fragmentation for certain species. Recent reviews agree that edge effects are a primary influence on biodiversity in habitat fragments. Edge effects are systematic changes in community composition or environment as a function of distance from a patch edge. The magnitude of edge effects depends on the type and degree of difference between the conditions on either side of the boundary, and the permeability of the edge to the movement of organisms, materials, or energy Since most human development contrasts sharply with natural habitat, edge effects adjacent to developed land may be particularly strong (Gieselman *et al.*, 2012).

Edge-related changes in community composition were not due to responses of one or a few species. Instead, different combinations of species changed in abundance with distance from the edge at each site (Gieselman, 2010). Common native grassland species were less frequent, on average, at the edges (negative edge bias), while exotic species were positively edge-biased.

The fragmentation caused by roads is alternatively measured by the amount of edge created by them. In many studies devoted to effects of roads on landscapes, references to the fragmentation of landscapes and the creation of edges are often coupled and used complementarily to describe the processes of change. Ecological edges occur naturally throughout the landscape. They create the spatial patterns that result from environmental heterogeneity and the interactions between and among organisms’ Ecological transitions, or ecotones, can result from changing resource availability, such as the transition from a marsh to a forest, corresponding with changing hydrologic conditions. Alternatively, edges are created when an ecological disturbance, such as a fire, creates a localized opening, like a gap in a forest. In this case, increased light and nutrients coupled with decreased competition from other plants allows for the colonization and establishment of other plant species, creating a distinctive edge (Spellerberg, 1998).

2.6.3. Habitat fragmentation by roads

Habitat fragmentation (sometimes referred to as landscape fragmentation) has become a major focus of research in conservation biology. This is because it is believed by many to have by far the greatest impact of all impacts on nature habitat fragmentation (Spellerberg, 1998).

2.7. Ecological road network theory

Cumulatively, road-effects interact with each other when roads are considered as systems. Ecological road network theory, which is comprised of basic principles of land use, transportation, network theory and ecology, provides a framework to interpret the ecological effects of road networks. With this theory as a basis, an analysis of the effects of a road network in a terrestrial ecosystem suggests that they extend over large areas of the landscape, that long-distance effects can saturate a landscape even in moderately road areas, and that isolated patches of habitat are created by road-effect patterns. They concluded that the effect of a gridded vs. parallel road network configuration depends on the target species' behavior, i.e. to what degree that species avoids crossing roads, and the probability of it being killed if it does. ''Bundling'' traffic (locating roads in close proximity to each other) is beneficial to population persistence, and core habitat areas that are fragmented should be protected from road construction. They also conclude that while their modeling studies are an important step in developing ecological road network theory, empirical analysis comparing the effects of different road network configurations should be done (Coffin, 2007)

2.8. Effects during construction

The impacts may occur beyond the immediate vicinity of the road: for example, changes in the hydrology. Mining for aggregates for the road may take place in a different area. The near linear surface creates change in microclimate and a change in other physical conditions extends varying distances from the road edge. The newly created edge provides habitat for edge species. Plant mortality increases along the edge: and such mortalities may extend from the road edge for varying distances. The mortality of plants has direct and secondary effects on other organisms. Some fauna moves from the area of the road as a result of habitat loss and physical disturbance (Spellerberg, 1998).

2.9. Exotic plant invasion

The study indicates that more than 162 naturalized exotic plant species have been recorded in Hong Kong. On other hand, On Tai Mo Shan, 29 exotic species were recorded in roadside vegetation, with the diversity but not percentage cover declining significantly with altitude. Fifteen exotic species were found along the stream, including two not found along the roadside. Only six exotic species were found away from roads and streams, all in unshaded areas disturbed by feral cattle. Despite centuries of massive human impacts, exotic plant invasions in Hong Kong are still largely confined to habitats that suffer from chronic human disturbance **(**Grace *et al.*, 2008)**.**

3. DESCRIPTION OF STUDY AREA

3.1. Study area

BMNP was first proposed in the late 1960s to protect Afroalpine habitat and populations of the rare and endemic species of the Mountain Nyala and the Ethiopian wolf. It was established as a National Park by the Ethiopian Wildlife Conservation Organization in 1971 with the primary objective of conserving the wildlife and other valuable natural resources in the area. The importance of the hydrological services that the area provides to south-eastern Ethiopia and parts of Somalia and Kenya have gradually been recognized over subsequent years and their conservation is now the primary purpose of the Park. It was finally formally gazetted by proclamation in 2014 under the Council of Ministers Regulation 338/2014 (GMP, 2017).

3.2. Location

BMNP is located in the southeast part of the Ethiopian highlands, within Oromia regional state, between two Zones which are Bale and West Arsi and about 400 km far from the capital Addis Ababa (EWCA, 2017a). The Park is also bordered with a total of six Woredas, four (Dinsho, Goba, Delomena, Berbere and Harena bulk) from Bale and one (Adaba) from West Arsi. It has 2,150 km2 area coverage and lies between 6° 7° 10‟ N and 39° 39° 57‟ (Bale Mountains National Park Gazettement, 2015) (fig.1).). The Park was first proposed in the late 1960s to protect the Africa's largest Afroalpine habitat and the rare and endemic species of the Mountain nyala (*Tragelaphus buxtoni*) and the Ethiopian wolf (*Canis simensis*) and was established by the Ethiopian Wildlife Conservation Organization (EWCO) in 1971 with the primary objective of conserving the wildlife and other valuable natural resources in the area.

The highland plateau and slopes of the Bale Mountains, areas over 3,500 m asl, encompass the largest area of Afroalpine habitat with total of 1,000 km^2 which is 17% of the total habitat in the continent (EWCA, 2017a). Many of the Bale and Ethiopian endemic species are found in this habitat type, whether plant (Lobelia spp.) or mammals, such as the Ethiopian wolf *(Canis* simensis), or the giant Molerats (*T. macrocephalus*) and other Rodent species. Overall, due to the extreme climate, plant diversity is low, but the grasses and herbs support an extraordinarily high density and diversity of rodents. The soil is constantly turned over by cryoturbation and rodent activity. Swamps and lakes are another key feature of this highland area. The entire Park liesis between altitude ranging from 1,500 to 4,377 m asl at Tullu dimtu which is the highest peak in south eastern Ethiopia and the second highest in Ethiopia (EWNHS, 1996). This particular study area is locally focused on paved road cross the afro alpine part of the Park as it has head from Goba to Delomena.

and stretch 73Km from North to South and 54Km from East to West (Hillman, 1986; EWNHS, 1996; Fishpoll and Evans, 2001). (OARDB, 2007; Mamo, 2007).

3.3. Water resources

The Park is also very important for its diverse ecological services globally, especially the hydrological services it provides to around 30 million population both in the eco-region and beyond within Ethiopia, Somalia and Kenya (OARDB, 2007).

The BMNP plateau is characterized by flat, swampy areas and many small shallow lakes that are crucial for flow regulation. A total of 40 rivers originate from BMNP area, contributing to five major rivers: The Web, Wabe Shebelle, Welmel, Dumal and Ganale. Some of these rivers were stocked with brown and rainbow trout in the 1960s and 1970s and good fishing under license is still available in some areas (BMNP, 2007). The Afroalpine wetlands and the Harenna forest hold the water, releasing it year-round to the arid and semi-arid areas of southeastern and southern Ethiopia, including the Ogaden and Somali agricultural belt. The livelihoods and food security of the people in these lowland areas are highly dependent on good environmental management in the highland areas. Water flow is regulated and stabilized during the dry and rainy season through the water retention properties of the highland wetland areas and dry season rainfall in the mountains is crucial to maintain river flow (Hillman, 1986; BMNP, 2007).

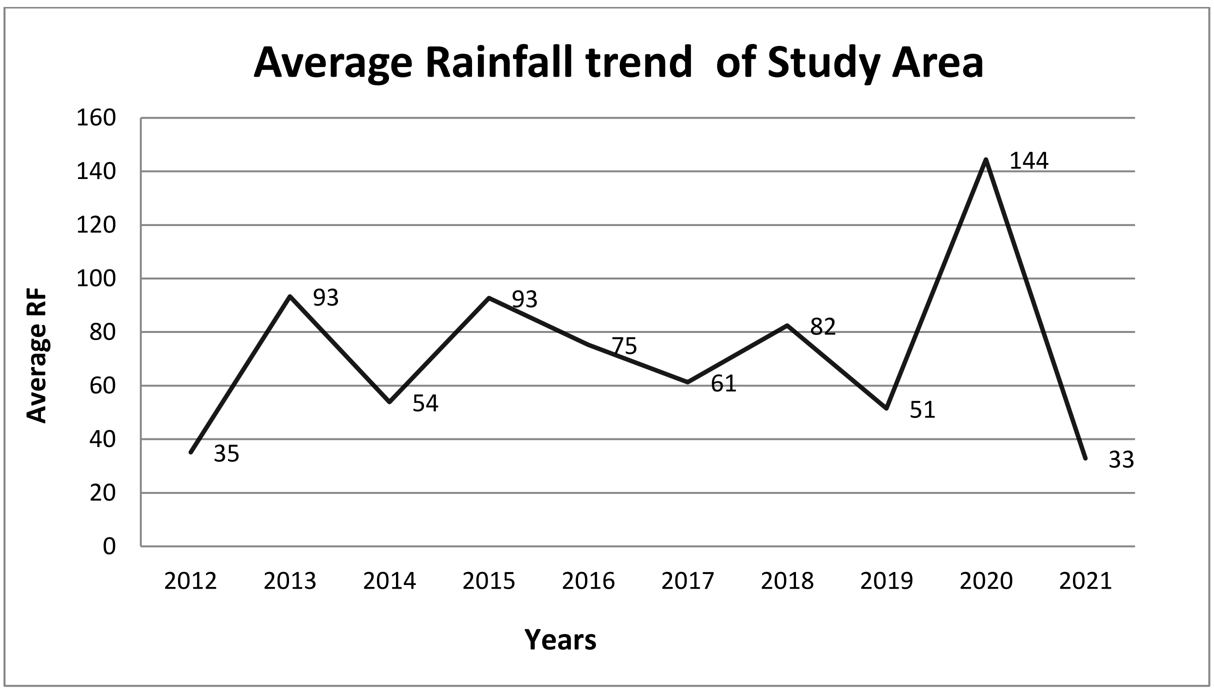
3.4. Climatic

I. Rainfall

There is a huge variation in climate over the area of the BMNP, primarily as a consequence of the great variation in altitude and by the bulk of the massif, which attracts orographic rainfall. The lower altitude receives 600 – 1,000 mm rainfall annually, whereas the higher altitude receives up to 1,200 mm (OARDB, 2007). The BMNP area experiences two rainy seasons:

heavy rain and small rain. The heavy rain is from July to October, with the highest peak in August and the small rain from March to June, with the highest peak in April (OARDB, 2007).

In general Bale Mountain area is characterized by eight months (March-October) of the rainy season and Gaysay grassland to provide a record of the current condition, to assess the variability within a habitat and to produce detailed information on the frequency or abundance of communities and species of both flora and fauna and the current relation of fauna and flora with the road ecology which will be used as baseline information in this study. Prior to data collection, field reconnaissance survey will be carried out to obtain an overall impression on the general physiognomy of vegetation within the study area. On the other hand, the amount of rainfall in the Park varies to some extent with altitude where, 600-1000 and 1000-1400-mm falls annually at the lower and higher altitude areas, respectively (IBC, 2007).



II. Temperature

In addition, the Park experiences temperature extremes, particularly in areas of the highest altitudes during the dry season and more or less the same pattern of temperature during the wet season. According to Hillman (1986), the highest temperature is around 18.4 ^{o}C in February and the lowest is 1.4 ^{o}C in January.

3.5. Human settlements

Different studies have revealed that human settlement in BMNP varies with the topography of the park. For instance, Stephen *et al.* (2001) reported that the settlement around the Sanetti plateau is less as compared to the upper web valley. The number of human populations in the BMNP is increasing with time and their impacts on forest resources degradation and loss of biodiversity is increasing. For example, in 1983, there was an estimated human population of just 2,500 and 10,500 head of livestock in the area (Hillman, 1986). However, in 2003, the number of inhabitants was estimated over 40,000, representing a 16-fold increase in 20 years' time (BMNP, 2004). This population growth and expansion has led the Park to experience greater expansion of farmlands with changes in the pattern and seasonality of land-uses in addition to high pressure from livestock grazing (BMNP, 2007).

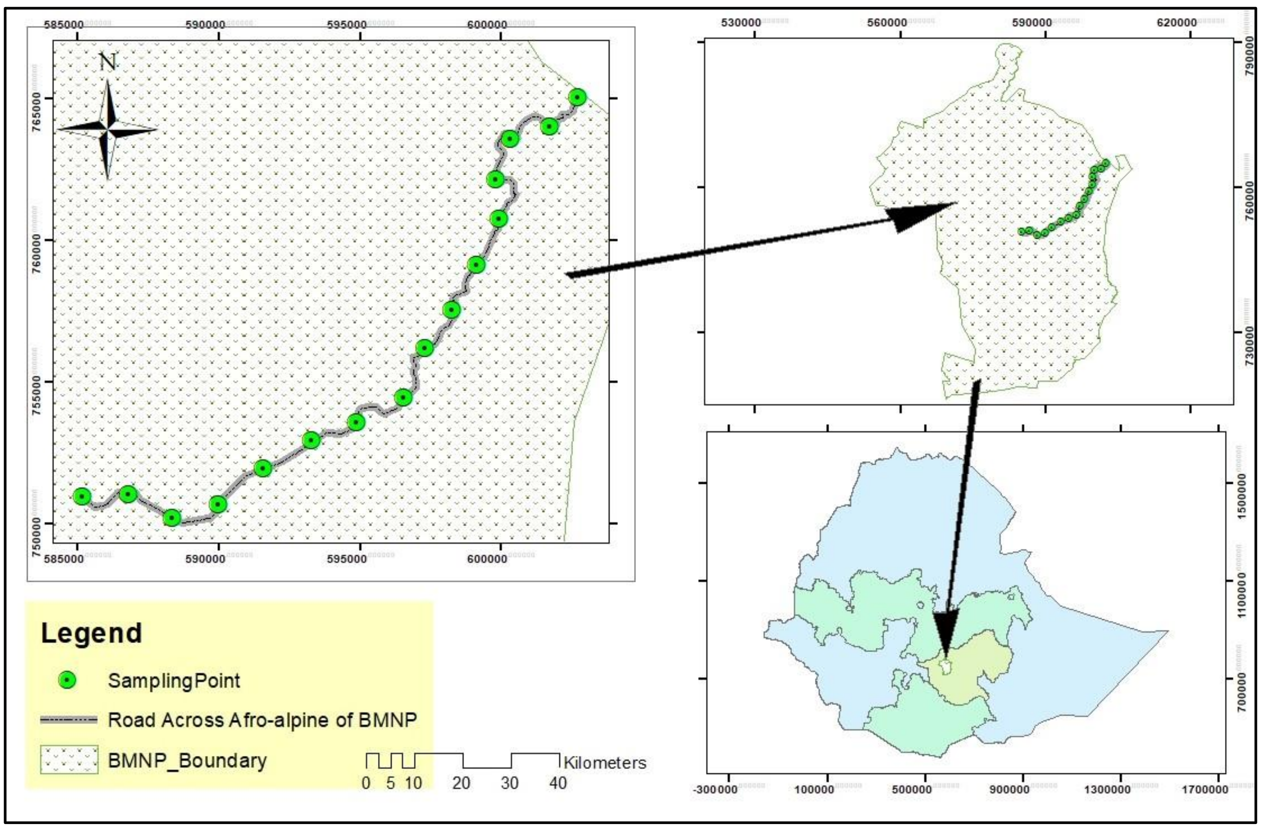


Figure 1: Map of Study Site

3.6. Fauna

In BMNP there are about 80 mammals; among which 20 are endemic to our country. For instance, Mountain Nyala, Ethiopian wolf, Menelik‶s bushbuck *(Tragelaphus scriptus meneliki),* Bale monkey *(Cercopithecus djamdjamensis)*, Starck‶s hare and Giant Molerat are some of the endemic mammals whereas Bale monkey and Giant Molerat are only restricted to the park. Also, Park is a home for the highest world population for a flagship and umbrella species, Ethiopian wolves and Mountain Nyala respectively. The Park endowed with more than 310 bird species among which 6 of them i.e. Blue-winged goose *(Cyanochen cyanoptera)* Spot-breasted lapwing/plover *(Vanellus melanochepalus)*, Yellow-fronted parrot *(Poicephalus flavifrons),* Abyssinian longclaw *(Macronyx flavicollis),* Abyssinian catbird *(Parophasma galinieri)*, (Black-headed siskin *(Serinus nigriceps)* are endemic to Ethiopia. Also, the park is rich in supporting various reptiles, amphibians, and fish species (OARDB, 2007). Among 64 amphibian species currently recorded in Ethiopia, 26 of them are endemic with a large proportion of this diversity found restricted to highland regions of the country. The Ethiopian Highlands are of particular importance as several endemic amphibian species with narrow distributions can be found in this region. The Bale Mountains, part of the Ethiopian Highlands on the eastern side of the Rift Valley, contains remarkable diversity of species, many with highly restricted distributions. Two remarkable monotypic genera of amphibians *(Balebreviceps*, and *Ericabatrachus*) are found only in Bale (EWNHS, 2011).

Gaysay grassland or study area is located on the northern parts of the park which is also known by its potential wolf habitat with up to 13 individuals organized under one pack in 1996/97 dry season, that was suffering decline to unfortunate by which the report by June 1997 that shows only four animals to survive and now there are no recorded individuals of the Ethiopian wolf.

3.7. Flora

The Park is also rich in flora and center of diversity and endemism with several threatened Ethiopian endemics (EWNHS, 2011). About 1660 plant species; with 160 endemics to Ethiopia and 31 are strictly endemic to Park are found in the area (OARDB, 2017).

The Park is classified into five vegetation zones: the northern montane grasslands, the northern dry Afromontane woodland, ericaceous forest, the Afro-alpine moorland and grassland, and the southern Harenna forest (Hillman, 1986; Addisu Asefa, 2011). This study primarily emphasizes in the Afro-alpine section of the Park, which is known as Sannate Plateau. The area between 3550 and 4000m asl. is covered by Erica shrub on ridges and Helichrysum moorland in the valleys. The flat moun-taintop is covered by Helichrysum moorland dotted with Lobelia spp. Much of the Sanetti plateau lies over 4000m asl. And there are several peaks ranging from 4050m (Worgona and Wasema) to Tullu Dimtuu at 4377m (EWCA, 2017).

4. MATERIALS AND METHODS

4.1. Materials

Materials which were used to undertake the study were GPS to take coordinate for plots and reach transect starting and end points, 2m x 2m quadrant for need of sampling plant, tape meter to measure width of plot and properly lay the plots, Field Guide Books for plant identification, Digital Camera to capture all work and plant photos, Map, Compass, Sleeping bags and Tent for Field activities and camping purpose

4.2. Methods

4.2.1. Reconnaissance survey

Prior to data collection, field reconnaissance survey will be carried out to obtain an overall impression on the general physiognomy of vegetation within the study area.

4.2.2. Research design

The study was conducted to identify and describe the impacts of road networks cross the Afroalpine of the Park on the plant diversity. This study designed to collect the possible information from primary and secondary sources using data collection tools such as field observation and field plant data collection.

4.2.3. Sampling design

The rough road crossing Afrol apine of the Bale Mountain national Park and heading from Goba to Dalo mana is there since park establishment (Hillman, 1986). The road elongated 110 km from Goba to Dalo mana since 84 km are all inside the park. Among this 84kms 34 kms of this road are cross in the Afroalpine part of the park. Considering Age effect of the habitat only 30 kms are surveyed for this particular study.

Total of 300 sub plots in 60 study plots of 10 sampling sites 2 kms apart lay adjacent to rough road across Afro alpine part of BMNP. At each sampling site habitat considered 5 quadrants has been placed in 20 x 20 base plots at perpendicular distance of 20 meters apart along both East and West side of the road has been used to quantify plant communities in plant bloom phase of July and August 2021 (Figure 1 and 2). The selected study plots were plain and far from human settlements and irrelevant human activities. By referring to the species area curve established by Zeng et al.(2010). the 2m × 2m quadrats were adopted for sampling. Two transects with opposite directions perpendicular to a selected road has been made in each site. The five quadrats were arranged at each coroner and one at center of the wider plots to the road verge in each transect. The presence, name, coverage, number, and dominance of all vascular plants were surveyed and recorded at each quadrat.

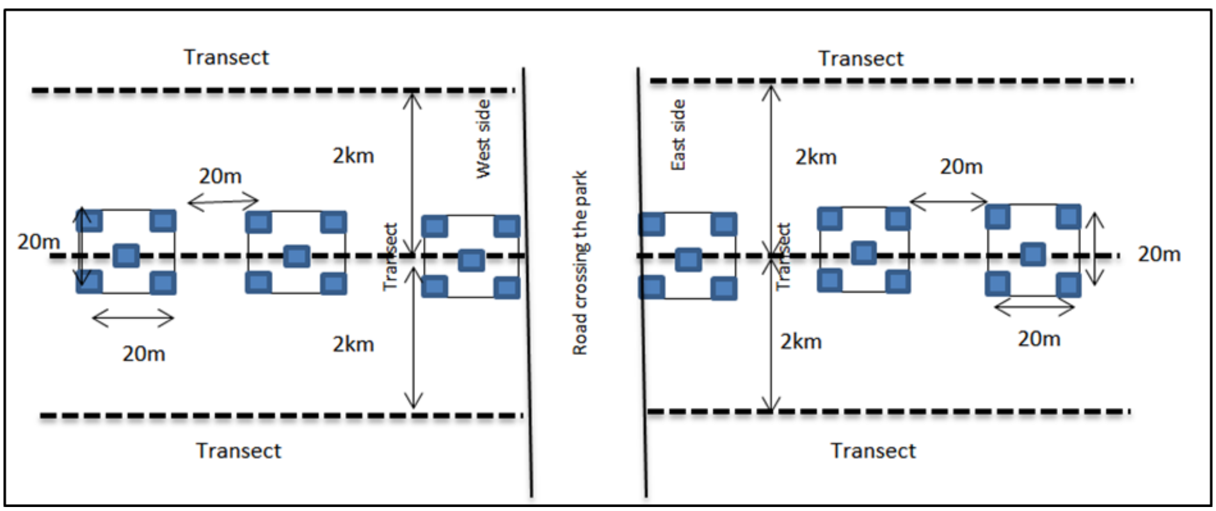


Figure 2: Vegetation Sampling Procedures

4.2.4. Data Collection

Stratified sampling technique was being used select sampling sites from the habitats of BMNP because the natural different vegetation cover, based on vegetation cover classification was performed (Brown, 2003). Plot has been adopted and used in this study (Gibbs *et al*, 2007). As recommended by Kent and Coke r, (1992), the size of the major plots for tree species will be

20m x20m (400m2). Within 400m^2 another sub- plots of size 5 m×5m=25m2 sample plot will be setup for shrubs at each corner and one at the center of the main sample plot. Finally, within each sub-plot other sub–plots 1 m x 1 m (1 ^{m2}) has been established for herbs and grass species including estimate of their percentage cover for community analysis (Abate et al., 2006). The number of sample plots and the distance between plots were determined by the following formula (Rembold *et al.*, 2009)

$$N = \frac{\text{TAxSi}}{\text{Psx1 0}}$$

Where T_A= Total area of vegetative Habitat

N = number of sample plots,

Si= Sampling intensity, the bush and bare land,

Ps= plot size

So according to this study:

- T_A = 600ha
- Si = 20%
- Ps = 400 m^2 = 0.04hec
- So that. $N = \frac{600\text{x}0.2}{0.04\text{x}1\ 0} = \frac{120}{0.4} = 300$

While the distance between plots was be determined by the formula:

$$D = \frac{\sqrt{Afx10000}}{\text{N}}$$

Where D = inter plots distance (m), Af = Area of the vegetation (ha) and N = number of plots. Accordingly distance between plots of this study sampling sites;

- $D = \frac{\sqrt{600x10000}}{300} = 20$

The adopted sampling intensity will be at least 0.2 % as cited by Japhet *et al*, (2013).

So, natural vegetation on Sannate plateau or Afro-alpine has 300 sample plots with 8m inters plot distance. According to Baret and Guyot (1991) plots need to be allocated systematically so as to achieve a certain level of accuracy (BERSMP, 2013). Sampling plots will be later located in the field using a GPS device. The use of GPS receivers enables in efficient and accurate placement of the plots (MacDicken 1997).

The presence of vegetation cover and abundance of shrubs, herbs and ground level have been measured in each quadrant. The density of each species has been calculated as the number of individuals per sampling sites.

In addition, most of the plant species were be identified in the field at the time of data collection following standard herbarium technique and using respondent ecological knowledge, and species not identified on spot were identified using published volumes 1-8 of the Flora of Ethiopia Eritrea for taxonomic identification.

3.4.1. Data analysis

All statistical analyses was carried out after the raw data were collected and organized in an excel sheet. In addition, data normality was checked using a Shapiro-Wilk's test, because it is highly recommended by researchers as well as its higher power of the measure of the value of test normality (Ghasemi and Zahediasl, 2012). Following this, those data which satisfied the standard normal distribution criteria has been subjected to parametric test such as ANOVA, Independent Sample t-test and Pearson Correlation.

Besides, a measure of plant species diversity and evenness was based on computations in ecological methodology software. Shannon - Wiener and Simpson's Diversity Index was employed to measure of diversity species present, as well as the relative abundance of each species. Menhinick's (I Mn) index was claimed to compare samples of different sizes and that the effect of the number of individuals or species richness.

Two tailed significance and differences will be considered statistically significant with 95% confidence intervals. Statistical Package for Social Sciences (SPSS) Version 20 and R studio has been used to compute all statistical analysis.

5. RESULT AND DISCUSSION

5.1. Results

In this particular study, forty eight Plant species at ground level (GL), Herb level (HL), and Shrub level (ShL) were identified and recorded within the area of 100 m from the road verge. Plant cover at the distances of 0–20, 40–60 and 80–100 m from edge of road lay in two wings (East and west) of the road is shown in (Table 1). The average records of plant for both east and west wings of the road, the ground cover was *Alchemilla pedata* and *Helichryssum splindidum* were higher compared to the other species. Ground cover of these two species decreased with distance and then they were very rare at a distance of 80–100 m (Table 1).

After the ANOVA, it was demonstrated that the position (East and West of the road wings) and distance to road (0–20, 40–60 and 80–100m) had significant effects on Simpson indices at P = 0.09 whereas, the analysis of variance in diversity was showed no differences for the Shannon-Wiener indices for the East and West of the road wings (P = 0.03). The maximum Simpson and Shannon indices were perceived at the distance of 0–20m from the road verge. Also the Shannon index decreased for the interaction effect of parameters for the Road wings and distance to the road and was not significant at P = 0.00 whereas Simpson indices still significant at p = 0.06 (Table 2)

Table 1: Ground cover of Plant Species frequency across described distance from the Road Verge

		East Wing (odd Numbers)			West Wings (even number)			Life form
ID	**Vescural Name of Plant**	**0-20**	**40-60**	**80-100**	**0 -20**	**40 - 60**	**80 - 100**	
P1	*Hyplocorpha ruppeli*	5	7	6	3	6	10	GL
P2	*Alchemilla pedata*	25	21	21	24	25	22	GL
P3	*Festuca abyssinica*	18	21	22	19	18	15	Grass
P4	*Veronica*	6	3	1	6	1	3	GL
P5	*Salivia marjame*	10	5	8	6	3	2	Herb
P6	*Artimissia simense*	8	3	5	6	1	4	GL
P7	*Ceneraria sebaldi*	3	1	0	0	1	0	Herb
P8	*Odelandia*	2	0	0	1	0	0	GL
P9	*Sagina afroalpine*	1	7	5	1	3	4	Grass
P10	*Hyplocorpha schimpen*	4	0	0	0	0	0	GL
P11	*Plantago afra*	1	3	0	0	1	0	Herb

P12	*Geranium arabicum*	7	7	3	5	10	5	Herb
P13	*kilimacharica*	2	0	0	0	0	0	Herb
P14	*Helichryssum splindidum*	20	16	16	18	17	15	Herb
P15	*Satureja simensi*	1	3	7	4	10	4	Herb
P16	*Hebenstratia dentata*	2	0	0	0	0	2	Herb
P17	*Trifolum aacule*	1	6	3	2	5	2	GL
P18	*Diclocephla variance*	10	12	10	11	12	7	herb
P19	*Alchimella humani*	1	0	3	0	0	0	Herb
P20	*Lichens spp*	1	0	3	0	1	0	GL
P21	*Thilaspi spp*	0	0	1	0	0	0	GL
P22	*Agrocaris melatha*	0	0	0	1	0	0	GL
P23	*Crepus shmmperi*	3	1	2	1	3	3	GL
P24	*Erigron pratatus*	4	2	4	4	11	2	Herb
P25	*Hyploscidum spp*	0	0	3	0	0	1	GL
p26	*Satureja punctata*	0	0	0	1	2	0	Herb
p27	*Bartisa spp*	0	1	3	0	1	1	Herb
p28	*Anthemis tigreensis*	2	1	2	0	0	0	GL
p29	*Europes prostratus*	1	2	3	3	2	0	Shrub
p30	*Alchemilla microbetula*	0	0	0	1	0	1	GL
p31	*Helichryssum forskhalii*	5	5	6	5	6	7	Herb
p32	*Helichryssum gofanse*	0	1	2	0	5	5	Herb
p33	*Ranunculus Spp*	3	3	1	0	2	0	GL
p34	*Swertia kilimanjcharica*	0	0	1	1	1	0	Herb
P35	*Cerastium ocadum*	0	0	2	0	0	0	shrun
p36	*Cropodum(grass)*	0	0	1	1	1	0	GL
p37	*Caramine obliqua*	3	2	0	0	0	2	GL
p38	*Cenecio spp*	4	2	0	2	0	0	Shrub
p39	*Cynotis spp*	2	0	0	2	0	0	GL
p40	*Charex spp*	1	1	1	0	0	0	GL
p41	*Arab dobis thaliana*	1	1	0	0	0	1	GL
p42	*Galium simensis*	0	1	0	0	0	0	herb
p43	*Kniphofi foliosa*	0	0	2	0	0	1	Herb
p44	*Cynoglossiym ocrophium*	0	0	1	0	0	1	Herb
p45	*Umblicus prionodes*	0	0	1	0	0	1	GL
p46	*Swertia abyssinica*	0	0	0	0	2	0	herb
p47	*Erica arboria*	0	0	0	0	0	1	Shrub
p48	*Cenecio schulti*	0	0	0	2	1	2	Shrub

Out of plots considered for this study salvia marjema was observed as a plant that highly affected by road construction as it aggressively grown apart its natural growth following the road verge. The modification on soil physical structure due to road construction is found as a factor change natural growth of native plant species as it has been observed salvia marjema differently grown along the roads out of its natural growth seen in other road free part of the same habitat.

Also there was *Argemone Mexicana* which is common exotic and invasive plant observation on the Afro-alpine habitat following the road verge. However, it is less and not determined in study plots the road construction in natural habitat is one of pulling factors for introduction of exotic and invasive plant species.

I. Biodiversity of Plant Community

Totally 48 plant species were identified within the area of 100 m far from the road verge. At different distances from the road verge and both east and west wings of the road, the occurrence of *Alchimella pedata* was significantly higher than that of the other species.

The diversity of plant under different indices analysis has shown significant in variation for both East and West Wings and for distance from road edge. Both Simpson and Shannon–Wiener diversity index shown higher variation in plant diversity for distance to the road than East and West Wings effects of the road analysis at $F= 28.98$, $df = 2$, $P = 0.99$ and $F= 24.48$, $df= 2$, $P=0.78$ respectively. Simpson diversity indices shown higher variation of plant species diversity computed for the combination of road wings and distance to the road than Shannon-wiener at $F= 4.10^{*}$, $df =2$, $P =0.06$ and $F=2.41^{ns}$, $P = 0.01$ (Table: 2).

Table 2: ANOVA for the road edge effect on all Plant biodiversity (Average of macro plots distance to road)

Indices		Sources	df	MS	*F*	*P*
Biodiversity	Simpson	East and West wings of the road	1	0.10	13.47*	0.09
		Distances to road	2	0.21	28.98**	0.99
		East and West sides of the roads × distances to road	2	0.03	4.10*	0.06
	Shannon - Wiener	East and West wings of the road	1	0.20	1.53^{ns}	0.03
		Distances to road	2	1.98	24.48**	0.78
		East and West wings of the road × distances to road	2	0.25	2.41^{ns}	0.01

Moreover, a significant relationship was determined between Simpson and road distance. Both Simpson and Shannon diversity index decreased with increasing distance to the road. The value of this index at the distance of 80–100 m was significantly lower than that at the other distances measurement class (Table: 3).

Table 3: Diversity index for all plant species across described distance from the road Verge

Distance to road	Simpson	Shannon-Wiener
0-20	0.84^{a}	2.10^{a}
40 - 60	0.75^{ab}	1.50^{b}
80 - 100	0.63^{b}	1.39^{b}
Different letters indicate a significant difference at α = 0.05 by Duncan's test		

Alchimella pedata and *Festuca Abyssinica* was significantly higher than that of the other species (Table 1). It was demonstrated that the location where these species present (East and west wings) and distance to the road had significant effects on plant species diversity. The interaction effect of parameters on different plant diversity indices was significant for Simpson at F = 4.10*, df = 2, P = 0.06 and not significant for Shannon-Wiener index at $F = 2.41^{ns}$ df= 2. P = 0.01.

Table 4: ANOVA Test for the road Edge Effect on the Biodiversity of all Considered Plant Species

Indices		Sources	df	MS	*F*	*P*
Biodiversity	Shannon-Wiener	Distance to road	2	0.21	28.98**	0.99
		East and West side of the road	1	0.20	1.53^{ns}	0.03
	Simpson	Distance to road	2	0.21	28.98**	0.99
		East and West wings of the road	1	0.10	13.47*	0.09
Richness	Menhenick	Distance to road	2	0.410	11.87**	0.61
		East and West wings of the road	1	1.870	81.23**	0.90
Evenness	Smith and Wilson	Distance to road	2	0.006	0.34^{ns}	0.04
		East and West wings of the road	1	0.040	1.89^{ns}	0.00
df = degree of freedom, MS = root mean square, *,** indicate significance at the 5 and 1% Probability level, respectively, ns = not significant						

Menhenick analysis computed species richness has shown significant for both East and West Wings of the road and increasing for distance from the road verge at F=81.23**, df= 1, P =0.90 and F=11.87**, df= 2, P =0.61 while no significant difference was found among distances from the road verge and the two wings for evenness indices (F= 0.34, df = 2 P = 0.04 and F = 1.89, df = 1 , P = 0.00) (Table 4).

5.2. Discussion

After the road construction, the processes of recovering and succession play an important role in increasing plant community changes (Lozano *et al.* 2005). The roadside may be a refuge for more species, and the pattern of vegetation distribution is affected by road age and distance from the road verge (Zeng *et al*. 2010). In this study it was found that plant species composition and diversity decreased with increasing distance from the road. A similar finding to this result was reported by Zeng *et al*. (2010), thus indicated species richness and diversity indices of the road verge group (0 m from the road) were higher than those of the other distance groups. The main reasons for the presence of different species along roads are often changes in physical and chemical properties of soil, light condition as well as microclimate (Ullman *et al*. 1995; Delgado et al. 2007; Pauchard, Alaback, 2006).

The ground level and herbaceous plant species was determined with higher coverage percentage at the road verge than shrub level. This implies that the road construction is higher affect and determines the regenerating degree and growth rate of shrubby plant community. This thought is consistent with some previous studies indicated that construction and maintenance of roads did a lot of negative effects to high level plant communities because of most communities were destroyed during construction of roads, leaving few survival plants (Pauchard, Alaback 2006, A. W. Coffin, 2007).

The biodiversity of plant species in the first 20m was higher than in the second and third 20m. The reason may be that the values of plant species biodiversity, richness and evenness indices have the highest correlation with the increasing gap area (Shabani *et al.* 2009). The abundance of *Alchimella pedata*, *Festuca Abyssinica* and *Helichryssum splindidum* increased significantly at the distances of 0–20 m from the road compared to other distances Moreover, my results agree with results from previous studies, where transportation corridors had a high abundance of native and non-native plants (Pauchard, Alaback 2006). I found also that the Shannon determine diversity of plant species at the West and East side of the road has no difference as both side shown no significant value (P=03). The reason toughed for this is that the maintenance and construction along road impacted and threated under the same pressure and microclimate which is afro-alpine at 4000asl and above in this case study.

The road verge highly affect the Grand level plant species that herb and shrub plant species as the Shannon-Weiner index decreased by 23%, 56% and 64% respectively. This finding was consistent with report of Li *et al.* (2010) that the plant species diversity of shrub Plant species and herb Plant species within the effect zone was less than that in adjacent habitats.

Constructing more roads causes destruction and alters the system in plant communities (Pormajidian *et al.* 2009) as it also approved for this research project too. So, it is recommended to conduct further research covering other Part of the park which has not covered under this project and other protected area, in the country having diverse eco-agro-climatic zones.

6. CONCLUSION AND RECOMMENDATION

6.1. Conclusion

According to this study result the biodiversity of plant communities are intensely affected by roads construction in the Afro-alpine of BMNP. Unfortunately, these are an expected impact as there often changes in physical and chemical properties of soil, light condition as well as microclimate.

The maximum plant species were observed in the range of 0–20m to the road verge. The similarity of plant communities in studied plots roadsides increased with the increasing distance to road verge. The impact is not only limited to the plant community it has also impact on plant diversity as the biodiversity of plant species in the first 20 m was higher than in the second and third 20m. The effect of roads on the diversity of plant species at the West and East side of the road has shown no significant difference. The road verge highly affects the ground level plant species than herb and shrub plant species as the response of shrub Plant species to the road effect was more stable than that of ground level and herb plant species.

In general, the road construction has impact on protected areas plant community as effect can be examined from distance of roads on plant diversity was limited within 20m to road verge. So that the results indicated that the construction and maintenance of roads protected area could increase the plant species diversities of communities and result risk of aggressive and alien exotic plant species invasion as *argemone mexicana* could be observed along the road verge and out of study plot.

6.2. Recommendation

- According to this study and other literature implies any road construction has impact on plant community (diversity, abundance and richness) as effect can be examined from distance of roads on plant diversity was limited within 20m to road verge. So that protected area has global significant as Bale Mountain National Park (BMNP) need to take care in expansion of road network in protected area.
- Road construction inside protected areas like BMNP has known for its have highest global plant diversity and center of endemic and endangered plant species need further attention as it leads alien invasive species expansion in protected area. So that continuous assessment of invasive plant species and action plan is required in order to control invasive plant occur due to road construction in BMNP.
- Beside road network on Afroalpine habitat of BMNP there are also Asphalt and rough road cross the Gaysay grassland and Harenna forest respectively. So that it needs further research to understand and come with management recommendation.

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