
GIS and Remote Sensing Based Spatiotemporal Analysis of Deforestation in Dati Wolel National Park, Western Ethiopia

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Abstract: Deforestation is extreme in tropical and subtropical regions in emerging economies. In Ethiopia, the rate of forest degradation has accelerated in recent years as a result of rising demand for agriculture, fuel wood, and charcoal, along with population growth. Excessive and destructive forest resource exploitation is currently a danger at Dati Wolel National Park. The overall objective of this study was to analyze the determinants and rate of spatiotemporal dynamics of deforestation in Dati Wolel National Park western Ethiopia through employing remote sensing and socioeconomic data. Three series of LANDSAT images (1987 TM, 2002 ETM+, and 2019 ETM+) which are obtained from USGS were used and supervised classification was done. Besides, Key informant interviews, observation, and focus group discussion were the data collection tools used in the study, and the data were analyzed by qualitative research approach. The result revealed that Agricultural land to be the most expanding land use type in the park. It increased from 9.6% (1987) to 18.6% (2019) at the rate of about 551.3 ha per year. The area covered by forest land, wetland, and water bodies has been reduced by the annual average rate of 733.5 ha, 50.2 ha, and 162.2 ha respectively. The issue of deforestation is inextricably tied to human activities, such as population pressure and socioeconomic reasons. So that, to overcome the problem of forest cover change and its implications, corrective actions should be implemented in both the short term and long term phases have been recommended.

Keywords: Biodiversity, Dati Wolel National Park, Deforestation, Forest, Land Use Land Cover, GIS, Remote Sensing

1. Introduction

Natural resources such as forests and wildlife were plentiful on the earth, but little thought was paid to their proper usage [5, 22]. These resources are becoming scarce as the human population continues to expand fast [26]. Unless wisely used these resources are vulnerable. In order to decrease the loss, humankind has started to become concerned about conserving natural resources, of which one is forest resources [30, 29].

Developing countries are highly dependent on primary economic activities and direct utilization of natural resources [17], particularly the forest that is currently under serious threat due to human economic activities [19, 13]. Forest ecosystems play a very important role in regulating the climate, however forest degradation exacerbated the climate

change problem and other environmental problems [16].

Ethiopia is noted by severe environmental degradation of which the most notable ones are soil erosion, deforestation, water depletion, and shrinking wetlands [23]. Historical documents show that forest and woodlands once covered over 40% of the total area at the beginning of 20th century [7]. Presently, it is estimated to be less than 10% [2, 4]. According to Woldeamlak [28], the country's annual deforestation rate is estimated to be about 62,000 hectares, attributed primarily to the increased demand for farmland, fuel wood, and settlement sites. Hailemariam et al. [14] have shown that the land use land cover has been rapidly changing in Ethiopia, owing to population pressure, resettlement programs, climate change, and other human and nature-induced driving forces. Particularly, anthropogenic activities are the single most significant factors adversely altering the natural status of the Ethiopian landscape. This resulted in shocking changes in the

land-use/cover patterns of the country over time [9].

It is believed that Ethiopia is characterized by severe environmental degradation and loss of biodiversity at present than ever before [2, 8]. In some areas, people are destroying forests owing to various factors such as expansion of farmlands, firewood and charcoal production, settlement, and construction [14].

Despite the government's effort of increasing the forest cover of the country through conservation, restoration, afforestation, rehabilitation, awareness creation, etc., the natural forests are being cleared and degraded [11, 31], mostly forests on privately held lands [10]. Since the landholders highly depend on the forestlands, the remaining forests on such lands are highly fragmented and degraded. The leftover indigenous forests that are capable and usually regenerate are being seasonally cleared for different economic activities before they mature [3].

Remote Sensing and GIS technology enable the provision of timely data and observed periodical change [20]. Satellite images are immensely used in forest resources estimation and monitoring. As a result, the spatiotemporal change of this resource plays a vital role in environmental protection.

According to the Office of Dati Wolel National park of Gawo Kebe Branch, even there is no research properly conducted so far to investigate the status of forest

degradation at present. Nothing is known about the existing and disappeared species of fauna and flora. The rate and extent of forest cover change in the Park are not precisely investigated. However, from available records and field visits, it is evident that forest cover change is very widespread and is continuing at an alarming rate.

Dati Wolel National Park is one of the protected areas in Ethiopia with the largest areas of continuous forest ecosystem. It has a unique ecosystem at the northwestern edge of the southwestern tropical forest of the country [12]. According to Rabira [24], biodiversity degradation is rapid and poses a severe threat to the survival of most fauna and flora in Dati Wolel National Park. Based on the views from the Office of Dati Wolel National Park extensive forest covered land has been converted into farmland in the past three decades. The forest resources have been deteriorating due to uncontrolled cutting and clearing for the expansion of cultivation and grazing lands, income as well as construction material and fuel wood supply for the people who are living around the park. As result, this study aimed to analyze the spatiotemporal dynamics of deforestation in Dati Wolel National Park, Western Ethiopia. The output of this study is essential for natural resources managers, socio-economic development planners, and environmentalists in order to have appropriate environmental protection and development interventions.

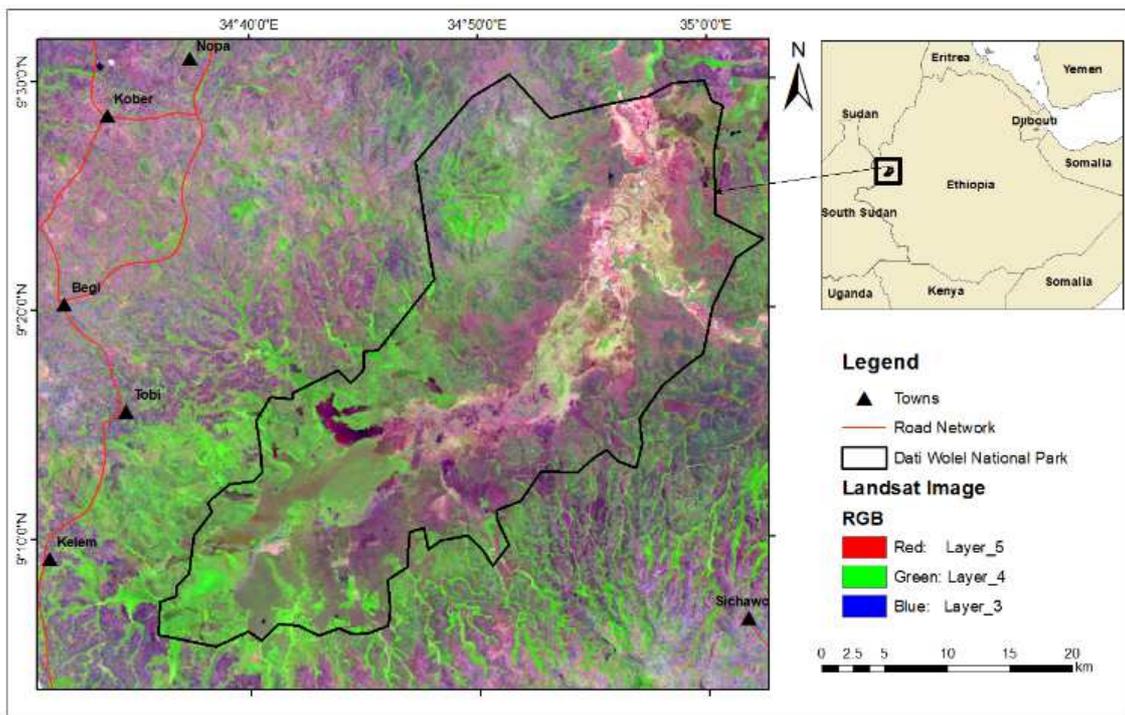


Figure 1. Location map of Dati Wolel National Park.

2. Materials and Methods

2.1. Study Area

This study was conducted in Dati Wolel National park, Oromia National Regional State, Western Ethiopia. The area

is located between $34^{\circ} 36' 0''$ to $35^{\circ} 2' 30''$ E longitude and between $9^{\circ} 6' 0''$ to $9^{\circ} 30' 0''$ N latitude (Figure 1). Relatively the area is located in six districts include: Gawo Kebe, Jimma Horro, and Gidami which are found in Kellel Wollega, Zone and Begi, Kondala, and Babbo Gambel are found in West Wollega Zone. The elevation within the park ranges between

1390 and 1500 m.a.s.l. and covers an area of 1,035 KM² [27]. The study area classified into four habitat types: Wetland, woodland, riverine forest and Savanna grass land. The national park shares the northwestern portion of the southwestern tropical forest part of the country and receives over 1,350mm average annual rainfall. As indicated in Rabira [24], the area is relatively hot with mean maximum and minimum temperature ranging between 29°C and 27°C and between 15°C and 17°C respectively.

2.2. Land Use / Land Cover Classification and Analysis

In the study, Multi-temporal Landsat images with path 171 and row 54 on January 1987, 2002, and 2019, which is downloaded from USGS Earth Explorer was used. Supervised image classification was carried out for the three images with the help of ERDAS Imagine 2015 Software. A Maximum likelihood image classification algorithm was utilized. The change detection analysis was carried out by visual comparison of features and detailed quantitative approaches.

2.3. Socioeconomic Data Collection and Analysis

Beside geospatial data, Key informant interviews and Field observation were the tools employed in the study for gathering of socioeconomic data on deforestation of the park. The key informants were elderly people who live around the park and they were purposively selected. Observation was designed for collecting all information during the field survey, i.e., land cover and land use types as well as illegal human activities on forest resources. Hence, the data were qualitative, the methodologies employed to analyze the collected data were descriptive statistics.

3. Results and Discussion

3.1. Land Cover Mapping of Dati Wole National Park

3.1.1. Change Between 1987 and 2002

The overall area of forest decreased from 34,291.0 ha in 1987 to 24,441.2 ha (by 9849.8 ha) in 2002, while agricultural land increased from 9,917.0 ha in 1987 to 19,125.3 ha in 2002. (by 19,208.3 ha). Furthermore, shrub land increased from 11,649.1 ha in 1987 to 13,943.8 ha in 2002. (by 2,294.7 ha). This period indicates a significant reduction in the quantity of forest compared to the 2002-2019 period.

After the collapse of the Dergue Regime in the early 1990s, the study area's forest resources were destroyed, indicating that rural development in general, and forestry operations in particular, could not flourish without the engagement of the rural community [27].

3.1.2. Changes Between 2002 and 2019

The decline in the area of forests land, and water bodies by 2,620.2 ha and 1,005.4 ha, respectively, was the most significant land use land cover change recorded during this time. A significant increase in the overall areas of shrub land and agricultural land by 4,741.2 ha and 163.7 ha has been registered respectively.

During this period, the rate of deforestation was declined when compared with the previous period. This result is consistent with what has been currently reported by the Ethiopian government regarding vegetation cover all over the country [26]. The improvement in these periods could be due to the effects of massive tree planting (afforestation and reforestation) over the last two decades.

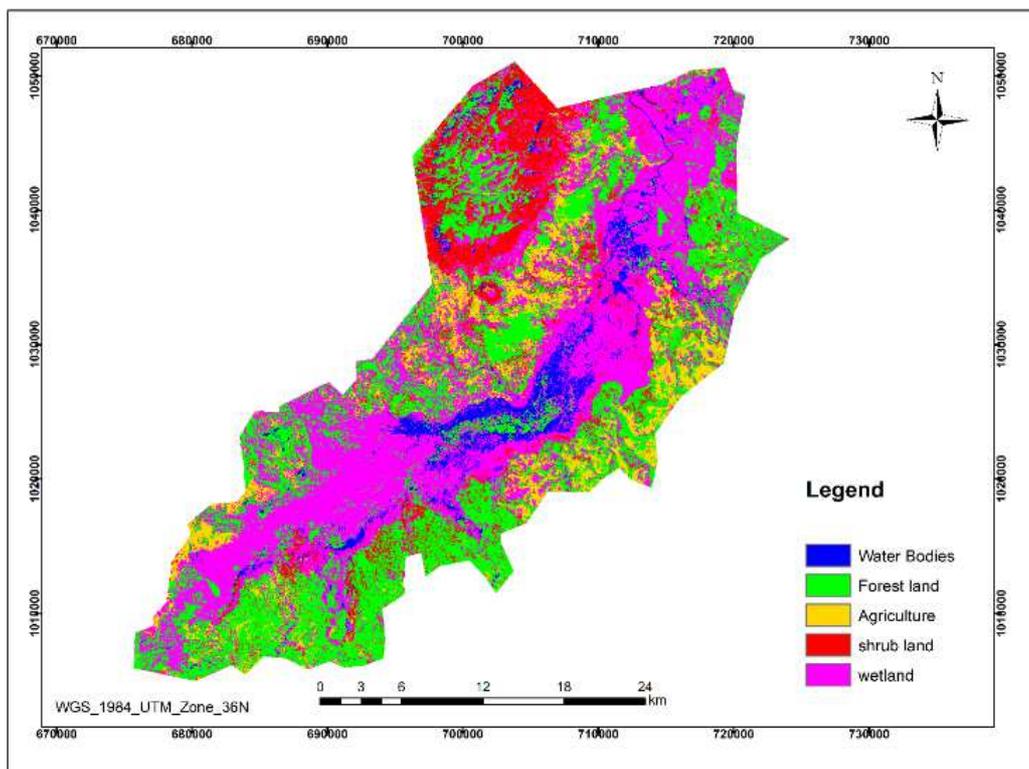


Figure 2. Land use/land cover map of Dati Wole National Park in 1987.

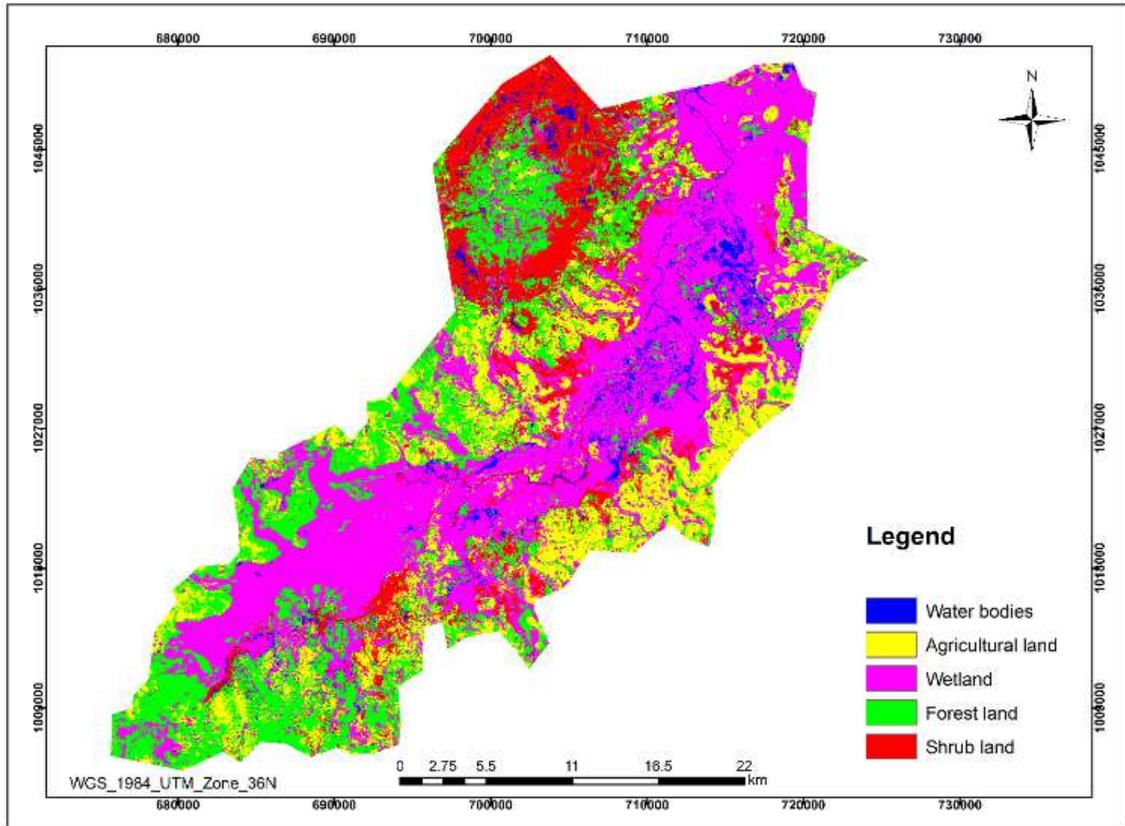


Figure 3. Land use/ land cover map of Dati Wolel National Park in 2002.

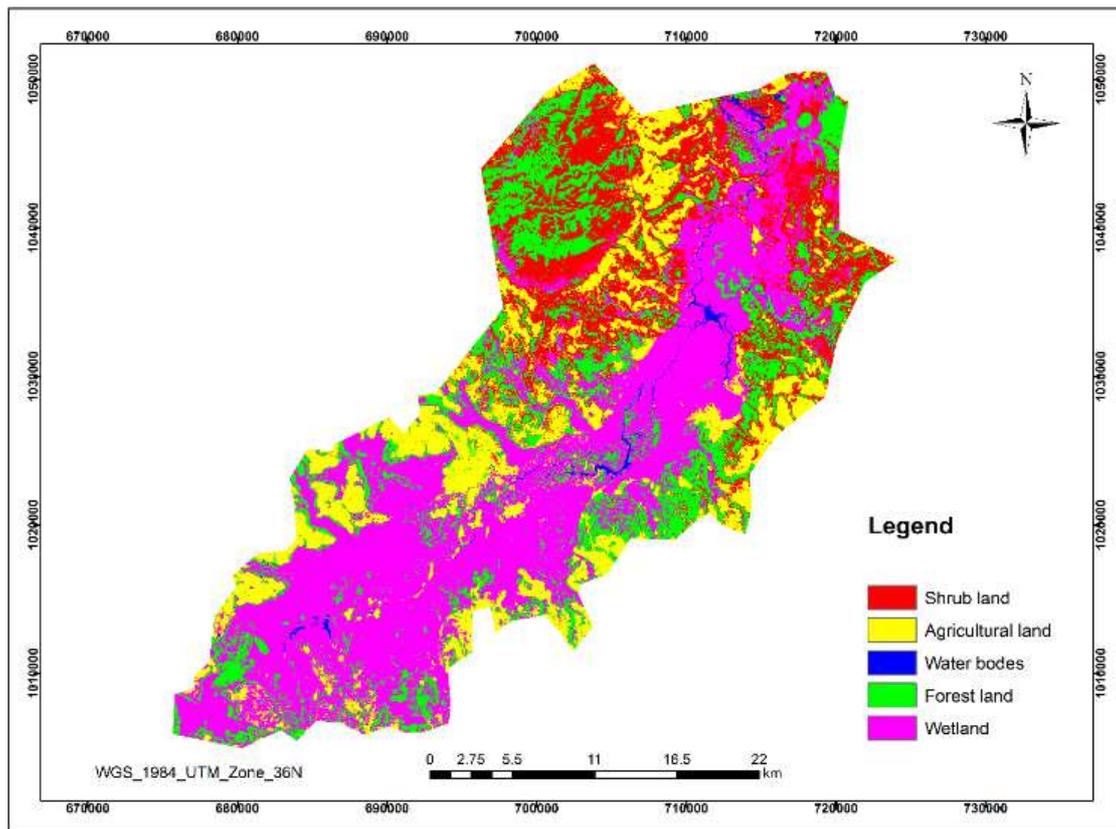


Figure 4. Land use/ land cover map of Dati Wolel National Park in 2019.

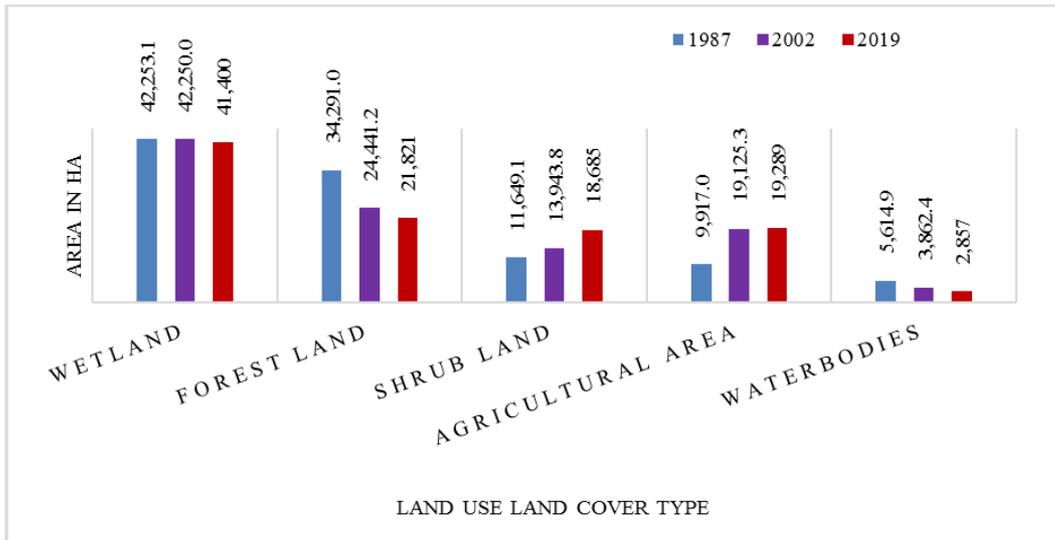


Figure 5. Patterns of land use land cover change units of Dati Wolel National Park in 1987, 2002 and 2019.

Moreover, Figure 5 was generated using satellite image interpretations from 1987, 2002, and 2019 to provide a clear understanding of land use land cover change and patterns in the park. It indicates that, Agricultural land was found to be the most expanding land use type in the study area. However, the area covered by forest land has been reduced continuously, but Agricultural land was increased in 1987 and 2002 because of forest land change to farm land and decreased 2002 due to forest land degradation. In addition, the increase in shrub land from 1987 to 2002 suggests a shift in the area's other land use land cover.

3.1.3. Areal Extent and Rate of Forest Cover Change in Dati Wolel National Park

In 1987, forest resources covered 33.1 percent of the Park's entire area, whereas, in 2002, forest resources covered 23.6 percent of the National Park's total area. Meanwhile, in the year 2019, this volume decreased by 21.1 percent. The rate of forest degradation increased dramatically between 1987 and 2002, with total forest cover falling from 34,291.0 ha (33.1%) in 1987 to 24,441.2 ha (23.6%) in 2002.

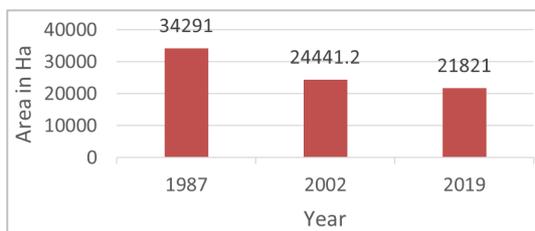


Figure 6. The Pattern of forest cover in hectare value in Dati Wolel National Park; 1987, 2002, and 2019.

3.2. Major Causes of Deforestation in Dati Wolel National Park

According to information from the park officers, deforestation in the park is triggered by a variety of causes that reduce forest cover potential and production, resulting in permanent degradation. Furthermore, changes in forest land

are a direct reflection of patterns in socioeconomic activity. In Dati Wolel National Park, several factors driven by human activity are responsible for the enormous shift of forest cover land into different land use and land cover units. In the study area, forest resources degradation is observable and setting ecological destruction. According to the information gathered from the respondents, the main causes of deforestation at the park are agricultural land expansion, Fuel wood, charcoal production, construction materials, Settlement expansion, and lack of awareness.

The agro-ecological condition of Dati Wolel National Park is suitable for agriculture. The farmers around the park are extending the farm lands to the fragile forest ecosystem in an attempt to meet the increasing demand for food. According to the informants of the park, the vegetation area of the park started to change into agricultural land in these three decades. This is due to the rising human population and food insecurity. In addition, the low productivity of traditional agricultural methods needs a large amount of land. Besides, the amount of agricultural land required to feed the growing population continues to rise. Agricultural production continues to lag behind population expansion, and the gap between existing and required agricultural land increases year after year. This resulted in significant land use conflicts between agricultural land, livestock pasture, and forests. As a result, the presence of peasants with their various types of agricultural activities (both crop production and livestock rearing) around the park's border, forest cover land, is thought to be a key element in the park's forest cover change.

The most significant source of forest decline in the park is the inevitably expanding need for charcoal. The demand for charcoal wood is far greater than the forest's ability to supply it. Charcoal has become more commercialized in recent years as demand has grown, particularly in the park's urban areas. The increased need for charcoal, among other things, was the main driver of deforestation. Furthermore, officers discovered that charcoal production is the primary cause of forest cover change.

Furthermore, depending on accessibility, forest resources for building purposes are collected or purchased commercially. Except in a few cases, all of the materials in most constructions come from the forest. The overexploitation of the forest ecosystem for local building purposes, as well as its commercialization, has put a significant impact on the area's forest resources. The emerging of new settlements is mainly associated with the rapid immigration from the surrounding. Moreover, due to the high expansion of settlements around the park people who had settled inside of the park make heavy use of the park's resources. Another factor for the degradation of forest resources was the lack of awareness of the communities on biodiversity conservation.

3.3. Impact of Deforestation in Dati Wolel National Park

Deterioration of biodiversity is the major problem which is resulted from forest resource degradation around and in the park. Deforestation and traditional farming activity close to the park are a cause for the destruction of wildlife's habitat in the park. Forest deterioration, both in terms of quality and quantity, results in a loss of biodiversity, both plants, and wildlife. As anthropogenic pressure rises from the surroundings, a variety of plant and animal species are threatened. Forest biomass decline has been connected to wildlife mortality and migration putting both forests bared floras and fauna species in the park in danger. Furthermore, an ever-increasing human population has put a strain on the Park. As a result of linear increasing of the population, settlements are expanding, and new ones are springing up in formerly undeveloped and ecologically sensitive regions.

Kumssa and Bekele [18] claim that obtaining baseline data is crucial for preserving and conserving national parks and natural resources like forests. As a result, the nature of the research demanded information from the responsible authority, which had long been aware of the park's condition. This condition was a way to understand the present and past status of forest resources and the cause and consequence of forest degradation in the park accurately.

Respondents stated that humans also put pressure on Dati Wolel National Park mostly by the expansion of agricultural lands which was the main cause of deforestation and biodiversity disturbance. A large area of forest resources had been deforested and changed into other land uses in few past three decades. The expansion of agricultural lands which have occupied large space has led to destructions of natural vegetations and reduced area available for wild animals grazing and movements. Zegeye [31] mentioned similar problems that the major drivers of deforestation and forest degradation are agricultural expansion which results in a number of challenges and constraints through influencing the potential of biodiversity. Similarly, a study in Madagascar found that the increment in demography determines the rate of deforestation which results in increasing pressure on the remaining forest habitat and biodiversity therein [6].

According to the respondents, another major threat to forest resources is settlement expansion, construction materials, fuel wood, charcoal, and lack of awareness. Expansion of

settlements and livestock grazing activities can have a wide range of negative impacts on forest areas. The growing human settlement in the area has considerably contributed to a shortage of open space for wildlife movement, as seen by the increased settlements seen in the park; this observation is also supported by Hansilo and Tiki [15] in Bale Mountains National Park. In Dati Wolel National Park, Extensive forestland degradation was not the only cause of agricultural land expansion, but also other factors like fuel wood and charcoal wood play a great role in deforestation. The community uses charcoal production mainly for urban dwellers to sale for their revival. It's difficult to track the forest damage caused by charcoal production, and it contributes to rising pollution. Similarly, Sedano [25] mentioned similar problems to be charcoal production were the source of environmental degradation in sub-Saharan Africa. The communities around the park cut a tree without replacing it due to the lack of awareness they have concerning afforestation. Aliyu *et al.* [1] Stated similar problems to be Knowledge about forest resource conservation is one of the most important for sustainable forest resource management. In Dati Wolel national park forest biodiversity was under pressure of human activities. Deforestation and forest degradation activities have a very significant and holistic impact on the circumstance of biodiversity. Morris [21] stated similar difficulties that are anthropogenic impacts on forest resource result decline in biodiversity.

4. Conclusion

Forest cover change is a major environmental problem manifested at Dati Wolel National Park. With a few scattered trees and plants, forestland has been transformed into farming and grassland. Land use and cover, as well as forest cover, in the Park, changed substantially between 1987 and 2019. As a result, expansion of farmland and decline of forest cover, wetland and water bodies were observed. According to the finding, around 34,291.2 ha of land was covered with forest in 1987, out of the entire area of the Park. However, in the year 2019, this amount declines to 21,821 ha. The computed result indicates that approximately 733.5 ha of forest land is changed into other land use land cover each year between 1987 and 2019. Forest resources have been utilized in an unsustainable manner due to the increment of the human population, demand for forest products for construction, firewood, and charcoal production, revenue creation, and the spread of other types of agricultural activities in the park. This was the major cause of the study area's forest degradation. As a result, the problem of deforestation has increased the deterioration of biodiversity in Dati Wolel National Park, and these causes and their consequences were identified using measurable and non-quantifiable data.

5. Recommendation

The following recommendations were forwarded depending on the findings of the study.

1. For a more accurate assessment of the spatiotemporal condition of deforestation in the park, further study is required.
2. The findings of the study could be suggested for concerned government and non-governmental bodies to protect the forest resources from degradation and to realize sustainable biodiversity conservation in the park.

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