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# Impact of Differences in Land Management on Natural Vegetation in Semi-Dry Areas: The Case Study of the Adi Zaboy Watershed in the Kilite Awlaelo District, Eastern Tigray Region, Ethiopia

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**Abstract:** The search for a sustainable land management has become a universal issue. It is especially necessary to discuss sustainable land management and to secure a site with enough feed supply to improve the lives of the farmers in the Ethiopian Highlands. This research studied the Adi Zaboy watershed in Tigray in order to reveal the changes in land management, assess how the different forms of land management affected the vegetation through unsupervised classification and normalized difference vegetation index (NDVI) analysis with geographic information system (GIS) 10.5 using a WorldView-2 satellite image taken in September 2016 and field investigation, and consider how to allow both environmental preservation and sustainable use of feed resources. The land management types at the research site were classified as “seasonally-closed grazing land”, “prohibited grazing and protected forest land”, and “free grazing land”. On comparing the NDVI of each type of land management, it was found that the seasonally-closed grazing land makes it highly possible to secure and supply feed resources by limiting the grazing period. The expansion of the prohibited grazing and protected forest land is likely to tighten the restriction on the use of resources. Therefore, sustainable land management to secure feed resources may be possible by securing and actively using seasonally-closed grazing land, securing feed by a cut-and-carry, and using satellite images and GIS.

**Keywords:** Ethiopia; sustainability; land management; satellite image; normalized difference vegetation index (NDVI)

## 1. Introduction

The search for a sustainable land management that can maintain the balance of preservation and use of environmental resources has become a universal issue. The alpine region of northern Ethiopia located over 2000 m above sea level is made up of a steep terrain created by abrupt uplift in the Pliocene period (about 2.58 million to 5 million years ago) and the Pleistocene period (about 10,000 to 2.58 million years ago). Furthermore, the unstable rainfall and frequent drought make this region very susceptible to soil erosion and soil fertility decline. This is why the region has a high risk of

desertification and it is less than suitable for agricultural production [1]. However, the people residing in this region have made a living mainly through farming and raising livestock. The rapid increase in population led to the expansion of croplands, which were developed from natural grasslands that were used as grazing land [2]. Furthermore, it is reported that the croplands have extended to the steep hills with a slope of more than 30% between 1957 and 1982 [3]. Ethiopia is also the country with the most livestock in all of Africa, and according to the Central Statistical Agency of Ethiopia [4] statistics, there are 53.4 million cattle, 25.5 million sheep, and 22.8 million goats raised in Ethiopia. Hawando's [5] investigation in 1994 reported that 75% of the livestock in Ethiopia were raised in alpine regions higher than 1500 m above sea level. This is because the farm work including plowing, transporting and threshing in the alpine region heavily relies on animal power. The livestock herds used as animal power intensively utilized the natural grasslands in the alpine region as grazing land. There was a great increase in soil erosion, a decrease in forests and natural grasslands, and a significant depletion of vegetation in alpine regions with a high risk of desertification as a result of cropland expansion from the rapid population increase and the use of natural resources through grazing of livestock used as animal power [6,7].

The Ethiopian government implemented various preservation activities from having experienced such land degradation. There are two major activities of note. The first are the Soil and Water Conservation (SWC) programs started in the mid-1970s with the funding from the World Food Program (WFP) and other various aid organizations. The SWC programs improved agricultural technology and created small dams and stone bunds to prevent soil erosion. The government instructed the SWC to launch the program in many alpine regions. The second is area enclosure, an activity that was started in the 1980s to recover natural vegetation in the degraded hill regions. The area enclosure prohibited farmers from grazing livestock and using natural resources in the degraded hill region. Its activities also included afforestation [8]. When the area enclosure was launched in 1980, it was implemented on more than 80,000 hectares of hill region in Tigray, northern Ethiopia. However, in the period of military regime, the military depleted vegetation once again when they utilized the natural vegetation that had been protected inside the area enclosure until 1985. After the military regime transitioned to the democratic regime in 1991, the preservation activities of the area enclosure resumed, expanding the area of area enclosure in Tigray from 143,000 hectares in 1996 to 895,220 hectares in 2011 [8–11].

In Tigray Region in northern Ethiopia where preservation activities had been conducted intensively, the effectiveness of the SWC programs is assessed by demonstrating the mechanism and the quantitative assessment of soil erosion [12,13]. The preservation effort of area enclosure is also assessed by identifying the amount of biomass, tree density, number of tree species, and vegetation coverage [14–16]. In addition to the impact assessment on the preservation activities, Babulo et al. [17] assessed the importance of environmental resources, including herbaceous plant species in the grazing land and woody plant species used as firewood, for the farming households in their livelihood strategy. Furthermore, high-resolution satellite images were used to create an extensive land-cover map to analyze the changes in land cover [18,19]. Haregeweyn et al. [20] summarized more than 258 studies, including the framework for policies on preservation activities and case studies on soil erosion and preservation activities. The Tigray Region received the Future Policy Gold Award from the World Future Council in August 2017 for these governmental preservation and research activities [21].

However, some researchers are concerned that the Ethiopian government's preservation policies for protecting vegetation may cause a negative effect on the farmers who had been utilizing the natural grassland's resources. The expansion of the area enclosure, which prohibits livestock grazing and gathering of woody plant species for firewood essential to a farm living, may cause serious problems for farmers, such as a decrease in the number of livestock that a farmer can raise in a region [22,23]. According to Hirata et al. [22], the decrease in the number of livestock in the Tigray farming villages may increase the likelihood of causing problems, such as (1) a shortage of oxen that are vital to farming if there is an accident, (2) the inability to obtain a substantial cash income from the sale of livestock, and (3) a lack of nutrients in a farmer's diet from the reduced amount of milk. It is necessary to

discuss sustainable land managements and to secure a site with enough feed supply to improve the lives of the farmers. Therefore, it is also necessary to discuss how these farmers, who had been using these natural resources all their lives, managed the land, analyze how the land management affected natural vegetation, and discuss land managements that can both preserve natural vegetation and secure feed supply.

The decision making regarding a farmer's use of land is strongly influenced by the government system [24]. To discuss the relationship between the government and natural vegetation in Ethiopia, Lanckriet et al. [25] divided the major historical events into the following three eras: (1) the feudal era (before the start of the civil war in 1974), (2) the military junta and civil war period (1975 to 1990), and (3) the post-war period (after 1991). This research divided and discussed the Ethiopian political structure changes under three periodical classifications: The Imperial era (before 1975), the Socialist era (1975 to 1990), and the Democratic era (after 1991). The boundaries and regulations on land management have changed along with the changes to the political system. People's use of land for various purposes affects the natural conditions, including the land's vegetation. Therefore, the changes to land management associated with the political system up to this point is thought to have affected the present formation of natural vegetation.

This research studied Adi Zaboy watershed in Kilite Awlaelo district in the eastern Tigray Region in Ethiopia in order to (1) reveal the changes in land management by farmers in the Imperial era, the Socialist era, and the Democratic era, (2) assess how the different forms of land management affected the vegetation through satellite images and field investigation, and (3) consider how the land should be used to allow both environmental preservation and sustainable use of resources for feed supply. The Adi Zaboy watershed was selected for this research, because there were various land managements beyond administrative divisions and it seemed to be an appropriate area for assessing how a land management might affect vegetation.

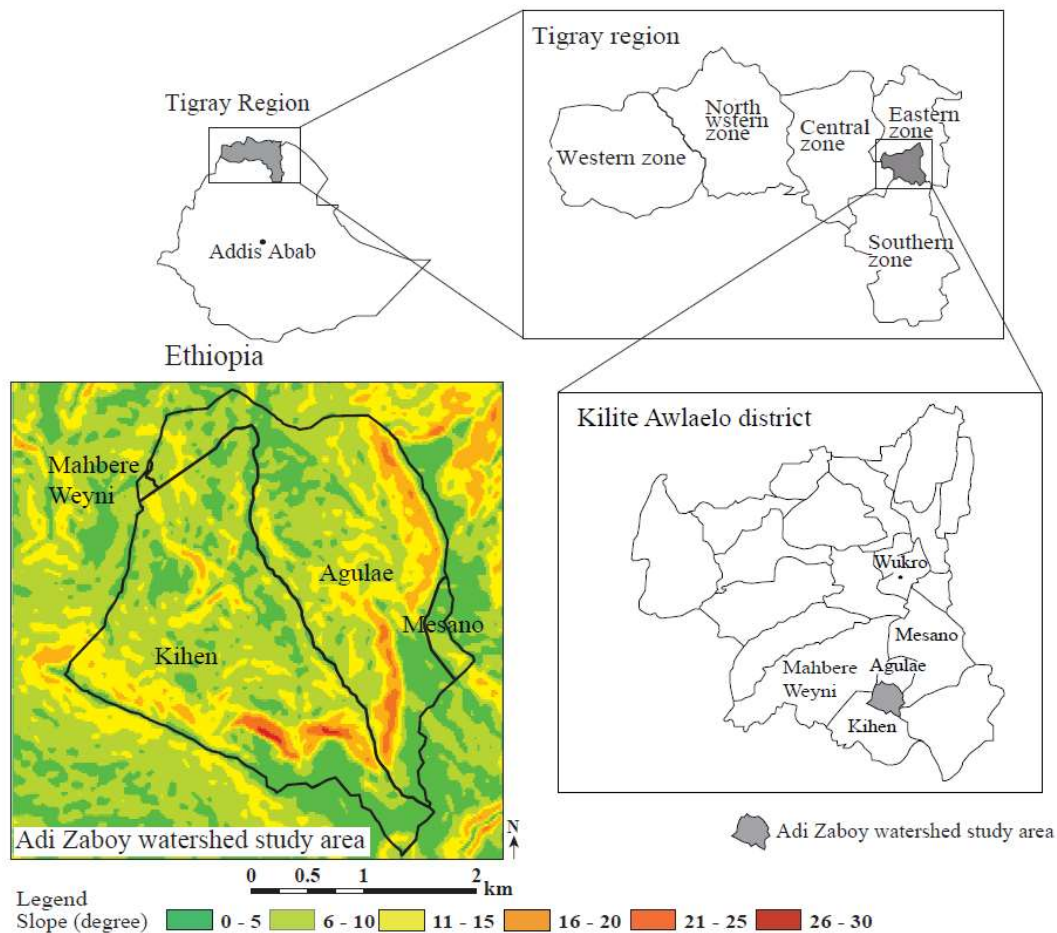
## 2. Research Site and Methods

### 2.1. Overview of the Research Site

The research site was conducted in Adi Zaboy watershed located at 13°38'30" to 13°40'30" N latitude and 39°34'0" to 39°36'0" E longitude in southern Kilite Awlaelo district, Tigray Region, in northern Ethiopia. The total area of the watershed is 8.84 km<sup>2</sup>, where 53.0% of the area is used by the Kihen community, 45.0% is used by Agulae town, 1.5% is used by the Measnu community, and 0.5% is used by the Mahbere Weyni community (Figure 1). This research reported on the land management by farmers from the Kihen community and Agulae town, which combined, make up more than 98% of Adi Zaboy watershed. The topographical information on the Adi Zaboy watershed was obtained from the AW3D Digital Surface Model with a 30-m spatial resolution. W3D Digital Surface Model with a 30 m spatial resolution is a dataset created by resampling the Digital Surface Model obtained from the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) on Advanced Land Observing Satellite, known as "Daichi", from the Japan Aerospace Exploration Agency (JAXA) to a horizontal resolution of 30 m [26]. The elevation difference in Adi Zaboy watershed is 290 m (maximum elevation of 2315 m above sea level, minimum elevation of 2025 m above sea level), and 24% of Adi Zaboy watershed is on a slope of more than 10°.

The average monthly temperature in Wukro town in the highland of northern Ethiopia is constant at about 20 °C throughout the year. The highest average monthly temperature is about 30 °C and the lowest average monthly temperature is about 10 °C. According to the meteorological data recorded by Wukro Town National Meteorological Agency [27] from 1992 to 2013, the average annual rainfall is 572 mm, making it possible to consider this research site as a semi-dry region. The amount of rainfall fluctuates a lot from year to year with 984 millimeters of rainfall in 2000, but only 305 mm in 1992. The rainfall is primarily concentrated between June and September. There is a mix of natural grasslands and rain fed croplands in the Adi Zaboy watershed. The farmers use two oxen to plow the

rain fed croplands, and their main crops are barley, wheat, and teff. The Kihen and Agulae farmers mainly graze cattle, goats, sheep and donkeys in the natural grassland in the Adi Zaboy watershed.



**Figure 1.** Location of the Adi Zaboy watershed study area, Agulae town, and the Kihen community in the Kilite Awlaelo district, eastern zone, Tigray region in northern Ethiopia and topography of the Adi Zaboy watershed.

## 2.2. Survey Method for Land Uses and Land Management

A local investigation and surveys were conducted for a month each in September, 2016 and July, 2017. MT (52 years old at the time) from the Kihen community and GH (51 years old at the time) from Agulae town, who are knowledgeable about the local land management, accompanied the exploration of Adi Zaboy watershed to identify the administrative divisions and the land management. A GPS (GARMIN GPSMAP 60CSx 42205) was used to obtain the location of the borders.

Both MT and GH were also interviewed on the land use, the management method, the changes to those boundaries, and the history of cropland expansion in the Imperial era, the Socialist era, and the Democratic era. BH (78 years old at the time) from the Kihen community and MY (73 years old at the time) from Agulae town were also interviewed to learn about the situation before the Imperial era in 1975.

## 2.3. Satellite Image Processing

The research used multispectral orthographic images taken on 8 September 2016 by the WorldView-2 Satellite. WorldView-2 is an 8-band multispectral commercial satellite designed and developed by Ball Aerospace & Technologies Corp and operated by Digital Globe Corporate [28]. These images, with a 2-meter ground resolution, have been processed orthographically and resampled



by cubic interpolation. The satellite image of WorldView-2 consists of eight bands. The red Band 5 (630–690 nm) and infrared Band 7 (770–895 nm) were used to calculate normalized difference vegetation index (NDVI) in this research. The research used the satellite images taken in September, because it was during the rainy season when the vegetation level was high, and the condition of the vegetation showed up well in the images.

The research utilized the normalized difference vegetation index (NDVI) as the index for assessing vegetation. NDVI can evaluate the amount and condition of vegetation from the difference in the NDVI values. Calculations of NDVI always result in a number that ranges from  $-1.0$  to  $+1.0$ . Very low values of NDVI (0.1 and below) correspond to barren areas of rock, sand, or snow. Moderate values represent shrub and grassland (0.2 to 0.3), while high values indicate temperate and tropical rainforests (0.6 to 0.8) [29]. The NDVI relates to the photosynthetic activity of living plants. The higher the NDVI value, the more “green” the cover type. In other words, the NDVI increases as the quantity of green biomass increases [30]. Tilahun’s [31] research on the surrounding Adi Zaboy watershed areas was referenced to classify the areas using NDVI to assess the vegetation in this research. The area with NDVI of less than 0.1 was classified as “water or building”, NDVI of 0.1 to 0.2 was classified as “small vegetation”, NDVI of 0.2 to 0.4 was classified as “medium vegetation”, and NDVI of more than 0.4 was classified as “high vegetation”. The small, medium and high vegetation represent coverage rates of natural vegetation in Adi Zaboy watershed of less than 20%, 20%–45% and more than 45%, respectively.

Iterative self-organizing (ISO) cluster unsupervised classification with the WorldView-2 multispectral orthography images was used to categorize the croplands in Adi Zaboy watershed, referenced the ground-truth data, and then its accuracy was evaluated by the field survey data at 101 points in croplands. The unsupervised classification using the ISO data analysis technique method is a mechanical classification method, which creates pixel clusters based on the homogeneity and distance of the spectral values [32]. The ISO cluster unsupervised classification is widely used as the tool to categorize cropland [33]. The unsupervised classification for processing NDVI and finding croplands distribution was interpreted using Esri ArcGIS 10.5.

### 3. Results and Discussion

#### 3.1. Land Managements of Natural Grassland

The land managements were classified into free land, free grazing land, seasonally-closed grazing land, and prohibited grazing and protected forest land. The free land is a land that has no designated use. There are houses and buildings built on the free land in the Adi Zaboy watershed. Farmers are free to develop the land for grazing or farming, and to collect fallen branches for fuel or herbaceous plant species for feed. The free grazing land is a land used for livestock grazing. Like the free land, farmers are free to graze livestock and collect branches and herbaceous plant species. However, a meeting of farmers from each village decided on a new cropland development on an as-needed basis based on the situation with the cropland or the grazing land. The seasonally-closed grazing land is a land that prohibits grazing only during the rainy season when vegetation grows from the concentrated rainfall. Its primary purpose is to secure feed for oxen that are essential to farming. People are also prohibited from gathering herbaceous plant species during the period when grazing is prohibited, but they are permitted to collect fallen branches throughout the year. The development of new croplands is not prohibited, but it is currently not taking place. These land managements were arranged voluntarily by farmers in a meeting, and the violators were fined. The prohibited grazing and protected forest land is a land where the government-led afforestation and water and soil conservation activities, such as building stone bunds for soil erosion prevention, were implemented. It is believed to have the same type of land management as the area enclosure previously presented by Nedessa and Ali et al. [8]. The government prohibits grazing in the prohibited grazing and protected forest land all year to prevent livestock from destroying the stone bunds and damaging the young planted trees. Farmers are only permitted to gather herbaceous plant species, and they are prohibited from

collecting fallen branches and developing new croplands. The government also prohibits cutting down of trees under all the land managements. A violation of government regulations is a criminal act. When the types of land management are classified from the perspective of livestock grazing restrictions, the free land and the free grazing land are the areas where the farmers could freely graze their livestock; the seasonally-closed grazing land is the land where the farmers decided to limit grazing by season; and the prohibited grazing and protected forest land involves the areas where the government completely prohibited grazing activities (Table 1).

**Table 1.** Land managements in the Adi Zaboy watershed study area.

Land managements (local name)	Grazing	Cropland Developing	Fallen Branch Collecting	Cut and Carry of Grasses	Tree Logging
Free land ( <i>Bada meret</i> )	○	○	○	○	×
Free grazing land ( <i>Habar meghatsi meret</i> )	○	Farmers decision	○	○	×
Seasonally-closed grazing land ( <i>Hizaeti meret</i> )	Seasonally	○ No area anymore	○	○	×
Prohibited grazing and protected forest land ( <i>Deni meret</i> )	×	×	×	○	×

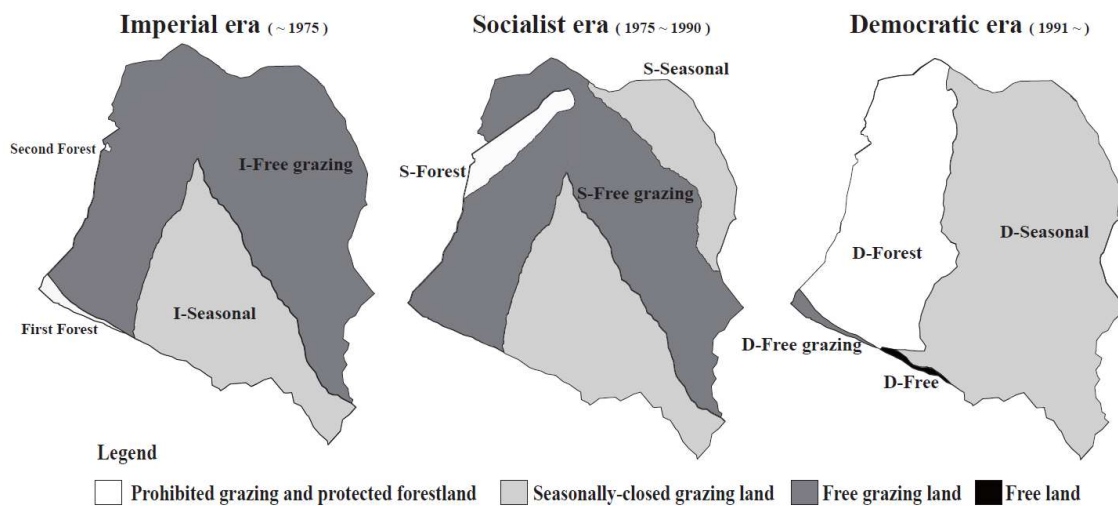
○: Available. ×: Not available.

### 3.2. Changes in the Seasonally-Closed Grazing Land

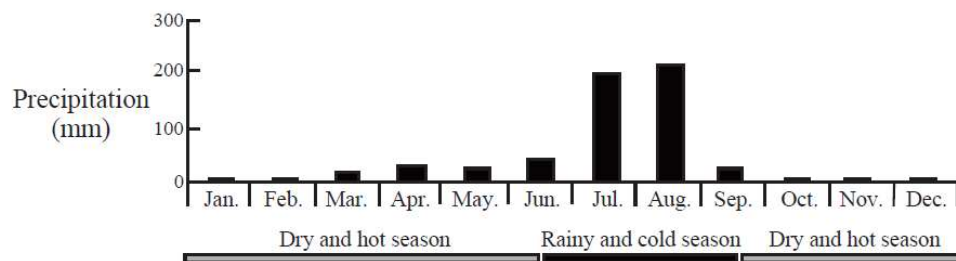
According to BH, the Adi Zaboy watershed used to be covered with forests with large trees that were taller than the farmers, like *Acasia* spp. and *Olea europaea* before 1975 (Imperial era). The farmers from the Kihen community and Agulae town grazed their livestock freely while they stayed in the Adi Zaboy watershed for an extended period. The farmers also freely developed croplands and cut down trees. This is how vegetation gradually depleted in the Adi Zaboy watershed.

As vegetation receded before 1975, the farmers from the Kihen community established the seasonally-closed grazing land, which limits livestock grazing, in the Adi Zaboy watershed (Figure 2: I-Seasonal). The seasonally-closed grazing land is locally called as *Hizaeti meret*. The farmers from the Kihen community used the places near a water source and the village to continue to freely graze their livestock and cut trees, and the places far from a water source and the village were established as the seasonally-closed grazing lands. In the seasonally-closed grazing land in the Imperial era, the farmers were prohibited from all livestock grazing from mid-July until December, a period which included the rainy season when vegetation grew from the concentrated amount of rain so that they could secure feed resources. The farmers were permitted to graze only oxen from early January to April, when feed resources started becoming scarce during the dry season. In the latter half of the dry season, they were permitted to take day-trip grazing to the seasonally-closed grazing land with the cows in May and June, because the feed resources became scarce at the free grazing land where they normally grazed. The voluntary grazing restriction at the seasonally-closed grazing land determined at the farmers' meeting was started to supply enough quality feed resources for oxen working in the farms when it became difficult to secure enough quality feed throughout the year.

This regulated grazing restriction started in the Imperial era before 1975 and is still in place today. The residents regard it as a form of traditional land management. The seasonally-closed grazing land in the natural grassland of Agulae town gradually expanded after the socialist era and the democratic era. The grazing restriction regulation changed after the democratic era in 1991. Until then, the grazing of oxen was only permitted between early January and April, but it also became possible between September and October (Figure 3). The factor that relaxed the oxen grazing restriction is thought to be the expansion of the prohibited grazing and protected forest land, which will be explained in later sections. Currently, there are 5.6 km<sup>2</sup> of seasonally-closed grazing lands, which constitute 65.2% of the Adi Zaboy watershed used by the farmers from the Kihen community and Agulae town.



**Figure 2.** Changes in land management in the Adi Zaboy watershed during the imperial, socialist, and democratic eras.



**Imperial era (~1975)**

Seasonally-closed grazing land

Free grazing land

Ox grazing	Ox&cow grazing	No grazing
All animal grazing		

**Socialist era (1975 ~ 1990)**

Seasonally-closed grazing land

Free grazing land

Ox grazing	Ox&cow grazing	No grazing
All animal grazing		

**Democratic era (1991~)**

Seasonally-closed grazing land

Free grazing land

Ox grazing	Ox&cow grazing	No grazing	Ox grazing	No grazing
All animal grazing				

**Figure 3.** Changes of grazing management in the Adi Zaboy watershed (Modified from [22]).

**3.3. Changes in the Prohibited Grazing and Protected Forest Land**

According to BH, farmers from the Kihen community established a seasonally-closed grazing land on top of a hill with severe vegetation depletion before 1975. The government planned to plant Eucalyptus trees in the seasonally-closed grazing land on this hilltop with severe vegetation depletion. At the same time, the government designated the afforested land as the prohibited grazing and protected forest land (Figure 2: First Forest). The prohibited grazing and protected forest land is called *Deni meret*.

The prohibited grazing and protected forest land where Eucalyptus trees were first planted in the Adi Zaboy watershed lasted two years, but the trees did not survive. The failed prohibited grazing and protected forest land was switched to a free grazing land. In its place, the government planted more eucalyptus trees on top of another hill nearby to establish a new prohibited grazing and protected forest land (Figure 2: Second Forest). The reforestation of the prohibited grazing and protected forest

land through afforestation expanded under the government initiative after 1975 (Figure 2: S-Forest). Furthermore, most of the free grazing land was changed to the prohibited grazing and protected forest land by the government after 1991 under the pretext of environmental conservation of land with severe vegetation depletion (Figure 2: D-Forest). As a result, 54% of the land belonging to Kihen Community in Adi Zaboy watershed became a prohibited grazing and protected forest land, and the lands far from a water source and relatively far from the villages were left as a seasonally-closed grazing land. The increase in the prohibited grazing and protected forest land in Adi Zaboy watershed since 1991 and the increase in the seasonally-closed grazing land established by the villages to secure feed for the oxen shrunk the free grazing land even more (Figure 2: D-Free grazing). There are currently 2.9 km<sup>2</sup> of prohibited grazing and protected forest lands in Adi Zaboy watershed, which make up 33.6% of the Adi Zaboy watershed used by the farmers from the Kihen community and Agulae town.

### 3.4. Spatial Distribution of Cropland Use-Land Cover

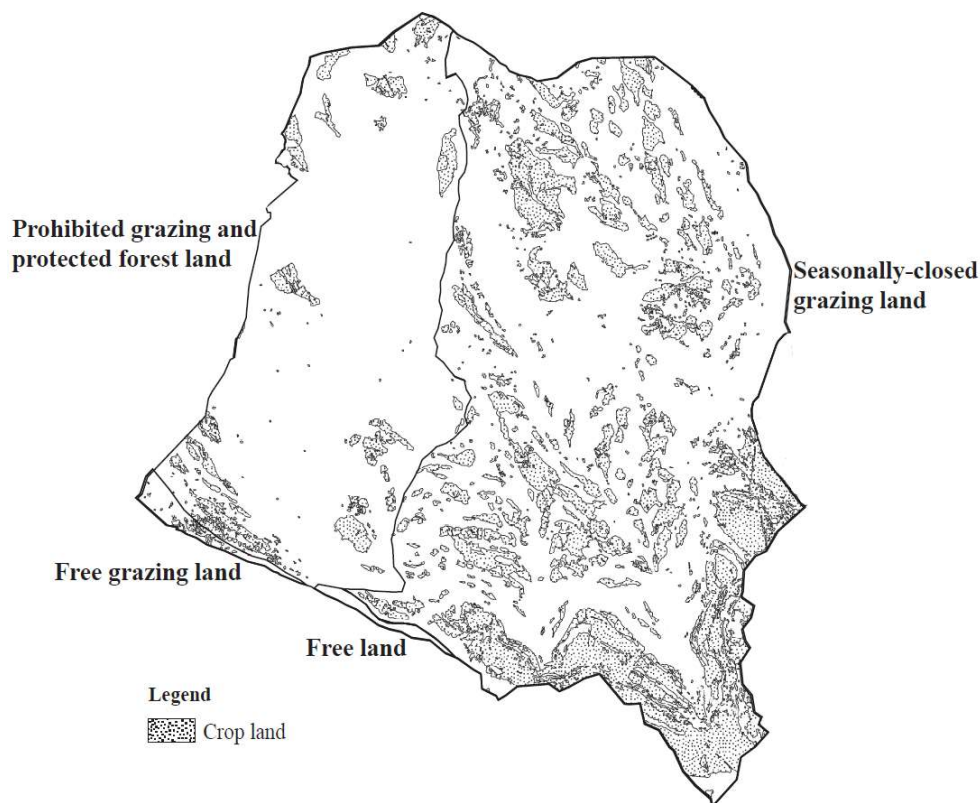
According to BH, there were no regulations on cropland development inside Adi Zaboy watershed before 1975. Hence, the farmers from the Kihen community and Agulae town individually developed their own croplands and many households developed farms on the natural grasslands. With the arrival of the socialist era in 1975, the government seized all cropland ownership and the right to use the cropland was distributed according to family composition using a lottery system [34,35]. Farmers were prohibited from developing new croplands during the Socialist era between 1975 and 1991. The croplands were redistributed after 1991. The croplands existing inside Adi Zaboy watershed today are lands that were developed freely in the imperial era. There are approximately 1.82 km<sup>2</sup> of croplands, which constitute 20% of the Adi Zaboy watershed used by the farmers from the Kihen community and Agulae town. Eighty-five percent of these croplands are mixed with seasonally-closed grazing land and 86% of the croplands are located on a relatively level land with less than a 10° slope. (Table 2). Figure 4 shows the results of spatial distribution of classified croplands in Adi Zaboy watershed. Its accuracy was 83% from the field survey data at 101 points.

**Table 2.** Spatial distribution of croplands by the land management and slope in Adi Zaboy watershed.

Ratio of Croplands to Land Managements					
Land Management Type	Seasonally-Closed Grazing Land	Prohibited Grazing and Protected Forest Land	Free Grazing Land and Free Land		
Croplands (km <sup>2</sup> )	1.55	0.23	0.01		
Ratio (%)	85.1	12.6	0.5		
Ratio of Croplands to Slope					
Slope	0–5°	5–10°	10–15°	15–20°	20–25°
Cropland (km <sup>2</sup> )	0.79	0.79	0.20	0.03	0.00
Ratio (%)	43.6	43.5	10.8	1.9	0.2

The expansion of croplands meant that the natural grasslands were developed. The livestock currently mainly grazes in the seasonally-closed grazing land. The seasonally-closed grazing lands where livestock can graze also shrunk from the expansion of croplands, resulting in the decrease of natural grasslands that can supply feed. With the croplands taking up the relatively level lands with less than a 10° slope, it meant that the steeper lands with more than a 10° slope were used for grazing land. It is believed that this led to the reduction of livestock feed supply, depletion of vegetation on the slopes from the grazing, and increase in risk of soil erosion.



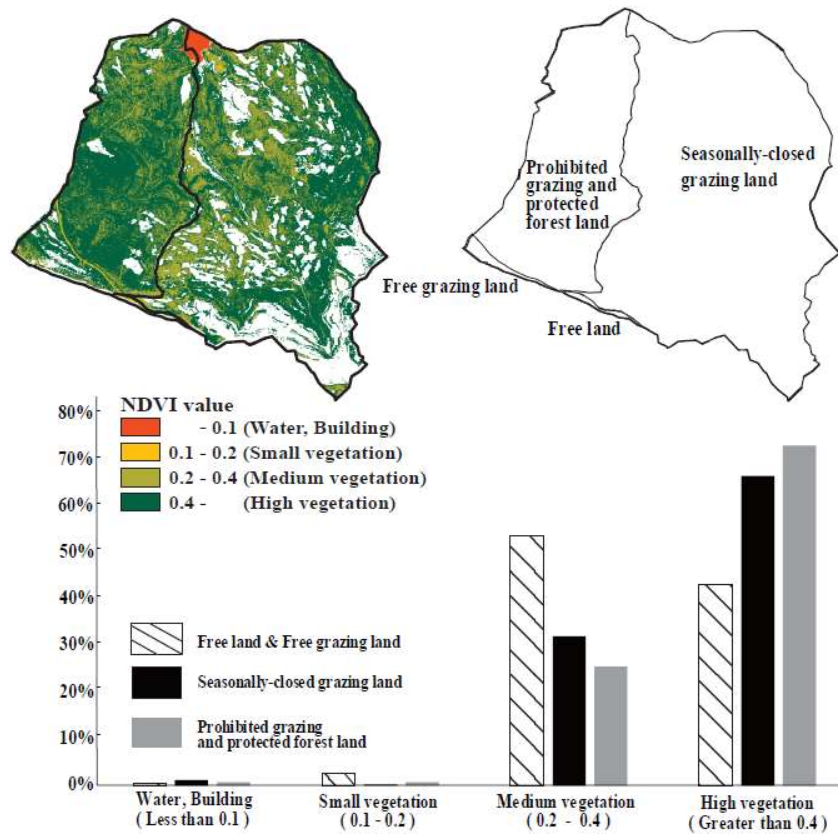


**Figure 4.** Spatial distribution of croplands in Adi Zaboy watershed.

### 3.5. NDVI Assessment of Vegetation in Each Land Managements

As the results of analyzing the ratio of NDVI value in the natural vegetation according to indicators of small, medium and high, the water or building was 0.6%, 1.1% and 0.3%, the small vegetation was 0.6%, 0.2% and 2.6%, the medium vegetation was 25.5%, 32.1%, and 53.9%, and the high vegetation was 73.3%, 66.6%, and 43.2%, respectively, in the prohibited grazing and protected forest land classification, the seasonally-closed grazing land classification and the free grazing land (Figure 5). When comparing the ratios of high vegetation in each type of land management, the prohibited grazing and protected forest land was 73.3%, the seasonally-closed grazing land was 66.6%, and the free grazing land was 43.2%, showing that the prohibited grazing and protected forest land tended to have the highest ratio of high vegetation. On the other hand, when the ratios of medium vegetation were compared, the prohibited grazing and protected forest land was 25.5%, the seasonally-closed grazing land was 32.1%, and the free grazing land was 53.9%. This high vegetation ratio indicated that wild herbaceous and woody plant species were able to flourish during the 20 years of restriction on the use of natural resources when most of the free grazing land had been converted into a prohibited grazing and protected forest land when its classification was established. Like the past researches, it is believed that natural vegetation can recover in the prohibited grazing and protected forest land [14,36]. In addition, many conservation activities (SWC) and afforestation activities have been carried out within the prohibited grazing and protected forest land by local farmers. Therefore, stone bunds and planted woody plants can keep rain water flowing on the slope. It was considered that vegetation growth was positively promoted by the increase of soil moisture content increase [37]. The seasonally-closed grazing land has 6.6% less high vegetation than the prohibited grazing and protected forest land. However, its ratio of high vegetation is 23.5% higher than the free grazing land where livestock is freely dispatched. Therefore, it showed that the grazing restriction during the rainy season in the seasonally-closed grazing land enhanced the growth of wild herbaceous and woody plant species and promoted regeneration of vegetation from seeds and fruition, which increased the capacity to secure

and supply more livestock feed resources. Also, the spray of livestock manure during grazing period which results in supplying organic matter and nutrients into the soil would positively promote the growth of wild herbaceous plants and wild wood plants in the seasonally-closed grazing land.



**Figure 5.** Ratio of normalized difference vegetation index (NDVI) values in each land management type in the Adi Zaboy watershed in September 2016.

### 3.6. Compatibility of Environmental Preservation and Securing of Feed Resources

The Ethiopian government announced that they planned to afforest 20,000 km<sup>2</sup> of land, reforest 1000 km<sup>2</sup> of land, and improve maintenance on 30,000 km<sup>2</sup> of natural grasslands by 2030 [38]. Hence, it is believed that the prohibited grazing and protected forest land will become more expanded throughout Ethiopia in the future. The expansion of the prohibited grazing and protected forest land is also likely to tighten the restriction on the use of natural resources in Adi Zaboy watershed for the Kihen community and Agulae town farmers [39]. On the other hand, the zero grazing movement has been implemented in Tigray Region since 2006 out of necessity in raising livestock. This system improves the cattle breed as well as the grassland, so that the farmers can cut and carry the feed resources and raise the livestock in a stall instead of leaving them out in the pasture [40,41]. The Tigray farmers are searching for a livestock-rearing method that can secure both livestock feed and vegetation preservation without the unlimited use of feed resources.

Gebremedhin et al. [42] believed that a proper management of livestock is important to a sustainable and environmental development of mixed crop-livestock farming from an economic perspective, and that a proper management of livestock requires a sustainable use of grassland and a mitigation of the feed shortage problem.

The result of the vegetation assessment in this research using local investigation and satellite images also showed that the traditional seasonally-closed grazing land makes it highly possible to secure and supply valuable livestock feed resources by limiting the grazing period, which enhances the

growth of wild herbaceous and woody plant species and promotes vegetation regeneration through seeds and fruition.

Based on the information above, environmental preservation and sustainable land management to secure feed resources may be possible by determining the appropriate period and number of livestock that can be grazed, and routinely assessing the amount and condition of herbaceous and woody plant species in the seasonally-closed grazing land and the prohibited grazing and protected forest land by: (1) securing and actively using seasonally-closed grazing land that has a grazing restriction during the rainy season, (2) securing livestock feed resources by a cut-and-carry method from the expanding prohibited grazing and protected forest land, and (3) using satellite images and GIS.

#### 4. Conclusions

In the northern part of the Ethiopian highlands, it is necessary to discuss sustainable land managements and to secure a site with enough feed supply to improve the lives of the farmers as well as conservation activities. The purpose and results of this research are summarized below.

1. To reveal the changes in land management by farmers in the imperial era, the socialist era, and the democratic era. The land managements were classified into free land, free grazing land, seasonally-closed grazing land, and prohibited grazing and protected forest land in the study area. Free grazing lands have decreased from the Imperial era to the democratic era. From the viewpoint of environmental protection, the government-led prohibited grazing and protected forest land are expanding during the democratic era. The expansion of the prohibited grazing and protected forest land has been tightened the restriction on the use of natural resources for feed supply.
2. To assess how the different forms of land management affected the vegetation through satellite images and field investigation. It was shown that the prohibited grazing and protected forest land keeps more vegetation by grazing restriction and conservation activities than the seasonally-closed grazing land and the free grazing land. The seasonally-closed grazing land also has kept vegetation as compared with the free grazing land. It was considered that the grazing restriction during the rainy season in the seasonally-closed grazing land enhanced the growth of wild herbaceous and woody plant species and promoted the regeneration of vegetation from seeds and fruition, which increased the capacity to secure and supply more livestock feed resources.
3. To consider how the land should be used to allow both environmental preservation and sustainable use of resources for feed supply. Expansion of prohibited grazing and protected forest land led to a limitation of the resources for feed supply available to farmers. For the point of securing feed resources, it is necessary not to decrease the area of seasonally-closed grazing land any more, and furthermore, important to promote the positive cut-and-carry activity from prohibited grazing and protected forest land. The strategy shown in this study was considered to be a possible sustainable land management method to secure resources for feed supply.

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