Forage productivity in native grasslands of Haharu Sub-district, East Sumba District, Indonesia

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Abstract. *Watuwaya BK, Syamsu JA, Budiman, Useng D. 2022. Forage productivity in native grasslands of Haharu Sub-district, East Sumba District, Indonesia. Biodiversitas 23: 1361-1367.* The identification and management of native grasslands are important to ensure the availability of beef cattle feed in smallholder farms. This study aims to identify the existing native grasslands in Haharu Sub-district, East Sumba District, East Nusa Tenggara Province, Indonesia and analyze the botanical composition, biomass and the carrying capacity of the native grasslands. We used the combination of remote sensing approach and field survey to identify and measure the productivity of native grasslands. Sentinel 2A imagery was used to identify the area of existing native grasslands using Supervised Classification-Maximum Likelihood method. Meanwhile, the productivity of native grasslands was measured using the Dry Weight Rank method. The results of remote sensing and spatial analysis showed that the existing area of native grasslands in Haharu Sub-district was 324,10 km² with an Overall Accuracy of 98.63% and Kappa Accuracy of 0.98. The vegetation analysis showed that the botanical composition of native grasslands consisted of grasses 94.42%, legumes 3.55% and weeds 2.07%. The carrying capacity of the studied grassland was 0.68 AU/ha/month in the wet season. In conclusion, the productivity of existing native grasslands in the wet season is still low and special efforts are needed to improve the quality.

Keyword: Carrying capacity, DWR, grasslands, maximum likelihood

INTRODUCTION

Forages are the primary sources of feed for raising beef cattle and other ruminants. Forage sources can be obtained from grasslands, either by letting the livestock freely graze in the field or collecting the grass to feed them in the stalls. The advantages of livestock grazing in grasslands are not only from the higher nutritional value obtained but also it can provide more exposure to fresh air and sunlight, the ability to move freely and the opportunity to live in social groups, resulting in the enhancement of animal health and welfare (Schuppli et al. 2014). In the eastern part of Indonesia, such as in East Sumba District, most native grasslands are areas for farmers to freely graze their livestock (Watuwaya et al. 2020).

Livestock grazing in grasslands requires a relatively large extent of the area. In recent years, however, there has been a reduction in grazing areas once used for raising beef cattle, buffalo, horses and goats (Djawa and Jacobs, 2021). The increasing population and human activities have caused significant loss and degradation of native grasslands (Guoa, 2018; Bamutaze et al. 2019; Bardgett et al. 2021). Globally, various human activities have caused the degradation of native grasslands by 32.53%, although this figure is still lower than the damage due to climate change, which is 45.51% (Gang et al. 2014). For example, in East Sumba District, many areas of native grasslands have been converted to sugarcane plantations, especially in Haharu Sub-district. The conversion and degradation of native grassland can indirectly have an impact on reducing the income of smallholder farmers.

Since the extent of grasslands is continuously reduced, optimizing the remaining grazing areas is essential to provide sufficient feed sources for the livestock. Therefore, the identification and management of grasslands are needed to ensure the suitability of botanical composition, the availability of forage biomass, and the carrying capacity (Mosisa et al. 2021). The botanical composition of grasslands can be defined as the proportion of species that grow in the grasslands. Botanical composition is dynamic, meaning that it is able to change whether caused by human, livestock, season or other management factors (Michaud et al. 2012; Pornaro et al. 2019). At the same time the biomass is related to the forages material above the land, generally associated as a dry weight product. Therefore, each grassland should be grazed according to its respective ability to produce forage biomass to suit its carrying capacity. Optimal use of grasslands can be done by setting a suitable balance between the quantity of available forage and the number of grazing livestock (Pornaro 2019).

This study aims to identify the existing native grasslands in Haharu Sub-district, East Sumba District, East Nusa Tenggara Province, Indonesia and analyze the botanical composition, biomass and the carrying capacity of the native grasslands. The identification of the native grasslands in the studied area used a remote sensing approach with a supervised classification maximum likelihood method by utilizing Sentinel 2A satellite

imagery, while the productivity of the native grasslands was measured using the Dry Weight Rank method.

MATERIALS AND METHODS

Study area

The research took place in Haharu Sub-district, located on the Island of Sumba, precisely in the northern part of East Sumba District (Figure 1). Geographically, Haharu Sub-district is located in -9.45168 latitude and 120.05792 longitudes. The Haharu Sub-district comprises seven villages. Every village has its own native grasslands for beef cattle grazing. The main occupation of the local community is farming. The topography of the area is mostly hilly with an altitude between 0-400 meters above sea level. Along the northern region is a coastal area. Generally, the north is hilly, and rainfall is very low and uneven every year. The wet season is relatively less than the dry season.

Remote sensing and spatial analysis

The spatial analysis used Sentinel Sattelite 2A imagery (Huang 2016) with an acquisition date on September 28, 2020, downloaded from the site Copernicus open Access Hub https://scihub.copernicus.eu. Furthermore, the image was processed using software ENVI 5.2 and Arcmap 10.5

at the National Institute of Aeronautics and Space (LAPAN) Remote Sensing Earth Station Parepare, South Sulawesi. When determining native grasslands using visual interpretation, the observer should compare the imagery used with higher resolution satellite imagery. In this study, we used very high satellite imagery resolution Maxar from Google Earth (Bey et al. 2016).

Maximum likelihood method

The supervised classification maximum likelihood method is a classification technique using the pixel value that is assigned to an object (i.e., land cover type) and made in a training (sampling) area. This determination is based on a user's knowledge of the existing land cover. The pixel values are then used by the computer's logarithm to identify other pixels (Jansen 2015) as follow:

$$P(i|X) = \frac{P(X|i)\,P(i)}{P(X)}$$

Where:
$P(i|X)$ is the likelihood function,

$P(i)$ is the a priori information, i.e the probability that class i occurs in the study area and
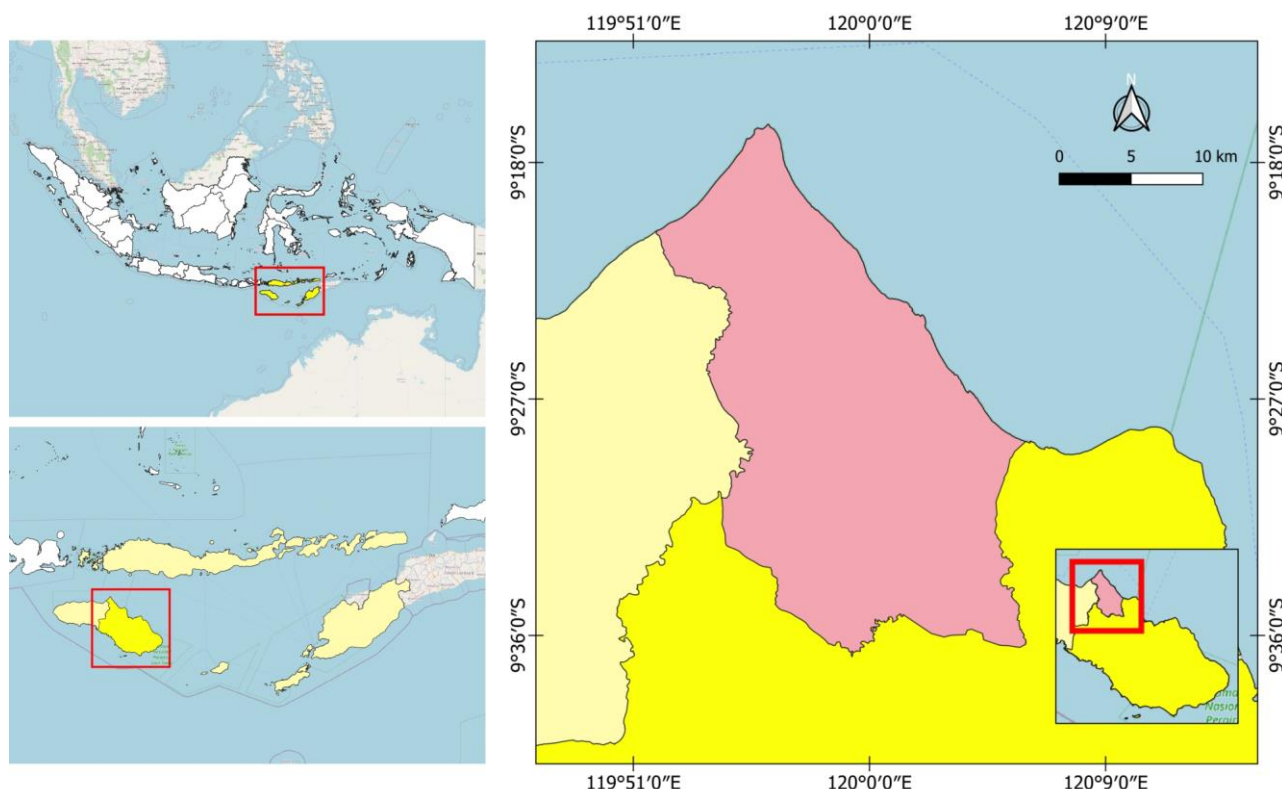
$P(X)$ is the probability that X is observed

Figure 1. Study area in Haharu Sub-district, East Sumba District, East Nusa Tenggara Province, Indonesia

The selection of a training sample that is not exact can result in less optimal classification so that the accuracy obtained is low. Thus, statistical analysis or accuracy testing of the sample is required. A confusion matrix (sometimes called an error matrix) was used to assess the accuracy of the maximum likelihood classification. It compares class-by-class the relationship between the reference data (ground truth) and the corresponding results of the classifier. Assessment of the accuracy of a classification can be calculated from overall accuracy, producer's accuracy, user accuracy, and Kappa accuracy (Verma 2020). Overall accuracy is the total value of the classification, i.e. the ratio of the total number of areas (pixels) that are correctly classified to the total area (pixels) of observation, showing the level of accuracy of the classified image (Jansen 2015). This is calculated as:

$$Overall\ Accuracy = \frac{D}{N} \times 100\%$$

Where is

D: Total value of correct rows that have been added diagonally

N: Total correct values in the error matrix

The Kappa coefficient is a measurement instrument of classification accuracy that incorporates both off-diagonal and diagonal elements to provide a more robust means of assessing accuracy than overall accuracy. It is computed as follow (Jansen, 2015):

$$Kappa\ Accuracy = \frac{\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i} . x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} . x_{+i})}$$

Where is:

r: Row number in matrix

x_{ii}: Actual total number of cells in the class

x_{i+}: Total for row i

x_{+i}: Total for column i

N: Number of cells in the error matrix

Dry weight rank, botanical composition and carrying capacity

The Dry Weight Rank method was developed by Mannetje and Haydock. This method is used to estimate the botanical composition of a pastoral in the form of dry weight without cutting and separating the types of plants. This method uses a square frame (quadrant) measuring 0.5 x 0.5 m. Quadrants were put randomly in the grasslands, then all species were recorded and the percentage (in numbers) of species that ranked first, second and third was calculated. Other species outside these three highest rank species (e.g., ranked fourth and so on) were ignored (Watuwaya et al. 2021). Considering the extent of the grazing area where the botanical composition and capacity will be tested, the sampling was carried out based on the stratified random sampling method that can be made using ArcGIS software.

The procedure for measuring the carrying capacity of the native grasslands was as follow: (i) a 100 x 100 cm quadrant frame was thrown randomly; (i) cutting the forage within the quadrant as short as possible to the ground, (ii) the cut forage samples were put into a special bag after which it was weighed, (iv) the second sample was taken to the left and right as far as 5 to 10 steps, (v) the first and second samples were referred to as clusters. Forage production data obtained from each sampling site were averaged (grams/meter^2), then the results obtained were converted to tons/hectare units. Measurement of production in one year and measurement of storage capacity was carried out using the estimation method. The collected forages sample was analyzed by proximate analysis and Van Soest methods in the Feed Chemistry Laboratory, Nusa Cendana University.

RESULTS AND DISCUSSION

Grasslands identification

Based on visual observations, it was found that the characteristics of native grasslands were light brown to brownish green in the form of an open expanse with little growth of trees or shrubs on it and in the varying shape of polygons (Figure 2).

The identification process of the native grasslands using Sentinel 2A imagery to distinguish grasslands from other land cover types was carried out by visual and digital approaches. Sentinel satellite imagery was set to 832 band composite to make the image appearance easier to interpret. Band 832 uses band 8, which is a band near-infrared. This band combination reflects chlorophyll very well, i.e. the more densely the vegetation, the darker the red color will be (Zhang et al. 2018; Berauer et al. 2020), while the built-up areas are a white or lighter color.

Figure 2. The circle shows land cover type on the same spot: A. Sentinel 2A Composite band 832; B. Maxar Imagery on Google Earth; C. Ground truth on the field

Based on the results of visual observations on Maxar images, the imagery is divided into five different classes based on the dominant objects on the land. The five classes consisted of bare lands, built area, waterbody, grassland and trees, forest, and agricultural land, merged into one class. Subsequently, a reclassification process was carried out to obtain areas of grasslands and non-grasslands area. The result showed that grasslands dominated the area with an extent of 324.10 km2 (62.76 %) and non-grasslands of 192.31 km^2 (37.24 %) (Figure 2).

The test of the accuracy using Maximum Likelihood classification deal with a contingency matrix or an error matrix or a confusion matrix (Kumar et al. 2015). Table 1 shows that the overall accuracy of the supervised classification the maximum likelihood for visual and ground truth classification is 98.63 % with a Kappa accuracy value of 0.98. According to the United States Geological Survey (USGS), the level of the minimum classification accuracy using remote sensing should not be less than 85% (Small and Daniel, 2016). Thus, the overall accuracy and Kappa accuracy of this study area are categorized as in the precision category. This is because the image used was intentionally taken during the dry season

so that there were no clouds. The condition of the land cover in the dry season was almost homogeneous and easy to distinguish from the color and shape of the object.

By far, the maximum likelihood classification method is the most widespread among the supervised classification methods. This procedure offers many benefits. Pre-classification activities are very meaningful in which object matching that uses very high resolutions such as Maxar and clean imagery selection greatly helps improve the accuracy.

Dry weight rank assessment

Based on data collection on the field, eleven species of plant were recorded on native grasslands in Haharu Sub-district (Table 2). The limited number of plants species recorded was likely because the Dry Weight Rank (DWR) method limits the data recording only to the three dominant species in each quadrant. Nonetheless, it can be said that the species on the native grasslands in Haharu Sub-district were quite diverse. The grasslands were dominated by seven species of grass, two species of legumes and two species of weeds.
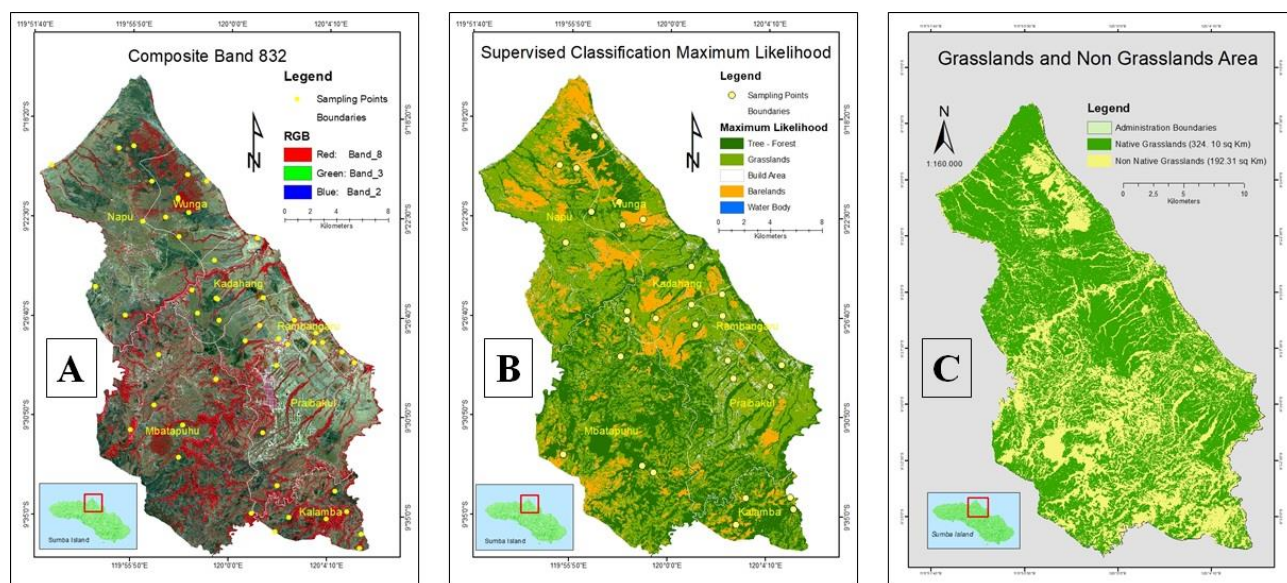

Figure 3. Map of land cover classes of the studied area: A. Composite band 832 from Sentinel 2A; B. Supervised Classification-Maximum Likelihood which divided the area into five classes; C. The area is divided into grassland and non-grasslands area

Table 1. Confusion Matrix from Supervised Classification-Maximum Likelihood

Class types determination from classified map (Visual and ground truth)					Total	User accuracy (%)	Producer accuracy (%)	Overall accuracy (%)	Kappa accuracy (%)
	T/F/A	GL	BA	BL	WB				
T/F/A	220	0	0	2	0	222	99.10	98.65	98.63	0.98
GL	1	325	2	3	0	331	98.19	99.69		
BA	0	0	210	3	0	213	98.59	98.13		
BL	2	1	1	252	1	257	98.05	99.53		
WB	0	0	1	0	213	214	99.53	99.53		
Total	223	326	214	260	214	1237				

Note: T/F/A: Tree/Forest/Farm land; GL: Grasslands; BA: Built Area; BL: Bare Lands; WB; Water Bodies

Table 2. Botanical composition of native grasslands in Haharu Sub-district, East Sumba District, Indonesia based on Dry Weight Rank (DWR)

Dry Weight Rank
Grass
Themeda triandra (23.8%)
Heteropogon contortus (23.4%)
Shorgum plumosum (21.5%)
Cynodon dactylon (8.4%)
Panicum maximum (3.4%)
Brachiaria decumbens (7.8%)
Iscahemun timorense (6.1%)
Legumes
Stylosantes humilis (2.2%)
Pueraria phaseoloides (1.3%)
Weeds
Mimosa pudica (1.7%)
Walteria indica (0.5%)

Results of observations and calculations of botanical composition in seven locations of native grasslands in Haharu Sub-district found three dominant species of forages, respectively 23.8% *Themeda triandra*, 23.4% *Heteropogon contortus*, and 21.5% *Sorghum plumosum*. It can be seen that grass species occupied the highest proportion in the grasslands studied, with 94.42% percent, while legumes and weeds only accounted for 3.55% and 2.07%, respectively. Despite the low proportion, the availability of sufficient legumes in grassland is very important because legumes have a higher nutrient (protein) content than grass. Beef cattle naturally utilize forage for their daily needs, especially forage species from the Gramineae/Poaceae family.

Research conducted by Sutter et al. (2015) for three consecutive years reported the value of Nitrogen total between mixed grass and legume in native grasslands was significantly different compared to grass monocultures. Total Nitrogen values continued to increase until the legumes was one third of the native grasslands. In other words, the ratio of botanical composition between grasses and legumes was 70 : 30. In comparison, Lűscher et al. (2014) reported that the most effective botanical composition in mixed grassland was if it has a 30-50% legume proportion.

The low quality of forages in native grasslands was likely due to the use of native grasslands for continuous grazing without a break period. Grasslands that are continuously used without break will cause forages in the grasslands, both grass and legumes, to be under heavy pressure, causing stunted growth of such forages. Legumes are the species most affected by this impact. The vulnerability of legumes is due to overgrazing because they have roots that are not strong enough and cannot withstand the stamping of livestock (Gonzalez and Ghermandi 2021).

The results of the proximate and Van Soest analysis of forage quality in the wet season in the Haharu native grasslands are shown in Table 3. The average content of crude protein was 6.17% and crude fiber was 32.23% which are categorized in the medium category. Categorized as moderate if the grass crude protein content is around 5-10%, and high category if it is more than 10%. One of the determinants of forage crude protein content is harvesting age. In this research, forages data was collected intentionally after the grass sprouted to ease the observer to distinguish the types of grass in the field. The value of crude protein and crude fiber content is inversely proportional, where the older the age of the forage, the crude protein content will decrease while the crude fiber content will increase (George et al. 2016).

The value of NDF and ADF content in forage is very important to observe. The lower the value of the NDF and ADF fractions, the higher the digestibility of the feed. The decrease in NDF value was caused by the increase in lignin content, which resulted in a decrease in hemicellulose content. Hemicellulose and cellulose are components of cell walls that can be digested by microbes. The high content of lignin causes the microbes to be unable to completely degrade hemicellulose and cellulose. Average NDF and ADF content in the grasslands area were 65.69 and 44.15 % dry matter. These values are categorized as normal for the post-head stage. The ADF and NDF range in grasses varied by age, on the stage head ADF was 36-44% and NDF was 60-65%, while post-head ADF was >45% and NDF was > 65%. The ADF and NDF content are used as standard forages testing for fiber analysis. Content of NDF approximates the total cell wall constituents, including hemicellulose, while ADF content represents cellulose and lignin. The NDF is used to predict intake potential and ADF is often used to calculate digestibility (Moore et al. 2020).

Table 3. Results of proximate and Van Soest analysis of feed samples collected from seven native grasslands in Haharu Sub-district, East Sumba District, Indonesia

Grasslands	DM	OM	CP	CF	C Fiber	NDF	ADF	Cellulose	Lignin	Hemicellulose
Wunga	90.98	81.82	6.48	3.07	32.54	66.28	44.74	24.33	14.21	21.48
Mbata Puhu	90.83	81.67	6.33	2.92	32.39	66.13	44.59	24.18	14.06	21.33
Napu	89.93	80.77	6.43	2.02	31.49	65.23	43.69	23.28	13.16	20.43
Kadahang	91.03	81.87	6.53	3.12	32.59	66.33	44.79	24.38	14.26	21.53
Rambangaru	88.03	78.87	6.25	2.12	31.59	63.33	41.79	21.38	11.26	18.53
Kalamba	91.13	81.97	6.63	3.22	32.69	66.43	44.89	24.48	14.36	21.63
Prai Bakul	90.78	81.62	6.28	2.87	32.34	66.08	44.54	24.13	14.01	21.28
Average	90.39	81.23	6.17	2.76	32.23	65.69	44.15	23.74	13.62	20.89

Note: DM: Dry Matter; OM: Organic Matter; CP: Crude Protein; CF: Crude Fat; CFibre: Crude Fibre; NDF: Neutral Detergent Fibre; ADF: Acid Detergent Fibre

Tabel 4. Carrying capacity of forages in seven native grasslands in Haharu Sub-district, East Sumba District, Indonesia

	Wungga	Mbata Puhu	Napu	Kadahang	Rambangaru	Kalamba	Prai Bakul
DM Production (Kg/hectare)	862.07	1001.79	911.04	862.07	937.07	892.07	982.07
Area Cover (%)	84.64	85.36	86.96	84.11	84.05	85.18	83.57
Proper Use Factor (PUF %)	70	70	70	70	70	70	70
Carrying Capacity (AU/month)	0.63	0.74	0.68	0.63	0.68	0.66	0.71

The carrying capacity is a reflection of the productivity of grassland. The calculation of the carrying capacity of each native grassland in Haharu Sub-district is presented in Table 4. The highest dry matter production was in Mbata Puhu Village with 1001.79 kg/hectare, while the largest percentage of the coverage area was in Napu Village with 86.96%. The PUF value will be greater in line with the greater possibility of erosion, overgrazing or other factors that can inhibit the growth of forage in a grassland. For light use of grasslands, the PUF ranges 25-30%, medium use ranges 40-45%, and for heavy use ranges 60-70%. Considering the topography, climate and soil conditions, the measurement of the carrying capacity of these native grasslands used PUF 70%. The results of this study indicate that the productivity of natural pastures is still low to support the development of beef cattle. The carrying capacity of native grassland was categorized as low, ranging from 0.63-0.71 AU/ha/month or average in 0.68 AU/ha/month during the wet season. This calculation used the standard 1 AU equivalent to an adult bull weighing 300 kg.

Forage quality is determined by the composition of the forage in the grasslands, which can change its composition due to the influence of climate, soil conditions and the effect of utilization by livestock. Special efforts that can be made to improve the quality of the grasslands include (i) letting the grasslands rest from grazing to give legumes an opportunity to grow better, (ii) increasing the abundance and types of legumes in the grasslands, and (iii) regulating the time and the individual number of livestock grazed on the grasslands (Sollenberger et al. 2019). In the case of native grasslands in Haharu Sub-district, the introduction of legumes should be shrubs or trees from the legumes plant. This type of plant is resistant to livestock snatching and footing and the important thing is they have deep roots.

Introducing legumes to the grasslands will increase the sustainability of the grasslands-based animal production because it can increase forage yields and fertilize the soil by biological nitrogen fixation mechanism. The least important thing for smallholder farmers is by increasing the nutritional value of forages to raise the efficiency of conversion of forages to animal protein, leading to the improvement of the well-being of the farmers (Lüscher et al. 2014; Syamsu et al. 2019).

To conclude, the existing native grassland in Haharu Sub-district identified using supervised classification-maximum likelihood method utilizing remote sensing image was 324.10 km^2 and non-grasslands were 92.31 km^2. The Overall Accuracy of the remote sensing and spatial analysis was 98.63% and Kappa Accuracy was 0.98. The botanical composition of seven native grasslands sampled consisted of grasses 94.42%, legumes 3.55% and weeds 2.07%. There were seven species of grasses, two species of legumes and two species of weeds recorded. Three dominant grass species respectively were *Themeda triandra* 23.8%, *Heteropogon contortus* 23.4%, and *Sorghum plumosum* 21.5%. The carrying capacity of the studied grassland was 0.68 AU/ha/month in the wet season. The results of this study suggest that the productivity of existing native grasslands is low and special efforts are needed to improve the quality.

ACKNOWLEDGEMENTS

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