Optimization Of Land Resources Through Forages Development

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ABSTRACT

The development of the livestock industry can be realized through the optimization of natural resources such as soil and vegetation that grows on it (forage, and legumes). Forage roles as animal feed, as well as land conservation plants, while leguminosae can improve soil nutrient elements. Changes in land use become a limiting factor in the availability of forage, giving and lack of animal feed. Optimization of land resources can be done through the use of marginal land, post-mining and watershed as an alternative to the development of forage. Appropriate land management according to the type of land which supported by technology has implications to the increasing of forages productivity and sustainability of land resources utilization in the long term as well as preserving the environment.

Keywords: Optimization, resources, land, feeds, forages, legumes

1. INTRODUCTION

The development of livestock industry can be realized through optimization of natural resources such as soil and vegetation that grows on it (forages and leguminosae). Forages role as livestock (ruminant) feeds as well as soil conversation plants while leguminosae can improve soil nutrients elements (Shewmaker *et al.,* 2010). The production of ruminant is limited by feeds shortage in term of quantity, quality and is characterized by by food insecurity, land degradation, land shortages, and declining of soil fertility (Abera, 2012). Competition in the use of arable land that is increasingly competing between food crops (agriculture) and ruminant food (forage) is a factor in hampering livestock development. The increase in human population is experiencing a rapid increase, the utilization of food crops continues to grow wider, while grazing areas continue to decline. Decreased production results in a shortage of feed, so ruminants are not able to meet the body's nutritional needs, lose weight, as well as decrease productivity. Ruminant production in the tropics depends on forage availability (Abera, 2012; Kraft *et al*., 2018).

Important factors in achieving high productivity, efficient, competitive and sustainable ruminant are must be able to provide adequate feed in quantity as well as providing perfect quality. The relationship between quantity and quality always changes, and depends on many factors, including forage varieties, production, variations between forage species, seasons, defoliation and forage structure (stem balance, and leaves). The availability of a good quality forage can save a lot of feed costs (Beetz and Rinehart, 2006). Land availability for future bioenergy production is an alternative in providing feed and determining the sustainability of livestock business (Martin *et al*., 2017).

The province of East Kalimantan has an area of +127 346,92 km^2, arable land area of +815,249 hectares, and supported by potential topographic and land use for the development of animal husbandry industry (SI of East Kalimantan, 2018). The development of forage resources is possible to be done through optimal use of alternative or complementary land including marginal land (post-mining land, saline land, acid soils, alkaline soils, limestone soils, swamps) and watersheds. Low local feed productivity provides an opportunity for the introduction of superior forages so that ruminant feed needs can be met (Delima *et al*., 2015). Intensification of forage planting can contribute to the conservation of natural resources, this is because forage has direct and indirect effects in increasing the efficiency of land resource use (Peters *et al.,* 2001; Kumar *et al.,* 2012; Delima *et al.*, 2015; Crotty *et al.,* 2016). The introduction of superior grass is carried out to provide forage in order to support increasing livestock populations programs and contribute to the development of sustainable livestock farming (Delima *et al*., 2015). Optimizing land use is not only limited to increasing productivity of forages, but also efficiency (sustainable intensification) of resources is a new challenge in the development of the livestock industry (Roy *et al.*, 2009; Luscher *et al.*, 2014).

2. SPATIAL DATA AVAILABILITY

Spatial data information can help to determine the location of land resources for livestock's forages and determine the potential of land resources in an area (Schellberg and Lock, 2009; Abadi *et al*., 2019). Regional mapping technology will ease land use optimization. East Kalimantan Province has humid tropical climate with wavy topography, sloping to steep slopes, altitude ranging from 0-1500 m above sea level, slope between 0-60%, land area (43,35%) included in slopes above 40% and 43,22 % is located at an altitude of 100-1000 m above sea level, so land use is adjusted to the characteristics of the land so that it can be optimally implemented (Bappeda of East Kalimantan, 2017).

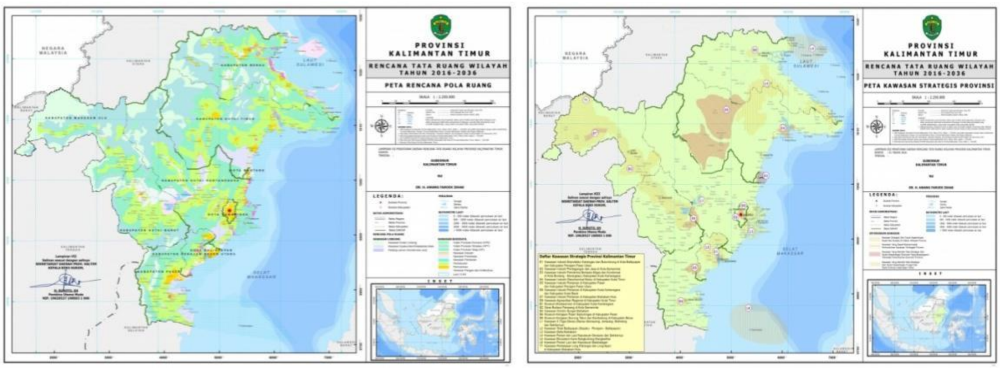

Figure 1. Map of Spatial Plan and Strategic Zone of East Kalimantan Province (Bappeda of East Kalimantan, 2017).

3. LAND RESOURCE

The global livestock sector is the largest user of land resources, reaching to 3,4 billion hectares for grazing and 0,5 billion hectares for food crops (Peters *et al*., 2012). Livestock area is an existing area or new location that has natural resources according to agroecosystem, and its location can be in the form of an expanse and / or partial spot (separate area) that is functionally connected through good accessibility in one area, equipped with adequate infrastructures and facilities to develop livestock areas. Soils in East Kalimantan Province are classified as those that can easily react with acids include soil types of *Potsolik (ultisol), Alluvial (entisol), Gleisol (gleisol), Latosol (ultisol), Andosol (incepsol), Regosol (entisol), Renjina (mollisol),* and *Mediteran (inceptisol)* (Budiana *et al*., 2017).

Inhibiting factors in the availability of forage, among others, is a change in the function of forages area into residential land, food crops, and industrial plants (Mayulu, 2019). Forages planted on an area can increase production efficiency, control erosion, improve soil, restore degraded land, and increase biodiversity. Soil quality is the ability of the soil to support plant growth, including other factors such as tilt, aggregation, organic matter, soil depth, water holding capacity, cation level infiltration, pH change, and soil nutrient capacity (Liu *et al*., 2006). Soil quality is related to the assessment and management of the land so that currently it functions optimal and is not degraded for future use (Liu *et al*., 2006).

Soil degradation and / or changes in soil quality are caused by wind, water erosion, salinization, organic matter and nutrient content and soil compaction. Soil management can increase soil respiration, including the availability of substrate, soil temperature, water, pH, oxidation reduction potential, type and number of microorganisms, and soil ecology. Soil quality cannot be measured directly, but can be determined through soil indicators. Fertilization is able to provide nutrients for the soil so that it can improve the physical, chemical and biological structure of the soil. Efficient use of fertilizers can be done through proper soil management (Liu *et al*., 2006).

Forages growth is influenced by soil fertility, namely the presence of organic matter, in the supply of nutrients for plants (Narendra, 2012). Soil type, soil texture, pH and drainage can affect the development, forage productivity, microbial content in the rhizosphere, those are related to the availability of soil nutrients. About 70% of livestock productivity is influenced by environmental factors (Ernawanto and Sudaryono, 2016)

4. MARGINAL LAND / SURPLUS LAND

Marginal land is land that has very low quality, due to inherent nature and land management activities that are detrimental to land resources. Marginal land has very poor physical, chemical, and / or biological soil properties that are unable to support optimal plant growth. Marginal land contains very low levels of macro nutrients and micro nutrients, while toxic nutrients (Aluminum, Mangan, and Iron) are very high.

Classification of marginal land includes acid soil, saline land, alkaline soil, lime soil, and swampy land and post-mining land (Riswandi *et al*., 2014). Land use according to the capacity, planting cover crops, increasing crop intensity and land management ratios through intercropping or crop rotation, ensuring ecosystem biodiversity by utilizing vegetation diversity and livestock are the principles in managing marginal land (Ernawanto and Sudaryono, 2016). Marginal land is not fully utilized because of limited knowledge in conserving or managing land. Poor soil quality and lack of water cause forages not be able to produce maximum yield, but this can be solved by the existence of sustainable marginal land conservation by planting forages that are able to produce high yield on marginal land (Toderich and Kalashnikov, 2014)

Increasing forages productivity in marginal land can be done through integrated management technologies that are environmentally and economically viable including superior varieties that can be accepted by farmers and do not have a negative impact on nature conservation (Ernawanto and Sudaryono, 2016). Marginal land is suitable for forages production (Kernebeek *et al*., 2016). Forages (grass and legumes) planted on marginal land role as a conservation crops, animal feed, and is able to increase soil fertility and nutrient cycles. Superior grass can be planted on the edge of the terrace +20 cm from the edge of the terrace, and legumes trees are planted on the side of the terrace under the grass (Peters *et al.,* 2001; Ernawanto and Sudaryono, 2016). Legumes species that is oftenly used as cover crops include *Pueraria javanica, Centrocema pubescent*, *Callopogonium mucunoides*,*Psophocarpus palustris, Callopogonnium caerulium, dan Muchuma cochinensisc* (Agustar *et al.,* 2015). The addition of organic fertilizer in the form of compost and biological fertilizer can overcome problems in marginal soils. Forages that have the potential to be developed in marginal lands include sorghum, *lamtoro* (*Leucaena leucocephala*) and calliandra.

Figure 2. Sorghum (Zubair, 2016)

Sorghum (*Sorghum bicolor (L.) Moench*) is a tolerant forage in all types of soil, fast growth (Uebergang, 2018), can grow at soil pH around 5,5, but is not resistant to acid soil (pH <5), very efficient in water use due to the presence of crassulacean acid metabolism (CAM) and physiological mechanisms of C4 and able to grow in the lowlands, moderate to highlands, (Diniz *et al*., 2016), drought resistant (Zubair, 2016) so they can be developed in marginal land. Sorghum has the potential to be a livestock feed source that is easily digested and supported by nutrient content including protein 9,01%, fat 3,6%, ash 1,49%, fiber 2,5%, harvested on 104-109 days with production reaching to 4,8 -5 tons/ha (spacing of 60 x 25 cm) (Zubair, 2016). Tree legumes namely *lamtoro* (*Leucaena leucocephala*) is a type of legumes which is potentially planted on dry land or in the dry season with forage production up to 40 tons DM/ha (Elfeel and Elmagboul., 2016). *Leucaena leucocephala* contains of 15-33% crude protein, 60% dry matter digestibility, and 8,7 MJ/kg DM metabolic energy. Deep root systems allow plants to continue to grow in the dry season (Bowen *et al*., 2015).

Calliandra is a tree legumes which is tolerant to several types of soil, especially acid soils with a pH of 4,5, but it is not tolerant of stagnant soils, grows at an altitude of 0-1.860 m with an average annual rainfall of 1.0004.000 mm, and an average annual minimum temperature of 18-22°C. Calliandra has two species, namely: red flower calliandra species (*Calliandra calothyrsus*) and white flower calliandra (*Caliandra tetragona*) (Narendra, 2012; Abqoriyah *et al.,* 2015; Mayulu, 2019). *Calliandra calothyrsus* has a height between 4-12 m, first harvest age is 9-12 months, and can be harvested then every 4-6 times a year depending on soil conditions (Abqoriyah *et al*., 2015).

Figure 3. *Calliandra calothyrsus* (Narendra, 2012).

Calliandra has potential as a source of protein as it contains 20-25% crude protein and anti-nutrient substances (tannins) to 11% (Narendra, 2012; Abqoriyah *et al*., 2015). *Calliandra calothyrsus* can be used as a conservation crop on marginal soils because of its ability to improve the chemical and physical conditions of the soil by providing green fertilizer for the soil (Narendra, 2012).

Soil marginality is the fundamental limiting factor for plant growth. The species selection that is able to adapt to extreme conditions is very important for sustainable biomass production (Gerwin *et al*., 2018). Optimization of marginal land resource management can be done by determining spatial planning in accordance with the physical condition of the land. The criteria used as consideration for regional planning include land slope, depth of solum, soil erodibility, and prospects of the commodity to be cultivated. Marginal land with a slope of> 45% can be planted with legumes that aim to protect the soil from erosion (Ernawanto and Sudaryono, 2016)

Post-Mining Land

East Kalimantan Province is one of the coal producing provinces in Indonesia, with total production in 2017 reaching 249.268.034,83 tones (SI of East Kalimantan 2018). Post mining is a planned, systematic activity, and sustainable after the completion of all mining business activities to restore the function of the natural environment and social functions according to local conditions throughout the mining area.

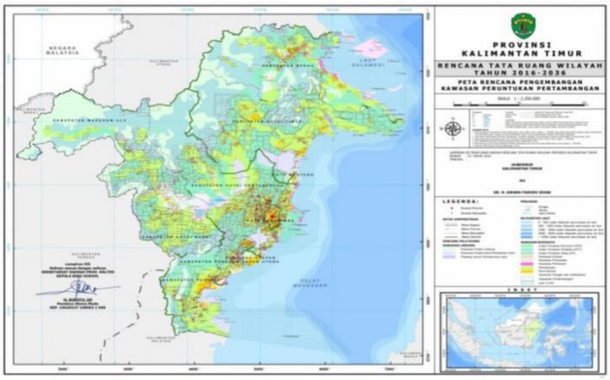

Figure 4. Map of Mining Zone in East Kalimantan Province (Bappeda of East Kalimantan, 2017).

Reclamation is an activity carried out throughout the stages of the mining business to organize, restore, improve the quality of the environment and ecosystem so that it can be used again in accordance with its purpose. Post-mining land is a critical land that has the potential to become an area of forages development after reclamation, recontouring by landfill arrangement adjusted to land topography and re-vegetation conditions (Mashud and Manaroinsong, 2014; Budiana *et al*., 2017; Oktorina, 2017). The land has a high level of density and is less fertile, this is due to the presence of soil deposits from the subsoil and tailings / waste land left over from the extraction process of the ore, as well as heavy equipment traffic during the mining process (Mayulu, 2009; Mashud and Manaroinsong, 2014; Oktorina, 2017).

Reclamation of land after coal mining that is used as pasture for livestock production, especially beef cattle, requires proper management, including weed control, and proper soil fertility maintenance (Abaye *et al*., 2011). Steep topography characterizes the region, making management of grasslands relatively difficult and sometimes dangerous. Low soil fertility, difficult topography and seed proliferation by plant species used in reclamation result in the invasion of undesirable plant species to grow and dominate the land so that superior grass production is disrupted and results in reduced quality and quantity of forage (Abaye *et al*., 2011).

Post-mining land has low nutrient content, low organic matter, toxicity of certain elements, low ability of soil to absorb nutrients and water, poor soil pH and soil physical properties so it requires forages with high adaptability to the land (Mashud and Manaroinsong, 2014). The results of research on superior grass productivity in mining sites conducted by Sulistya and Mariyon (2013) showed that *Brachiaria decumbens cv. Mulato* is the most potentially developed grass in the post-mining land with the highest fresh production in September reaching to 9.520,50 g/plot with a fertilizer dose of 200 kg/ha and nutrient productivity (based on dry matter) 3,888.83 kg DM/ha, crude protein 300,32 kg/ha, crude fiber 1.297,33 kg/ha and crude fat 70,90 kg/ha.

Watershed

Law Number 32 Year 2009 Article 1 states that watershed is a land area which is an integral part of a river and its tributaries, which functions to accommodate, store and drain water originating from rainfall into lakes or into the sea naturally, the boundary on land is the topographic separator and the boundary in the sea is to the waters that are still affected by land activities. The Mahakam Watershed is an area in East Kalimantan which has an area of 8,2 million hectares or around 41% of the total area of East Kalimantan Province, with 27 Sub-Watersheds in the Mahakam Watershed. Increased land productivity of watershed can be done through optimizing land use in accordance with the functions and carrying capacity of the area, soil conservation and management of vegetation (forages planting) especially superior grass.

Maintenance Management

Sustainable land management is an effort to optimally utilize land resources for the benefit of present and future generations, focusing on being inclusive, with a participatory approach to the use of integrated and sustainable natural resources, involving stakeholders at all levels (Nyandiga and Currea, 2017). Soil is the foundation and source of nutrition for plants so that proper management is needed. Appropriate land management can help sustainable land use in the long term and provide benefits to the environment.

Animal husbandry productivity continues to maximize the use of the soil base in the planting system to optimize the nutrients needed by livestock and can be metabolized by livestock (Martin *et al.*, 2017). The use of legumes in cropping systems enables to supply nitrogen for soil improvement as well as supplying high-quality feed for livestock and grass can increase soil fertility by increasing soil organic matter (Stur and Horne, 2000).

Legumes can increase soil fertility because of its ability to fix nitrogen by returning nitrogen to the soil through fallen leaves, root nodules, manure and urine of grazing cattle. Legumes have more protein than grass, which is 15-25% and if converted to N is equivalent to 2,4-4,0%, whereas grass has protein 5-15% and if converted to N equals to 0,8-2,4%.Soil texture is a measure of the proportion of sand, silt, and clay in the soil. Excessive tillage and loss of soil organic matter often occur in a reduced infiltration rate due to loss of surface porosity (Stur and Horne, 2000).

The mixed cropping system between grasses and legumes is the most common practice in realizing sustainable agriculture and as an effort to improve soil fertility, forage quality, increase resource use and the environment as well as land use efficiency. The main purpose of mixed planting is to produce higher forages per unit area of land by optimizing more environmental resources, more efficiently than planting each crop in a single crop system. Intensive forage production system aims at efficient land use and other inputs for maximum animal feed production per unit area per unit time (Kumar *et al.*, 2012; Aydemir *et al.*, 2017).

Saline Soil

Saline soil is a soil with a high salt content, has an electrical conductivity (EC) of 4.0 mmhos/cm or higher, sodium <15% and pH <8,5. High salt content is a limiting factor for crop cultivation, due to the lack of water availability due to higher osmotic pressure from the soil solution, and high electrical conductivity (> 12 mmhos/cm) can inhibit seed germination and plant growth. Soil with high salt content is divided into three types based on physical properties, namely saline, saline-sodic soils, and sodic soils. Saline and saline-sodic soil have normal physical properties, while sodic soil has poor physical properties, namely in the wet season in the form of mud and dry season/dry land hardens such as salt, this is because the soil is easily decomposed into mud so it does not support growth plants (Kumar *et al.,* 2012; Cook *et al.,* 2018).

Reclamation of saline soil can be done by removing excess salt in the soil. The salinity reclamation strategy is determined by good quality of leaching and adequate drainage. Water management, selection of forage species and proper planting systems are important aspects of saline soil management. Selection of the proper forages species is able to optimize the development of forages in saline soils. Appropriate forages planted in saline soils include sorghum and grass such as *Cenchrus ciliaris, Saccharum spontanium, Penesetum pedicellatum, Dichanthium annulatum, Phaseolus atroperpureus* (Kumar *et al.*, 2012).

Acid Soil

Soil becomes acidic due to several things including rainfall, decomposition of organic matter, forages production, use of N fertilizer, and planted forages species. Excessive rainfall acts as an effective agent for removing alkaline earth ions so the soil becomes acidic. Carbon dioxide (CO_2) produced by the decay of organic matter reacts with water (H_2O) in the soil and forms a weak acid called carbonic acid (H_2CO_3). The harvest period has an effect on increasing soil acidity, this is because plants (forages) absorb nutrient elements (lime; cations) to grow and produce, thus causing the loss of some of the basic ingredients responsible for warding off acidity. Increased forages production will cause more basic ingredients to be removed. The loss of these elements has an impact on increasing soil acidity. Acidity is produced when material containing ammonium is transformed into nitrate in the soil (Arnall, 2006; Zhang, 2006).

The degree of acidity of the soil determines the solubility of compounds in the soil, especially the availability of toxic elements, nutrients, and soil pH (> 5,5), the pH drops (<5,5) causes the Al-containing material begin to dissolve, resulting in reactive Al closes to toxic level, optimum soil pH in providing soil nutrition ranges from 6,0 to 7,0. The acidity of the soil can be improved by neutralizing acid by adding a basic ingredient, agricultural limestone (aglime). Calcification increases the pH of the soil, neutralizing Al and Mn from the soil back into a solid chemical form (non-toxic) (Arnall, 2006; Zhang, 2006; Kumar *et al.,* 2012).

Alkaline Soil

Alkaline soils contain sodium (> 15%), carbonate and bicarbonate from high sodium salts, pH ranges from 8,5-10,0. Plant growth is very low in alkaline soils, this is due to the large amount of dissolved salt content. Excess sodium salts such as sodium carbonate and sodium bicarbonate have problems in land preparation and soil aeration. Forages that can be planted on alkaline soils include sorghum, *Cynodon dactylon, Bracharia mutica, Pannisetum sp dan Chloris gayana* (Kumar *et al.,* 2012).

Alkaline soils can be reclaimed using gypsum, calcium salts, sulfuric acid sulfur, and pyrite. The quantity of gypsum given is determined by soil testing, including alkalinity status. Application of 5-10 t/ha gypsum is recommended for land reclamation. Application of 5,2 t/ha gypsum gives a 1,1 to 4-fold increases in yield of different grasses. The addition of 2,5 t/ha pyrite to alkaline soils is effective in increasing yields in the range of 29-237 percent. Application of 5 t/ha pyrite in alkaline soils (pH 10.0) provides higher forage yields than perennial grasses such as *Karnal, Rhodes* and *Napier* (Kumar *et al*., 2012).

Limestone Soil

Limestone soil is characterized by very hard physical soils, lack of sulfur, there is a secondary carbonate accumulation layer (Ca or Mg) more than 15%. Excess of calcium and lack of micronutrients can limit the production of forages. Forages suitable for planting in limestone soils is sorghum (Kumar *et al*., 2012).

Swampy Area

Swampy soils can be defined as areas of stagnant water at the soil surface or the water level rises to a certain extent so that the soil pores in the plant root zone become saturated, resulting in restrictions on normal air circulation, decreases oxygen levels and increases in carbon dioxide levels. Prolonged over logged water in the root zone causes poor aeration, and in turn causes poor growth and absorption of nutrients and low nitrification process. The land can be used for forages production, but crop production is limited by poor drainage conditions causing temporary or prolonged anoxic conditions. The selection of suitable forages types that can hold waterlogging is an important effort that must be done in optimizing the use of swampy so that it is able to produce maximum yield such as *supan-supan* legumes (*Neptunia plena L. Benth*), *kumpai mining* grass (*Paspalum commersoni*), and *kumpai minyak* grass (*Hymeneche amplexicaulis Haes*) (Mayulu *et al.,* 2018).

FORAGES

Forages are the main source of feeds for ruminants, which is able to increase livestock production, so it is necessary to increase the supply of forages both in quantity and quality (Mayulu, 2019). Forages planting can help to increase the availability of feed quality, especially in the dry season which is often acting as major problem in feeding livestock and is identical to the poor quality of feed. Forages can be given directly (fresh) or after processing (partial drying). Animal feeds which includes as forages including grass (*Poaceae*) and legume (*Fabaceae*). Grass species includes 1) short grass, horizontal grass (stolons and rhizomes), for example *Brachiaria humidicola*; and 2) tussock grass is grass that forms different clumps for example *Paspalum atratum*. Grass species that widely grown in the tropics includes Napier grass (*Pennisetum purpureum*), Brachiaria, and *Panicum* species (Stur and Horne, 2000; Capstaff and Miller, 2018).

The use of low-quality feed can be improved by providing ruminant protein supplements such as tree legumes leaves. Ruminants need lot of protein to grow, production and reproduction. Legumes can be a source of additional protein, because legumes have a much higher level of protein in their leaves than grass. Legumes leaves provide essential minerals and vitamins for livestock growth. Legumes types include 1) short legumes, namely legumes with horizontal stems (stolons and rhizomes) that grow roots and can form new plants such as *Arachis pintoi*; 2) wrapped legumes such as *Centrosema macrocarpum*; 3) dense upright legumes such as *Stylosanthes guianensis*; 4) shrub legumes such as *Desmodium cinerea*; and 5) tree legumes such as *Calliandra calothyrsus* (Stur and Horne, 2000).

Forages can be planted in various ways to stop erosion, such as contour fences and ground cover. Legumes types can act as cover crops, control weeds and increase soil fertility. Legumes offer important opportunities for sustainable livestock production because legumes contribute to replacing inorganic nitrogen fertilizer inputs with N fixation, being able to adapt to climate change and the environment. The development of sustainable forages and used for nature conservation, is very important to become a source of animal feeds by implementing a proper system of cutting and transportation (Shiferaw *et al*., 2018). Forages production is influenced by the ability of rapid vegetative growth, the ability to regrow, soil fertility, and climate. Forages cultivation is characterized by the ability of plants to respond quickly to cutting, can grow back in a short time and has high productivity (Capstaff and Miller, 2018).

5. CONCLUSION

Optimization of land resources can be done through the use of marginal land, post-mining and watershed as an alternative for forages development. Forages role as feeds and land conservation plants (improving soil nutrients), especially legumes. Appropriate land management in accordance with the type of the soil, supported by technology has implications for increasing the productivity of forages and the sustainability use of land resources in the long term as well as providing benefits to the environmental.

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