O 136. FORAGE CROPS IN ACID SOILS OF INDONESIA

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ABSTRACT: Indonesia is a country located on the equator, between two continents and two oceans. For this reason, Indonesia has a tropical sea climate. The amount of precipitation and humidity in Indonesia is very high. Due to the high amount of precipitation, water availability and groundwater with a shallow water table of the land are also very high in Indonesia. However, wet climatic conditions and high precipitation amount intensively cause alkaline washing in the soil. Consequently, it causes most of the lands in Indonesia to become acidic. Approximately 70% of the total land in Indonesia is acid soils with a pH less than 5. As a tropical country, Indonesia has a very high biodiversity of plants. There are many plant species that can be used as fodder. These plants originate from various families. This paper tries to give general information about some plants grown in acid soils (low pH levels) used as the most common animal feed in Indonesia.

Keywords: Animal Feed, Fodder Plants, Pasture and Rangeland, Tropical Forage Crops, Water Tabel Depth

1. INTRODUCTION

Indonesia has unique and rich natural resources and biodiversity, as it is located between two continents (Asia and Australia) and two oceans (Indian and Pacific) (KLH, 2011). The world's second largest biodiversity is found in Indonesia (Brown, 1997) and Indonesia is the world's richest submarine biodiversity country (Tamindael, 2011). Indonesia is also located on the equatorial line that causes Indonesia has a tropical climate (KLH, 2011) and causes Indonesia has a very high biodiversity of plants. However, because of wet climatic conditions and high precipitation intensively cause alkaline washing in the soil and consequently cause around 70% of the soils in Indonesia to become acidic (Mulyani et al. 2010). There are many plant species that can be used as fodder in Indonesia. These plants originate from various families. This paper tries to give general information about some forage crops. These crops are mostly from grasses and legumes (and two plants from other families). The crops presented in this paper are the most common forage crops in Indonesia and most of these crops grow on acid soils (at low pH levels).

2. GENERAL INFORMATION ABOUT THE NATURE OF INDONESIA

2.1.

2.2. Geography of Indonesia

Indonesia, an archipelago country of 17 504 islands, is the world's largest archipelago country with a land area of 1.91 million km^2 (BPS, 2015), and as the 14th largest country in the world. Geographically, Indonesia is located on the equatorial line between 06^o 08' North and 11^o 15' South Latitudes, and between 94^o 45' and 141^o 05' East Longitude (KLH, 2011). Latitude position causes Indonesia has a tropical climate. While the long longitude position causes Indonesia has three time zones, namely West Indonesia Time (UTC +7), Central Indonesia Time (UTC +8) and Eastern Indonesia Time (UTC +9) (KEPPRES RI No. 41/1987).

2.3. Climate and Water Table of Indonesia

Indonesia is located on the equator, between two continents, and between two oceans. For this reason, Indonesia has a tropical sea climate. Indonesia has two seasons, the dry season (May-September) and the rainy season (October-April). The air temperature of Indonesia is between 20-30 ^{o}C. The precipitation amount is very high and the average annual rainfall is 2000-3000 mm (Hidayat, 2008). As

it is surrounded by oceans and seas, humidity is also very high ranging from 85-100% (BPS, 2018). Water availability is very high in Indonesia (BMKG, 2016). Due to the very high amount of rainfall, water availability is generally very high (BMKG, 2016), which two-thirds of Indonesia's area is a water territory and makes Indonesia is included in the world's 10 countries that are rich in water (BPS, 2018). In most of Indonesia's land, water table is very shallow. The water table is deeper only in areas around volcanoes and in areas close to Australia (Fan et al. 2013) as shown in Figure 1.

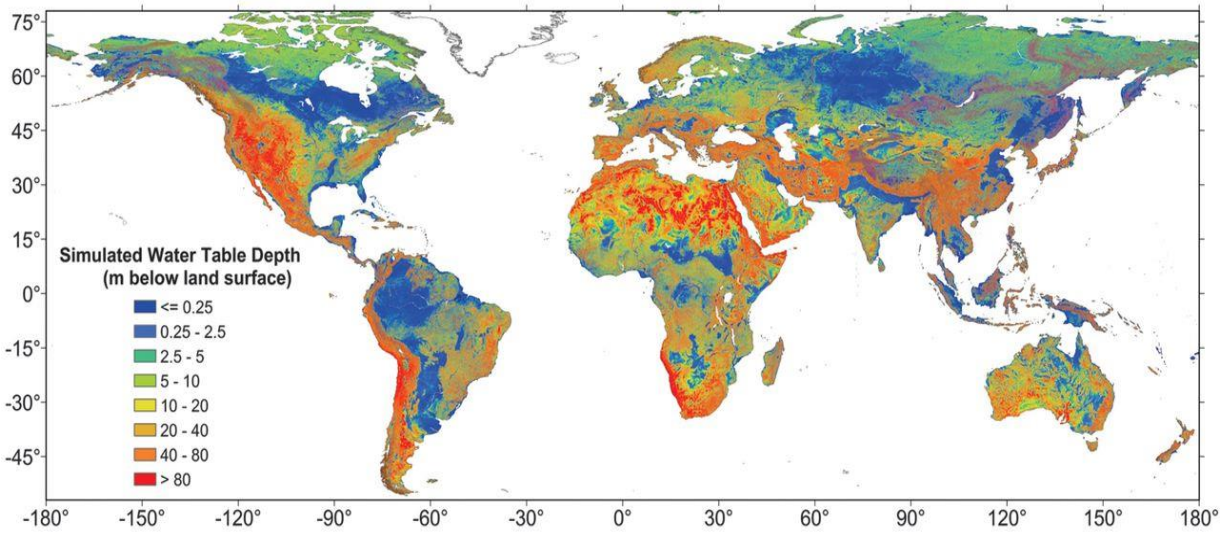

Figure 1. The map of the simulated world's water table depth (Fan et al. 2013)

2.4. Acid Soils of Indonesia

There are 10 soil orders found in Indonesia, they are Histosols, Entisols, Inceptisols, Alfisols, Mollisols, Vertisols, Ultisols, Oxisols, Andisols and Spodosols (Figure 2). Wet climatic conditions and high precipitation of Indonesia intensively cause alkaline washing in the soil. Consequently, it causes most of the soils in Indonesia to become acidic. Approximately 70% of the total land in Indonesia is acid soils with a pH less than 5. These acid soils are originated from Histosols, Entisols, Inceptisols, Oxisols, Ultisols and Spodosols soil orders (Mulyani et al. 2010).

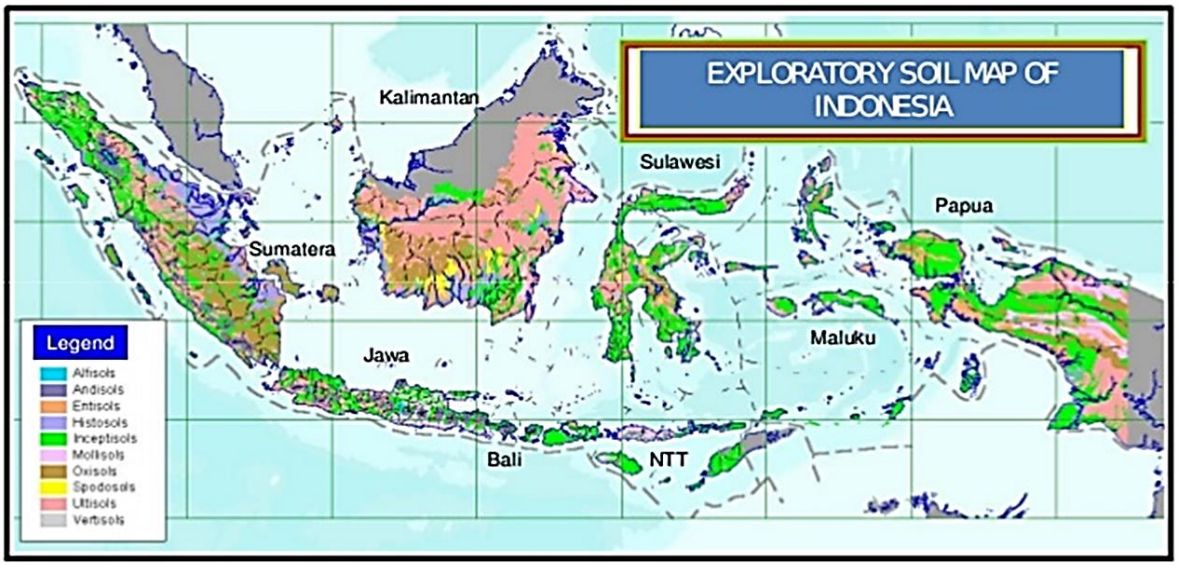

Figure 2. The map of soils of Indonesia (Sarwani et al. 2012)

3. FORAGE CROPS IN ACID SOILS OF INDONESIA

There are many plant species that can be used as fodder in Indonesia. In this section, general information about most common forage crops in acid soils (at low pH levels) of Indonesia. These crops are mostly from grasses and legumes families (and two plants from other families).

3.1. Grasses Forage Crops

3.1.1. *Pennisetum purpureum* Shumach.

Pennisetum purpureum originates from sub-Saharan tropical Africa (Govaerts, 2013). It has been introduced as a forage crop to most tropical and subtropical regions of the world. *Pennisetum purpureum* is usually found between 10° N and 20° S (Rojas-Sandoval and Acevedo Rodriguez, 2013). This plant grows in areas up to 2000 m above sea with annual precipitation above 1500 mm. It gives good yields at temperatures ranging from 25-40°C (Francis, 2004). *Pennisetum purpureum* is a robust perennial grass with a strong root system (Duke, 1983). The plant is resistant to drought and it grows in areas where rainfall is 200-4000 mm (Göhl, 1982). It grows better in rich and deep soils, but it can grow in poorly dried with poorly drained clays or in extremely dry sandy soils with pH between 4.5-8.2 (Duke, 1983). *Pennisetum purpureum* is a full sunlight plant species, but can grow under partial shade (Francis, 2004). It requires a high rate of fertilizer and regular water supply (Mannetje, 1992). The yield varies between 20-80 tons dry matter (DM) ha^{-1} $year^{-1}$ with high fertilizer application (Francis, 2004). And the yield without fertilizer is in the range of 2.4-5.3 tons DM ha^{-1} $year^{-1}$. Grass cut can be done at 45-90 day intervals depending on location (Duke, 1983).

3.1.2. *Brachiaria decumbens* (Stapf.)

Brachiaria decumbens, originates from the African continent (FAO, 2016). It is now common in tropical and subtropical regions (Pizzaro et al. 1996; FAO, 2016). It has been extensively naturalized in Southeast Asia and the Pacific (Schultze-Kraft et al. 1992a). *Brachiaria decumbens* are naturally found in open grasslands or partially shaded areas, from 27° N to 27° S, up to 1750 m above sea level. Grows at temperatures above 19 °C. Optimum growth occurs between 30-35 °C and where the average rainfall is above 1500 mm (FAO, 2016). *Brachiaria decumbens* is a perennial (5 years) grass (Husson et al. 2008). It has a deep root system that effectively removes P and N from the soil. It can grow on a wide variety of soils including poor soils with low pH (up to 3.5) and high Al concentration. It is moderately tolerant of Mn and is sensitive to salinity (Deifel et al. 2006). It does not develop well in waterlogged heavy clays, but resistant to 4 or 5-month dry season. The average yield is generally about 10 tons DM ha^{-1} (FAO, 2016).

3.1.3. *Brachiaria humidicola* (Rendle) Schweick

Brachiaria humidicola is a tropical perennial grass from East and South-East Africa and has been introduced to Australia, the Pacific Islands and South America (Cook et al., 2005; FAO, 2016). It is an important pasture plant in humid tropical areas. In the natural environment, it can be found in areas up to 2400 m above sea level. Optimal growth conditions; The annual rainfall varies between 600-4000 mm and the average daily temperatures of 32-35 ° C. Grows in a wide variety of soils including low acidic (pH 3.5) and infertile soils with low P levels, high Al saturated soil, heavy cracking clays and high pH coral sands (Cook et al. 2005). *Brachiaria humidicola* is poor drainage tolerant and can withstand short flood pressure at the bottom of the valley. It also can withstand drought periods (3-4 months) but it is not resistant to freezing (Tergas, 1981). The dry matter yield is in the range of 7-34 tons ha^{-1} $year^{-1}$ and is greatly affected by soil fertility. The most suitable harvest stage is 35 to 65 days after the last cut (Bereau, 1990).

3.1.4. *Paspalum dilatatum* Poir.

Paspalum dilatatum is native to South America (Brazil, Argentina, Bolivia, Chile, Paraguay, Uruguay). Nowadays, it is common in tropical, subtropical and warm climate areas (Cook et al. 2005). It can be found in humid areas between 28 °N - 35 °S (FAO, 2016). It grows in areas up to 2300 m above sea level. Optimal growth conditions; heavy, humid, alluvial and basaltic clay soils or red loams, average daily temperatures ranging from 23-30 °C, annual rainfall of 900-1300 mm or with good irrigation. This plant can grow at an annual rainfall of less than 750 mm and a pH range of 4.5-8. It is very resistant to

drought and has a slight tolerance to frost (Cook et al., 2005). *Paspalum dilatatum* is a valuable feed and is one of the first species used for permanent sown meadows (Cook et al. 2005; FAO, 2016). It is a very tasseled, leafy perennial grass. *Paspalum dilatatum* yields a medium yield (3-15 tons DM ha^{-1}) and a short grazing season in rain-fed pastures (Cook et al., 2005).

3.1.5. *Imperata cylindrica* (L.) P. Beauv.

Imperata cylindrica grows and becomes widespread in tropical regions of the world. It is naturalized in Australia, New Zealand, Central and South America, West Indies, Cape Verde Islands, Madagascar, Melanesia and Polynesia (USDA, 2015). It grows well in humid or semi humid pastures or in open forested areas up to 2000 m above sea level in the Himalayas. Its optimal growth conditions are 25-35 °C daytime temperatures, 250-6250 mm annual precipitation, full sun or slightly shaded, light sandy soils with a pH between 4-7.5. It is tolerant of long drought periods. It cannot withstand flood and low temperature (FAO, 2016). *Imperata cylindrica* is a perennial grass. It is used as feed when young in height of 15-25 cm. The annual average dry matter yield is 11.5 tons ha^{-1} (FAO, 2016).

3.1.6. Sorghum *(Sorghum bicolor* (L.) Moench)

Sorghum is a grass native to eastern Africa, probably from Ethiopia. Nowadays it is found in areas between 50 °N - 40 °S and up to 1000 m above sea level (Cook et al. 2005). Optimal growth conditions for sorghum are the day temperatures during seedlings are 25-30 °C and during the growth is 30 °C, the annual rainfall is 400-750 mm. Grows best in deep, well-drained loam clay with a pH of 5.5-7.5. Sorghum shows tolerance to drought and slightly tolerance to waterlogging (for short periods). However, it is sensitive to freezing and continued flood conditions. (FAO, 2016). Sweet sorghum is tolerant of salinity (Cook et al. 2005). Sorghum plant is a tall (height up to 5 m) and perpendicular annual grass. Sorghum is used as grain and feed. The forage sorghum produces about 20 tons of fresh matter ha^{-1} $year^{-1}$ (Balole and Legwaila, 2006), but can reach 75 tons ha^{-1} under optimum growth conditions (FAO, 2016).

3.1.7. Corn *(Zea mays* L.)

Corn is native to Central America and later spread to Central America, the Caribbean, South America and North America. It is now growing worldwide including from 58 °N in Canada and Russia to 40 °S in Chile and Argentina, and up to 3800 m above sea level in Andean mountains (Cook et al., 2005). Its optimal growth conditions are average daytime temperature between 18-21 °C, annual rainfall higher than 750 mm, well-drained rich soils. Corn can withstand annual rainfall of 230-4100 mm, a pH of 4.3-8.7 and a wide variety of soils. There is no tolerance for freezing and flooding of corn (Heuze et al. 2016a). Corn is an annual grass (OGTR, 2008). The green matter yield of corn varies between 10-50 tons ha^{-1} (FAO, 2016). The yields obtained from small corn plants ranged between 31-46 tons ha^{-1} (21-25 tons DM ha^{-1}) (Chaudhary et al. 2012).

3.1.8. Rice straw (*Oryza sativa* L.)

Rice straw is the vegetative part of the rice plant (*Oryza sativa* L.), which is cut in or after the grain harvest. Rice straw can be burned and left in the field after harvesting, it can be spread for soil improvement or it can be used as a feed for livestock (Kadam et al. 2000). Rice straw is an important feed in rice production areas. Rice originated from Asia, which has been cultivated since 6500 BC and is now naturalized in most tropical and subtropical regions. Rice grows from 53 °N in China to 35 °S in Australia. Its optimum growing conditions: average daily temperatures of 20-30 °C, night temperature above 15 °C; productive and heavy soils; pH 6.5-7. Most types ("swamp rice", "plain rice") should be planted in stagnant water and require an equivalent amount of 200 mm precipitation or equal amount of irrigation per month, while others ("mountain rice" or "upland rice") require a lesser irrigation and a rainfall of 750 mm for 3-4 months without dry period (Heuze and Tran, 2015a). Its annual yield ranges from 12 to 15 tons ha^{-1} (FFTC, 2005).

3.2. Legumes Forage Crops

3.2.1. *Sesbania sesban* (L.) Merr.

Sesbania sesban is a fast growing, long-lasting legume tree that reaches a height of up to 8 meters. It is widely distributed and produced in semi-arid and humid tropics. It grows in riversides and swamp sides with altitude up to 2300 m above sea level (Cook et al. 2005). Optimal growth conditions for *Sesbania sesban* are annual rainfall of 500-2000 mm and average annual temperature of 17-20 °C. It is tolerant of saline, alkaline and acid soils and soils with low P levels (Heering and Gutteridge, 1992a; Cook et al. 2005; FAO, 2016). Sesban yields up to 20 ton DM ha^{-1} $year^{-1}$ under optimum conditions. The average yield worldwide is 4-12 tons DM ha^{-1} $year^{-1}$ and it is cut 3-5 times a year (Heering and Gutteridge, 1992a).

3.2.2. *Pueraria phaseoloides* (Roxb.) Benth.

Pueraria phaseoloides is a legume species grown in tropical countries as a cover crop, green manure and forage crop. *Pueraria phaseoloides* is thought to be native to East and Southeast Asia. It has been introduced to be grown in most tropical areas and has now become naturalized and widespread in all humid tropics (Halim, 1997). It grows in an altitude of 1000-1500 m above sea level (Cook et al. 2005). It can grow in areas with annual rainfall ranging from 850 mm to 2000 mm, but gives better results when the annual rainfall is above 1500 mm and day/night temperatures are 32/24 °C. *Pueraria phaseoloides* can withstand dry, short term water logging and flood conditions (Halim, 1997). It is very tolerant to shadows and highly preferred in tropical tree plantation (Halim, 1997; Cook et al., 2005; FAO, 2016). It is resistant to acidic conditions (pH varies between 3.5-6) and tolerant to Al. However, it cannot withstand saline soils (Halim, 1997). This plant is a strongly curled and climbing perennial legume. It can be grazed or used as straw or silage. Dry matter yield is up to 20 tons ha^{-1} (Ezenwa et al., 1996).

3.2.3. *Calliandra calothyrsus* Meisn.

Calliandra calothyrsus is a valuable small tropical legume tree as a multipurpose tree. It is native to the humid regions of Central America and Mexico. In 1936 it was brought to Indonesia for green manure and shadow production. It has been introduced to many tropical countries, particularly to Southeast Asia and Africa, as well as to Australia, Brazil, Bolivia, Colombia and Hawaii (Hess et al., 2006). It grows up to 1800-2200 m above sea level but gives better results up to 1300 m. The plant develops optimally with annual precipitation between 700-3000 (-4000) mm (rainy tropical) and annual temperatures 22-28 °C. *Calliandra calothyrsus* does not rely on freezing but tolerates dry conditions lasting 1-7 months (Wambugu et al., 2006). This plant grows in very light-textured and low-productive soils from acid sandy soils to deep volcanic soils. *Calliandra calothyrsus* does not rely on compressed, poorly drained and alkaline soils, but can survive on acid soils (Orwa et al., 2009). Calliandra is a small perennial legume tree with about 5-6 m tall and can reach 12 cm tall, and almost evergreen. It has a flat body with a diameter of up to 30 cm and has many branches (Orwa et al., 2009). The annual feed productivity is 7-10 tons DM ha^{-1} (Kabi and Bareeba, 2008).

3.2.4. *Desmanthus virgatus* (L.) Willd.

Desmanthus virgatus is mainly used as feed. It can be highly edible and grazed to ruminants or freshly fed in cutting-handling systems. This legume originated from the tropical and subtropical Americas (Cook et al. 2005). It is naturalized to African dry soil (Senegal, Zambia, South Africa), Pacific Islands (New Caledonia, Hawaii), Indonesia, India and Australia (FAO, 2016). It can be found in areas with an altitude up to 2000 m above sea level but mostly found in coastal bushes, roadside and overly degraded areas with altitude below 500 m above sea level. *Desmanthus virgatus* is very compatible and grows in a wide temperature range (including frost conditions) and in wide precipitation conditions (between 250-2000 mm) (Cook et al., 2005). It prefers alkaline clay or clayey-loam soils, can also grow well in acid and unproductive soils (Gutteridge and Shelton, 1994). It is a drought-resistant legume. But it does not rely on shaded conditions (Cook et al. 2005). *Desmanthus virgatus* is a perennial legume. The yield of *Desmanthus virgatus* is 7.6 ton DM ha^{-1} in humid tropical regions (2000 mm rainfall), and 2-2.4 ton DM ha^{-1} in low rainfall areas (600-750 mm). *Desmanthus virgatus* is based on regular cuts and can be cut 4-6 times per year for feed (Cook et al., 2005).

3.2.5. *Leucaena leucocephala* (Lam.) de Wit.

Leucaena is one of the finest and most palatable forage trees of the tropics. Leucaena is native to Guatemala and Mexico. It was introduced to the Philippines and Southeast Asia in the 16th century, spread to the Asia Pacific region and reached Australia in the late 19th century. It is commonly found between 30 °N - 30 °S and grows well in regions where the annual precipitation is between 650-3000 mm and the day temperatures are at 25-30 °C. It prefers neutral to slightly acidic and well-drained soils. This plant is resistant to dry climates (300 mm) and drought periods (up to 6-7 months). It can withstand mild frost, moderate salinity and short-term waterlogging (less than three weeks) (Cook et al. 2005).
Leucaena leucocephala grows fast, evergreen, steep and grows up to a length of 5-20 m (FAO, 2016). It is a long-lasting perennial legume (up to about 23 years in Australian conditions). Leucaena can be lightly grazed in the first year after the seedling is finished and graze heavily after the second year. The average yield is 3-30 ton DM ha^{-1} $year^{-1}$ depending on soil, temperature and humidity conditions. For optimum yield, the harvesting interval can be made between 6-8 weeks in very productive areas and 12 weeks in lower productive areas (Cook et al. 2005).

3.2.6. *Sesbania grandiflora* (L.) Pers.

Sesbania grandiflora is a legume tree used for animal feeding in humid tropical regions. *Sesbania grandiflora* is native to Asia and is now widespread in the most humid tropical regions around the world (Göhl, 1981). Its optimal growth conditions are an altitude of 800-1000 m above sea level, an average annual temperature of 22-30 °C, and an annual rainfall of 2000-4000 mm (Cook et al. 2005). This plant is adapted to a wide range of precipitation zones and soil types. It can be grown in heavy clay, alkaline and saline soils as well as poorly drained and low fertile soils (FAO, 2016). This plant is also resistant to drought periods of 6-7 months in acid soils and can live with 800 mm annual precipitation. It is tolerant to waterlogging and flooding (Cook et al., 2005). It does not develop at temperatures below 10 °C (FAO, 2016). *Sesbania grandiflora* is a perennial, evergreen, fast-growing leguminous tree that can reach a 10-15 m tall (Cook et al., 2005). The life span is about 20 years (Heering and Gutteridge, 1992b). In Java, an annual yield of 27 kg (up to 50 tons ha^{-1}) of green leaves is obtained and can be cut every 3-4 months (Cook et al. 2005).

3.2.7. *Calopogonium mucunoides* Desv.

Calopogonium mucunoides originated from tropical America and Western India. It is now found in the most humid tropical regions (Africa, Asia, Australia). *Calopogonium mucunoides* are introduced and naturalized in Indonesia and Malaysia as a cover crop and are found at an altitude of up to 2000 m above sea level (Peng and Aminah, 1997). Its optimal growth conditions are daily temperature is between 24-36 °C (Cook et al. 2005) and annual rainfall is 1000-1500 mm (Peng and Aminah, 1997). *Calopogonium mucunoides* can withstand the flood conditions. It can grow on a wide variety of soils, but it gives better results in acid clay soils (pH 4.5-5). It is also tolerant to high Al saturation but does not rely on saline soils. *Calopogonium mucunoides* is not freezing and drought resistant. It is tolerant to moderate shading and can grow in plantations where light transmission is between 60-100% (Cook et al. 2005). *Calopogonium mucunoides* is a strong, pubescent, perennial or short-lived perennial legume. It can reach a few meters in length, its roots are 30-50 cm in depth, with dense leaves (Cook et al. 2005; FAO, 2016). It can be grazed or cut and fed fresh. If the crusts are harvested in a single cut, they can yield up to 14 tons DM ha^{-1}. However, if it is cut every 9-12 weeks, the DM yield is about 4-6 tons ha^{-1}. It is recommended to be grazed with a rest period of 8-12 weeks (Peng and Aminah, 1997).

3.2.8. *Gliricidia sepium* (Jacq.) Kunth ex Walp.

Gliricidia sepium is native to the Pacific coast of Central America, which is seasonally dry and is now widespread in tropical regions between 6 °S and 19 °N of the equator. It grows in the areas with an altitude up to 1600 m above sea level with the average temperature varies between 20-29 °C and annual precipitation is between 650-3500 mm and has a dry period of five months. It can adapt to a wide range of well-drained soils with pH in the range of 4.5-6.2. It does not withstand night temperatures below 15 °C. It is tolerant of waterlogging and non-fertile soils (Cook et al. 2005). It is one of the important tropical feed trees due to its protein-rich feed and high nutritional value. It is also possible to make silage from chopped feed which can be mixed with grass or corn. *Gliricidia sepium* produces 9-16 tons DM

ha^{-1} in forage areas. The cutting can be done about 7 months after previous cutting and 14 months after the establishment of the plants that grow from the seedlings. Then, the cluster can be done every 2-3 months during the rainy season and every 3-4 months during the dry season (Wiersum and Nitis, 1992).

3.3. Forage Crops from Other Families

3.3.1. Cassava leaves (*Manihot esculenta* Crantz.)

Cassava (*Manihot esculenta* Crantz) is mainly grown for tubers used as basic food or starch, but cassava leaves can be a valuable feed (Phengvilaysouk and Wanapat, 2008). Cassava is native to South America and is common in tropical and subtropical regions including Sub-Saharan Africa and Southeast Asia. The main production areas are at 30 °N - 30 °S. It grows in areas up to 2000 m above sea level. Its optimal growth conditions are the annual average daytime temperature is above 18-20 °C, the annual rainfall ranges from 500 mm to 3500 mm, high solar radiation and light, well-drained and acid soils. It is very tolerant to bad soil conditions, drought and insects, but does not grow well in heavy, rocky and gravely soils. It is sensitive to water-saturated, saline or alkaline soils. Very low P levels are considered to be good while zinc deficiency should be avoided (Vongsamphanh and Wanapat, 2004). Cassava is mostly grown in marginal environments, acid and fertile soil (Man and Wiktorsson, 2001). Cassava is a perennial plant which is mostly grown as an annual (Dominguez, 1983). The leaves of cassava can be fed freshly, but it is generally preferred to be dried or silted because the leaves contain hydrogen cyanide which may be toxic to livestock (Wanapat, 2002). The annual dry matter yield varies between 7.5-9 tons ha^{-1} (Ravindran, 2018).

3.3.2. Sweet potato (*Ipomoea batatas* (L.) Lam.)

Sweet potato is thought to come from the mouth of the Orinoco River in Mexico and the Yucatan Peninsula. It grows between 40 °N and 32 °S at an altitude up to 2000 m above sea level (and 2800 m in equatorial regions) (Ramirez, 1992). Sweet potatoes are grown in more than 100 countries, sometimes as basic food, but often as an alternative food. Great sweet potato producers are China, Indonesia, Vietnam, India, Philippines and Japan in Asia, Brazil and the US in America, And Nigeria, Uganda, Tanzania, Rwanda, Burundi, Madagascar, Angola and Mozambique in Africa (FAO, 2016).

Sweet potato is a perennial plant but mostly grown as an annual. Roots are adventurous, mostly found in 25 cm of the top soil (Duke, 1983). Sweet potatoes can be grown everywhere with enough water to support their growth and the annual rainfall for optimal growth should be between 750-2000 mm. Sweet potato requires full sunlight with an average temperature of 20-25 °C for optimal development. Sweet potatoes grow in soils that have a high humus content and well-drained which provide a warm and moist environment for the growth of good roots. The optimal soil pH is between 5-7. Sweet potato is slightly drought resistant (Ramirez, 1992). Although sweet potato tubers are the main agricultural product, vegetative parts are a very valuable feed for animals. The vegetative parts of sweet potato can be used as fresh, dry or silage. For the best leaf and root production, it is recommended that 50% of the total leaves should be cut by an interval of 20 days, as excess leaves can reduce the production of tuber roots. Vegetative parts of sweet potatoes can be harvested three or four times during a growing season (Scott, 1992). The dry matter yield varies between 5.4-9.1 ton ha^{-1} (Lam, 2016).

4. CONCLUSION

As a tropical country, Indonesia has rich natural resources and biodiversity including very high biodiversity of plants. However, because of wet climatic conditions and high precipitation intensively cause alkaline washing in the soil and consequently cause around 70% of the soils in Indonesia to become acidic. There are many plant species that can be used as fodder in Indonesia. This paper presents 8 species of grasses forage crops, 8 species legume forage crops and 2 species forage crops from other families. These crops are only some of the most common crops used for animal feeding in Indonesia especially grow in acid soils, however there are so many plants that are used as forage crops in Indonesia which cannot be presented in this paper.

Figure 3. *Pennisetum purpureum* Shumach.
(Heuze et al. 2016b)

Figure 4. *Brachiaria decumbens*
(Heuze et al. 2016c)

Figure 5. *Brachiaria humidicola*
(www.germipasto.agr.br)

Figure 6. *Paspalum dilatatum*
(http://flowers.la.coocan.jp/)

Figure 7. *Imperata cylindrica*
(https://facultystaff.richmond.edu)

Figure 8. *Sorghum bicolor* (L.) Moench.
(www.botany.wisc.edu)

Figure 9. *Zea mays* L.
(www.aphotoflora.com)

Figure 10. *Oryza sativa* L.
(www.skrmindia.com)

Figure 11. *Sesbania sesban*
(www.westafricanplants.senckenberg.de)

Figure 12. *Calliandra calothyrsus*
(www.tropicalforages.info)

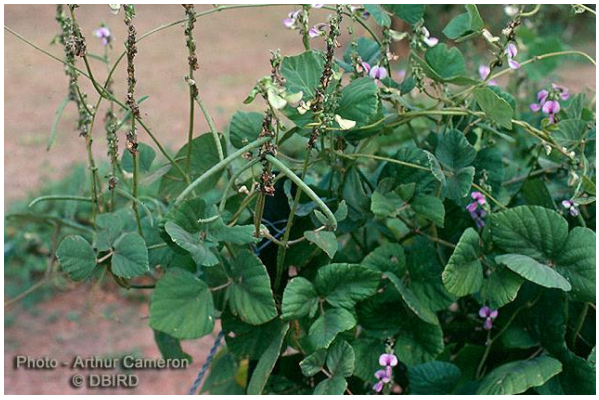

Figure 13. *Pueraria phaseoloides*
(www.tropicalforages.info)

Figure 14. *Desmanthus virgatus*
(www.tropicalforages.info)

Figure 15. *Leucaena leucocephala*
(http://keyserver.lucidcentral.org/)

Figure 16. *Sesbania grandiflora*
(www.flickr.com)

Figure 17. *Calopogonium mucunoides*
(www.medicinalplantsinnigeria.com)

Figure 18. *Gliricidia sepium*
(toptropical.com)

Figure 19. *Manihot esculenta*
(www.livestrong.com)

Figure 20. *Ipomoea batatas*
(www.legom.info)

Table 1. Main chemical components and ruminant nutritional values of forage crops (fresh) (modified from http://www.feedipedia.org/)

Forage Crop	Dry Matter (%)	Crude Protein (% DM)	Crude Fiber (% DM)	Neutral Detergent Cellulose (% DM)	Acid Detergent Cellulose (% DM)	Lignin (% DM)	Ash (% DM)	Brute Energy (MJ kg^{-1} DM)	Digestible Organic Matter (%)	Digestible Energy (%)
Grasses Forage Crops										
Pennisetum purpureum	17.9	9.7	36.1	71.5	42.5	5.7	13.8	17.4	61.4	58.7
Brachiaria decumbens	26.8	8.9	31.4	68.1	37.2	5.7	8.6	18.1	55.2	52.7
Brachiaria humidicola	26.0	9.0	34.8	67.7	40.8	6.0	6.7	18.7	55.6	53.2
Paspalum dilatatum	23.8	10.3	35.1	68.5	41.0	5.6	9.4	18.3	62.4	59.7
Imperata cylindrica	31.9	6.5	39.4	74.3	45.7	6.6	7.0	18.6	57.2	54.7
Sorghum bicolor	28.1	8.2	33.6	57.9	35.0	3.3	9.1	18.1	63.1	60.3
Zea mays	36.6	11.4	29.0	63.6	31.5	4.3	12.2	17.6	68.4	65.8
Oryza sativa	92.8	4.2	35.1	69.1	42.4	4.8	18.1	15.5	49.8	46.5
Legumes Forage Crops										
Sesbania sesban	26.0	24.4	12.9	27.1	18.8	4.5	9.7	18.3	85.2	78.9
Pueraria phaseoloides	19.0	19.3	33.0	49.4	38.0	7.1	8.7	18.9	62.2	59.4
Calliandra calothyrsus	34.9	20.8	25.2	55.6	37.1	14.0	6.3	19.1	70.0	68.3
Desmanthus virgatus	35.2	15.8	34.0	46.7	37.0	13.1	6.4	19.3	61.2	58.5
Arachis pintoi	21.2	21.4	27.3	53.3	32.8	8.1	6.6	19.0	64.6	61.8
Leucaena leucocephala	29.9	23.3	19.9	40.9	25.4	10.8	8.5	19.0	75.4	73.3
Sesbania grandiflora	17.3	25.5	16.2	25.5	19.5	5.8	8.5	19.2	79.2	75.5
Calopogonium mucunoides	33.1	12.8	34.8	54.4	41.5	9.7	8.8	18.7	60.4	57.7
Gliciridia sepium	25.3	22.3	19.7	49.7	34.8	13.0	10.0	19.7	75.6	73.3
Forage Crops from Other Families										
Manihot esculenta	22.5	24.9	17.7	42.3	27.2	9.4	7.4	19.9	63.9	62.6
Ipomoea batatas	13.0	16.5	21.1	42.7	31.7	8.3	11.2	18.3	66.0	61.8

Table 2. Mineral and secondary metabolite contents of forage crops (fresh) (modified from http://www.feedipedia.org/)

Forage Crop	Calcium (g kg^{-1})	Phosphorus (g kg^{-1})	Potasium (g kg^{-1})	Sodium (g kg^{-1})	Magnesium (g kg^{-1})	Manganese (g kg^{-1})	Zinc (g kg^{-1})	Copper (g kg^{-1})	Iron (g kg^{-1})	Tannic Acid (g kg^{-1})	Catechin (g kg^{-1})
Grasses Forage Crops											
Pennisetum purpureum	3.6	2.9	29.0	0.3	3.0	91.0	45.0	11.0	413.0	22.2	12.4
Brachiaria decumbens	3.6	2.3	18.4	0.5	2.2	132.0	30.0	4.0	389.0	-	-
Brachiaria humidicola	2.3	2.1	13.7	3.5	2.8	2.8	21.0	8.0	-	-	-
Paspalum dilatatum	3.4	2.3	25.7	2.6	1.8	259.0	21.0	8.0	-	-	-
Imperata cylindrica	3.3	1.4	11.7	0.2	2.1	89.0	13.0	3.0	-	-	-
Sorghum bicolor	4.1	2.0	19.3	2.5	2.2	82.0	45.0	13.0	919.0	-	
Zea mays	6.3	1.5	16.6	1.0	3.5	256.0	69.0	11.0	-	12.3	-
Oryza sativa	2.9	0.9	18.0	2.7	1.9	454.0	34.0	6.0	335.0	0.1	-
Legumes Forage Crops											
Sesbania sesban	15.9	3.3	11.6	0.3	3.5	-	-	-	-	-	2.0
Pueraria phaseoloides	9.6	2.7	23.6	0.1	3.0	98.0	40.0	12.0	206.0	-	-
Calliandra calothyrsus	7.1	2.8	6.0	0.1	3.6	-	84.0	14.0	351.0	10.5	55.1
Desmanthus virgatus	7.1	2.8	6.0	0.1	3.6	-	-	-	-	73.5	-
Arachis pintoi	15.4	4.1	-	-	-	-	-	-	-	36.9	-
Leucaena leucocephala	10.7	2.1	18.9	0.2	3.9	-	65.0	30.0	13.0	23.8	27.6
Sesbania grandiflora	14.1	4.6	20.4	2.4	3.8	-	179.0	18.0	881.0	43.2	28.6
Calopogonium mucunoides	11.1	2.0	9.3	0.6	3.7	44.0	33.0	9.0	557.0	-	1.0
Gliciridia sepium	11.9	2.3	27.1	0.4	4.5	79.0	35.0	12.0	153.0	11.0	10.9
Forage Crops from Other Families											
Manihot esculenta	11.9	3.7	12.5	0.6	7.3	-	25.0	29.0	-	65.9	26.3
Ipomoea batatas	9.5	2.9	24.9	0.8	4.0	141.0	70.0	2.0	1690.0	6.2	-

REFERENCES

Balole, T. V. and Legwaila, G.M., 2006, *Sorghum bicolor* (L.) Moench [online], PROTA (Plant Resources of Tropical Africa), Wageningen, The Netherlands, www.prota4u.org/database/protav8.asp?h=M4,M5&t=sorghum,bicolor&p=Sorghum+bicolor#Synonyms [Access Date: December 14, 2016].

Bereau, M., 1990, A new grass for French Guiana: *Brachiaria humidicola* (Rendle) Schweickt, *Bulletin Agronomique des Antilles et de la Guyane* 10, 35-41.

BMKG, 2016, Ketersediaan Air Tanah di Indonesia Oktober 2016 [online], Badan Meteorologi, Klimatologi dan Geofosika, Jakarta, Indonesia, http://www.bmkg.go.id/berita/?p=ketersediaan-air-tanah-di-indonesia-update-oktober-2016&lang=ID&s=detil [Access Date: December 12, 2016].

BPS, 2015, Luas Wilayah dan Jumlah Pulau Berdasarkan Provinsi 2002-2014 [online], BPS-Satistics Indonesia, Jakarta, Indonesia, https://www.bps.go.id/linkTabelStatis/view/id/136 [Access Date: December 2, 2016].

BPS, 2018, *Environment Statisics of Indonesia*. BPS-Statistics Indonesia, Jakarta, Indonesia.

Brown, L. R., 1997, State of the World: A Worldwatch Institute Report on Progress Toward a Sustainable Society (14th Ed.), WW Norton & Company, New York, USA.

Chaudhary, D. P., Kumar, A., Mandhania, S. S., Srivastava, P. and Kumar, R. S., 2012, Maize As Fodder? An Alternative Approach, Directorate of Maize Research, New Delhi, India.

Cook, B. G., Pengelly, B. C., Brown, S. D., Donnely, J. L., Eagles, D. A., Franco, M. A., Hanson, J., Mullen, B. F., Partridge, I. J., Peters, M. and Schultze-Kraft, R., 2005, Tropical Forage: An Interactive Selection Tool [online], CSIRO, DPI&F(Qld), CIAT and ILRI, Brisbane, Australia, http://www.tropicalforages.info/ [Access Date: December 14, 2016].

Deifel, K. S., Kopittke, P. M. and Menzies, N. W., 2006, Growth response of various perennial grasses to increasing salinity. *J. Plant Nutr.* 29(9), 1573-1584.

Dominguez, C. E., 1983, *Morphology of the Cassava Plant,* Centro Internacional de Agricultura Tropical (CIAT). Cali, Colombia.

Duke, J. A., 1983, Handbook of Energy Crops [online], NewCROPS, Purdue University, https://hort.purdue.edu/newcrop/duke_energy/Pennisetum_purpureum.html [Access Date: December 14, 2016]

Ezenwa, I., Aribisala, O. A. and Akenova, M. M., 1996, Research note: Dry matter yields of *Panicum* and B*rachiaria* with nitrogen fertilisation or *Pueraria* in an oil palm plantation, *Trop. Grassl.* 30(4), 414-417.

Fan, Y., Li, H. and Miguez-Macho, G., 2013, Global patterns of ground water table depth. *Science* 339, 940-943.

FFTC, 2005, Processing of Fermented Rice Straw [online], Food and Fertilizer Technology Center, www.agnet.org/library.php?func=view&id=20110729180718 [Access Date: April 3, 2018]

FAO, 2016, Grassland Index, A searchable catalogue and forage legume [online], Food and Agricultural Organization, Rome, Italy, www.fao.org/ag/AGP/AGPC/doc/GBASE/mainmenu.htm. [Access Date: December 14, 2016]

Francis, J. K., 2004, *Pennisetum purpureum* Schumacher. *In*: Francis, J. K., (Ed.), *Wildland Shrubs of the United States and its Territories: Thamnic Descriptions: Volume 1, General Technical Repeport IITF-GTR-26,* USDA Forest Service, International Institute of Tropical Forestry, 542-544.

Göhl, B., 1981, *Tropical Feeds: Feeds Information Summaries and Nutritive Values.* Food and Agriculture Organization of the United Nations. Roma. Italy.

Govaerts, R., 2013, *Cenchrus purpureus* [online], Kew Royal Botanic Gardens, Richmond, UK, http://apps.kew.org/wcsp/namedetail.do?name_id=462651 [Access Date: December 14, 2016].

Gutteridge, R. C. and Shelton, H. M., 1994, *Forage Tree Legumes in Tropical Agriculture* [online], The Tropical Grassland Society of Australia, Queensland, Australia, http://www.fao.org/ag/AGP/AGPC/doc/Publicat/Gutt-shel/x5556e00.htm [Access Date: December 15, 2016].

Halim, R. A., 1997, *Pueraria phaseoloides* (Roxb.) Benth. [online], PROSEA (Plant Resources of South-East Asia) Foundation, Bogor, Indonesia, http://proseanet.org/prosea/e-prosea_detail.php?frt=&id=3037. [Access Date: December 15, 2016].

Heering, J. H., and Gutteridge, R. C., 1992a, *Sesbania sesban* (L.) Merrill. [online], PROSEA (Plant Resources of South-East Asia) Foundation, Bogor, Indonesia, http://proseanet.org/prosea/e-prosea_detail.php?frt=&id=1919 [Access Date: December 15, 2016].

Heering, J. H. and Gutteridge, R. C., 1992b**,** *Sesbania grandiflora* (L.) Poiret [online], PROSEA (Plant Resources of South-East Asia) Foundation, Bogor, Indonesia, http://proseanet.org/prosea/e-prosea_detail.php?frt=&id=1918 [Access Date: December 15, 2016].

Hess, H. D., Tiemann, T. T., Noto, F., Franzel, S., Lascano, C. E. and Kreuzer, M., 2006, The effects of cultivation site on forage quality of *Calliandra calothyrsus* var. Patulul, *Agroforest. Syst.* 68(3), 209-220.

Heuze, V. and Tran, G., 2015, Rice straw [online], Feedipedia, a programme by INRA, CIRAD, AFZ and FAO, http://www.feedipedia.org/node/557 [Access Date: December 14, 2016].

Heuze, V., Tran, G., Edouard, N. and Lebas, F., 2016a, Maize green forage [online], Feedipedia, a programme by INRA, CIRAD, AFZ and FAO, http://www.feedipedia.org/node/358 [Access Date: December 14, 2016].

Heuze, V., Tran, G., Giger-Reverdin, S. and Lebas, F., 2016b**,** Elephant grass *(Pennisetum purpureum)* [online], Feedipedia, a programme by INRA, CIRAD, AFZ and FAO, http://www.feedipedia.org/node/395. [Access Date: December 14, 2016].

Heuze, V., Tran, G., Boval, M. and Lebas, F., 2016c, Signal grass *(Brachiaria decumbens)* [online], Feedipedia, a programme by INRA, CIRAD, AFZ and FAO, http://www.feedipedia.org/node/489 [Access Date: December 14, 2016].

Hidayat, S., 2008, Iklim Indonesia, Pusat Pengembangan Bahan Ajar Universitas Mercu Buana, Jakarta, Indonesia.

Husson, O., Charpentier, H., Razanamparany, C., Moussa, N., Michellon, R., Naudin, K., Razafintsalama, H., Rakotoarinivo, C., Rakotondramanana and Seguy, L., 2008, *Brachiaria* sp., *B. ruziziensis*, *B. brizantha*, *B. decumbens*, *B. humidicola,* Manuel pratique du semis direct à Madagascar, Vol. III, CIRAD,Antananarivo, Madagascar.

Kabi, F. and Bareeba F. B., 2008, Herbage biomass production and nutritive value of mulberry (*Morus alba*) and *Calliandra calothyrsus* harvested at different cutting frequencies, *Anim. Feed Sci. Technol.* 140(1-2), 178-190.

Kadam, K. L., Forrest, L. H. and Jacobson, W. A., 2000, Rice straw as a lignocellulosic resource: collection, processing, transportation, and environmental aspects. *Biomass and Bioenergy* 18, 369-389.

KEPPRES RI (Keputusan Presiden Republik Indonesia) Nomor 41 Tahun 1987 Tentang Pembagian Wilayah Republik Indonesia Menjadi 3 (Tiga) Wilayah Waktu.

KLH, 2011, Status Lingkungan Hidup Indonesia 2010, Ministry of Environment of Republic of Indonesia, Jakarta, Indonesia.

Lam, V., 2016, Agricultural potential of sweet potato (*Ipomea batatas* L. (Lam)) for forage production. *Livestock Research for Rural Development* 28(6), *Artikel 101* [online], http://www.lrrd.org/lrrd28/6/lam28101.html. [Access Date: April 3, 2018]

Man, V. M. and Wiktorsson, H., 2001, The effect of molasses on quality, feed intake and digestibility by heifers of silage made from cassava tops [online], *International Workshop, Current research and development on use of cassava as animal feed*, Khon Kaen University, Thailand, http://www.mekarn.org/procKK/man.htm [Access Date: December 16, 2016].

Mannetje, L., 1992, *Pennisetum purpureum* Schumach. [online], PROSEA (Plant Resources of South-East Asia) Foundation, Bogor, Indonesia, http://proseanet.org/prosea/e-prosea_detail.php?frt=&id=1915 [Access Date: December 14, 2016].

Mulyani, A., Rachman, A. and Dariah, A., 2010, Penyebaran Lahan Masam, Potensi dan Ketersediaannya untuk Pembangunan Pertanian. *Prosiding Simposium Nasional Pendayagunaan Tanah Masam*, Bogor-Indonesia, 23-34.

OGTR (Office of the Gene Technology Regulator), 2008, *The Biology of Zea mays L. spp. mays (Maize or Corn)*. Department of Health and Ageing, Australia.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Anthony, S., 2009, *Agroforestree Database: a tree reference and selection guide version 4.0* [online], World Agroforestry Centre, Kenya, http://www.worldagroforestry.org/output/agroforestree-database [Access Date: December 15, 2016].

Peng, C. C., and Aminah, A., 1997, *Calopogonium mucunoides* Desv. [online], PROSEA (Plant Resources of South-East Asia) Foundation, Bogor, Indonesia, http://www.proseanet.org/prosea/e-prosea_detail.php?frt=&id=61 [Access Date: December 15, 2016].

Phengvilaysouk, A. and Wanapat, M., 2008, Study on the effect of harvesting frequency on cassava foliage for cassava hay production and its nutritive value, *Livest. Res. Rural Dev., 20 (Suppl.)* [online], http://www.lrrd.org/lrrd20/supplement/amma1.htm [Access Date: December 16, 2016].

Pizarro, E. A., do Valle, C. B., Keller-Grein, G., Schultze-Kraft, R. and Zimmer, A. H., 1996, Regional expertise with Brachiaria: Tropical America – Savannas, *Brachiaria: Biology, Agronomy and Improvement,* CIAT & Embrapa, Colombia, 225-246.

Ramirez, G. P., 1992, Cultivation harvesting and storage of sweet potato products, *Proceedings of the FAO Expert Consultation - Roots, Tubers, Plantains and Bananas in Animal Feeding*, CIAT, Cali, Colombia, 203-215.

Ravindran, V., 2018, Preparation of cassava leaf products and their use as animal feeds, Food and Agriculture Organization (FAO), Rome, Italy.

Rojas-Sandoval, J. and Acevedo-Rodriguez, P., 2013, *Pennisetum purpureum* (elephant grass), *Invasive Species Compendium* [online], CABI, Wallingford, UK, http://www.cabi.org/isc/datasheet/39771 [Access Date: December 14, 2016].

Sarwani, M., Anda, M. and Shofiyati, R., 2012, Policy and development of agricultural land resource mapping in Indonesia: experiences, achievments and impacts, *Regional Conference on the Asian Soil Partnership*. Nanjing, China.

Schultze-Kraft, R. and Teitzel, J. K., 1992. *Brachiaria decumbens* Stapf. [online], PROSEA (Plant Resources of South-East Asia) Foundation, Bogor, Indonesia, http://proseanet.org/prosea/e-prosea_detail.php?frt=&id=1842 [Access Date: December 14, 2016].

Scott, G. J., 1992, Sweet potato as animal feed in developing countries: present patterns and future prospects, *Proceedings of the FAO Expert Consultation - Roots, Tubers, Plantains and Bananas in Animal Feeding,* CIAT, Cali, Colombia, 183-202.

Tamindael, O., 2011, Coral reef destruction spells humanitarian disaster [online], Antara News, http://www.antaranews.com/en/news/71545/coral-reef-destruction-spells-humanitarian-disaster. [Access Date: December 26, 2016].

Tergas, L. E., 1981, The potential of *Brachiaria humidicola* for acid-infertile soils in tropical America. *Pastos Tropicales Boletin Informativo* 4, 12-13.

USDA, 2015, GRIN - Germplasm Resources Information Network [online], National Germplasm Resources Laboratory, Beltsville, Maryland, USA, http://www.ars-grin.gov/npgs/index.html [Access Date: December 14, 2016].

Vongsamphanh, P. and Wanapat, M., 2004, Comparison of cassava hay yield and chemical composition of local and introduced varieties and effects of levels of cassava hay supplementation in native beef cattle fed on rice straw, *Livest. Res. Rural Dev.,* 16(8) [online], http://www.lrrd.org/lrrd16/8/vong16055.htm [Access Date: December 16, 2016].

Wambugu, C., Franzel, S., Cordero, J. and Stewart, J., 2006, *Fodder Shrubs for Dairy Farmers in East Africa: Making Extension Decisions and Putting Them into Practice*. World Agroforestry Centre, Nairobi, Kenya and Oxford Forestry Institute, Oxford, UK.

Wanapat, M., 2002, The role of cassava hay as animal feed. *Proceeding of 7th Regional Cassava Workshop -Research and Development in Asia: Exploring New Opportunities for an Ancient Crop*, 504-518.

Wiersum, K. F. and Nitis, I. M., 1992, *Gliricidia sepium* (Jacq.) Kunth ex Walp. [online], PROSEA (Plant Resources of South-East Asia) Foundation, Bogor, Indonesia, http://proseanet.org/prosea [Access Date: December 15, 2016].