Productivity of five herbaceous legumes species in the post tin mining area as forage sources in Bangka Island

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Abstract. The objective of this study was to determine the adaptability of some herbaceous legumes grown on the soil as source of forage in post tin mining areas. The forage legumes tested were Arachis pintoi, Clitoria ternatea, Stylosanthes guianensis, Centrosema pascuorum cv Bundey and Lab-lab purpureus. The experiment was designed for a randomized block of five treatments and three replications. The plants were grown in plots of 5 m x 4 m with planting distance 0.5 m x 0.5 m. Plants have been pruned every 2 months at forage production. Parameter measures the production, quality and capacity of forage. Analysis of forage nutrition and digestibility in the laboratory of dry matter and organic matter. The growth rate for transplantation of three legumes A. pintoi, C. ternatea and S. guianensis, was 100%. The highest total forage for one year was S. guianensis 514.29 kg plot-1 with a carrying capacity of 12.33 AU (animal unit) and 74.02% dry matter digestibility and 73.96% organic matter. This study indicated that three (3) species C. ternatea, S. guianensis and A. pintoi showed an average high-life ability of up to 100%. In general, the type of legume selected in this study showed good adaptability.

1. Introduction
Availability of feed for ruminant, in particular forages under seasonal effects. Forage is abundantly available during the rainy season, but rarely throughout the dry season. To ensure that in quantity, quality and continuity of the forage are not guaranteed throughout the year leading to an under-optimal production [1]. The absence of sufficient forage, especially during the dry season, is a common in ruminant breeding. Also, during the dry season, the quality of the forage is generally low with productivity in the dry land area.

Tin mining activities on Bangka Island play an important role in state revenue and hurt the environment. Large- and small-scale tin mining activities have kept vast areas of forest and agricultural land open without proper reclamation [2]. The topsoil is peeled off during the mining process and is not stored properly for post-mining activities. This condition causes many lands to be dominated by sand after mining. Open mining causes irregular land surfaces, that do not contain nutrients and reduces soil microbial activity [3,4]. Furthermore, it causes land degradation and increases the size of abandoned land. Ex-tin mining land contains a very high fraction of sand with a low content of clay and organic...
matter; therefore, its water buffering capacity is very low. Post-mining land rehabilitation is performed when it only relies on a natural succession process which takes a long time and the land condition deteriorates due to uncontrolled erosion processes. The effort required to improve soil conditions by land reclamation is determined by the selection of suitable plant types.

The integration of herbaceous legumes (Centrosema pubescens and Pueraria javanica) after mining has been reported as a potential crop to improve ex-mining problems. By producing organic matter, plant species of Leguminosae have the potential to increase soil fertility, cation exchange capacity and soil microbial activity [5]. The use of herbaceous legumes in soil rehabilitation has been shown to rapidly cover the soil surface and reduce erosion. Rehabilitation of ex-tin mining land using cover crops of Centrosema increased nitrogen (N) and phosphorus (P) availabilities by 1.76 kg ha\(^{-1}\) year\(^{-1}\) and 0.64 kg ha\(^{-1}\) year\(^{-1}\), respectively. Pueraria increases the N and P by 1.59 kg ha\(^{-1}\) year\(^{-1}\) and 0.47 kg ha\(^{-1}\) year\(^{-1}\) [6,7].

Gliricidia legume also increases the nutritional content of soil-produced in the leaves [8]. Furthermore, the leguminous plants combine with Rhizobium in the capture of air nitrogen to enrich soil nutrients [9,10]. The roots and litter of legume plants increase the organic matter as well as the green manure content [11]. As a result, leguminous plants containing nitrogen and phosphorus have increased the production of forage products [12]. Besides, the supply of nutrients, as well as high-quality animal feed, is increased by C.ternatea, C.pascuorum and L.purpureus [13]. The purpose of this study is to determine the productivity of several herbaceous legumes grown on soil in post tin mining as well as a quality feed source for ruminant animals.

2. Materials and methods

2.1. Materials
This study was conducted in the Bukit Kijang village, Namang Sub District, Central Bangka, Bangka Belitung Province. The soil is classified as Entisols (USDA). The experiment was conducted from December 2016 until December 2017 with rainfall of 2,237.2 mm year\(^{-1}\) (figure 1).

The type of legumes used in this study was (Arachis pintoi, Centrosema pascuorum cv Bundey, Clitoria ternatea, Stylosanthes guianensis and Lab-lab purpureus) from collection laboratory Agrostology IRIAP (Indonesian Research Institute for Animal Production). Seeds were planted into polybags of 5 cm x 10 cm. The seedlings were splashed with water every day before they were transferred to the plot area. Polybag was kept in the nursery. All the seedlings were grown in the nursery for 2 months before being transplanted into the field.

2.2. Methods
There were 15 plots. The plants were planted in plots of 5 m x 4 m with a planting distance of 0.5 m x 0.5 m and a spacing of 1 m between the plot. Plots were fertilized with 2 kg plant\(^{-1}\) (equal 40 t ha\(^{-1}\)) of organic fertilizers, superphosphate (SP-36) 5 g plant\(^{-1}\) (equal 100 kg ha\(^{-1}\)), KCl 5 g plant\(^{-1}\) (equal 100 kg ha\(^{-1}\)) and urea 10 g plant\(^{-1}\) (equal 200 kg ha\(^{-1}\)). Five treatments were arranged in a randomized block design with three replicates. All plots were manually weeded and kept free of weed during the experiment. The biomass (leaf and stem) of each legume species was pruned from all areas in the plot, planted after three months and cut at an average interval of two months. Observation of harvesting was carried out six times. Plant sample for analysis of nutrients by composite in IRIAP laboratory crude protein (CP), energy, calcium (Ca) and phosphorus (P) [14]. Neutral detergent fiber (NDF), acid detergent fiber (ADF) has been estimated using the methods described [8]. In vitro digestibility of dry matter (DMD) and organic digestibility (OMD) [16]. Data were tabulated in the excel program and statistically analyzed using SAS.
Figure 1. Rainfall and rainy days for 13 months of research in the Bukit Kijang village, Namang sub-district, Central Bangka district.

3. Results and discussion
The chemical characteristic of the soil in this study consisted of 82.94% sand, 9.38% fine clay, 3.96% coarse clay, 3.72% dust and pH 4.9, organic carbon content 0.64%, N 0.05%, available P$_2$O$_5$ 3.42 ppm, available K$_2$O 8 ppm and cation exchange capacity (CEC) 5.2 cmol kg$^{-1}$ and heavy metal (Pb 13.16 ppm, Cu 0.374 ppm, Hg 11.26 ppm, Cd 0.16 ppm). Post tin mining areas generally show less fertile soils with low organic matter. In terms of morphological, physical and chemical characteristics, the ex-tin mining land in Bangka has suffered enormous biophysical damage and degradation [8,4] The plant nutrient reserves are very low and 51% are classified as unsuitable [3]. Organic fertilizers are needed to meet plant nutrient needs according to the standard of forage cultivation to make agricultural land productive. Furthermore, the use of inorganic fertilizers increases growth and production since it is rapidly available to plants [17]. This research uses organic fertilizers, which are twice the standard for forage cultivation and production show in table 1.

3.1. Fresh forage production
The productivity of five forage herbaceous legumes varied and this variation occurred during the experiment. The first harvest in three (3) months after planting and total production of forage from 6 times pruned was shown in table 1.

Table 1. Total fresh forage production of 5 herbaceous legumes on post tin mining Bukit Kijang Village Central Bangka

| Type of species       | Fresh production (kg plot$^{-1}$ year$^{-1}$) | Fresh production (ton ha$^{-1}$ year$^{-1}$) | Carrying capacity (AU)* |
|-----------------------|---------------------------------------------|---------------------------------------------|-------------------------|
| A. pintoi             | 331.83$^{b}$                                | 116.14$^{b}$                                | 7.95$^{b}$              |
| C. ternatea           | 167.52$^{c}$                                | 58.63$^{c}$                                 | 4.02$^{c}$              |
| S. guiyanensis        | 514.29$^{a}$                                | 180.00$^{a}$                                | 12.33$^{a}$             |
| L. purpureus          | 17.93$^{e}$                                 | 6.28$^{e}$                                  | 0.43$^{d}$              |
| C. pascourum cv Bunday | 65.83$^{d}$                                | 23.04$^{d}$                                | 1.58$^{d}$              |

Notes: The numbers followed by the same letter in the same column do not differ from the actual P <0.01; AU: animal unit. *Formula [18].

In table 1, the forage productivity of the five herbaceous legumes has different growth responses. Forage production ranges from 17.93 to 514.29 kg plot$^{-1}$ year$^{-1}$ (equivalent to 6.28 to 180.00 t ha$^{-1}$ year$^{-1}$). S. guiyanensis achieved the highest production (12.86 t ha$^{-1}$ year$^{-1}$) with carrying capacity and an average body weight animal of 400 kg, as well as 12.33 animal units (AU). This was followed by A. pintoi
at 116.14 t ha\(^{-1}\) year\(^{-1}\) (carrying capacity of 7.95 AU), \textit{C. ternatea} at 58.63 t ha\(^{-1}\) year\(^{-1}\) (carrying capacity of 4.02 AU) and the lowest is \textit{C. pascuorum} at 23.04 t ha\(^{-1}\) year\(^{-1}\) and \textit{L. purpureus} at 6.28 kg plot\(^{-1}\) year\(^{-1}\), with livestock carrying capacity of 1.58 AU and 0.43 AU, respectively.

Forage production of 5 herbaceous legumes in the ex-tin mining area is higher [19]. Soil pH research of 5.05 with a sand texture of 52.32% and produces dry matter of \textit{S. guiyanensis} at 8.16 t ha\(^{-1}\) year\(^{-1}\), while \textit{C. ternatea} is lower at 16.15 t ha\(^{-1}\) year\(^{-1}\). Furthermore, \textit{S. guiyanensis} at 15.5 kg\(100\ m^2\) harvest \[6\]. The decrease in production of forage in the ex-mining areas is due to the dominant sandy soil condition of sandy soil (82.94%), soil pH 4.9 and C/N 11%. The high proportion of sand and acidic soil, as well as rainfall also affects the adaptation of \textit{C. pascuorum} and \textit{L. purpureus} species, therefore there is no production in the third harvest compared to other species. Forage production per harvest is shown in figure 2.

![Forage production of 5 species herbaceous legumes from six-time harvests in post tin mining](image)

**Figure 2.** Forage production of 5 species herbaceous legumes from six-time harvests in post tin mining

Figure 2 shows the fluctuation of fresh forage weight from the first to the sixth harvest. Generally, highly stylo, arachis and clitoria were produced 40 to 60 times as much forage as the other species (figure 2) which means that this species is the highest.

Even though production \textit{C. pascuorum} and \textit{L. purpureus} were decreased in the third harvest. This is thought to be the effect of soil nutrients on acidic soil pH (4.9). The same thing was also reported \textit{C. pascuorum} and \textit{L. purpureus} including plant survival in the low dry season and could not grow back \[5\]. Then \textit{C. pascuorum} and \textit{L. purpureus} did not produce after the third harvest due to the low pH influence of the soil pH \[20\]. This is also reflected in the results of research in ex-tin mining land following the second harvest of low rainfall at irregular frequency. Also, low phosphorus (P) soil nutrients are not sufficient for plant growth. Low phosphorus (P) nutrients are insufficient for plant growth because it is essential for growth and metabolism. However, the lack of P inhibits certain processes in cell division and development \[11,21,22\].
3.2. Nutrition composition
The nutritional composition of five herbaceous legumes shows that the contents were varied. The results of the composite analysis of protein content varied between 9.70% to 24.46% of the dry matter, while the NDF values ranged from 41.16% to 55.02% and ADF 32.50% to 49.04%, mineral P 0.22% to 0.38% and Ca 2.31% to 3.73%, Ash 6.07% to 15.37% and energy 3,512 to 4,270 cal kg⁻¹ (table 2).

Table 2. Nutrition of 5 species herbaceous legumes on post tin mining at Central Bangka, Bangka Belitung Province

| Species            | Crude protein (%) | Energi (cal kg⁻¹) | Ash (%) | NDF (%) | ADF (%) | P (%) | Ca (%) |
|--------------------|------------------|------------------|--------|---------|---------|-------|-------|
| A. pintoi          | 10.92 c           | 3512 c           | 15.37 a | 41.16 d | 32.50 b | 0.33 b | 3.72 a |
| C. ternatea        | 18.62 a           | 4270 a           | 6.07 c  | 45.12 c | 34.35 b | 0.31 b | 2.31 c |
| S. guianensis      | 9.70 c            | 3905 b           | 7.89 c  | 53.29 b | 47.36 a | 0.22 c | 2.68 c |
| L. purpureus       | 14.37 b           | 3958 b           | 9.94 b  | 55.02 a | 49.04 a | 0.38 a | 3.73 a |
| C. pascuorum cv Bundey | 24.46 a       | 4033 b           | 9.47 b  | 52.37 b | 46.79 a | 0.26 b | 3.07 b |

Notes: NDF: neutral detergent fiber; ADF: acid detergent fiber; P: phosphor; Ca: calcium
The numbers followed by the same letter in the same column do not differ from the actual P <0.01

Table 2 shows the forage nutrient content of five herbaceous legumes, the crude protein of C. pascuorum and L. purpureus in ex-mining areas is higher than other types but has the lowest production. In the meanwhile, S. guianensis had the lowest crude protein of 9.70% but had the highest forage production for one year. It seems that the accumulation of crude protein in plants is closely related to the availability of the organic material, especially N nutrient. The crude protein content of plants is affected by the absorption of N from the soil. Furthermore, the function of N fertilizer also affects the growth of plants including stems, branches and leaves and plays an important role in the formation of green leaves [22,23]. Another function is the formation of protein, fat and various organic compounds. Herbaceous legumes as cover crops are known to increase the soil organic matter and soil fertilizer. This due to rhizobium legume symbiosis which can fix nitrogen from the air [24,25].

The crude protein content of S. guianensis is the lowest but has the highest NDF and ADF levels compared to other types. Increased in NDF and ADF also affect the digestibility of dry and organic matter (table 3).

Table 3. Invitro dry matter digestibility and in-vitro organic matter digestibility 3 species of herbaceous legumes on post tin mining.

| Species            | In vitro dry matter digestibility (IVDMD) (%) | In vitro organic matter digestibility (IVOMD) (%) |
|--------------------|---------------------------------------------|-----------------------------------------------|
| A. pintoi          | 82.73 a                                      | 82.14 a                                       |
| C. ternatea        | 70.77 b                                      | 68.43 c                                       |
| S. guianensis      | 74.02 b                                      | 73.96 b                                       |

Note: The numbers followed by the same letter in the same column do not differ from the actual P <0.01

Table 3 shows the results of the analysis of the digestibility of dry and organic matter produced by on feed plants after 6 different cuttings (A. pintoi, C. ternatea, S. guianensis). The digestibility level in feed is used to measure the quality indicators of feed. In vitro dry matter digestibility (IVODMD) was also high (70.77%-82.73%), followed by IVOMD within which most reported values were 54.16% to 61.50% [19]. The highest IVDMD values for most species post tin mining species seem to be due to a
A higher proportion of leaf than stems. The results were 82.74% and 82.14% for *A. pintoi*, followed by 74.02% and 73.96% for *S. guiyanensis* and 70.77% and 68.43% for *C. ternata*, respectively. Furthermore, the low digestibility of *C. ternata* and *S. guiyanensis* is due to the different content of NDF and ADF levels. The difference in performance between the *C. ternata* and *S. guiyanensis* plants was due to the trunkey plants containing higher lignin. Also, lignin is a limiting factor for the digestibility of ruminants in plant cell walls [16,26]. It causes low degradation or fermentation of feed in the rumen, as crude fibres in the form of cellulose and hemicellulose bonded with lignin and will be difficult to breakdown by digestive enzymes [27].

4. Conclusions
It can be concluded from the experiment that three (3) species of herbaceous legume in post tin mining area showed good adaptability *A. pintoi, C. ternata* and *S. guiyanensis*. Species *S. guiyanensis* was superior to other species of herbaceous legumes. The highest fresh weight of forage production from six times harvest was 514.29 kg plot⁻¹ year⁻¹ equal to 180 t ha⁻¹ which carrying capacity 12.33 AU (animal unit). These legumes are promising to be developed for multipurpose crops.

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