Land Management in Optimizing Productivity of Limited Land to Deal with Rural Food, Feed and Fuel (3F) Security

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Abstract. Study aims to observe the best practice in optimizing land productivity for succeeding rural food and energy sovereignty. This study was carried out in Majalengka District on 2 ha land, arranged as monoculture calliandra plantation (2 x 3 m spacing), agroforestry (2 x 5 m spacing), and agro-sylvo-pasture (2 x 5 m spacing). Calliandra planted in agroforestry was combined with maize, beans, and peas; while agro-sylvo-pasture planted with the same commodities mixed with utilizing waste of corn and calliandra for forage of cattle or goats. Calliandra were harvested in 2 years age by applying coppice system. Yield of 2 years fire-woods, annual (food crops), and 6 months coppice sprouting capacity of calliandra, were calculated as land productivity. The result showed that productivity of grown in monoculture was 28 tons/ha, higher than agroforestry (15) or agro-sylvo-pasture (13.8). However, agro-sylvo-pasture could significantly improve number of 6 months age coppice (diameter 4-6 cm) by 8-10 coppices/trees higher than agroforestry (6-8) or monoculture (3-5). Agroforestry was also successfully improve land productivity; such as produced corn grain (8.4 tons), mung bean (1.6 tons), groundnut grain (2.5 tons), pigeon pea (0.8 tons) respectively, per year. Income for farmer can be calculated per years per hectar, as 3,050,000 IDR (monoculture); 26,575,000 IDR (agroforestry), and 28,375,000 IDR (agro-sylvo-pasture). Whereas agro-sylvo-pasture was not significantly different in increasing land productivity compare to agroforestry, nevertheless, cattle or goat breeder not only gained 3 tons maize waste and 2.2 tons leaf during a season but also saved fertilizers due to manure production. It can be concluded that developing energy plantation forest through agroforestry or agrosylvopasture can be the promising program to realize the rural food, feed, fuel security.

1. Introduction
In the future, sovereignty of a nation is determined by their capability in providing sufficient national food and energy. In line with the diminution of fossil energy deposits, country with varies energy sources will be the most powerfull, as well as the national food security. Indonesia with the archipelago geography will face food and energy scarcity, particularly due to hard acceccability to those commodities. Currently, some small islands still depended on the supply from the closest bigger island. Furthermore, it need an effort to empower the local community to real food and energy self-sufficient by optimizing land utilization. Forestry Sector play important role in shorting the problem related to food and energy scarcity. Therefore, The Ministry of Environment and Forestry of Indonesia have planned the energy plantation forest (EPF) under the Directorate of Sustainable Forest Productivity (Ditjen PHPL). This institution have allocated 2 millions hectare of expired-licensed of some plantation forest land to convert as the EPF. The EPF program aimed not only to provide...
alternative energy for the people-adjacent forest, to mitigate climate change and disaster, to conserve the water resource, but also to improve people prosperity.

A species can be cultivated as energy wood characterized as fast growing, adaptable at any side conditions, can be harvested in coppice system, have a good spouting power for regeneration, high calory content, and the most important it is not an invasive species [1]. One of the most familiar energy wood is *callothrysus*. This species have origin from Central America and Mexico, that is successfully cultivated around the tropical region. In Indonesia recognized as the multipurpose tree species (MPTS), which is successfully planted as the nitrogen fixer, landslide protector and bee feeder in the agroforestry program. In Uganda this species is intensively developed in the agroforestry since the 1989 for producing the multiple goods and services such as livestock feed, fire-wood, media for climbing liana peas, erosion control, and soil fertility improvement [2]. ICRAF in collaboration with the *Forestry Resources Research Institute, Uganda* (FORRI), developed a program *Agroforestry Research Network for Africa* (AFRENA) project, conducted a study on cultivation of in Uganda since the 1990s [3]. Farmer community in Uganda have been familiar in planting in their gardens and backyards, averagely they planted 973 stems per house hold. There are varies systems in planting in Uganda, such as direct showing, seedling from nursery, or stumps from wild collection with the survival rate 70% [2]. Lesson learnt from the success story in developing in Uganda is the resting stumps height depend on the purposes. Harvesting for fodder they cut up to 50 cm height, since from their experience that is the best stump for producing maximum coppices. Whereas for producing fire wood, the best practice was 1-2 meter height of resting stumps [2]. Another important factor in energy wood cultivation is the frequency of harvesting. People in Uganda harvest the branches six times a year (every 2 months) for harvesting livestock feed, once a year for yielding fire wood, and 2-3 times a year in order to improve the soil fertility [4]. The most effective spacing in developing intensive agroforestry for plantation was 2 x 5 meters [3].

Since the price of wood is very cheap in Indonesia, so fire-wood is not a promising commodity for being the main income for the people in the rural area. Before can be harvested at least at the age 18 months, people need a cash-crop during the cultivation, so EPF in the rural area need to arrange for producing multiple commodities. This study aimed to observed the land productivity, farmer income, and soil improvement in 2 ha land managed as energy estate plantation.

2. Method

2.1. Materials

The study was conducted in Majalengka company estate forest, West Java Province of Indonesia (6°46’44.618”S, 108°17’6.738”E) in April - November 2018, at the stands 12, 18, and 24 months old. The soil properties of the site is classified as latosol and regosol, annual rainfall 2,400-3,800 mm/year with eight rainy months.

2.2. Procedure

The experiments were arranged in a complete-randomize-block design in two replications, thus the 2 ha site of study was divided into 6 plots each was in 3000 m square. were planted as the energy wood, with the following treatments; planted in monoculture spacing 2x3 m; planted in agroforestry (spacing 2 x 5 m) with maize, beans, and peas; planted in agrosylvo-pasture (spacing 2 x 5 m) mixed with maize, beans, and peas as well as combined with utilizing waste of corn and forage of cattle or goats. In agro-sylvo-pastures there is a regularly and intensively harvested the unproductive branches for feeding the livestocks. Agroforestry plot was maintained with fertilizers in the following dosages: urea (500 kg/ha); NPK (120 kg/ha); TSP (200 kg/ha). Whereas the agro-sylvo-pastures plot was fertilized with manure (800 kg/ha), urea (250 kg/ha); NPK (60 kg/ha); TSP (100 kg/ha). The wood were harvested in 2 years age by applying coppice system, the next harvested will be planned conducted in every year.
Data collected in the study were land productivity and income of farmers. Land productivity are calculated by measuring the yield of 2 years fire-woods, annual (food crops), and 6 months coppice sprouting capacity of. Income gained by the farmers were calculated as the price of fire-woods, and crops, as well as corn waste and leaves using as the cattle or goats feeding; after reducing with the operational budgets.

2.3. Data Analysis
The Analysis of Variance (ANOVA) for single-way factorial in randomized completed-block design was conducted using SPSS 22 software. To observe the most influential factor the Duncan’s multiple range test was further analyzed at the 95% level of confidence.

3. Result and discussion
ANOVA analysis showed that agroforestry and agrosylvopasture land management have a significant different with the monoculture (p<0.05). It can be understood since the monoculture only cultivate with the different spacing compare to the other treatments. The analysis of variance showed that among agroforestry and agro-sylvo-pasture did not give a significant in producing fire-wood and crop commodities. It mean that either agroforestry or agro-sylvo-pasture can be significantly improve land productivity and the income for the farmers.

Table 1 showed that monoculture plantation gave the biggest productivity for fire-wood (28 ton/ha). This result showed a better yield than the same age of plantation in Madura in spacing 1 m x 1 m that only produced 16 ton/ha/year [5]. Because is a multi stem species (Figure 1 a) that need a proper space to grow better. Spacing 1 m x 1 m in Madura push the trees in a hardest competition among them. Table 1 showed that space allocation for crops through agroforestry or agrosylvopasture reduced the fire-wood productivity. However, farmers have opportunity to produce other commodities.

3.1. Productivity of Wood 2 years after planting

| Plantation pattern (spacing) | Block I (t/ha) | Block II (t/ha) | Average (t/ha) |
|-----------------------------|---------------|----------------|---------------|
| Monoculture (2 x 3)         | 28.4a         | 27.6a          | 28a           |
| Agroforestry (2 x 5)        | 16.2b         | 13.8b          | 15b           |
| Agrosilvopasture (2 x 5)   | 12.2c         | 14.4b          | 13.8bc        |

Values followed by the same letter in the same column illustrated that there are no significantly different

Table 1 showed that wood productivity harvested at the 24 month age are significantly better in the plot where cultivated in monoculture than the other patterns. Because the density of the plants is much higher than other plots arranged for crops cultivation. Among agroforestry and agrosylvopasture treatment shown was not significantly different.

3.2. Productivity of Coppice

| Plantation pattern (spacing) | Diameter (cm) | Number | Height (cm) |
|-----------------------------|---------------|--------|-------------|
| Monoculture (2 x 3)         | 4.1a          | 3.8a   | 345a        |
| Agroforestry (2 x 5)        | 6.3b          | 7.6b   | 458b        |
| Agrosilvopasture (2 x 5)   | 5.9b          | 8.4b   | 478b        |

Values followed by the same letter in the same column illustrated that there are no significantly different

Table 2 illustrated that the growth of the coppice cultivated on the land that are managed in agroforestry and agro-silvopasture showed better than the monoculture treatment. However, among
agroforestry and agrosylvopasture were indicated non significant difference. The improvement caused by the better space for growing of the coppice that accept adequate light requiring for photosynthesis activities. The improvement of the coppice growth also come from the increament of soil characteristic due to land management. It is illustrated in Table 5 that agroforestry and agrosylvopasture that utilize intensive fertilizer have been improve the nutrient availability in soil. The best improvement in soil characteristics were given by agrosylvopasture (Table 5) because this treatment using manure that improve the soil organic matter properties, afterwards improve CEC, C/N, base saturation, soil porosity and soil moisture that will make the most adequate environment for better growth. However, the productivity of the fire-wood in the agrosylvopasture system is the least level compare to the monoculture and agroforestry pattern, it is assumed that in this treatment were regularly harvested to yield the unproductive branches that may be give depletion effect to the wood productivity (Table 1).

3.3. Productivity of crops

| Plantation pattern | Maize (kg) | Pea nut (kg) | Pigeon pea (kg) | Mung bean (kg) | Livestock Feed (kg)* |
|--------------------|-----------|-------------|-----------------|----------------|----------------------|
| Agroforestry       | 8,400     | 2,500       | -               | 1,800          | -                    |
| Agrosilvopasture   | 8,300     | 2,300       | 800             | -              | 3,000 CL             |

*CL = leaves; CW = corn waste

Agroforestry shown give a better productivity on maize and peanut grains. Pigeon pea and Mung bean were not painted on the all plots because that is depend on the preference of the farmers. Pigeon pea and mung bean can not be compared each other because they have a significant difference in their growth performance. However, the total of income can be compared among the variation of land utility in this study (Table 4). People developing agrosylvopasture seem to obtain more income than their cultivating in agroforestry system. They can earn more than 2 million higher than other group developing agroforestry. That is caused by saving from the fertilizer allocation using manure that collecting from their own ranch. They also save budged allocating for livestock feed by harvesting the non productive branches (Figure 1c) up to 8,900,000 IDR per year.

3.4. Land productivity and farmer income

| Plantation pattern | Woods | Price (250 K) | Crops* x price (K) | Obtain | Capital | Gros | Income (/year) |
|--------------------|-------|---------------|---------------------|--------|---------|------|----------------|
| Monoculture        | 38    | 9,500         | -                   | -      | 3,400   | 6,100| 3,050          |
| Agroforestry (shifting crops) | 15    | 3,750         | 8,4 x 4             | 33,600 | 14,000  | 19,600| 26,575         |
| Maize              |       |               | 2,5 x 10            | 25,000 | 8,600   | 16,400|                 |
| Ground nut         |       |               | 1,8 x 12            | 21,600 | 8,200   | 13,400|                 |
| Mung bean          |       |               |                     |        |         |       |                 |

*in tons; **not for sale, only for owner consumption for livestock feed; K = x 1000; income = gros/2

| Plantation pattern | Woods | Price (250 K) | Crops* x price (K) | Obtain | Capital | Gros | Income (/year) |
|--------------------|-------|---------------|---------------------|--------|---------|------|----------------|
| Agrosilvopasture (shifting crops) | 13.8  | 3,450         | 8,2 x 4             | 32,800 | 12,000  | 20,800| 28,375         |
| Maize              |       |               | 2,3 x 10            | 23,000 | 6,600   | 16,400|                 |
| Ground nut         |       |               |                     |        |         |       |                 |
Table 5. Soil properties

| Soil characteristic               | Monoculture | Agroforestry | Agro-sylvo-pasture |
|-----------------------------------|-------------|--------------|--------------------|
| Soil Organic Carbon (%)           | 3.56a       | 4.87b        | 7.03c              |
| pH                                | 6.69a       | 7.01b        | 7.04b              |
| N total (%)                       | 0.09a       | 0.24b        | 0.49c              |
| P available (ppm)                 | 9.41a       | 14.68b       | 17.85c             |
| C/N                               | 39.56       | 20.29        | 14.35              |
| K exchangeable (me/100 g)         | 11.41a      | 26.78b       | 22.41b             |
| Soil porosity (%)                 | 36.87a      | 56.53b       | 64.71c             |
| Soil Moisture (%)                 | 84.22a      | 72.41b       | 74.62b             |
| CEC (me/100 g)                    | 15.33a      | 16.48a       | 21.66b             |
| Base saturation (%)               | 52.36a      | 68.94ab      | 86.44b             |

Values followed by the same letter in the same rows indicated the non significant different, $\alpha = 0.05$

Table 5 showed that agroforestry and agro-sylvo-pasture improved soil properties at all soil character. Due to tillage and fertilizer application the treatment increase soil porosity hence the water can infiltrate into the soil that make available to the plants. Majalengka has high rainfall, however the location is windy and has dry season in a long period, so porosity will improve the water retention in soil. Agro-sylvo-pasture gave the best improvement in soil property, particularly the soil organic carbon (SOC), N total, P availability, and soil porosity. C/N in the agrosylvopasture depleted is assumed that the manure is better decomposed that increase significant N then decrease the C/N (Table 5).

Figure 1. Performance of plantations

- a. Monoculture
- b. Calyandra with corn
- c. with harvesting leaves for livestocks feed
Figure 2. Performance of 6 months age of coppice

4. Conclusion
It can be concluded tha developing energy plantation forest through agroforestry or agrosylvopasture can be the promising program to realize the rural food, feed, fuel security.

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