Optimizing Land Suitability and Rehabilitation Techniques for *Falcataria falcata, Durio zibethinus,* and *Callophyllum inophyllum* in the Critical Land of Tenjolaya District, Bogor Regency, West Java

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Abstract. Critical land is a significant problem for environmental sustainability. Rehabilitation of critical land can be conducted by optimizing land suitability, planting adaptive species, and rehabilitation techniques (fertilizers and planting techniques consist of direct planting and drone seeders). Drone seeders must be applied to access remote areas. This study aimed to analyze the land suitability for *Falcataria falcata*, *Durio zibethinus*, and *Callophyllum inophyllum* and the effect of fertilizers and planting techniques on their growth. The method used was a spatial analysis using remote sensing and an experimental design using a completely randomized block design with two factors (fertilizers and planting techniques). The result showed that suitable land analysis for *F. falcata* is S3-eh (38.40%), *D. zibethinus* is S3 (38.40%), and *C. inophyllum* is S (39.28%). The C treatment (no fertilizers + direct planting) resulted in the best germination percentage for *F. falcata* (42.86%), *D. zibethinus* (85.71%), and *C. inophyllum* (100%). The land condition is full of rocks; hence, the height at which the seeds are dropped causes damage to the fertilizers and seeds. The application of fertilizers and drone seeders can be a potential for rehabilitation in remote areas by considering the biophysical area and composition of seed-coating.

1 Introduction

Critical land is a significant problem for environmental sustainability. Generally, reed vegetation indicated critical land with a low pH value (4.8 - 5.2) caused by soil abstersion [1]. The limited carrying capacity of the land, followed by non-sustainable land use, makes land critical. Furthermore, this impacts the ecosystem physically, environmentally, and socio-economically.

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Land evaluation is a crucial step in determining the suitability and potential of land classes for specific use. The analysis of land suitability is a cornerstone of effective land use management. Given the long-term implications of forest management decisions, it is imperative to employ appropriate planning and decision-support techniques [2]. Land suitability analysis, in particular, can provide valuable insights for environmental managers and planners, facilitating a comprehensive understanding of the interplay between location, development actions, and environmental factors [3]. Hence, it is a crucial component of the critical land rehabilitation program.

According to *Dinas Kehutanan Provinsi Jawa Barat* (West Java Province Forestry Service), Bogor Regency had approximately 69,203.47 hectares of critical land in 2023. The Forestry Service has conducted critical land rehabilitation efforts through the Participatory Critical Land Rehabilitation program [4]. The process of critical land rehabilitation is not without its challenges. Low soil fertility, low plant survival rates, and difficult access areas pose significant hurdles. To overcome these, the application of fertilizers, the plantation of adaptive plant species, and the use of suitable plantation techniques are essential. Among the alternative plant species that have shown promise in critical land rehabilitation are *Falcataria falcata*, *Durio zibethinus*, and *Callophyllum inophyllum*.

Oil palm-based micro-fertilizers can be an alternative to improve peatland fertility. [5] reported that approximately 23% of oil palm empty fruit bunch (OPEFB) from oil palm total waste was generated from producing crude palm oil. Thus, the abundance of waste could be harnessed to obtain value-added products, such as bio-composite, bio-pellets, bioethanol [6], and fertilizers. [7] reported that chitosan nanocomposite (chitosan-oil palm carbon nanoparticles and chitosan-oil palm lignocellulose nanofibre) provide the best Dendang and Indragiri paddy variety growth patterns. [8] also reported that Nanochitosan/NPK/PMAA/AC 1% and chitosan/NPK/AC 5% resulting the highest score for paddy germination percentage at five days and seedling survival rate, whereas chitosan/NPK/CC and chitosan/NPK/PMAA/LC composite resulted in the highest germination percentage at 21 days.

The direct seeding technique is the plantation technique for degraded land. Direct seeding is an increasingly used alternative for large-scale restoration [9] [10]. The lower cost of labor and transportation and direct seeding do not require specific machinery and nurseries [9] [11] [12]. The effectiveness of direct seeding could be improved by applying the aerial seedling technique. Aerial seedling, popularly known as "seed bombing/seed ball," is an innovative approach to ecological restoration [13]. Aerial seed balls are made from various substances to deliver multiple seeds [10]. In its most basic form, these seed balls are made with a clay shell, which could also contain nutrients, chemicals to deter seed predators, symbiotic microbes, and hydrogels [14].

According to this background, this study aimed to analyze the land suitability for *F. falcata*, *D. zibethinus*, and *C. inophyllum* and how fertilizers and planting techniques affect their growth.

2 Method

2.1 Land suitability analysis

The land suitability analysis was conducted on several commodities: *Falcataria falcata*, *Durio zibethinus*, and *Callophyllum inophyllum*. This study was conducted in two levels of analysis: class level and subclass level. The class level has four possible results: S1 (very suitable), S2 (suitable), S3 (marginally suitable), and N (not suitable). The subclass level will show the specific limiting factors: annual rainfall (wa), average temperature (tc), soil drainage level (oa), soil texture (rc), and slope (eh).

2.2 Plantation

2.2.1 Fertilizers preparation

Fertilizers used in this research were Chitosan/AA/PMAA/NPK/Microfertilizers. Fertilizers were synthesized using the method from [8]. Microfertilizers used for the fertilizers are made from oil palm biomass waste that is synthesized using the method from [7]. The fertilizers were made using various materials such as chitosan, methacrylic acid, liquid NPK fertilizers, and oil palm fibre-based micro-fertilizers. The fertilizers were synthesized by dissolving one gram of chitosan in 50 mL of methacrylic acid (MAA) 0.5% (v/v) solution, oil palm fibre-based micro-fertilizers, and 50 mL of 1% acetic acid (CH_3COOH) (v/v) an hour. Then 62.5 mL of NPK fertilizers were added to the fertilizer solution and stirred for an hour. Then, the solution was oven-dried at 100^{o}C for six hours. Furthermore, the fertilizers were oven-dried again at 100^{o}C for seven days.

2.2.2 Seed preparation

The seed used in this research was obtained from the local nursery at Bogor, West Java. Free fungus seeds were selected for this research, and dormancy breaking was done. The dormancy breaking was only conducted for *F. falcata* seed [15]. The *F. falcata* seeds were soaked in hot water for five minutes, then soaked for 24 hours using room temperature water.

2.2.3 Experimental design and treatment detail

A single factor of a completely randomized design was used for the experiment. The treatments were replicated four times. The treatments of this experiment are A (seedball + no fertilizers), B (seedball + fertilizers), and C (direct planting + no fertilizers). The seedball treatments in this study are shown in Figure 1.

Fig. 1. Seed ball used in this study

2.2.4 Data collection and analysis

The parameter was observed for 30 days. The observed parameter was a germinated seed. The collected data was then analyzed based on the germination parameter, which is germination percentage.

2.2.5 Soil characteristic analysis

Soil properties analysis was conducted before the plantation process. This test used the destructive method with 500 g of sample weight. The soil samples were then analyzed at the Indonesia Center for Biodiversity and Biotechnology (ICBB). The collected data were soil acidity (pH), water content, C-Organic, Total N, C/N ratio, available P_2O_5, potential P_2O_5, potential K_2O, exchangeable cations, cation exchange capacity (CEC), base saturation, exchangeable acidity, and soil texture.

3 Result

3.1 Plant species characteristics

F. falcata is the pioneer species from the Fabaceae family and belongs to the fast-growing species [16]. This species is widely planted in plantation forests because of its rapid growth, well-adapted to various soils, and wood quality acceptable to the panel and carpentry industry [17]. *D. zibethinus* was distributed in Malaysia's Peninsular, Thailand, Sumatra, and Kalimantan. This species grew on dry land or rocky ground with a wet tropical climate. *D. zibethinus* can be sown on a polybag using growing media of soil and compost (1:1) and should be placed in a shaded place with 50% intensity of sunlight [18]. The seedlings that are ready to plant are the seedlings that are 1.5 years old and have a minimum height of 75 cm [19]. *C. inophyllum* was distributed in Africa, India, Southeast Asia, North Australia, and other locations [20]. This species can be found in Indonesia almost all over the region, especially in the coastal areas, such as Alas Purwo National Park, Kepulauan Seribu National Park, Baluran National Park, etc. [21]. *C. inophyllum* can grow up to 25 m in height and 150 cm in diameter. The seed of each species are shown in Figure 2.

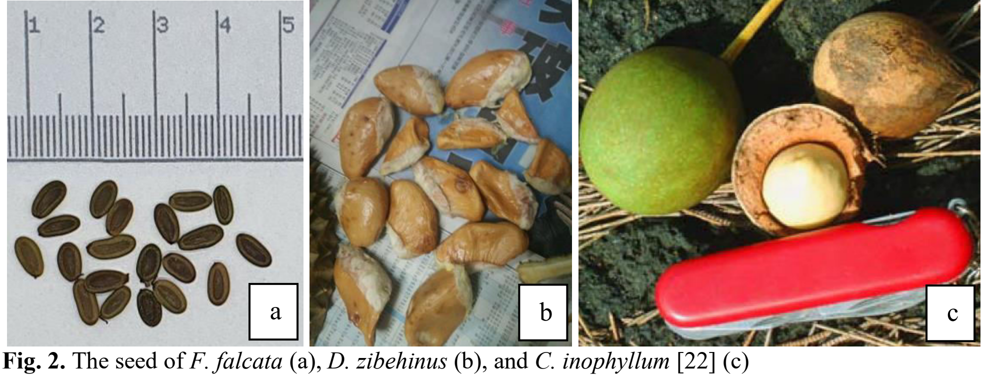

Fig. 2. The seed of *F. falcata* (a), *D. zibehinus* (b), and *C. inophyllum* [22] (c)

3.2 General conditions

The planting location is land owned by the surrounding community. This land needs to be better managed and is overgrown with weeds. The land clearing showed that the land's soil surface had a hard texture and had lots of rocks (Figure 3). The land also has a slope that is not too steep, making it suitable for conducting trial planting. The soil characteristics test result showed that the research site's soil type is clay (Table 1).

Table 1 Result of soil characteristics test

Parameters		Value
pH	H2O	7.1
	N KCl	6.0
C-Organic		1.82 %
Total-N		0.14 %
C/N Ratio		13
Available P_2O_5		4.50 mg/Kg
Potential P_2O_5		34.20 mg/100g
Potential K_2O		6.22 mg/100g
Exchangeable cations	K^+	0.16 cmol(+)/kg
	Na^+	0.15 cmol(+)/kg
	Ca^{2+}	15.04 cmol(+)/kg
	Mg^{2+}	1.01 cmol(+)/kg
Cation exchange capacity		25.45 cmol(+)/kg
Base saturation		64 %
Exchangeable acidity	Al^{3+}	< 0.05 cmol(+)/kg
	H^+	0.18 cmol(+)/kg
Soil texture	Sand	29 %
	Silt	13 %
	Clay	58 %

Fig. 3. Study area's visual conditions

3.3 Land suitability

Figure 4 shows that the study area has three classes: S2, S3, and N. The N class with the slope limiting factor dominates with the value of 60.72%. The S3 class with slope limiting factor has a total area of 1392.82 Ha, which covers 38.40% of the study area.

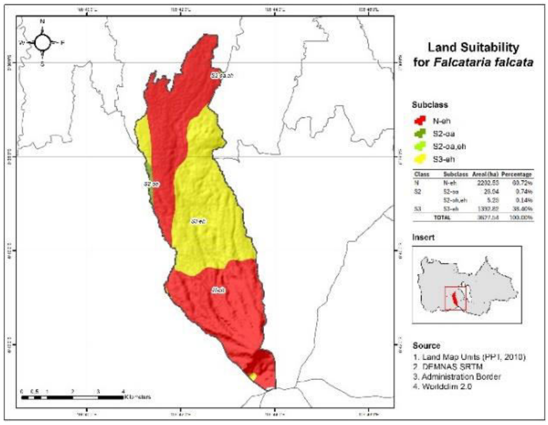

Fig. 4. The result of land suitability analysis for *F. falcata* in the study area.

Figure 5 shows that the study area has three land suitability classes: N, S2, and S3. The N-eh (unsuitable with slope limiting factor) dominates the study area with a total area of 2202.53 Ha (60.72%). The S3-eh (marginally suitable with slope limiting factor) has covered the study area's 38.40% (1392.82 Ha). The S2-tc-wa (suitable with average temperature and annual rainfall limiting factors) only covered the study area's 0.74% (26.94 Ha). The S2-wa-eh (suitable with annual rainfall and slope limiting factors) only covered the study area's 0.14% (5.25 Ha).

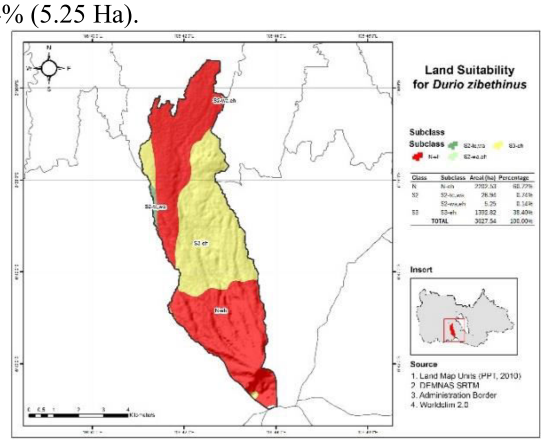

Fig. 5. The result of land suitability analysis for *D. zibethinus* in the study area.

Figure 6 shows that the study area has two land suitability classes: N and S. The N class dominates the study area with a total area of 2202.53 Ha (60.72%). The S class only covered 1425.01 Ha (39.28%).

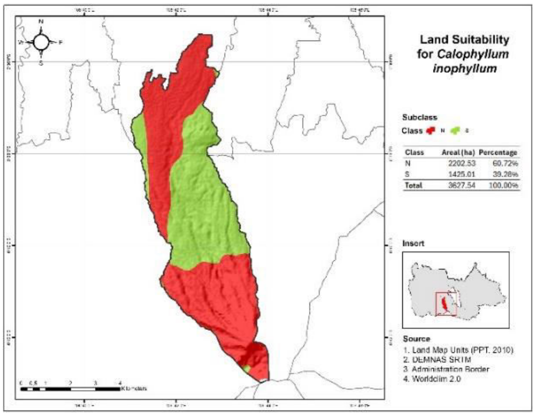

Fig. 6. The result of land suitability analysis for *C. inophyllum* in the study area.

3.4 Plantation

The seed balls used as seed wrappers are dropped using a drone (Figure 7) specially set up for planting seed balls. Seedballs are dropped from a height of 5 m above the ground. Several seed balls do not fall according to the specified point; this happens because the land has a slight slope, so the seedball moves right after touching the ground surface. Some seed balls also fall on hard surfaces, causing the seed balls to crack and break.

Fig. 7. Plantation process

Figure 8 shows that the C treatment (direct planting + no fertilizers) had the highest germination percentage. The *F. falcata*, *D. zibethinus*, and *C. inophyllum* have a 42.86%, 85.71%, and 100% germination percentage values, respectively. The other treatments have a lower germination percentage.

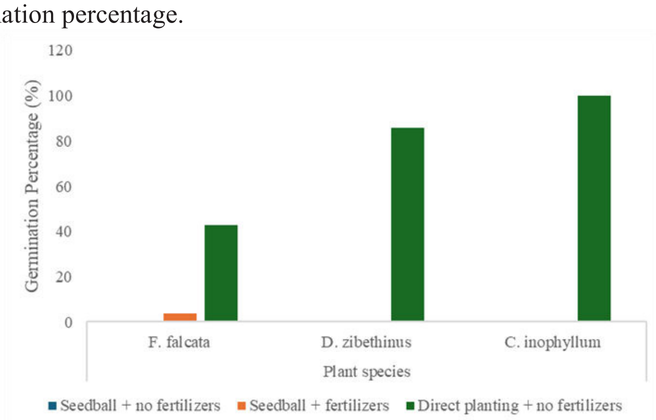

Fig. 8. Germination percentage

4 Discussion

According to the result of land suitability analysis, each species could be planted at the specific site in the study area. *F. falcata* can be planted at the S3-eh areal using terracing (Figure 9). Terraces help to protect the soil by increasing infiltration rates and decreasing runoff and sediment production [23]. The *D. zibethinus* can be planted in S3 and S2 classes. The analysis of *C. inophyllum* was only conducted at class levels because more information about land suitability criteria was needed.

Fig. 9. Cultivated terraces with stone walls [23]

Germination percentage indicates the number of seeds that could produce normal sprouts from the sown seeds in a certain period [24]. A lower germination percentage on A and B treatments is thought to be caused by poor soil surface conditions. The surface of the study area is filled with rocks and rigid material; hence, the height at which the seeds are dropped causes damage to the fertilizers and seeds. The sunlight and rainfall also exposed the damaged seed. Therefore, the seed condition is transformed into dry-out and rot seeds, as shown in Figures 10 and 11. In its basic form, seed balls are made with a clay shell, which could also contain nutrients, chemicals to deter seed predators, symbiotic microbes, and hydrogels [14]. The C treatment (direct planting + no fertilizer treatment) had the best germination percentage because the seed did not drop from the height. Therefore, the seeds are not damaged and can germinate well.

Fig. 10. Dry-out seed of *C. inophyllum*.

Fig. 11. Rot seed of *D. zibethinus*

5 Conclusions

The suitable land analysis for F. falcata is S3-eh (38.40%), D. zibethinus is S3 (38.40%), and C. inophyllum is S (39.28%). The C treatment (no fertilizers + direct planting) resulted in the best germination percentage for F. falcata (42.86%), D. zibethinus (85.71%), and C. inophyllum (100%).

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