The potential of area under young oil palm plantation on tidal swamps for soybean development

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Abstract. In Indonesia, soybean production during 2011–2020 only met 20-30% of the total need due to the decrease of the harvested area from 660 to 285 thousand ha. To achieve soybean self-sufficiency, the area of young oil palm plantations on tidal lands is potential for soybean development. In 2020, the areas reached 14.9 million ha with a growth rate of 8.68% year\(^{-1}\), meaning that at least every year, there is around 1.29 million ha of new oil palm areas potential for soybean production. Constraining for soybean growth on these lands are shading, low soil pH, and high Al-soil saturation. A solution for the shading problem is planting tolerant soybean varieties such as Dena1, Dena2, Denasa1, Denasa2, Argomulyo, and Dega1. The low soil pH and high Al saturation can be improved by using dolomite until the Al-dd saturation decreases to 20-30%. Soybeans can grow well under oil palm crops until the trees are 4 years old, with a potential production of >1.0 t ha\(^{-1}\), increases LER up to 1.8, and increases farmers’ income until the oil palm starts producing. Good planning and coordination among stakeholders for the input procurement, assistance, and farmers’ readiness would determine the success of soybean development on such lands.

Keywords: Land potential, production, soybean development, oil palm plantation.

1. Introduction
In Indonesia, soybean (\textit{Glycine max} (L.) Merr) is the third staple food crop after rice and maize. It is mostly consumed in the form of tofu, tempeh (fermented soy), soy sauce, and other snacks. During 2011–2020, the demand for soybean continuously increased every year due to the increase in population. In contrast, the production tended to decrease during the same period, of which only 20-30% of total national needs were met [1]. The domestic production of soybean in 2020 is around 0.63 million tons, whereas the total need is around 3.28 million tons, thus the soybean import dominated by 81%.

The soybean productivity in Indonesia in the last 10 years did not increase significantly, in the range of 1.50-1.54 t ha\(^{-1}\) [2]. During this period, the harvested area decreased from 660 thousand ha in 2010 to 285 thousand ha in 2019 [1]. This was caused by several problems, namely: (a) competition for land use with other commodities which has a higher economic value, b) soybean is quite susceptible to pests and diseases leading to yield instability, (c) efforts for area expansion to a new land is quite difficult, (d) the soybean seed industry has not yet developed; therefore most farmers do not use high-quality seeds, (e) farmers do not cultivate soybean intensively with advanced cultivation techniques, and (g) the profit level of soybean farming is low so that it cannot compete with the profits of other crop farming, especially maize [2].
The government has various programs to increase soybean production to achieve self-sufficiency, one of which is expanding soybean cultivation area on suboptimal lands, such as under young oil palm plantations on tidal swamps. This paper discusses crucial matters of soybeans in Indonesia, namely: (a) soybean production, demand, and program, (b) the potential of the area under young oil palm plantation, and (c) the production technology for soybean under young oil palm plantation on tidal swamps.

2. Soybean production, demand, and program

The estimation of soybean harvested area, productivity, production, and imports in Indonesia beginning from 2018 to 2024 are presented in Table 1. Until 2020, the harvested area and production fluctuate, whereas productivity tends to increase. It is estimated that the soybean harvested area in Indonesia until 2024 will not develop significantly because soybean is unable to compete with other commodities, especially maize. However, soybean production during this period will grow positively on average 7.36% year$^{-1}$, because there was an increase in harvested area (2.69% year$^{-1}$) and productivity (3.98% year$^{-2}$). The increase in production is said to be artificial because there was only a real increase from 2019 - 2020, namely 49.07% (from 424.19 thousand tons to 632.33 thousand tons).

Four years later, production will continue to decline at around 3% year$^{-1}$ to reach 558.29 thousand tons in 2024 [1]. This decline was due to intense competition in land use with other strategic commodities, namely maize and chilies. This resulted in a decrease in the harvested area of about 5% per year. Although productivity increased around 2% year$^{-1}$, it was still below the decline rate in harvested area, so that it could not contribute to support an increase in production (Table 1).

Per capita consumption of soybeans in Indonesia during 2020-2024 is predicted to fluctuate and tends to increase by 1.46% year$^{-3}$. In 2019, the figure was 10.17 kg\text{capita}^{-1}\text{year}^{-1}, and in 2020 it is 12.15 kg\text{capita}^{-1}\text{year}^{-1} [1]. This increase was thought to be related to the global Covid-19 pandemic, which led to an economic recession, which resulted in a decline in people's spending budget for animal protein hence the shift to processed soybeans such as tofu and tempeh for their source of protein, which were relatively cheaper/affordable. On the other hand, the increase in soybean consumption is also influenced by the increasing lifestyle of some of the middle and upper classes people who prioritize a diet of vegetarian products. In 2024, the level of soybean consumption is estimated to decrease to 10.74 kg\text{capita}/year. Based on the forecast of the development of the harvested area, productivity, per capita consumption, and national needs, it requires an additional harvested area of 1.3-1.5 million hectares year$^{-1}$ if the productivity can be reached to 1.7 -1.8 t ha$^{-1}$ to achieve self-sufficiency in soybeans (Table 1). To achieve self-sufficiency in soybeans in the next four years (2021-2024). For those reasons, the government continues to strive to increase national soybean production to achieve the program for self-sufficiency on soybean.

Table 1. The development and the projected harvested area, production, and import of soybean in Indonesia 2018-2024.

| Years | Harvest area (ha) | Productivity (t ha$^{-1}$) | National production (t) | National demand (t) | Net Import (t) | The need for additional harvested area (ha) |
|-------|-------------------|-----------------------------|-------------------------|---------------------|---------------|-------------------------------------------|
| 2018  | 493,546           | 1.31                        | 650,000                 | 3,215,258           | 2,565,258     | 1,958,212                                 |
| 2019  | 285,265           | 1.48                        | 424,189                 | 2,726,091           | 2,301,902     | 1,555,339                                 |
| 2020* | 381,331           | 1.65                        | 632,326                 | 3,293,377           | 2,661,051     | 1,612,758                                 |
| 2021* | 262,612           | 1.69                        | 613,318                 | 3,279,452           | 2,666,134     | 1,577,594                                 |
| 2022* | 344,455           | 1.72                        | 594,629                 | 3,240,236           | 2,645,607     | 1,538,144                                 |
| 2023* | 326,861           | 1.76                        | 576,278                 | 3,163,759           | 2,587,481     | 1,470,160                                 |
| 2024* | 309,849           | 1.80                        | 558,293                 | 3,030,085           | 2,471,792     | 1,373,218                                 |

*Prediction based on data 2019. Source: [1].
Since 2000, the government has been working hard to increase soybean production in order to achieve self-sufficiency, including through the program called “Gema Palagung”, “Bangkit Kedelai”, “Farmer’s School for Integrated Crop Management/FSICM for soybean”, and in 2018 there was an intercropping program of soybean with upland paddy or with maize covering an area of 22 thousand hectares in 22 provinces [3]. It seems that the target for self-sufficiency on soybean is quite difficult to achieve. For those reasons, the government has postponed the target of achieving self-sufficiency up to three times, which was originally in 2017 to be postponed to 2018, then to 2020. To realize the soybean self-sufficiency target, starting from 2017, the Ministry of Agriculture targeted the planting area for soybeans up to 2 million ha by 2018. The planting began in October 2017 and was projected to accomplish at least 25% of the targeted size (500 thousand ha). The remaining 1.5 million ha is expected to be realized in the next planting season in 20 provinces, from Aceh to East Nusa Tenggara/NTT (not all provinces are stated here). The rest is met from the land owned by traditional farmers, which covers 500 thousand hectares. As a result, soybean farming is expected to exceed 2.5 million hectares in 2018 [4]. If each acre can yield 1.5 tons of soybeans, the country’s demand for the crop will be fulfilled.

It should be noted that soybeans cultivation, from land preparation to processing, requires high costs i.e around 7–9 million IRD per hectare, 60% of which is for labor costs. In addition, the soybean production process in the field has been inefficient because most of it is done manually. Thus, to have a more efficient soybean production in the future, the use of agricultural machinery (mechanization) must be pushed.

### 3. Potential of land under young oil palm plantation for soybean development

In Indonesia, oil palm plantations with immature plants (aged 1-4 years) have great potential for soybean development. In 2020, for example, the area of oil palm plantations in Indonesia is estimated to reach 15 million ha, with an average growth during 2016-2020 up to 8.68% a year (Table 2). It means that at least there is around 1.29 million ha of such lands every year potential for soybean production. Five provinces that have the largest area of oil palm plantations are Riau, North Sumatra, West Kalimantan, Central Kalimantan, and East Kalimantan. Tidal lands generally dominate the types of land in those five provinces. In Indonesia, the tidal swamplands are potential for food crops development, including soybean, which reached 5.25 million ha [5].

| Provinces            | Oil palm plantation area (ha) | Growth rate during 2016-2020 (%) |
|----------------------|-------------------------------|----------------------------------|
|                      | 2016  | 2017  | 2018  | 2019  | 2020  |                        |
| Riau                 | 2012951 | 2703199 | 2706892 | 2808668 | 2850003 | 9.91 |
| North Sumatra        | 1342523 | 1706135 | 1551603 | 1601901 | 1630744 | 5.77 |
| West Kalimantan      | 1264435 | 1504787 | 1815133 | 1864635 | 1904015 | 11.12 |
| Central Kalimantan   | 1288128 | 1480988 | 1640883 | 1675753 | 1714660 | 7.55 |
| East Kalimantan      | 1021314 | 1059990 | 1434485 | 1461168 | 1492934 | 10.79 |
| Other provinces      | 4272114 | 5593623 | 5177354 | 5312295 | 5403654 | 6.95 |
| Indonesia            | 11201465 | 14048722 | 14326350 | 14724420 | 14996010 | 8.68 |

Source: [9]

The main constrain of soybean development in the area of young oil palm plantations on tidal land are mainly shading by oil palm trees (>40%), acidic soil (soils pH <5.0), and high soil Al saturation (>30%). Asima [6] reported that shade on land between oil palm trees aged 4-7 years could reach more than 60%. Meanwhile, the tolerance of soybean plants to shading is generally <25%, optimal pH is 6.5.0-7.0, and tolerance to Al saturation ranges from 20-30% [7, 8]. Therefore, the successful development of soybean on these lands requires a site-specific cultivation technological package.
4. Soybean cultivation under oil palm plantation on tidal swamps

There are three technological aspects related to soybean cultivation under oil palm plantation on tidal swamps, namely: (1) shading levels under oil palm and soybean varieties tolerance to shading, (2) improvement of soil chemical properties, especially in soil acidity and high soil Al saturation for soybean production, and (3) Feasibility of soybean cultivation technology package on these lands.

4.1 Shade levels under oil palm and soybean tolerance to shading

Oil palm plantations in Indonesia reach 14.9 million hectares, and 8.68% of those (around 1.3 million hectares) are young plants [9]. These lands are potential for developing seasonal crops through intercropping, including soybeans. Shading is one of the constrains for soybean cultivation among the young oil palm crops on tidal swamps. The level of shading among four years and eight years old of oil palm crops reached 29.8% and 49.8%, respectively [10]. Interception of solar radiation by oil palm crops increased as the age of the plant also increased [11]. However, the transmission of solar radiation reaching the land surface that can be utilized by intercropping decreases (Figure 1). The intensity of solar radiation under 4-years old oil palm crops reached 155.65 Wm$^{-2}$ (Table 3) [12]. The amount was sufficient for soybean to grow because the optimal solar radiation intensity ranged from 143-381 Wm$^{-2}$[13].

![Figure 1. Interception and transmission of solar radiation on oil palm crops [11].](image)

**Table 3.** The intensity of solar radiation in open land and under oil palm at several plant ages.

| *Oil palm age (Year)| *Global radiation (W m$^{-2}$) | *Radiation under oil palm crops (Wm$^{-2}$) | *Radiation under oil palm crops (%) | **Radiation needed for soybean crops (Wm$^{-2}$) |
|---------------------|-------------------------------|--------------------------------------------|-------------------------------------|---------------------------------------------|
| 2                   | 369.52                        | 156.01                                     | 42.21                               |                                              |
| 4                   | 494.89                        | 155.63                                     | 31.44                               |                                              |
| 8                   | 489.56                        | 65.79                                      | 13.43                               | 143-381                                     |
| 10                  | 501.86                        | 70.09                                      | 13.96                               |                                              |

Source: [*12, **13].

Plants under a lack of light, their photosynthetic activity, and carbohydrate synthesis will decrease because there is a decrease in mesophyll conductance due to changes in leaf structure and thickness [14, 15]. Soybeans, which is included in the C3 photosynthetic cycle, does not require full light for their survival, so it can grow either in the land with relatively low intensity of solar radiation [16].
Therefore, soybeans are often grown as intercropping to increase land-use efficiency and crop yields, including on the land under plantation crops [17, 18, 19]. According to Hidayat [11], the land proportion between the palm stands with a spacing of 9 m x 7 m at the age of 4 years to plant soybeans is about 52%. This is similar to the research results of Harsono [8], which showed that the land between palm trees aged 2 years that can be used to grow soybeans ranged 70%, depending on the growth rate of the oil palm plants. In the oil palm plantations 1 to 2 years old, the closest distance to oil palm trees that can be planted for soybeans ranges from 1.0 to 2.3 m. They stated that the use of land under young oil palm crops for growing soybean could increase income and have a positive impact on its main crop, namely oil palm. However, it requires the introduction of technology so that the limited intensity of solar radiation under the stand can be reduced, including the use of shade-tolerant soybean varieties, and the use of reflective mulch such as inorganic (plastic) or organic (grass litter) mulch (if it can be considered quite economical) to increase the efficiency of solar radiation used [11, 17]. It was also reported that there have been several soybean varieties released adaptive to shading up to 50%, namely Argomulyo and Dega 1 which have been tested for intercropping with maize [20]. Several Indonesian soybean varieties that are shade tolerant up to 50% are presented in table 4.

| No. | Varieties | Year released | Maturity age (Days) | 100 seeds weight (g) | Yield potential (t/ha) | Protein (%) | Fat (%) | Shade tolerance (%) |
|-----|-----------|---------------|---------------------|----------------------|------------------------|-------------|---------|-------------------|
| 1   | Dena 1    | 2014          | 78                  | 14.3                 | 2.9                    | 36.7        | 18.8    | 50*               |
| 2   | Dena 2    | 2014          | 81                  | 13.0                 | 2.8                    | 36.5        | 18.2    | 50*               |
| 3   | Denasa 1  | 2021          | 83                  | 18.0                 | 3.4                    | 36.3        | 19.6    | 50*               |
| 4   | Denasa 2  | 2021          | 78                  | 18.0                 | 3.4                    | 34.1        | 20.6    | 50*               |
| 5   | Argomulyo | 1998          | 82                  | 16.0                 | 2.0                    | 39.4        | 20.8    | 40-50**           |
| 6   | Dega 1    | 2016          | 71                  | 22.9                 | 3.8                    | 37.8        | 17.3    | 40-50**           |

Source :[*21, ** 20].

The solar radiation among oil palm crops for soybean cultivation can also be improved by using inorganic or organic reflective mulch, increasing solar radiation interception on soybean crops by 30% and 26%, respectively [11]. They also showed that the increase in soybean photosynthesis rate on lower leaves was from 20.89 mol CO$_2$ m$^{-2}$S$^{-1}$ on land without mulch, to 23.64 mol CO$_2$ m$^{-2}$S$^{-1}$ on inorganic reflective mulch and 24.74 mol CO$_2$ m$^{-2}$S$^{-1}$ on organic reflective mulch. The soybean productivity under organic and inorganic reflective mulch was not different, but higher as compared to those without mulch (Table 5).

| Mulch reflection | Increased solar radiation interception on lower leaves (%) | Increased photosynthesis rate (CO$_2$m$^{-2}$S$^{-1}$) | Seeds yield* (t/ha) |
|------------------|--------------------------------------------------------|-----------------------------------------------------|---------------------|
| Without          | 0                                                      | 20.89 a                                             | 1.12 a              |
| Inorganic        | 30                                                     | 23.64 b                                             | 1.47 b              |
| Organic          | 26                                                     | 24.74 b                                             | 1.55 b              |

*Note: Land under oil palm crops which planted with soybeans around 52%. Values in same column followed by the same letter were not significantly different based on Duncan Multiple Range Test at 5%.

Source : [11].
4.2. Improvement of soil chemical properties for soybean on tidal lands

The most influencing soil chemical properties for soybean growth on tidal swamps were low soil pH and high Al saturation [8, 22]. This can cause a decrease in nitrogen fixation and nutrients uptake, especially phosphorus which is important for cell growth and photosynthesis [23, 24]. It was reported that liming can improve the growth and yield of soybeans in the tidal swamp of South Kalimantan [25]. The highest yield was obtained at a rate of liming equivalent to 10% of Al saturation, applied mixed with soil within 20 cm depth (Table 6).

Table 6. Effect of lime rate and application method on soybean yield on tidal land in South Kalimantan.

| Lime rate            | Soybean yield (t ha⁻¹) | Means (t ha⁻¹) |
|----------------------|------------------------|----------------|
|                      | Surface application    | Mixed within 20 cm soil depth |                         |
| No lime              | 0.63 e                 | 0.74 de        | 0.68                      |
| 10% of Al saturation | 1.29 c                 | 2.15 a         | 1.72                      |
| 20% of Al saturation | 1.29 c                 | 1.57 bc        | 1.43                      |
| 30% of Al saturation | 1.17 cd                | 1.42 c         | 1.30                      |
| 1.5 x Al-exchangeable| 1.22 cd                | 1.05 cde       | 1.13                      |
| 1.0 x Al-exchangeable| 1.23 cd                | 1.98 ab        | 1.61                      |
| Means                |                        | 1019           | 1.44                      |

Note: Values in the same column followed by the same letter were not significantly different based on Duncan Multiple Range Test at 5%. Soil pH = 4.2, and Al soil saturation 52%.

Source :[25].

Harsono [26] reported that the high Al saturation and nutrient problems in soybean plants on tidal swamps in South Kalimantan can be corrected by using dolomite until the Al-ds saturation decreases to around 30% by using organic fertilizers 1.25 t/ha, bio-fertilizer Agrisoy 0.25 kg/50 kg seeds, Urea 50 kg/ha, SP36 75 kg/ha and 50 kg KCl/ha. With this fertilization package, soybean yields on tidal swamps in South Kalimantan can reach 2.0 t/ha. In addition, another researcher [27] reported that soil water management can be applied to reduce pyrite content where the soil is in a reductive condition. The branch number, fill pod number, seed dry weight per plant, seed dry weight per plot, and soybean productivity on saturated soil culture were higher than temporary flooding. Tanggamus, Anjasmoro, and Detap 2 were grouped as sensitive varieties, while Wilis and Malika were grouped as moderate-tolerant varieties. Malika is a potential soybean variety to be developed on tidal swamps on B overflow type with high productivity and low risk if it is affected by temporary flooding. The productivity of Malika on saturated soil conditions (SSC) was 4.264 t/ha, and on temporary flooding (TF) was 3.230 t/ha (Tabel 7).

Table 7. Productivity and sensitivity of soybean varieties to temporary flooding on tidal swamp.

| Variety | Productivity (t/ha) | Average (t/ha) | Sensitivity Index | Sensitivity Level |
|---------|---------------------|----------------|------------------|-------------------|
|         | Temporary Flooding  | Saturated soil condition | | |
| Tanggamua | 2.34                | 3.70           | 3.06             | 1.20              | Sensitive |
| Anjasmoro | 2.73                | 3.91           | 3.32             | 1.06              | Sensitive |
| Wilis    | 3.08                | 3.72           | 3.40             | 0.68              | Moderate tolerant |
| Detap 2  | 3.02                | 4.60           | 3.81             | 1.22              | Sensitive |
| Malika   | 3.23                | 4.26           | 3.74             | 085               | Moderate tolerant |
| Average  | 2.89                | 4.04           |                  |                   |            |

Source :[28].
Interesting results had been shown by Harsono [26] which reported that on tidal swamps in South Kalimantan, soybean varieties of Anjasmoro, Panderman, Dega 1, and Demas can grow well at 30% of soil Al saturation. At this soil Al saturation, by applying of 50 kg urea + 75 kg SP36 + 50 kg KCl + 1500 kg organic fertilizers/ha + rhizobium Agrisoy fertilizer 0.25 kg/50 g seeds (Alternative technological package). These varieties yielded 2.52 t/ha, 2.29 t/ha, 2.72 t/ha, and 1.78 t/ha, respectively. The alternative technological package formulated from the first research using Anjasmoro variety was able to provide higher yields (2,625 t/ha) then the existing and saturated soil culture (SSC) technological packages, which yielded 2,067 t/ha and 2,442 t/ha, respectively. The alternative technological package was feasible for farmers to adopt with a profit of up to IRD 11,595,000 per hectare, with B/C values of 1.71 higher as compared to the existing and WSC technological packages (Table 8).

Table 8. Yield and income of soybean cultivation with existing technology, saturated soil culture (SSC), and alternative technology packages on tidal land in Barito Kuala, South Kalimantan.

| No | Components                  | Existing | SSC      | Alternative |
|----|------------------------------|----------|----------|-------------|
| 1  | Cost production (Rp/ha)      | 2,695,000| 4,065,000| 2,930,000   |
|    | a. Inputs                   | 2,695,000| 4,065,000| 2,930,000   |
|    | b. Labour                   | 3,850,000| 4,500,000| 3,850,000   |
| 2  | Total cost (Rp/ha)           | 6,545,000| 8,565,000| 6,780,000   |
| 3  | Seeds yield (kg/ha)          | 2,067    | 2,422    | 2,625       |
| 4  | Total revenue (Rp/ha)        | 14,469,000| 16,954,000| 18,375,000  |
| 5  | Total benefit (Rp/ha)        | 7,924,000| 8,389,000| 11,595,000  |
| 6  | R/C                         | 2.21     | 1.98     | 2.71        |
| 7  | B/C                         | 1.21     | 0.98     | 1.71        |

Soybean price = Rp. 7000/kg. Source :[26].

4.3. Feasibility of soybean cultivation under oil palm

Plantation of oil palm under 2 years old on type C of tidal swamps land is suitable for soybean development [8]. On this lands with pH soils 4.30, low of K and Ca, the technology packages by using dolomite until soil Al saturation decreased to 20%, using urea 50 kg+ SP36 75 kg+ KCl 50 kg ha⁻¹, organic fertilizer 1250 kg ha⁻¹, and rhizobium 4 g kg⁻¹ seeds can produce soybean seeds 2.00 t ha⁻¹. Soybean development under oil palm stands can only be implemented until the oil palm trees are four years old because above four years old, the soybean yield was very low due to the shading effect (Table 9) [11].

Table 9. Productivity, land-use efficiency, and soybean farming income under oil palm stands

| No | Croping system                 | Yield (t/ha) Oil palm | Soybean | LER   | Farming income (IDR/ha) | Increasing income (%) |
|----|--------------------------------|-----------------------|--------|-------|-------------------------|-----------------------|
| 1  | Oil palm 4 years old           | 6.23                  | 0      | 1.0   | 7,158,391               | 0                     |
| 2  | Oil palm 5 years old           | 9.75                  | 0      | 1.0   | 11,499,158              | 0                     |
| 3  | Oil palm 8 years old           | 12.78                 | 0      | 1.0   | 15,578,157              | 0                     |
| 4  | Monoculture soybean            | 0                     | 3.07   | 1.0   | 15,258,119              | 0                     |
| 5  | Oil palm 4 years old + Soybean | 9.85                  | 1.00   | 1.8   | 13,721,240              | 85.31                 |
| 6  | Oil palm 5 years old + Soybean | 13.41                 | 0.41   | 1.5   | 13,489,611              | 17.31                 |
| 7  | Oil palm 8 years old + Soybean | 14.61                 | 0.00   | 1.1   | 11,633,238              | -25.30                |

Source: Data processed from Hidayat [11].
The introduction of soybeans on an area of oil palm crops under 4 years old was able to increase land-use efficiency (LER) up to 1.8, and increased farmers' income from monoculture oil palm 7,158,391 IDR ha\(^{-1}\) to 13,721,240 IDR ha\(^{-1}\). When soybeans were planted together with 5 years old of oil palm crop, although the yield of soybean was only 0.4 t ha\(^{-1}\), it could increase the income from monoculture oil palm from 11,499,158 IDR ha\(^{-1}\) to 13,489,611 IDR ha\(^{-1}\) (Table 9). On the oil palm crops of 8 years old, soybeans could not produce seeds because the shading effect was more than 70% (Table 9, Figure 1).

To accelerate the implementation of technology for soybean development on young oil palm plantations area in tidal land, the use of ICT (Information and Communication Tecnology) needs to be pushed so that farmers can easily access such technology. There are at least two sources of model/product developed by The Agency for Agricultural Research and Development (IAARD) which farmers can access, namely: (1) Web-based Summary Model of Soybean Self-Sufficiency Simulation 2020−2045 (SIWAKA.INS v.03), which can be used to predict the area and productivity of soybeans needed to achieve self-sufficiency both nationally and regionally, and (2) an Integrated Katam Information System that can be used as a tool to access information about climate predictions, planting time, disasters prediction, recommendations for agricultural production facilities, and monitoring systems. This Katam information has been designed based on predicted climate conditions and land typology up to the sub-district level [4].

5. Policy recommendations
Realizing that soybean development in young oil palm plantations in tidal land is not easy, it requires careful planning and good coordination among stakeholders. The following points can be considered to formulate policy operational for soybean development on these lands:

1. The development of soybean needs to be directed not only to potential lands but also to sub-optimal lands such as young oil palm plantations on tidal land.
2. Technological packages for soybean cultivation on this land are available, but their development needs to be coordinated with stakeholders, including regional policymakers, landowners, providers of production facilities, and market players.
3. Development of a soybean cultivation technological package on new land requires enough seeds supply, production inputs, and machinery that can reduce the need for labor and guarantee a good market so that farmers get adequate profits.
4. The acceleration of dissemination of soybean cultivation technological packages needs to be supported by IT, so that farmers can easily access their needs and sell the soybean yield via smartphones.
5. The program named “SIWAKA.INS V.03” can be used to predict the area and productivity of soybeans needed to achieve self-sufficiency both nationally and regionally, and the information in “INTEGRATED KATAM MODEL” can be used to access climate prediction information, planting time, disasters, recommendations for production facilities, and monitoring in the fields up to the sub-district level.

6. Conclusions
1. Soybean production in Indonesia during 2011-2019 is only met 19-30% of the total national need due to a decrease in harvested areas so that to achieve self-sufficiency, it is necessary to increase the planting area.
2. One of the lands that is potential for soybean development in the future is the area on young oil palm plantations on tidal lands. In 2020, these plantations area reaches 14.9 million ha with a growth rate of 8.68%/year, mostly spread on tidal swamplands in Sumatera, Kalimantan, dan Papua islands.
3. Constrains for soybean growth on these lands are shading, low soil pH, and high Al-soil saturation. Shading can be solved by planting tolerant soybean varieties such as Dena 1, Dena
2, Denasa 1, Denasa 2, Argomulyo, and Dega 1. The low soil pH and high Al saturation can be corrected by using dolomite until the Al saturation decreases to 20-30%.

4. Soybeans can grow well under oil palm crops until 4 years old, yield >1.0 t/ha, increase LER up to 1.8, and increase farmers’ income compared to that of monoculture oil palm farming. The development of soybean on such agroecological condition requires careful planning and good coordination among stakeholders for the input procurement, assistance, and product marketing.

References
[1] Center for Agricultural Data and Information Systems 2020 Food and agricultural commodity outlook: Soybean. Secretary General of the Ministry of Agriculture, Indonesia. p 47
[2] Harsono A, Harnowo D, Ginting E, and Elisabeth DAA 2021 Soybean in Indonesia: current status, challenges and opportunities to achieve self-sufficiency. Manuscript in the process of publication in the IntechOpen. p 15
[3] Directorate General of Food Crops. 2018. Instructions for intercropping. Ministry of Agriculture p 24
[4] Harsono A 2019. Soybean self-sufficiency has not been achieved: Problems and solutions. The Policy Brief, presented at the Research Professor Communication Forum, Bogor 23-24 April 2019. Ministry of Agriculture p 6
[5] Mulyani A, Nursyamsi D, and Harnowo D 2017 Proceedings of the National Seminar on legume and tuber crops 2016 IAARD Press p 16-30
[6] Asima N, Rosmayati, and Mahmud SLA 2017 Jurnal Pertanian. 4 (1) 1-8
[7] Sumarno dan Manshuri AG 2013 Eds Sumarno et al. (Penyunting). Kedelai: Teknik Produksi dan Pengembangan. Pusat Penelitian dan Pengembangan Tanaman Pangan Badan Litbang Pertanian p 74-103
[8] Harsono A, Wijanarko A, and Lestari SAD 2020 Proc. of IOP Conf. Series: Earth and Environmental Science 456 (2020) 012052 doi:10.1088/1755-1315/45611012052
[9] Directorate General of Estates 2020 Palm Oil Area by Province in Indonesia 2016-2020. Ministry of Agriculture
[10] Fahrozi, Mawarni L, and Hanum Ch 2018 Jurnal Agroekoteknologi FP USU E-ISSN No 2337-659 6 (3) 634-639
[11] Hidayat T 2020 Pengembangan Agroekosistem Kelapa Sawit-Kedelai Dengan Penggunaan Mulsa Reflektif Untuk Peningkatan Produktivitas Kedelai Pada Lahan Perkebunan Kelapa Sawit. Disertasi pada Klimatologi Terapan Sekolah Pascasarjana Institut Pertanian Bogor. Bogor p 107
[12] Afandi AB 2014 Karakteristik radiasi matahari pertanaman kelapa sawit (implikasinya terhadap iklim mikro dan potensi tanaman sela) [skripsi] Institut Pertanian Bogor. Bogor
[13] Mahmud Z 1998. Jurnal Penelitian dan Pengembangan Pertanian 1 7(2) 61-67
[14] Koesmaryono Y, Sugimoto H, Ito D, Haseba T, and Sato T. 1998. Photosynthetica 35(4) 573-578 DOI:10.1023/A:1006935125111
[15] Sopandie D, Chozin MA, Sastrosumarjo S, Juhaeti T, and Sahardi 2003 . HAYATI Journal of Biosciences 10 (2) 71-75
[16] Sugimoto H, Koesmaryono Y, and Miyahara N 2005 Journal of Agricultural Meteorology 60(5) 937-940 DOI 10.2480/agromet.937
[17] Suhartina 2019 The development of soybean production under teak stand at Blora District, Central Java Technical Report of Research Result of ILETRI (Indonesian Legume and Tuber Crops Research Institute) 2018 (unpublished)
[18] Mahallati MN, Koocheki A, Mondani F, Feizi H, and Amirmoradi S 2014 J. Clean Prod. 106 (3) 390-404 DOI: 10.1016/j.jclepro.2014.10.009
[19] Yang F, Wang XC, Liao DP, Lu FZ, Gao RC, Liu WG, Yong TW, Wu XL, Du JB, Liu J, and Yang WY 2015 Yield response to different planting geometries in maize-soybean relay strip intercropping systems. *Agron J* **107**(1) 296-304 DOI org/10.13057/biodiv/d210842

[20] Harsono A, Elisabeth DAA, Muzaiyanyah S, and Rianto SA 2020 *Biodiversitas* ISSN: 1412-033X. **21**(8) 3744-3754 DOI 10.13057/biodiv/d21084

[21] ILETRI 2021 Description of various superior legume and tuber crops varieties. *Indonesian Legume and Tuber Crops Research Institute* The Agency for Agricultural Research and Development

[22] Pujiwati H, Ghulamahdi M, Yahya S, Aziz S A, and Haridjaja O 2016 *J. Agron. Indonesia* **44**(3) : 248 - 254

[23] Alves LA, Ambrosini VG, Denardin LGO, Flores JPM, Martins AP, Filippi D, Bremm C, Paulo C, Carvalho F, Farias GD, Ciampitti IA, Tiecher T. 2021. *Soil and Tillage Research.* **209**,104-923

[24] Yu HN, Liu P, Wang ZW, Chen WR, Xu GD. 2011 *Crop Protection.* **30**(3):323-328. DOI : 10.1016/j.cropro. 2010.11.024

[25] Ijanarko A and Taufiq A 2016 *Agrivita* **38**(1) 14-23 DOI [http://dx.doi.org/10.17503/agrivita.v38i1.683](http://dx.doi.org/10.17503/agrivita.v38i1.683)

[26] Harsono A, Elisabeth DAA, Indiati SW, Rozy F, Harnowo D, Sundari T, Widodo Y, Krisdiana R, and Mejaya MJ.2021 *Annual Research & Review in Biology* **36**(7) 47-57 Article no.ARRB.70930 ISSN 2347-565X, NLM ID 101632869. DOI 10.9734/ARRB/2021/v36i730398

[27] Ghulamahdi M, Melati M, and Sagala D 2009 *J Agron Indonesia* **37**(3) 226-232. DOI [https://doi.org/10.24831/jai.v37i3.1301](https://doi.org/10.24831/jai.v37i3.1301)

[28] Ghulamahdi M, Chaerunisa SR, Lubisa I, and Taylor P 2016 *Procedia Environmental Sciences* **33** (2016) 87 - 93 DOI 10.1016/j.proenv.2016.03.060