Chapter

Soybean in Indonesia: Current Status, Challenges and Opportunities to Achieve Self-Sufficiency

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Abstract

Soybean is the third important food crop in Indonesia after rice and maize, particularly as a good source of protein. The demand for soybean consumption tends to increase annually. In 2020, the figure was about 3.28 million tons, while the domestic production was 0.63 million tons, thus around 81% of the soybean needed was imported. Efforts to increase the domestic soybean production have been conducted since the last decade, which is concerned with increasing the current productivity (1.5 t/ha) through introducing the high-yielding improved varieties and extending the harvested area, particularly to outside of Java. The potential planting area is focused on the irrigated lowland after rice (optimal land) and suboptimal lands (dry, acid, tidal, and shaded lands). The series of the study showed that the yield potential of soybean grown in such lands varied from 1.8 t/ha to 3.0 t/ha. A number of soybeans improved varieties adapted to different land types or agro-ecological conditions also have been released and supported with advanced cultivation technology. The results, challenges, and opportunities to achieve soybean self-sufficiency are discussed in this paper.

Keywords: Indonesia, soybean, self-sufficiency

1. Introduction

Soybean (*Glycine max* L. Merr.) is the third most important food crop in Indonesia after rice and maize. Soybean plays an important role as a vegetable protein source for most of the community in the country, which is predominantly consumed as tempe and tofu. In 2020, the average soybean consumption level was around 11–12 kg/capita/year. The need for this commodity tends to increase along with the population increase. During the period 2000 to 2019, domestic production contributed 30–35% to the total need, while the rest (65–70%) was imported. The latest report [1] showed that the domestic production of soybean in 2020 was approximately 0.63 million tons, whereas the total need was approaching 3.29 million tons, thus about 81% of soybean was imported.

This condition was related to the discouraged situation of soybean production during the last 10 years (2010–2020). The average productivity during this period was 1.50–1.54 t/ha and no significant increase was recorded [2]. Also, only a slight increase in the harvested area occurred. A number of problems were noted regarding such conditions, including (a) high competition of land use with other commodities, (b) low stability of the yield as soybeans are highly susceptible to pest and disease attacks, (c) efforts to extend the planting area has not been fully succeeded, (d) relatively low quality of seeds as the soybean seed industry has not been well developed, (e) less conducive of soybean trading system, (f) less intensive cultivation techniques, and (g) low profit of soybean farming relative to other crops.

Soybean was targeted to be self-sufficiency by the Government in 2014 through four main strategies as follows: (1) gradually increasing the productivity (2) improving the roles of public and private sectors as well as local government in soybean development, (3) improving the marketing and trading system to be more conducive to farmers, and (4) improving the source of farming capital and partnerships. As a follow-up of such strategies, action steps were undertaken to achieve soybean self-sufficiency, including (a) supporting the research activities, which concerned on the release of new improved varieties with high yield potential, resistance to biotic and abiotic stress, short maturity; assembling the advanced cultivation technologies; and implementing different methods of dissemination, (b) initiating the growth of seed industry in soybean producing areas, (c) subsidizing the fertilizer prices, and (d) improving the access for agricultural tools and machinery application. However, these efforts have not fully succeeded as the increased rate of soybean productivity at the farmer level was considerably low, the planting and harvested areas were stagnant and even tended to decline, resulting in a decreased domestic production. As a consequence, a large amount of soybean is imported annually, suggesting more efforts and proper strategies are needed to achieve soybean self-sufficiency in Indonesia.

This paper will discuss the soybean production matters in Indonesia, including the current status and predicted soybean production and demand, the national program for increasing production, land availability for soybean development and specific production technologies for the different agroecosystems as well as the essential socio-economic aspects to support the achievement of soybean self-sufficiency in Indonesia.

2. Soybean production and demand

The development of the harvested area, productivity, production, and import of soybean in Indonesia during the period 2016–2020 and the prediction for the year 2024 are presented in **Table 1**. Until 2020, the harvested area and production highly fluctuated, whereas the productivity tended to increase. It is estimated that the soybean harvested area until 2024 will not significantly expand as soybean hardly competes with other commodities, particularly maize. There was a considerable increase in soybean production (49.07%) during 2019–2020 as a result of expanding the harvested area. However, for the next four years, it is predicted that soybean production will tend to decline by 3% per year [3]. This was due to the competition of land use with other profitable commodities, such as corn and chili, resulting in a decrease in the harvested area of about 5% per year. Even though the productivity increased by 2% per year, this value was set below the rate of declined harvested area, thus giving no significant increase in soybean production. As a result, a large amount of soybean needs to be imported with an average of 2.49 million tons per year.

Years	Harvest area (ha)	Productivity (t/ha)	National production (t)	National demand (t)	Net Import (t)	The additional need of harvested area (ha)
2016	576,987	1.49	859,653	3,121,456	2,261,803	1,517,989
2017	355,800	1.51	538,730	3,103,475	2,671,914	1,698,507
2018*	493,546	1.31	650,000	3,215,258	2,565,257	1,958,212
2019*	285,270	1.49	424,190	2,726,091	2,301,902	1,544,900
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

Note:
**Agreement figures of Central Bureau of Statistics (BPS) and the Indonesian Ministry of Agriculture.*
***Forecast of the Indonesian Agricultural Data and Information Center.*

Table 1.
The development and projected of harvested area, production, and import of soybean in Indonesia during the period 2016–2024 [3].

The national demand ranged from 2.73 up to 3.29 million tons during the period 2020–2024, which is mostly for consumption purposes. The consumption level of soybeans during this period is predicted to fluctuate and tends to increase by 1.46% per year. In 2019, the figure was 10.17 kg and it slightly increased to 12.15 kg/capita/year in 2020 [3]. It is assumed to be associated with the global pandemic of Covid-19, which led to a decline in people's purchasing power for animal protein sources and shifting to soybean as an affordable protein source, particularly as tempe and tofu. In addition, the increase in soybean consumption is also influenced by the healthy lifestyle of the middle and upper class who prefer a vegetarian diet. It seems that the consumption level will go back to 10.74 kg/capita/year in 2024. **Table 1** shows that the self-sufficiency in soybean within the next four years (2021–2024) can be achieved with an additional harvested area of 1.3–1.5 million hectares per year and productivity of 1.7–1.8 t/ha. Even though it seems hard to achieve such figures, the Government relentlessly encourages both the Ministry of Agriculture and farmers to increase the national soybean production.

3. National soybean program

Since 2000, the Government has been working hard to increase soybean production in order to achieve self-sufficiency through the program entitled "Gema Palagung", "Bangkit Kedelai", and "Farmer's School for Integrated Crop Management/FSICM for soybean". In 2018, a particular intercropping program between soybean with upland paddy or maize was launched, covering an area of 22 thousand hectares in 22 provinces [4]. Initially, the Government established the target for soybean self-sufficiently in 2014. However, as it unsucceded, the target was postponed to be 2017 and again postponed to be 2018, and then to 2020. In 2017–2018, the Ministry of Agriculture had a target of soybean planting area approaching 2 million hectares. Planting started from October to December 2017 with the first target of 500 thousand ha (approximately 25% of the total target). The remaining 1.5 million hectares expectedly can be fulfilled in the next planting season in 20 provinces, from Aceh in the west to East Nusa Tenggara in the eastern part of Indonesia. Meanwhile, another 500 hectares of land were available from the existing traditional farmers. It is estimated that in 2018, the soybean planting area will be becoming 2.5 million hectares [5] and would meet the domestic demand if the productivity was 1.5 t/ha.

Nevertheless, such a target was hard to be achieved as in fact, the total soybean production was only 650,000 tons in 2018 with a harvesting area of 493,546 hectares. In addition to climate and technical/cultivation factors, this failure was also related to economic aspects. It is obvious that soybean farming requires high input, possesses a high risk of crop failure, particularly due to pest and disease attacks, and inadequate income or less profitability. Planting of soybean starting from land preparation to harvesting and processing costs seven to nine million IRD per hectare and 60% of which is accounted for labor cost. The soybean production process in the field is also inefficient as most of the activities are done manually. In fact, the Government has established the selling price of soybean at the farm level that was about IDR 8,500 per kg in 2017 as Minister of Trade's Regulation no 27/2017. However, the price is normally following the market conditions and frequently is below the selling price determined by the Government, particularly during the harvesting season giving a low profit to soybean farming.

4. Land availability for soybean development

Indonesia has a wide and diverse potential land for the development of soybean. **Table 2** shows that there are 3.8 million hectares of irrigated paddy fields and 3.6 million hectares of non-irrigated paddy fields available (optimal land). In irrigated paddy fields, soybean can be grown using a cropping system of paddy-paddy-soybean, and a paddy-soybean cropping system in non-irrigated paddy fields. The main obstacle of soybean cultivation in optimal land is competition with other commodities that have higher economic value, especially maize. Therefore, soybean development in this optimal land should be selected to those lands that have less water available for growing maize. The need for water to grow soybean is only about half compared to growing maize.

There is also the potential of sub-optimal lands for the development of soybean in Indonesia, including dry acidic land, dryland with dry climate, and tidal land area, accounting for 4.5 million ha, 1.2 million ha, and 0.8 million ha, respectively (**Table 3**). The acidic land showed the least favorable for soybean production due to

Islands as central of soybean production	Irrigated lowland (ha)	Non-irrigated lowland (ha)	Drylands (ha)
Sumatera	676,816	852,985	3,655,378
Jawa	2,258,066	1,549,255	2,613,514
Bali+Nusa Tenggara	197,316	245,619	921,281
Kalimantan	214,298	432,462	1,605,806
Sulawesi	430,621	508,033	1,981,629
Maluku	10,094	9,448	252,032
Papua	17,180	8,558	468,358
Indonesia	3,804,391	3,606,360	11,497,998

Table 2.
Irrigated and non-irrigated lowlands available for soybean development in Indonesia [6].

Island	Dry acidic soil (× 1,000 ha)			Dryland with dry climate (× 1,000 ha)			Tidal swampland (× 1,000 ha)			Total (× 1,000 ha)
	AOU	AFC	AFP	AOU	AFC	AFP	AOU	AFC	AFP	
Sumatera	536.6	104.3	659.5	24.9	34.0	58.3	137.4	13.5	271.2	1,839.7
Jawa	46.3	0.0	202.2	8.7	0.0	31.6	0.3	0.0	0.0	289.1
Bali+NT	1.6	0.0	0.0	257.8	10.7	30.4	0.0	0.0	0.0	300.5
Kalimantan	329.9	227.9	1,297.8	0.0	0.0	0.0	82.1	1.6	46.5	1,985.8
Sulawesi	25.8	14.2	0.0	61.0	42.8	0.0	0.8	0.0	0.0	144.6
Maluku	0.0	39.6	0.0	0.0	0.0	0.0	2.7	3.3	0.3	45.9
Papua	11.0	304.3	671.4	9.7	163.5	437.2	0.4	84.8	128.0	1,810.3
Indonesia	951.2	690.3	2,830.9	362.1	251.0	557.5	223.7	103.2	446.0	6,415.9

Note: AOU = Area of Other Uses, AFC = Area of Forest Conversion, AFP = Area of Forest Production, NT = Nusa Tenggara.

Table 3.
The suboptimal lands available for soybean development in Indonesia [7].

lower fertility, potential toxicity from soluble forms of microelements such as Al, Mn, and Fe, and unfavorable physical properties [8–10]. Therefore, to obtain high soybean productivity in this type of land (soil), use of ameliorants and high doses of inorganic fertilizers are needed. On the dry land with a dry climate, the main constraint faced is the short wet month that is only around 3–4 months/year with a rainfall >200 mm/month. In this region, soybean needs to compete with other staple food crops, such as upland rice and maize. In tidal swampland, constraints like water-saturated root, high pyrite, the toxicity of Al, Fe, and Mn, as well as deficiencies of N, P, K, Ca, and Mg may limit soybean production [10, 11]. Therefore, specific cultivation technology is essential for such different types of land.

5. Cultivation technology for various agroecosystem

5.1 Lowland

Soybean cultivation in the irrigated paddy lowland generally follows the cropping pattern of paddy-secondary food crop, while the pattern is paddy-secondary food crop in the non-irrigated paddy land (rainfed land). It seems that soybeans yet have to compete with other commodities, especially maize or other food crops. Currently, the productivity of soybean using existing farmer's technology is about 1.5–1.8 t/ha. Using high-yielding improved varieties and good environmental management through the application of advanced cultivation technology makes it possible to achieve soybean productivity as high as 3.0 t/ha in the lowland.

A number of new improved soybean varieties have the yield potential of more than 3.0 t/ha, namely Dega1, Detap 1, Mutiara 1, Dering 2, Biosoy 1, and Demas 2 [12] as presented in **Table 5**. In additon to new improved varieties, plant spacing is also an important factor in achieving high yield through optimal plant populations. Planting Burangrang, Grobogan, and Anjasmoro varieties at a spacing of 20–30 cm × 40 cm, two plants per hole with optimal fertilization in Malang, East Java gave a grain yield of 3.96 t/ha, 3.93 t/ha, and 3.36 t/ha, respectively [13]. Thus, to achieve the soybean yield >3.0 t/ha, the population of >340 thousand plants/ha which is obtained using a plant spacing of 30 cm × 15 cm needs to be applied as well

Soybean variety	Plant spacing (cm), two plants/hill		
	50×15	**40×15**	**30×15**
	Number of crops can be harvested (×1,000)		
Dega 1	240.68bc	255.20 b	345.29 a
Detap 1	204.41 c	252.01 b	344.62 a
Derap 1	202.60 c	249.16 b	350.24 a
Devon 1	204.72 c	260.55 b	358.90 a
	Seed yield (t/ha)		
Dega 1	1.98 d	2.21 d	3.12 b
Detap 1	2.14 d	2.61 c	3.53 a
Derap 1	1.90 d	1.97 d	3.15 b
Devon 1	2.11 d	2.69 c	3.75 a

Note: The values within the same observation followed by the same letter are not significantly different at 5% DMRT level.

Table 4.
The yield of soybean varieties in several plant spacing in irrigated paddy fields in Banyuwangi-East Java [14].

as planting 2 plants/hole and optimal fertilizer application *i.e.*: 11.5 kg/ha N + 36 kg/ha P_2O_5+ 30 kg/ha K_2O at 10 days after planting, and 21.1 kg/ha N + 11.1 kg/ha S at 25 days after planting (**Table 4**).

A study in the rainfed Alfisol soil of Maros, South Sulawesi, which had a pH level of 6.2–6.7 and moderate soil fertility showed that soybean yield increased from 1.6 t/ha (existing technology) to 2.7 t/ha through the application of advanced cultivation technology [15]. This technology consisted of using good quality seed, sufficient fertilizer (30 kg/ha N + 48 kg/ha P_2O_4 + 30 kg/ha K_2O), rhizobium inoculant 250 g/50 kg of seeds, and organic fertilizer (1.5 t/ha). The performance of soybean crops grown after paddy in the irrigated lowland is presented in **Figure 1**. Using such technology, the labor cost accounts for the largest portion of the total production costs, reaching about 65% and 72% for advanced and existing technology, respectively. Nevertheless, both the R/C and B/C ratio of applying the advanced technology is higher relative to those of the existing technology (**Table 5**).

Figure 1.
The performance of soybean crop grown after paddy in the irrigated low land.

Components	Soybean cultivation technology	
	New technology	Existing (Farmers') technology
Production costs (IDR/ha)		
a. Production facilities	2,593,000 (34.7%)	1,470,000 (27.5%)
b. Labor	4,876,667 (65.3%)	3,880,000 (72.5%)
Total costs (IDR/ha)	7,469,667 (100.0%)	5,350,000 (100.0%)
Productivity (kg/ha)	2,725	1,590
Total revenue (IDR/ha)*	16,350,000	9,540,000
Total profit (IDR/ha)	8,880,333	4,190,000
R/C ratio	2.2	1.8
B/C ratio	1.2	0.8

Note:
**With a selling price of soybean IDR 6,000/kg.*

Table 5.
Financial analysis of soybean farming for advanced and farmer's technologies in the rainfed land of South Sulawesi in the dry season (May to August) of 2017 [15].

5.2 Dryland

The cropping patterns in the dryland are generally maize-maize, upland paddy-maize, maize-peanuts, or maize-soybeans. Meanwhile, in a dryland with a dry climate, farmers normally only grow maize or upland paddy during the rainy season. The rainfall in the dryland with a dry climate is approximately <2000 mm per year with a dry period >7 months per year (<100 mm rainfall per month). This type of agroecology is mostly found in Bali and Nusa Tenggara, Sulawesi, and Java [11]. However, the insufficient and non-uniform distribution of rainfall in the dryland considerably results in drought stress during the growing period of soybean and may cause yield reduction and even harvesting failure [16]. In this particular land, soybean development can only be performed through intercropping with maize as it is one of the major staple foods as well as a source of cash income for farmers [17]. Maize productivity in the dryland is relatively low, which ranges from 2.5 to 5.0 t/ha [2]. This is caused by the erratic distribution of rainfall and less optimal maize cultivation by farmers. The introduction of soybean in the dryland through intercropping with maize is expectedly would increase the land productivity and farmer's income. Intercropping system has been adopted all over the world as it can increase land-use efficiency [18, 19].

The use of adapted cultivars and optimal plant spacing in soybean intercropping systems can increase land productivity, reduce the risk of crop failure, increase crop yields and farmers' income [19–21]. The cropping pattern of soybean monoculture in the dryland with a dry climate could produce dry seed about 1.4–2.4 t/ha depending on the variety used and distribution of rainfall. However, this cropping pattern is difficult to be developed in the dryland as such a pattern was less profitable relative to growing maize [9]. Therefore, the development of soybean in the dryland, particularly in the maize producing area should be done by intercropping. Soybean intercropping with a plant spacing of 30 cm × 15 cm, planting two seeds per-hill and planting maize in a double row with a plant spacing of (40 × 20) cm × 200 cm and one seed per hill (**Figure 2**) is able to produce high maize yield and increase the farming profit. Intercropping soybean variety of Dena 1 with maize in the dry land with dry climate (Tuban, East Java) showed higher benefit than using Argomulyo and Dega 1 varieties (**Table 6**). Dena 1 variety is particularly

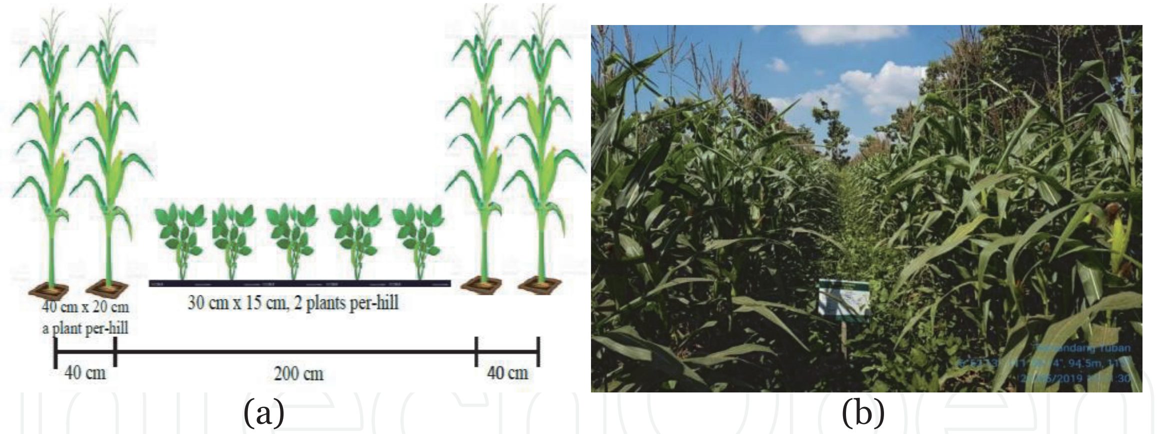

Figure 2.
The optimal crop layout for soybean intercropping with maize in the dryland (a) and the crop performances in the field (b) [9].

Planting patterns	Yield (t/ha)		Total revenue (IDR 000/ha)	Cost production (IDR 000/ha)		Total cost (IDR 000/ha)	Total benefit (IDR 000/ha)
	Maize	Soybean		Maize	Soybean		
Semanding							
'Maize NK212' monoculture	5.488	0	21,952	8,032	0	8,032	13,920
'Argomulyo' monoculture	0	2.430	15,795	0	7,022	7,022	8,773
'Dena 1' monoculture	0	1.873	12,174.5	0	6,802	6,802	5,372.5
'Dega 1' monoculture	0	1.417	9,210.5	0	6,622	6,622	2,588.5
'Maize NK 212' + 'Argomulyo'	4.876	1.447	28,909.5	7,972	4,540	12,512	16,397.5
'Maize NK212' + 'Dena 1'	6.297	1.017	31,798.5	8,252	4,400	12,652	19,146.5
'Maize NK212' + 'Dega 1'	5.635	0.820	27,870	8,047	4,180	12,227	15,643
Merakurak							
'Maize NK212' monoculture	5.648	0	22,592	9,737	0	9,737	12,855
'Argomulyo' monoculture	0	2.880	18,720	0	7,342	7,342	11,378
'Dena 1' monoculture	0	2.280	14,820	0	6,962	6,962	7,858
'Dega 1' monoculture	0	3.060	19,890	0	7,542	7,542	12,348
'Maize NK212' + 'Argomulyo'	3.657	1.927	27,153.5	9,817	4,520	14,337	12,816
'Maize NK212' + 'Dena 1'	4.157	1.687	27,595.5	9,927	4,360	14,287	13,306.5
'Maize NK212' + 'Dega 1'	3.367	1.613	23,952.5	9,787	4,380	14,167	9,785.5

Notes: The population of maize crops 100% (plant spacing of 80 cm × 20 cm, 2 seeds per-hill) was 62,500 crops/ha and soybean 333,333 crops/ha. The selling price of maize and soybean (dry seeds) were IDR 4,000/kg and IDR 6,500/kg, respectively.

Table 6.
Farming income of soybean intercropping with maize, Tuban District, East Java, Indonesia, planting season 2019 [9].

released for intercropping purposes as it is tolerant to shading up to 50%. Other soybean varieties that are suitable for intercropping with other crops, including young plantation crops are Dena 2, Denasa 1, and Denasa 2 (**Table 5**). Also, there are soybean varieties tolerant to drought stress, namely Dering 1, Dering 2, and Dering 3 (**Table 7**).

Variety	Seed coat color	100-seed weight (g)	Protein (% dw)	Fat (% dw)	Potential yield (t/ha)	Specific characters	Year of release
Gepak Kuning	Yellow	8.3–10.3	35.4–41.1	13.4–15.1	2.9	Adaptive in irrigated lowland and upland, both in rainy and dry seasons	2008
Dering 1	Yellow	10.7	34.2	17.1	2.8	Drought tolerant; adaptive in irrigated lowland and dry land (upland)	2012
Dering 2	Light yellow	14.8	35.9	19.7	3.3	Drought tolerant during the reproductive phase	2019
Dering 3	Light yellow	13.9	40.5	17.5	3.0	Drought tolerant during the reproductive phase	2019
Gema	Light yellow	11.3–11.9	37.8–39.1	15.6–19.1	3.1	Adaptive in irrigated lowland and dryland (upland)	2011
Dena 1	Yellow	14.3	36.7	18.8	2.9	Tolerant up to 50% crop-shading	2014
Dena 2	Yellow	13.0	36.5	18.2	2.8	Highly tolerant up to 50% crop-shading	2014
Demas 1	Yellow	13.0	36.1	19.9	2.5	Adaptive in a dryland with acidic soil; good planted at the altitude of 0–600 m asl	2014
Demas 2	Light yellow	14.9	37.5	19.7	3.3	Adaptive in dryland with acidic soil; early maturity; large-seed size	2019
Demas 3	Light yellow	14.4	37.2	17.7	2.9	Adaptive in dryland with acidic soil; early maturity; large-seed size; break-pods tolerant	2019
Devon 1	Yellow	14.3	34.8	17.3	3.1	High isoflavone content (2219.7 μg/g)	2015
Devon 2	Yellow	17.0	37.9	18.8	2.9	High isoflavone content (303.7 μg/g)	2017
Anjasmoro	Yellow	14.8–15.3	41.8–42.1	17.2–18.6	2.3	Broadly adaptive in all land conditions	2001
Panderman	Light yellow	18.0–19.0	36.9	17.7	2.4	—	2003
Grobogan	Yellow	18.0	43.9	18.4	3.4	Broadly adaptive in all land conditions, particularly irrigated lowland	2008
Burangrang	Yellow	20.0	39.0–41.6	14.9–17.0	2.5	—	1999
Argomulyo	Yellow	19.3–20.8	37.0–40.2	18.0–19.0	2.0	—	1998
Dega 1	Yellow	22.9	37.8	17.3	3.8	Adaptive in irrigated lowland	2016

Variety	Seed coat color	100-seed weight (g)	Protein (% dw)	Fat (% dw)	Potential yield (t/ha)	Specific characters	Year of release
Detap 1	Yellow	15.4	40.1	16.2	3.6	Resistant to leaf rust	2017
Deja 1	Yellow	12.9	39.6	17.3	2.9	Highly tolerant to water saturation stress	2017
Deja 2	Yellow	14.8	37.9	17.2	2.8	Tolerant to water saturation stress	2017
Depas 1	Yellow	11.9	39.8	19.5	2.8	Adaptive in tidal land type C; good planted at the altitude of 0–600 m asl	2020
Depas 2	Yellow	11.4	39.7	19.2	2.9	Adaptive in tidal land type C; good planted at the altitude of 0–600 m asl	2020
Denasa 1	Yellow	18.1	36.4	19.6	3.4	Highly tolerant up to 50% crop-shading	2021
Denasa 2	Light yellow	18.6	34.1	20.6	3.4	Tolerant up to 50% crop-shading	2021
Biosoy 1	Yellow	21.7	39.7	18.4	3.3	Gamma irradiated soybean	2018
Biosoy 2	Yellow	22.4	40.5	20.1	3.6	Gamma irradiated soybean	2018
Mutiara 1	Yellow	23.2	37.7	13.8	4.1	High production in irrigated lowland; adaptive in irrigated lowland and dryland (upland)	2010
Mallika	Black	9.0–10.0	37.0	20.0	2.9	Well adaptive in low land and high land; in rainy and dry season	2007
Detam 1	Black	14.8	45.4	13.1	3.5	High protein, suitable for soy sauce	2008
Detam 2	Black	13.5	45.6	14.8	3.0	High protein, moderate drought tolerant, suitable for soy sauce	2008
Detam 3 Prida	Black	11.8	36.4	18.7	3.2	Moderate drought tolerant; early maturity	2013
Detam 4 Prida	Black	11.0	40.3	19.7	2.9	Drought tolerant; early maturity	2013

Note: db = dry basis.

Table 7.
Physicochemical composition and specific characteristic of Indonesia soybean varieties [12, 22, 23].

5.3 Acidic soil

As discussed previously, acidic soils are the least favorable condition for soybean cultivation, therefore the use of ameliorants and high doses of inorganic fertilizers is essential in terms of increasing productivity. The application of 23 kg/ha N + 27 kg/ha P_2O_5+ 30 kg/ha K_2O + 1,500 kg/ha organic fertilizers and rhizobium biofertilizer 0.25 kg/50 g seeds in acidic soil with a pH of 5.30 and Al saturation of 30% exhibits a good growing performance of four soybean varieties, namely Anjasmoro, Panderman, Dega 1, and Demas 1 [24]. These varieties give a yield of 2.52 t, 2.29 t, 2.72 t, and 1.78 t per hectare, respectively. Demas 1, Demas 2, and Demas 3 varieties are tolerant to acid soil with a potential yield ranging from 2.5 t up to 3.3 t/ha (**Table 7**). Biofertilizers also have a significant role in increasing soybean yield through the natural processes of nitrogen fixation, solubilizing phosphorus, stimulating plant growth, improving soil texture, pH, and other soil properties [25, 26].

In the acidic soil of Banten with a pH of 5.5, the use of 200 g/ha of biofertilizer could substitute 50% of the recommended inorganic fertilizer [27]. Another study in acidic soil in Lampung reported that the use of Rhizobium biofertilizer tolerant to acidic soil about 1.5 t/ha and organic fertilizer enriched with P and Ca, could replace the use of 100% N and P, and 50% of K. The yield also increased more than 50% relative to control and gave higher yield compared to recommended NPK dosage [28]. The performance of soybean crops grown in acidic soil is presented in **Figure 3**.

5.4 Tidal swampland

In tidal swampland, water-saturated roots, high pyrite, the toxicity of Al, Fe, and Mn, deficiencies of N, P, K, Ca, and Mg are the major constraints in soybean development [8, 10]. Among such limitations, low soil pH and high Al saturation are more concerned regarding soybean growth as they may cause a decrease in nitrogen fixation and nutrient uptake, particularly phosphorus which is important for cell growth and photosynthesis. It was reported that liming can improve the growth and yield of soybean in the tidal swampland of South Kalimantan [10]. The highest yield was obtained at a rate of liming equivalent to 10% of Al saturation, which was applied by mixing the lime with soil up to 20 cm depth. Another study in tidal swampland of South Kalimantan investigated that using dolomite to decrease the Al-dd saturation by 20% by using organic fertilizers (1.25 t/ha), application of bio-fertilizer (0.25 kg/50 kg seeds), and inorganic fertilizer (23 kg/ha N, 27 kg/ha P_2O_5 and 30 kg/ha K_2O) gave the yield about 2.0 t/ha [24].

In addition, soil water management can be applied to reduce the pyrite content as the soil is in a reductive condition [29]. The response to water-saturated conditions varied among soybean varieties. Tanggamus and Anjasmoro, the yellow-

Figure 3.
The performance of soybean crop at 40 days after planting in the acidic soil in Lampung, Indonesia.

seeded soybean are classified as adaptive varieties, while the black-seeded soybean varieties, such as Cikuray, Ceneng, and Lokal Malang are less adaptive when grown under the saturated condition in tidal swampland. However, using the technology called water-saturated soybean farming [30], which consisted of appropriate application of Ca (dolomit) and NPK fertilizers with optimal plant population, the yield of soybean cultivation in tidal swampland in South Sumatera could reach 3.2–3.5 t/ha. There are some soybean varieties adapted to tidal swampland, namely Depas 1 and Depas 2 (**Table 7**).

A study on soybean cultivation in tidal swampland of South Kalimantan [22] also reported that the use of technological package (listed as an alternative technology in **Table 8**) consisting of the application of dolomite until soil Al saturation is reduced to 30%, NPK fertilizer with a dosage of 23 kg/ha N + 27 kg/ha P_2O_5 + 30 kg/ha K_2O + 1,500 kg/ha organic fertilizers, and rhizobium inoculant of 0.25 kg/50 kg seed as well as the saturated soil culture (SSC) technology was able to increase the number of filled pods per plant and yield per hectare relative to farmer's existing technology. Using the SSC and alternative technology packages, the seed yield increased by 27% and 17%, respectively compared to that of farmers' existing technology (**Table 8**). The performance of soybean crops treated with an alternative technology is presented in **Figure 4**.

5.5 Shaded land

In addition to several types of agroecosystem as described previously, growing soybean under shading is also potential for soybean development. Shaded land is available under young high state crop plantations, such as teak, palm oil, and

Technological package	Number of filled pods/plant	100 seeds weight (g)	Seed yield (t/ha)	Increased yield (%)
Existing	30.70 b	15.52 a	2.067 a	100
SSC	34.55 ab	15.40 a	2.422 b	117
Alternative	40.80 a	15.45 a	2.625 c	127

Note: The values followed by the same letter do not differ at the 5% DMRT level. SSC = Saturated Soil Culture.

Table 8.
Number of filled pods, 100-seed weight, and soybean seed yield obtained from the application of different technological packages in tidal swampland. Wanaraya District, Barito Kuala Regency, South Kalimantan [24].

Figure 4.
An example of the performance of 40 days after planting of soybean crops in tidal swamps with soil Al saturation of 30% in South Kalimantan Province, Indonesia.

eucalyptus trees. The land associated with teak and eucalyptus trees is generally under the management of State Company, namely Perhutani where the lands/areas are managed by the local community (FACI/Forest Area Community Institution), while the land planted with palm oil crops belongs to the Government. However, there is no accurate data regarding the potential shaded land that can be used for soybean development. This includes the dry land agroecology with flat or hilly topography. Therefore, soybean planting in this agroecology can be only done in the beginning of the rainy season.

The yield of soybean grown under the shading of four to six-year-old of palm oil tree (50% shading) was relatively lower (0.54 t/ha) than that of without shading (2.6 t/ha). Burangrang, Anjasmoro, and Grobogan varieties show similar tolerance to such shading. The recommended N fertilizer application is 100–150 kg/ha [31]. In another study, the application of 34.5 kg/ha N + 36 kg/ha P_2O_5 + 60 kg/ha K_2O + 20 t/ha manure and planting space of 20 cm × 20 cm using three soybean varieties (Dena 1, Anjasmoro, and Grobogan) were able to produce seeds of about 1.8 t/ha at 25% shading level and about 1.4 t/ha at 50% shading level [32]. In particular, Dena 1, Dena 2, Denasa 1, and Denasa 2 varieties are released for shading cultivation of soybean (**Table 7**).

Components of performance	Soybean variety				
	Dega 1[1]	**Dena 1[1]**	**Anjasmoro[1]**	**Argomulyo[1]**	**Local[2]**
Average of productivity (t/ha)	1.35	1.10	1.05	0.99	0.63
a. Production input (IDR/ha)	3,844,000	3,844,000	3,844,000	3,844,000	3,844,000
b. Labor (IDR/ha)	1,350,000	1,350,000	1,350,000	1,350,000	1,350,000
Total production cost (IDR/ha)	5,194,000	5,194,000	5,194,000	5,194,000	5,194,000
Total revenue* (IDR/ha)	9,450,000	7,700,000	7,350,000	6,930,000	4,410,000
Total income (IDR/ha)	4,256,000	2,506,000	2,156,000	1,736,000	(784,000)
R/C ratio	1.8	1.5	1.4	1.3	0.7
B/C ratio	0.8	0.5	0.4	0.3	

Note:
[1]Planting spacing was 40 cm × 15 cm (technology of Iletri).
[2]Planting spacing was 20 cm × 20 cm (existing technology).
**Revenue = the average of yield multiplied by the selling price of soybean seeds i.e. IDR 7,000/kg. Figure in the bracket showed total income was minus or soybean farming lost.*

Table 9.
Farming income of soybean farming under teak shade, Blora Regency, Central Java, 2018 [33].

Figure 5.
Soybean grown under the teak stands (left) and eucalyptus trees (right) in Blora, Central Java.

In terms of soybean grown under the two-year-old teak tree in Blora, Central Java, using the technological package of NPK fertilization (30 kg/ha N+ 66 kg/ha P_2O_5 + 30 kg K_2O), biofertilizer (20 g/10 kg of seed), "legowo" planting space (30 cm–50 cm × 15 cm) or regular planting space (40 cm × 15 cm), gave a yield about 1.5 t/ha. Meanwhile, using the existing technology (farmer's method), only 0.75 t/ha of seeds was obtained (**Table 9**) [33]. Soybean grown under the young teak stands and eucalyptus trees is presented in **Figure 5**.

6. Challenges and opportunities to achieve soybean self-sufficiency

6.1 Challenges

There are three primary challenges in terms of increasing the soybean production in Indonesia in order to achieve self-sufficiency, i.e. low fertility of the available land, less competition of existing soybean varieties in terms of the quality traits, and relatively low selling price of locally produced soybean.

Java Island is the most fertile and largest planted area of soybean in Indonesia. Shifting the soybean planting area to outside of Java has been started since the 1980s. The available land for crop cultivation in such areas, including soybean, is more than 40 million hectares, however, the major soil type is ultisol. This mostly exists in Sumatra, Bali, Kalimantan, Sulawesi, and Papua. Constraints, like acidity, low content of organic matter, and phosphorus (P) availability naturally occurred in ultisol soil, thus more inputs are needed to provide optimal conditions for producing soybean [34].

Quality traits of local or domestic soybean are also important to drive or push the production of soybean in Indonesia. However, there is a limited quality trait of local soybean to compete with imported soybean. Previously, the improved soybean varieties belonged to small and medium-seeded, which is not desired for tempeh ingredients. Large-seeded (> 14 g/100 seeds) is favored for tempeh preparation as it would give a good appearance and high volume development, while small to large seed sizes are suitable for tofu making [22]. Therefore, for the last two decades, a number of improved varieties with large seed sizes have been released (**Table 7**) to meet such preferences. However, the released varieties concerning health benefits, such as Devon 1 and Devon 2 with high isoflavone content (**Table 7**) that has antioxidant activity, have not been attractive for consumers and farmers based on this superiority or character as the market is not yet available. Therefore, lack of market quality traits is also an essential challenge for producing local soybean.

In the case of price, the imported soybean always has a lower price than the local soybean. It is calculated [35] that the profitable price for farmers is minimally IDR 9,000 per kg or US$ 0.6/kg (US$ 1 = IDR 14,000). With this selling price, farmers would be able to cover the expenses for soybean production activity and gain some profit. However, the price of local soybean at the farm level is frequently around IDR 6,500 per kg, causing less interest of farmers to grow soybean. Therefore, the current average soybean productivity at the farm level (1.5 t/ha) needs to be increased to at least 3.0 t/ha, thus soybean farming income can compete with those of other commodities, such as maize as presented in **Table 10**.

6.2 Opportunities

Indonesia has a good chance to increase soybean production and fulfills domestic needs. This opportunity can be seen from the market demand, land and improved varieties availability, and the Government's strong will. Soybean demand as food

Parameter	Commodity farming		
	Maize	**Soybean (Farmer technology)**	**Soybean (Improved technology)**
Productivity (t/ha)	5,648	1,873	3,060
Selling price (IDR/kg)	4,000	6,500	6,500
Revenue (IDR/ha)	22,592,000	12,174,500	19,890,000
Production cost (IDR/ha)	9,737,000	6,800,200	7,542,000
Profit (IDR/ha)	12,855,000	5,372,500	12,348,000
B/C	1.32	0.79	1.64

Table 10.
Income of maize farming compared to soybean farming using existing farmer technology and improved technology [9].

and feed increases continuously and be expected to increase in the next years. The highest portion of demand comes from processed food mainly tempeh and tofu. Another high demand is coming from the cattle feed industry which is expected to increase continuously as part of increasing cattle production. Therefore, by increasing the national soybean production, the Government wants to fulfill these demands by using national production and reducing imports [36].

Other potential opportunities are the availability of source seeds, especially in the form of "Breeder Seeds" for the production of certified seed of "Foundation Seeds", "Stock Seeds", and "Extension Seeds" to fulfill the need for quality soybean seed for the area of production. The "Breeder Seeds" available are various soybean varieties with a various specific traits, including the variety tolerance to pod borer and pod sucking insect, shading, flooding, and drought. The readiness of soybean production technology for various agroecosystems can also be stated as an opportunity because those significantly contribute to the high productivity and also for the production of soybean in the country.

7. Conclusion

Soybean in Indonesia is the third important staple food after rice and maize. The need for this commodity continuously increases every year due to the increase in population. The trend of domestic soybean production tended to decline and do not meet the demand leading to the increase of soybean import every year. There are three challenges that require drastic changes so that local soybean production is able to meet domestic needs. First, the current productivity at the farm level, which is around 1.5 t/ha must be increased to at least 2.0–3.0 t/ha. It will also help soybean farming income compete with those of other commodities. Second, the soybean harvested area which only reaches 0.3 million hectares in 2019 must be increased at least become 1.7 million hectares. The potential soybean planting areas in Indonesia are the optimal land including irrigated lowland and rainfed after paddy (rice), as well as suboptimal lands such as dryland, acidic land, tidal land, and shaded land under young plantation crops. Soybean productivity in those kinds of agroecosystems can reach 1.8–3.0 t/ha, depending on the type of land, the improved varieties used, and the applied of cultivation technological package. Third, it is necessary to develop agricultural machinery that can reduce the farming cost, so that soybean farming is more efficient and able to provide higher profit.

Some efforts should be made to increase national soybean production to achieve self-sufficiency, including improving the attractiveness point of soybean farming, launching the program(s) to increase soybean production starting from the central government to the regions, accelerating technology transfer dan adoption of the high yielding improved varieties, reducing soybean import gradually, improving the cooperation among stakeholders, and providing a good market guarantee for soybean farming.

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Conflicts of interest

We declare that we have no conflicts of interest on the entire manuscript.

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