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Research article

Agricultural land resource allocation to develop food crop commodities: lesson from Indonesia

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ABSTRACT

This study estimates agricultural land resource allocation to develop food-crop commodities in order to safeguard food security in Indonesia in the middle of the coronavirus pandemic. The recommended commodities to be developed in Indonesia are corn, soybean, mungbean, peanut, and rice that are produced with advanced technology and input-output coefficient. There are five introduced scenarios namely, basic scenario, I, II, III, and IV. There are problems related to resource allocation such as limited resources, the ways of using it, and time constraints. In order to maintain and improve the comparative advantage of agricultural production as well as to broaden the agricultural activities, agricultural development is directed to increase business efficiency, improvements in agricultural science, technology, and human resource quality. The utilization of agricultural land resources should be well-planned for better development.

1. Introduction

Nowadays, income inequality in provinces across Indonesia still becomes a problem. The income in urban areas is indeed different from the earnings made in rural areas. The economic development in rural areas is highly dependent upon the agricultural sector, especially the utilization and use of agricultural land (Haryanto et al., 2019; Ruel et al., 2018). In line with the program to increase farmers' incomes, particularly in the provinces with narrow land are carried out continuously. On the other hand, the farmers with limited land try to improve their production whilst being concerned about the land conservation area in order to maintain its productivity (Choudhary et al., 2018; Pishgar-Komleh et al., 2013). The challenges for Indonesian farmers are as they don't know how to develop the land to boost production, maintain and preserve resources, and increase their income and well-being (Herrero et al., 2017; Jat et al., 2019; Jat et al., 2013; Nasikh, 2016; Yoga et al., 2018). This is not worsened by the coronavirus pandemic. The current pandemic began in December 2019 and declared as an international pandemic in April 2020. The agricultural sector has not been always affected by the coronavirus. Limited land with low productivity becomes the new problem that should be solved. There are many efforts should be implemented to improve agricultural products in the limited land that requires a proper farming system (Haryanto et al., 2019) whereas (Herforth et al., 2016; Saad et al., 2016) emphasizes there is a need to conserve the land. Land conservation becomes the new alternative to improve the agricultural product in the middle of coronavirus pandemic (Roe et al., 2020; Waibel et al., 2020; Elleby et al., 2020; Mukhamedjanova, 2020; Zhang et al., 2020; Gregorio and Ancog, 2020; Verikios, 2020; Bartik et al., 2020; Beland et al., 2020).

Limited agricultural land poses complicated problems which it has limited water supply relies on rain, and facing erosion risk. Therefore, it requires the right choice of cultivated commodities for suitable land resource allocation. In order to utilize the land, the farmers should have a basic understanding of the physical conditions and characteristics of the land (Haryanto et al., 2019; Jat et al., 2015, 2019).

The choice of cultivated crops in relatively limited land and methods to grow them determines the erosion (Avraamidoul and Pistikopoulos, 2018; Binswanger, 1986; Jat et al., 2019). Moreover, it also determines farmers' income which is depending on where the land is located. According to (Boukouvala and Floudas, 2017; Joodavi et al., 2015; Nasikh, 2018; Soltani et al., 2013; Yoga et al., 2018) (Chapagain and Good, 2015; Haryanto et al., 2019; Nasikh, 2013, 2018; Parihar et al., 2013; Soltani et al., 2013; Yoga et al., 2018) stated land productivity is influenced by environmental and resource determinants.

Optimization signifies findings of maximum and minimum values from some multiple objective programming by deciding prices for the controllable variable until certain limits. Maximization is a process to

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find a maximum value of an objective function, whereas minimalization is a process to find a minimal value (Avraamidou & Pistikopoulos, 2019a, 2020b; Beykal et al., 2018; Binswanger, 1986; Das et al., 2015; Liu et al., 2016; Lohan et al., 2018; Wezel et al., 2017).

This research raises an innovation in the agricultural sector in Indonesia. It was first conducted to develop the food crop commodity as the leading agricultural commodity in four provinces that analyzes two aspects, namely the agricultural aspect (agricultural land area with five scenario areas) and the economic aspect (the employment rate, income, capital, food consumption needs, and comparative advantage). They are analyzed in an integrated manner to obtain the prioritized alternative that is most beneficial for the farmers and the agricultural agency at the provincial level. This research contributes to the development of food crop commodity farming in Indonesia by using an analysis approach called the dual goal programming model. It offers three priority targets, namely farming income, job opportunity, and farming capital utilization with five available scenarios of choices (the basic scenario, scenario 1, scenario 2, scenario 3, and scenario 4). Furthermore, this research contributes to the farmers in terms of allowing them to choose the food crop commodity that gives high-income alternatives in four provinces (East Java, Central Java, West Nusa Tenggara, and South Sulawesi) and other provinces in Indonesia. In addition, this study also commits to the Food Crop Agricultural Agency of the Republic of Indonesia as the policymaker at the provincial level to develop the food crop commodity that can open higher job opportunities.

2. Theoretical review

2.1. Identifying the agricultural land resource allocation in Indonesia

The relatively narrow agricultural land poses complex problems because it is narrow, has limited water supply that relies on rain, and in a risk of erosion. Therefore, it requires a correct choice of commodities. In order to utilize the relatively narrow agricultural land, the farmers need to have a basic understanding about the physical characteristic and activities of the land.

The choice of crops cultivated in the relatively narrow agricultural land and ways to grow them determine the land erosion (Avraamidoul and Pistikopoulos, 2018; Jat et al., 2015, 2019; Parihar et al., 2013). In addition, it also decides farmers' income and the success of economic development in which the land is located. According to (Chapagain and Good, 2015; Haryanto et al., 2019; Nasikh, 2013, 2018; Parihar et al., 2013; Soltani et al., 2013) a land productivity is influenced by environmental and resource factors.

According to the previous research investigating about the appropriate crops for relatively narrow agricultural land in Indonesia and the potential target market (highly needed commodity/staple food), the research finding recommends some commodities to develop. Some leading commodities are treated with advanced technology. The technology includes how to use the input and output of each commodity, employment rate, and comparative excellence. They are relevant to the physical condition in each province in the research setting (East Java, Central Java, South Sulawesi and West Nusa Tenggara).

The leading commodities that are recommended to be developed in the provinces are corn, soybean, mungbean, peanut, and rice that are produced with advanced technology and determined input – output coefficient.

2.2. The development of food crop commodity in Indonesia

Nowadays, Indonesia has got five concerns, namely food, fuel, fiber, financial, and environment. Economic observers predict that the global food price will get higher as the coronavirus pandemic has not ended yet. Most of the food is produced in the rice field and dryland. The challenge of the food produced in the rice field is shifts of land function. The dryland also faces lower productivity due to the limited growing season. In order to improve the food crop commodity, there should be a program to enhance the quality of existing resources, especially the agricultural land which becomes narrower. Therefore, there should be more attempts to increase the food crop production because the food self-sufficiency is not enough to achieve food independence. Some food crop commodities, namely rice, corn, soybean, nut, and mungbean are the main food crop commodities whose self-sufficiency is attempted by Indonesia. In regard to the position of those five food crop commodities, they are potential to be developed in four provinces in Indonesia, namely East Java, Central Java, West Nusa Tenggara, and South Sulawesi.

As a social organization, a farmer group becomes a medium of learning and teaching for its members to improve their knowledge, skill, and behavior as well as to grow their independence in farming business to gain more productivity, income, and welfare. In addition, the farmer group also plays a role as a medium of collaboration among members of the farmer group. The cooperation is also done among farmer groups and other parties. By establishing this collaboration, it is expected that the farming business will run more efficiently and be able to overcome threads, challenges, obstacles, and obstructions.

Furthermore, the farmer group is also a production unit that is run by each farmer group member as a whole business entity to achieve the economic scale in terms of quantity, quality, and continuity. Indonesian government through its Agricultural Ministry has declared four main targets of agricultural development. First, it is to gain self-sufficiency and sustainable self-sufficiency. Second, it is to achieve food diversification. Next, it is to carry out improvement in added value, competitiveness, and export. Last but not least, it is to increase the farmers' welfare.

Particularly in the development of food crop sub-sector, the achievement of the four main targets is expected to be able to give a significant impact to the national demand and food security. The national demand includes the need of food, feed, energy, and raw materials for industries. In addition, the impact of the food crop development is expected to be able to lower the poverty level and increase the national income. In this regard, the food crop development is categorized into the development of main commodity, namely rice, corn, soybean, peanut, mungbean, and other alternatives. There are four strategies to achieve the food crop production, namely (1) productivity improvement, (2) area expansion and land optimization, (3) reduction of rice consumption, and (4) management improvement. The direction and policy of Food Crop Production, Productivity, and Quality Improvement Program are prioritized in (1) the main and national leading commodities, namely rice, corn, and soybean, and (2) the alternative/regional leading commodities (Ministry of Agriculture, 2019; BKP, 2019a; 2019b; Dewi, 2018; Food Security Agency, 2018; Gerintya, 2019; Hadi et al., 2019; Hanafie et al., 2018; Perdinan et al., 2018).

The problem is the need for food (rice, corn, soybean, peanut, and mungbean) keeps increasing as the population becomes larger. The attempt to stabilize the food security includes quantitative and qualitative aspects. The consumption pattern of most Indonesian people is dominated by rice. In fact, excessive dependance to a particular commodity is vulnerable. Seen from the consumption side, the dependance to rice narrows down the spectrum of commodity choices that should be utilized for food. In terms of production, it is also vulnerable because of three reasons: (i) the growth of rice highly depends on the sufficient water irrigation, whereas it is getting scarce, (ii) the rate of conversion from rice field to non-rice field become more uncontrollable, and (iii) the ability to expand the rice field (new construction) is very limited (Sellberg et al., 2020; Bhaduri et al., 2018; Miyinzi et al., 2019; Müller et al., 2020; Mulwa, & Visser, 2019, 2020).

The expansion of area should be done extensively, particularly outside Java Island, as the acceleration and expansion of national economy are done simultaneously. Research finding by Purnono et al. (2019), Dewi (2018), Miyinzi et al. (2019), and Hadi et al. (2019) shows that the undeveloped food crop area reflects low incentives of the farmers to grow the food crop commodity. In the future, the regional development in the four provinces of East Java, Central Java, West Nusa Tenggara, and South

Sulawesi is directed to be one of the national food barns by increasing productivity and added value of food crop agriculture as well as escalating and expanding the area of food crop. The regional development in the four provinces as the center of agricultural production and national food barn is done by applying strategies to increase the production and productivity of food crop and plantation. In order to develop the potential of food crop production as the national food barn, the regional development policy should be aware of other economic developments. Besides, the four provinces (East Java, Central Java, West Nusa Tenggara, and South Sulawesi) are the centers of staple food production, especially rice, corn, soybean, peanut, and mungbean. In those provinces, there is some unutilized agricultural land that is potential to increase the food crop productivity, so the policy of production improvement can be applied easily by the area expansion strategy.

2.3. Linear goal programming (LGP) concept of agricultural land allocation for food crop in Indonesia

The linear goal programming (henceforth LGP) is an expansion of the linear programming to achieve the desired target. In addition, all purposes in LGP are incorporated to an objective function. It can be carried out by expressing the purposes in the form of constraint, putting the deviation variable in the constraint to reflect the extend to which the purpose is achieved, and incorporating the deviation variable to the objective function. LGP is a mathematic model that is considered appropriate to overcome multi-objectives. Through the deviation variable, the goal programming automatically catches information about the relative achievement from the existing purposes (Jat et al., 2015, 2019; Avraamidoul and Pistikopoulos, 2018; Hadi et al., 2019; Hanafie et al., 2018; Purnono et al., 2019; Dewi, 2018; Parihar et al., 2013).

In general, the goal programming is used to solve problems that have multiple purposes (or more than one objective). It is a special modification or variation of the linear programming that have various purposes. LGP aims to minimize deviations by considering a priority hierarchy. The initial formulation of the goal programming is basically similar to the linear programming formulation in which the decision variable should be defined in advance. After that, the objective of the raw materials should be specified according to its degree of significance. Next, solution to minimize the deviations is sought. In other words, the goal programming is an analysis tool to minimize the deviation of various objectives and targets that have been set, so the targets can be achieved according to each priority scale established for a particular method. It is even conflicted in the formulation process. Therefore, the goal programming method is used to solve problems which have multiple objectives. This method results in an efficient solution because the consequence cannot be optimal for all existing problems. The deviational variable works to accommodate the deviations that will occur on the left side of the equation. To minimize the deviation, the value on the left side of the equation is made as closest as possible to the value on the right side.

On the other words, the deviational variable should be minimized in the objective function. In the goal programming, constraints are means to achieve the desired target. In this case, the targets are expressed in the constant value on the right side, for example, the farmers' income, limited capital, and limited agricultural land. Thus, achieving a target means making effort to make the value on the left side of the equation equal to the right side. It is a reason why the constraint in the goal programming method is always in the form of the equation and they are called the target constraint. In addition, the target constraint is marked with deviational variables so that every target constraint must have a deviational variable. The goal programming modelling of the goal programming is the existence of deviational variable. The deviational variable can be distinguished to two types. First, the deviational variable accommodates the deviation under the desired target. The target is reflected on the right side of the target constraint. In other words, the deviational variable has a function to accommodate the negative deviation.

The goal programming model has been widely applied in some decision-making situations, such as the agriculture and fish farming. The deviational variable works to accommodate the deviation that will occur on the left side of the equation towards the right side. The deviational variable is divided into two: (1) The deviational variable to accommodate the deviation occurring under the desired target (d_i^-); (2) The deviational variable to accommodate the deviation occurring above the desired target (d_i^+)

Basically, the framework of LGP method of agricultural land allocation for food crop is an attempt to minimize the deviation of some sets of agricultural land allocation for food crop established by the decision maker. Every deviation of the modifiers in the objective function is represented to the positive (p) and negative (n) deviation values of every objective. Therefore, the algorithm of agricultural land allocation for food crop has a purpose to minimize the deviation, especially if related to the priorities or interests relative to the decision maker.

The approach utilized in this study is the dual goal programming that can solve and offer alternative solutions to the food crop commodity with more than one priority target. It has more than one achieved scenario by minimalizing deviations from each existing target. In dual goal programming, constraints are the means to achieve the targets are expressed in the constant value, for example, limited capital, and limited agricultural land. The dual goal programming method is always in the form of the equation and they are called the target constraint. This model needs various inputs from the production system of agricultural land allocation (for example the one in Indonesia) to encourage the decision that will be generated. The required inputs include the targets to be achieved, constraint function technology coefficient, resources to be employed (land to limit the target, labors to generate production in three growing seasons, and investments or capital), comparative excellence that is a domestic resource coefficient, income per hectare of commodity, and the needs to food consumption, and etcetera (Hadi et al., 2019; Hanafie et al., 2018; Purnono et al., 2019; Dewi, 2018; Avraamidou and Pistikopoulos, 2018, 2019a,b, 2020a,b).

According to the theoretical base, it is clear that the choice of commodity will maximize the profit when meeting certain requirements as follows: (a) Rate of product transformation (RPT) of pairs of output is equal to the ratio of price; (b) Value of marginal product (VMP) for each input is equal to input price; (c) Rate of technical substitution (RTS) of pairs of input is equal to the ratio of input price.

Dual goal programming implies that there are several objectives of agricultural land allocation aimed for production combination. In other words, when a challenge has more than one goal (dual goals), the modification result is called goal programming or multiple objective programming (MOP) (Avraamidou and Pistikopoulos, 2018, 2019a,b, 2020a,b). MOP analysis is generally aimed to minimize the deviation towards various goals and targets by implementing efforts to achieve certain goals satisfactorily in regard to the existing constraint. The procedure analysis can be implemented to achieve the target as closest possible according to the priority scale (Avraamidou and Pistikopoulos, 2019a,b; 2020a,b) multiple objective programming (MOP) can be formulated as follows.Minimize:

$$Z = \sum_{i=1}^{m} W_i \left(d_i^+ + d_i^+\right) \tag{1}$$

The bond terms:

$$\sum_{j=1}^{m} a_{ij} X_j + d_i^- - d_i^+$$

$$\text{for i} = 1, 2, \ldots \text{m}$$

$$\sum_{j=1}^{n} g_{kj} \ x_j \le \ \text{or} \ \ge c_k$$

$$\text{For k} = 1, 2, \ldots \text{p}$$

$J = 1, 2, \ldots n$
$x_j, d_i^-, d_i^+ \geq 0$
$d_I^+, d_i^- = 0$In which,

$d_i^+; d_i^-$: the number of deviation unit that is deficient (-) or surplus (+) towards the objectives

w_i : weight (ordinal or cardinal) towards a deviation of objectives
a_{ij} : the coefficient of constraint function that is related to the decision-making variables
X_j : decision-making variables or the planting area to grow the commodity in each province
b_i : the goals or targets that are going to be achieved
q_{yj} : the coefficient of ordinary constraint function
c_k : the number of resources k
Z: scalar value from the decision-making criteria; it is an objective function

The problem formulated in Eq. (1) can only be used to solve all objectives that have the same priority rank. If the decision making has some characteristic objectives that are characterized by priority based on the necessity of each objective, the problem-solving procedure is done by weighting the objective in regard to the necessity.

When there are some objectives with various ranks, the priority factor is P_i ($_i = 1, 2, \ldots$ m). P_1 means that P_1 is more prioritized than P_2 and so forth, so that these priority factors are related with formulation as follows.

$$P_1 > P_2 > P_i > P_{i+1}$$

The priority correlation shows that even though factor W is multiplied n-times (n > 0), the prioritized factor will be at the top.

In matrix notation, multiple objective programming (MOP) can be formulated as follows.

Minimize bond terms: $Z = \alpha^1 d^- + \beta d^+$

$$A_x + d^+ - d^- = b$$

$G_x \leq$ or $\geq$ c
$x, d^+, d^- \geq 0$
$d^+, d^- = 0$

In which a and β are the priority factors and the relative weigh that is relevant to d^+ and d^-

Indonesia is an agrarian country that gives a growth consequence to most Indonesian citizens, so the government needs to pay attention to the strong and tough agricultural sector. One of sectors which encourages the economic growth is the agricultural sector. This study urges the importance of agricultural land allocation to improve income, employment opportunity, and investment through five scenarios that are applied to the crop commodities, namely rice, corn, soybean, peanut, and mungbean in four provinces.

3. Research method

3.1. Study area

Rice, corn, soybean, peanut, and mung bean are the most planted food crop commodity in Indonesia. It is because they are the leading commodity in Indonesia. It is no longer a secret that the problems challenged by Indonesian farmers are limited productive land, low farming capital, and insignificant numbers of job opportunities in the agricultural sector. In regards to these problems, the optimization function of food crop commodity should be developed with the limited productive land, low farming capital, and insignificant numbers of job opportunities in the agricultural sector. The optimization function can give higher farmer incomes, more job opportunities, and efficient farming capital utilization.

The objective of this study is to identify the agricultural land allocation in four provinces (East Java, South Sulawesi, West Nusa Tenggara, and Central Java) whose land is relatively narrow. This study was conducted in four provinces with potential food crop production. It employed descriptive case study. Data were collected by purposive sampling done in eight regencies in four provinces: East Java (Lamongan and Ngawi regencies), Central Java (Sragen and Grobongan regencies), South Sulawesi (Wajo and Sidrap regencies), and West Nusa Tenggara (Lombok Tengah and Lombok Timur regencies). The location was selected purposively based on the potential to produce the food crop commodity. It was conducted in April 2019 to June 2020. Types of data used in this study were primary and secondary data that were quantitative and qualitative. The primary data were obtained from the direct interview with farmers of the food crop commodity (in 2019 before the Covid-19 pandemic). The secondary data were taken from the associated departments, namely the Central Bureau of Statistics, Regional Development Planning Agency, and Economic Agency in each regency. The respondents were the farmers who used their land to produce the food crop commodity.

3.2. Data collection

During Covid-19 pandemic, the agricultural sector becomes the toughest sector, even it becomes the only sector that saves the country's economy. In section 3, the optimization function model is not affected by the pandemic. It is because (1) in terms of agricultural land allocation to develop the food crop commodity during pandemic, the government does not apply the lockdown policy; instead, it applies the large-scale social restrictions which enables resource (labor, capital, and etc.) mobility in the agricultural sector, especially in the food crop commodity development, and (2) the assumed model is the production function, so the research model is not affected by the pandemic.

Data collection method used in this study was the data of cropping pattern in the rice field that were collected from the respondents in the working area of Agricultural Extension Office in each province. To ensure privacy rules and study ethics, we kept the respondents anonymous on the questionnaire. The data included the food crop farming business. Considering the aspects of *Panca Usaha Tani,* the first-stage regional level categorization was carried out based on the production potential. There were three categories: First, regions whose potential farming business was rice, corn, and peanut with mixed support of *palawija.* Second, regions whose potential farming business was rice, corn, and soybean with mixed support of *palawija*. Third, regions whose potential farming business was rice, corn, and mung bean with mixed support of *palawija.*

Based on the first-stage level, two regencies were chosen as the sample of the next stage. From each regency, 20 respondents were chosen randomly as the element analysis unit. This procedure made 4 × 2 × 20 units of the smallest analysis unit. Furthermore, the supporting data for other purposes were obtained from the statistical information of the related institutions.

The secondary data was collected from the Central Bureau of Statistics, Department of Agriculture, and Department of Food Crop. The primary data was collected from interviews and questionnaires distributed to key people in the Department of Agriculture and Department of Food Crop as well as farmers who grew the food crop in order to develop the food crop in Indonesia. In 2020, the primary data was collected by using google form (https://forms.gle/a51JR4zc3kQnMDpy8), google meet and using questionnaires before the Covid-19 pandemic). The sample was collected by the purposive sampling and snowball sampling. The purposive sampling was applied to the key people who worked in the Department of Agriculture and Department of Food Crop. They were the section chief of food crop and horticulture business developments, and coordinator of Technical Implementing Unit of the Agricultural and Agricultural Extension Offices. The snowball sampling was conducted among farmers, namely the head of farmer group and the farmers. The decision to choose the key people was a perception of those who understood about the research problem. Scoring criteria and alternatives in this study were done by the key people. Consequently, experts' opinions should be checked for their consistency. The rational opinions were combined by using a geometric average to avoid bias. The key people in this study were the related stakeholders (experts of Department of Agriculture and Department of Food Crop) who played roles in the food crop development in each province. They included a section chief of food crop and horticulture business developments, a coordinator of Technical Implementing Unit of the Agricultural Offices, three agricultural extension staffs, three heads of farmer groups, and thirty-seven farmers. Therefore, there were 160 respondents of food crop farmers.

Data used in this study were the basic scenarios I, II, III, and IV of cropping pattern collected from the farmers in four provinces. The data included the rice, corn, peanut, soybean, and mungbean farming business. The type of collected data was cross-section data. "The representative farm" data collection was based on the guided interview. The procedure of respondent sampling was based on the purpose of the study. This study aimed to collect data of the scenarios of cropping pattern as well as the farmers' decision.

The research was conducted in four provinces in Indonesia, namely East Java, South Sulawesi, West Nusa Tenggara, and Central Java. They are selected because of their productive role to produce food crops in Indonesia and indirectly affected by coronavirus (Haryanto et al., 2016, 2019; Setiati and Azwar, 2020). Most of their agricultural lands are productive for food crop commodities.

3.3. Assumptions in this study

There are assumptions in the specification model of the agricultural land for food crop commodities in which the agricultural resources are used to develop five commodities (rice, corn, soybean, peanut, and mung bean) in four provinces. They are the assumption in deciding a modifier and decision parameter. The planner is those who make rational decisions based on the objective function, constraint, and functional constraint collected during the research. They have been established in advance (deterministic).

In regard to the agricultural land area in each province, East Java (see Table 1; 8421.1 thousand hectares), South Sulawesi (see Table 2; 426.3 thousand hectares), West Nusa Tenggara (see Table 3; 473.6 thousand hectares), and Central Java (see Table 4; 947.4 thousand hectares) use one-third of their area to grow the food crop commodities. In this case, the land used as the research object is the rainfed land with homogenous physical and agroclimatology conditions. The recommended food crop commodities that are developed in those four provinces are rice, corn, soybean, peanut, and mungbean produced with advanced technology and determined input-output coefficients.

Data of the capital/investment per hectare, labors per hectare, domestic resource coefficient of each commodity and income generated per hectare by each commodity in each province are obtained from the Department of Agriculture and Department of Food Crop.

Linear goal programming (LGP) model assumption in agricultural land resource allocation in Indonesia:

- Linearity

It shows the fixed ratio of one input to another input, or one input to output. It does not depend on the production rate.

- Additivity

It states that the optimization criteria of the objective function are the sum of parameter value (C_j) in the separated activities (X_j). In addition, the number of resources used is equal to the sum of resources in each activity.

- Proportionality

If the decision-making variable X_j changes, the effect will distribute evenly to the objective function C_jX_j and constraint a_jX_j. In this case, the law of increasing reduced output does not apply.

- Deterministic

It expects that all parameters (C_j, a_j, and b_j) are fixed, identified, and determined previously.

3.4. Data analysis

Multiple objective programming (MOP) model that is used to develop the food crop in order to utilize the relatively narrow agricultural land in Indonesia is formulated as follows.
Minimize

$$z = \sum_{i=1}^{m} P_Y w_{i,y}^{+} d_i^{+} + P_s w_{i,s}^{-} d_i^{-} \tag{2}$$

The bond terms:

$$\sum_{j=1}^{m} a_{ij}\, x_j + d_i^{-} - d_i^{+} = b_i$$

Table 1. Data input-output dual program East Java province.

Activity	Soybean (X1)	Corn (X2)	Mung bean (X3)	Peanut (X4)	Rice (X5)	Constraints/Target
Constraints:						
1. Land area (thousand ha)	1	1	1	1	1	8421.1
2. Labors needed (thousand Man-Days per hectare)						
- growing season I	0.24	0.185	0.09	0.18	0.22	2250
- growing season II	0.237	0.09	0.135	0.165	0.2	2150
- growing season III	0.242	0.17	0.16	0.198	0.195	2150
3. Investment						
(thousand IDR/hectare)	2.45	2.88	3,852	4.8	3.55	5052
4. Income						
(thousand IDR/hectare)	5.64	8.24	4.25	4.78	7.25	7197
5. Comparative						
advantage	0.57	0.94	0.72	0.69	0.98	1
6. Food consumption						
need (thousand/hectare)					1	285.9

Table 2. Data input-output dual program South Sulawesi province.

Activity	Soybean (X1)	Corn (X2)	Mung bean (X3)	Peanut (X4)	Rice (X5)	Constraints/Target
Constraints:						
1. Land area (thousand ha)	1	1	1	1	1	426.3
2. Labors needed (thousand Man-Days per hectare)						
- growing season I	0.24	0.185	0.09	0.18	0.22	2000
- growing season II	0.237	0.09	0.135	0.165	0.2	1800
- growing season III	0.242	0.17	0.16	0.198	0.195	1800
3. Investment						
(thousand IDR/hectare)	2.45	2.88	3,852	4.8	3.55	2174
4. Income						
(thousand IDR/hectare)	5.64	8.24	4.25	4.78	7.25	2732
5. Comparative						
advantage	0.57	0.94	0.72	0.69	0.98	1
6. Food consumption						
need (thousand/hectare)					1	146.2

Table 3. Data input-output dual program West Nusa Tenggara province.

Activity	Soybean (X1)	Corn (X2)	Mung bean (X3)	Peanut (X4)	Rice (X5)	Constraints/Target
Constraints:						
1. Land area (thousand ha)	1	1	1	1	1	473.6
2. Labors needed (thousand Man-Days per hectare)						
- growing season I	0.24	0.185	0.09	0.18	0.22	1880
- growing season II	0.237	0.09	0.135	0.165	0.2	1680
- growing season III	0.242	0.17	0.16	0.198	0.195	1680
3. Investment						
(thousand IDR/hectare)	2.45	2.88	3,852	4.8	3.55	2320
4. Income						
(thousand IDR/hectare)	5.64	8.24	4.25	4.78	7.25	3409.9
5. Comparative						
advantage	0.57	0.94	0.72	0.69	0.98	1
6. Food consumption						
need (thousand/hectare)					1	158.62

Table 4. Data input-output dual program central Java province.

Activity	Soybean (X1)	Corn (X2)	Mung bean (X3)	Peanut (X4)	Rice (X5)	Constraints/Target
Constraints:						
1. Land area (thousand ha)	1	1	1	1	1	947.4
2. Labors needed (thousand Man-Days per hectare)						
- growing season I	0.24	0.185	0.09	0.18	0.22	2400
- growing season II	0.237	0.09	0.135	0.165	0.2	2150
- growing season III	0.242	0.17	0.16	0.198	0.195	2350
3. Investment						
(thousand IDR/hectare)	2.45	2.88	3,852	4.8	3.55	4547
4. Income						
(thousand IDR/hectare)	5.64	8.24	4.25	4.78	7.25	7579
5. Comparative						
advantage	0.57	0.94	0.72	0.69	0.98	1
6. Food consumption						
need (thousand/hectare)					1	318.02

In which i = 1, 2, …, m

$$\sum_{j=1}^{n} g_{kj}\, x_j \leq or \geq c_k$$

In which k = 1, 2, …., p

j = 1, 2, …., n

$$x_j, \quad d^{+}i, \quad d^{-}i \geq 0$$

$$d^{+}i, \quad d^{-}i = 0$$

In which:

$d^{+}i$, and $d^{-}i$: the number of deviation unit that is deficient (-) or abundant (+) towards the objectives
w_i : weight (ordinal or cardinal) towards a deviation of objectives
a_{ij} : the coefficient of constraint function that is related to the decision-making variables
X_j : decision-making variables or the planting area to grow the commodity in each province
b_i : the goals or targets that are going to be achieved
q_{yj} : the coefficient of ordinary constraint function
c_k : the number of resources k
Z: scalar value from the decision-making criteria; it is an objective function
P_yP_s: priority factors of the objective
$W^{+}i$, j: relative weight of $d^{+}i$ in the rank order y
$W^{+}i$, s: relative weight of $d^{-}i$ in s order and there are m objectives, constraint function p, and decision-making variable n.

The identification is done based on the changes of target or desired scenarios including (i) Obtaining solutions for the basic condition based on the existing input-output coefficients and the demand of food consumption by using one-third of the total land area in each province (basic scenario); (ii) Making income the primary priority. In this case, the income is targeted to reach 100% by maintaining other conditions as they are in (a) (basic scenario); (iii) Making higher employment the priority. It is aimed to boost the number of labors to 50% by maintaining other conditions as they are in (a) (basic scenario). There are different priorities of employment for each growing season (GS) namely Priority I for growing season I, Priority II for growing season II, and Priority III for growing season III; (iv) Making capital/investment the priority. It is done by maintaining other conditions as they are in (a) (basic scenario). In this case, the capital reduces to 50% from the original state; and (v) Putting Scenarios I, II, III, and IV into priority scales. The orders are increasing income, boosting the employment rate, and limiting the capital.

3.4.1. Decision variables, constraint and target formulation

The decision variable used in this model is the planting area of five food crop commodities. The decision variable is limited to several food crops that are recommended by previous researchers to be developed in four provinces. They are corn, soybean, mungbean, peanut, and rice.

Constraint and Target Formulation

(i) **Land**

The land area limits the objective. The area that is provided by each r province is j, and the commodity that is going to be developed is i. The developing commodity cannot exceed the land area (L), so the formulation is as follows.

$$\sum_{i=1}^{n} X_{ij} \leq i_j$$

In which, i = commodity type, and j = province area;

(ii) **Employment**

The labour hired for production is grouped into three growing seasons, namely GS I, GS II, and GS III. In this case, the employment rate is the average number of labours that are needed per hectare for each growing season. If the average number of labours needed to grow the commodity in each province X_{ij} is e_{ij} (i indicates the commodity type, and j is province j) and the employment that is provided in each province is Ej_{TK}, the labour constraint can be formulated as follows.

Growing-Season I:

$$\sum_{i=1}^{n} x_{ij}\, ea_{ij} + d_{j2}^{-} - d_{j2}^{+} = Eaj_{TK,} \tag{3}$$

The objective is to minimize d_{j2}^{-}

Growing Season II:

$$\sum_{i=1}^{n} x_{ij}\, eb_{ij} + d_{j3}^{-} - d_{j3}^{+} = Ebj_{TK,} \tag{4}$$

The objective is to minimize d_{j3}^{-}

Growing Season III:

$$\sum_{i=1}^{n} x_{ij}\, ec_{ij} + d_{j4}^{-} - d_{j4}^{+} = Ecj_{TK,} \tag{5}$$

The objective is to minimize d_{j4}^{-}.

(iii) **Capital/Investment**

If the capital that is needed per hectare in commodity-type i in province j is q_{ij}, and the capital that is provided in each province is Qj_T, the capital constraint is defined as follows.

$$\sum_{i=1}^{n} x_{ij}\, q_{ij} + d_{j5}^{-} - d_{j5}^{+} = Qj_{T,} \tag{6}$$

The objective is to minimize d_{j5}^{+}.

(iv) **Comparative Advantage**

If B_i is a comparative advantage that becomes the domestic resource coefficient (DR) of an agribusiness (1 ha) in commodity $X_{i,}$ in dollars or rupiahs, DR is the efficiency target of the domestic resource of the agribusiness. If it is equal to 1 and the comparative advantage is closer to 1, the constraint is formulated as follows.

$$\sum_{i=1}^{n} B_{ij}\, x_{ij} + d_{j6}^{-} - d_{j6}^{+} = 1 \tag{7}$$

The objective is to minimize d_{j6}^{-};

(v) **Income**

If the income gained from a hectare of land with commodity i in province j is X_{Ij}, and the income target is Qj_T, the constraint is formulated as follows.

$$\sum_{i=1}^{n} x_{ij}\, qj_{pi} + d_{j7}^{-} - d_{j7}^{+} = Qj_p \tag{8}$$

The objective is to minimize d_{j7}^{-}.

(vi) **Need for Food Consumption**

Each province has a food consumption target that is marked by the obligation to provide one-third of their agricultural land area to grow rice. The land area of each province is Xj_{ip}, and the provided land is 1/3 L, so the formation is as follows:

$Xj_{ip} = 1/3Lj_{pt}$.

The scenario to decide the land allocation for each commodity in each province is displayed in Table 5.

3.4.2. Measurement of constraint coefficient and limiting constraint

The variable measurement used in this study is as follows:

(i) The land area: it is the land area in each province that is provided for the agricultural purpose. The unit of measurement is a thousand hectares;
(ii) The employment rate: it is the number of labours for each commodity provided for each growing season: I, II, and III per hectare in each province. The province defines the employment rate which needs to be fulfilled. The unit of measurement is a thousand Man-Days;
(iii) Capital/investment; it is the value of money that is needed to produce each commodity per hectare in each province. Each province has a different income target. The unit of measurement is million rupiahs;
(iv) Income; it is the earnings gained by each commodity per hectare in each province. Each province has a different income target that they have to meet. The unit of measurement is million rupiahs;
(v) Food consumption needs; it is the minimum physical need that should be provided by each province. One-third of the total agricultural land area in each province should grow food crops. The unit of measurement is a thousand hectares, and
(vi) Comparative Advantage; it is measured by the domestic resource coefficient of an agribusiness in dollars or rupiahs (1 ha). The comparative advantage target can be achieved by coefficient 1.

4. Results and discussion

Based on the analysis results of the basic scenario and scenarios I, II, III, and IV, the summary of optimal solutions for all scenarios are displayed in Table 6.

The results and discussion of Table 6 informs the proposed commodities for each province. The change in planting area composition is shown in the scenarios. According to the scenarios, the optimal solutions for land use in each province are as follows: (i) East Java province: the basic scenario chooses corn, peanut, and rice, whereas in Scenario I is peanut and rice. Corn, peanut, and rice are picked in Scenario II. Meanwhile, in the last scenario, corn, and rice are selected; (ii) South Sulawesi province: the appointed commodities in the basic scenario, Scenarios I and II are corn and rice. Despite the same types of commodities, the optimum planting area varies greatly (Ditzler et al., 2018, 2019; Osama et al., 2017; Sedami et al., 2017; Verger et al., 2019). In addition, soybean and rice are elected in Scenario III; (iii) West Nusa Tenggara province: mungbean, peanut, and rice are three selected commodities in the basic and second scenarios, while the first and fourth scenarios decide to appoint corn and rice. The third scenario picks soybean and rice; and (iv) Central Java province: in the basic scenario, there are two commodities, namely soybean and mungbean. The lone commodity of Scenario I is the mungbean. Furthermore, corn, mungbean, and rice are chosen in Scenario II. Scenario III has two commodities: mungbean and rice. Last but not least, Scenario IV takes corn and rice.

Regarding the types of food crop commodities introduced in each province, the explanation is shown as follows: (i) East Java province: the planting area for soybean will appear as the only choice when the planner or policymaker chooses Scenario IV (the priority combination), whereas other scenarios are zero. When the basic, second, and third scenarios are chosen, corn becomes an alternative commodity to develop. If the priority is increasing the employment rate, the second priority is picked (Francis et al., 2017; Haryanto et al., 2016). This is really important to be implemented in the middle of coronavirus because the employment rate remains increasing despite the pandemic. However, if the capital is getting limited, the third scenario will be implemented (Smith et al., 2017; Zolin et al., 2017).

In all scenarios, the mungbean is not an option. When choosing basic, first, and second scenarios, peanut becomes the only option to choose. Rice always appears as an option in all scenarios because of the obligation to grow rice in one-third of the total area of the province; (ii) South Sulawesi province: As the planner picks Scenario III, soybean appears as an option to choose. In addition, corn almost becomes a choice in all options, except in Scenario III. However, in all scenarios, mungbean and peanut do not come up at all. In contrast, rice always becomes an option in all scenarios; (iii) West Nusa Tenggara province: in basic, second, and third scenarios, soybean always emerges as an option. Meanwhile, corn will only appear if scenario I and IV are chosen. However, there is no mungbean in all scenarios. When the basic and second scenarios are implemented, peanut can be chosen as an option.

Similar to two explanation above, rice always exists as the option in all scenarios; and (iv) Central Java province: when the basic scenario is implemented, the only alternative option is soybean. Corn becomes an option if Scenario II and IV are carried out. However, mungbean has always been an option in all scenarios, except Scenario IV. In contrast, peanut does not appear in all scenarios. Last but not least, Scenario II, III and combination have rice as their alternative option (Daulay et al., 2016a; Osama et al., 2017).

According to Table 6, the amount of total income can be calculated when a different scenario is implemented. Besides, the employment rate and the amount of capital needed to grow the selected commodity can also be predicted (Ciliberti and Frascarelli, 2018; Daulay et al., 2016b). Table 7 shows the results of the employment rate, capital, and income gained when five different scenarios are implemented.

The results and discussion of Table 7 are as follows: (i) The employment rate in different scenarios is generally similar. The employment rates in the basic scenario and Scenario II are higher than in other

Table 5. The scenario for food crop commodity development policy.

Scenario	Policy Parameter
Basic Scenario	The original model (basic model)
Scenario I	The priority is the income, in which the income target increases to 100%
Scenario II	The priority is the employment rate, in which the employment rate target increases to 50%
Scenario III	The priority is the capital/investment, in which the capital target reduces to 50%
Scenario IV	The combination of Scenarios I, II, and III. The order of priority is income, employment rate, and capital.

Table 6. Results of the optimal solutions of all scenarios.

Decision variable	Areal optimal solution (in thousand hectares)				
	Basic scenario	Scenario I	Scenario II	Scenario III	Scenario IV
1. East Java province					
- Soybean (X1)	0	0	0	0	563.6
- Corn (X2)	214.15	0	214.15	622.57	0
- Mungbean (X3)	0	0	0	0	0
- Peanut (X4)	718.75	847	718.75	0	0
- Rice (X5)	285.9	285.9	285.9	285.9	285.9
2. South Sulawesi province					
- Soybean (X6)	0	0	0	255.42	0
- Corn (X7)	85.35	3.794	311.92	0	157.66
- Mungbean (X8)	0	0	0	0	0
- Peanut (X9)	0	0	0	0	0
- Rice (X10)	341.78	461.82	146.2	146.2	146.2
3. West Nusa Tenggara province					
- Soybean (X11)	73.74	0	47.27	299.97	0
- Corn (X12)	0	371.64	0	0	317.15
- Mungbean (X13)	0	0	0	0	0
- Peanut (X14)	288.12	0	371.32	0	0
- Rice (X15)	218.12	158.62	158.62	175.83	158.62
4. Central Java province					
- Soybean (X16)	290.11	0	0	0	0
- Corn (X17)	0	0	495.24	0	762.93
- Mungbean (X18)	1,273.23	1,424.13	477.86	1,431.22	0
- Peanut (X19)	0	0	0	0	0
- Rice (X20)	0	0	317.2	248.21	318.02

Table 7. Results of employment rate, capital, and income gained when five different scenarios are implemented.

Description	The selected scenario				
	Basic scenario	Scenario I	Scenario II	Scenario III	Scenario IV
1. East Java province					
- Employment rate	658	632	658	449	579
- Capital	5.054	5.053	5.054	2.786	2.373
- Income	7.216	6.076	7.216	7.154	5.203
2. South Sulawesi province					
- Employment rate	333	336	256	273	179
- Capital	2.176	2.176	1.779	1.360	1.198
- Income	2.734	2.547	2.734	2.018	1.756
3. West Nusa Tenggara province					
- Employment rate	359	319	343	313	290
- Capital	2.322	2.322	2.322	1.163	2.096
- Income	3.412	2.503	3.411	3.411	2.245
4. Central Java province					
- Employment rate	714	558	657	750	595
- Capital	4,996	4.549	4.549	5.790	3.832
- Income	7.577	6.253	7.580	7.580	7.580
Total of 4 provinces					
- Employment rate	2.058	1.842	1.908	1.782	1.640
- Capital	14.542	14.094	13.698	11.096	9.497
- Income	20.933	17.376	20.935	20.159	16.781

scenarios; (b) There is a tendency of the ratio of capital needed to produce the commodity in different scenarios (Defrancesco et al., 2018; Melesse et al., 2019). The capital needed in Scenarios III and IV is relatively lower than other scenarios; (iii) There is a tendency of the ratio of income gained in different scenarios. The highest income is in the basic, second, and third scenarios, and (iv) When the basic scenario is compared to Scenario IV, there is a shift of optimal solution of employment rate, capital, and income. The employment rate in Scenario IV is higher than the basic scenario. However, the capital needed in Scenario IV is lower than the basic scenario. The bigger income in the basic, first, and second scenarios, the higher employment rate, and income. The productive agricultural land will be utilized as the food crop agribusiness, particularly the leading commodity in Indonesia (Groot et al., 2016; Jat et al., 2019; Nasikh, 2017).

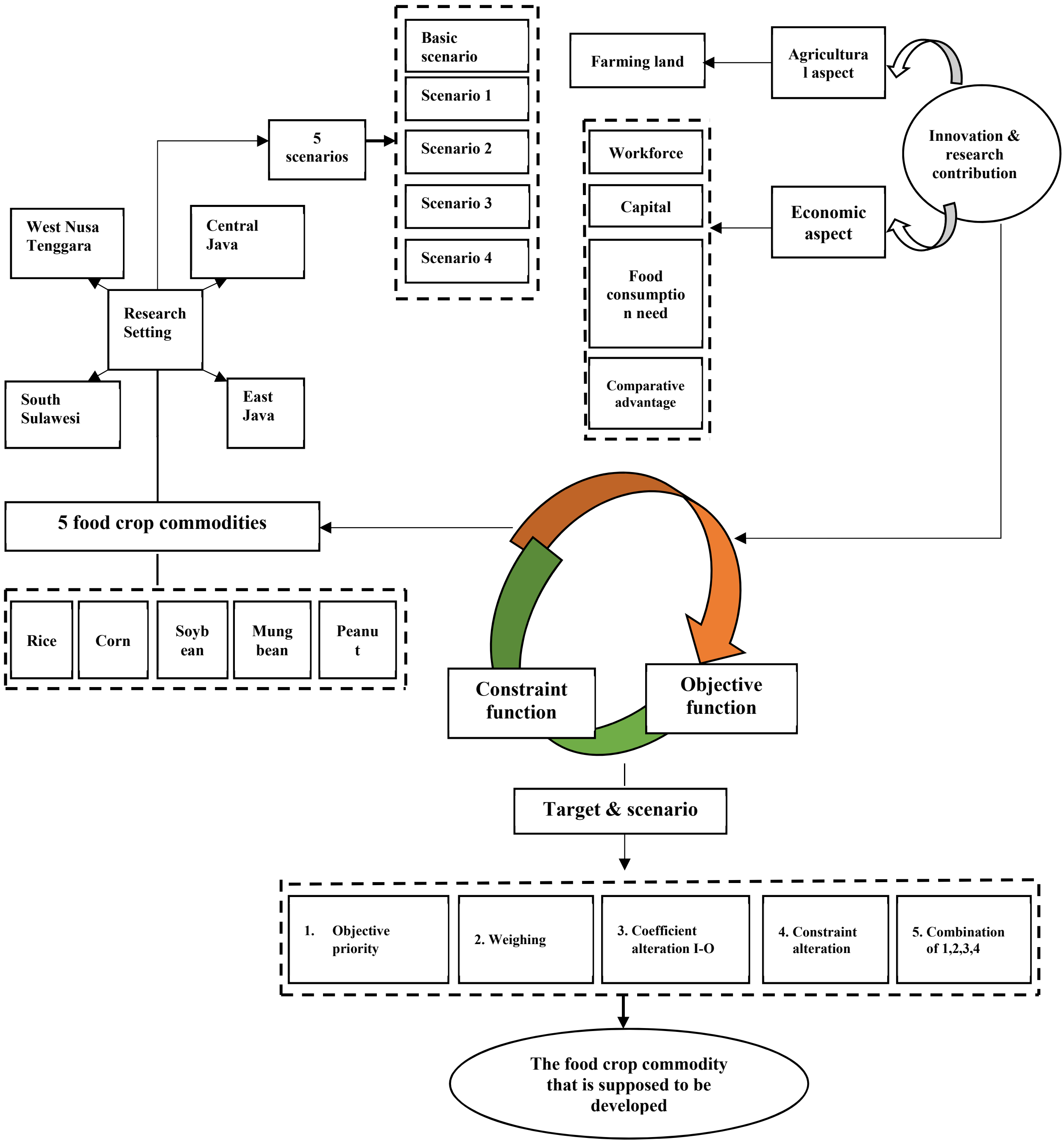

Figure 1. The agricultural land resource allocation to develop the food crop commodity in Indonesia.

There are some determinants that should be considered when utilizing the land that applies sustainable farming in the reformation era. They include the environmental condition, land resource, change of agricultural climate, and social economy. The land productivity assessment requires knowledge about types of soil, its distribution, and its input to solve and improve its productivity and its response towards the technology application (Haryanto et al., 2019; Soltani et al., 2013).

The utilization and improvement of the agricultural land resource should be well-planned, particularly in agricultural development. As a result, researches should be reviewed to improve and develop agricultural land resource allocation to achieve sustainable agricultural development. At the national level, the main target of developing agricultural land resources is to achieve some objectives. First, it is to determine the provinces that give the most biological, social, and economic benefits of a commodity. Next, it aims to choose commodities that contribute biotic, social, and economic benefits to a province. Third, it is to improve and conserve the productivity of a commodity in a province. They become an approach to the agricultural development system whose principle is the integration of commodity, region, and agribusiness.

The agricultural development is directed to effective and efficient commodity production to meet the market's demand (the leading commodity). It is also addressed to increase the employment rate, carry out effective and efficient capital investment, and implement a sustainable and equitable agricultural system (Groot et al., 2016; Jat et al., 2019).

In the context of sustainable agricultural development, the agricultural land resource should be utilized in a pattern that guarantees the living environment sustainability, maintains the biological balance, and improves the land resource quality. Sustainable agricultural development means that agricultural land can be utilized continuously, and it applies effective and efficient agricultural land utilization.

The agricultural development should be directed by increasing business productivity, fully utilize and coping agricultural science and technology, and improve human resource quality in order to maintain and improve the comparative advantage of agricultural production as well as to broaden agricultural activities. In line with the agricultural development, there are several main attempts to be implemented sustainability, namely (1) diversification, (2) intensification, (3) extensification, and (4) rehabilitation. It should also be supported by agroclimatic, spatial patterns, environmental sustainability, development in other sectors, the social and economic condition of local communities and supported by advanced technology. Land degradation occurred if the land resource is not utilized based on its potential and proper management techniques. The environmental damage will eventually make it difficult to manage the land for various agricultural commodities in the free-trade area or globalization (Haryanto et al., 2019; Ruel et al., 2018). The analysis result and research finding of this study is shown in the form of a flowchart as follows (see Figure 1).

5. Conclusion

In this study, multiple objective programming (MOP) has been employed in the planning of optimal land resource allocation for crops in Indonesia. This study established five scenarios such as basic scenario, I, II, III, and IV. The basic scenario emphasizes physical and economic conditions, where there is a constraint that limits the development: the land area to grow the rice is only one-third of the total agricultural area in each province. Therefore, the suggested commodity is as follows; (i) East Java province: corn (214.15 thousand hectares), peanut (718.75 thousand hectares), and rice (285.9 thousand hectares); (ii) South Sulawesi province: corn (85.35 thousand hectares), and rice (341.78 thousand hectares); (iii)West Nusa Tenggara province: corn (73.74 thousand hectares), peanut (288.12 thousand hectares), and rice (218.12 thousand hectares); and (iv) Central Java province: soybean (290.11 thousand hectares), and mungbean (1,273.23 thousand hectares).

While Scenario I prioritize the increasing income to 100% when other components are similar to the basic scenario. The suggested commodity in this scenario, such as (i) East Java province: peanut (847 thousand hectares), and rice (285.9 thousand hectares); (ii) South Sulawesi province: corn (3.794 thousand hectares) and rice (461.82 thousand hectares); (iii) West Nusa Tenggara province: corn (371.64 thousand hectares), peanut (286.72 thousand hectares) and rice (158.62 thousand hectares); and (iv) Central Java province: mungbean (1,424.13 thousand hectares).

About fifty percent increasing employment rate becomes the priority of Scenario II. Other components are still similar to the basic scenario. Consequently, the suggested commodity is as follows; (i) East Java province: corn (214.15 thousand hectares), peanut (718.75 thousand hectares), and rice (285.9 thousand hectares); (ii) South Sulawesi province: corn (311.92 thousand hectares) and rice (146.2 thousand hectares); (iii) West Nusa Tenggara province: soybean (47.27 thousand hectares), and peanut (371.32 thousand hectares); and rice (158.62 thousand hectares); and (iv) Central Java province: corn (495.24 thousand hectares), mungbean (477.86 thousand hectares), and rice (317.2 thousand hectares).

Scenario III highlights a fifty percent reduction in capital/investment. Other components are similar to the basic scenario. Therefore, the suggested commodity is as follows: (i) East Java province: corn (622.57 thousand hectares), and rice (285.9 thousand hectares); (ii) South Sulawesi province: soybean (255.42 thousand hectares) and rice (146.2 thousand hectares); (iii) West Nusa Tenggara province: soybean (299.97 thousand hectares) and rice (175.83 thousand hectares); and (iv) Central Java province: mungbean (1,431.22 thousand hectares) and rice (248.21 thousand hectares).

Scenario IV is a combination of three scenarios. Its order of priority is the income increased to 100%, employment rate escalating to 50%, and capital/investment reducing to 50%. In regards to the priority, the suggested commodity is as follows: (i) East Java province: soybean (563.6 thousand hectares) and rice (285.9 thousand hectares); (ii) South Sulawesi province: corn (157.66 thousand hectares) and rice (146.2 thousand hectares); (iii) West Nusa Tenggara province: corn (317.15 thousand hectares) and rice (158.62 thousand hectares); and (iv) Central Java province: corn (762.93 thousand hectares) and rice (318.02 thousand hectares).

Declarations

Author contribution statement

Nasikh Nasikh, Mahirah Kamaludin, Bagus Shandy Narmaditya and Agus Wibowo: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Indra Febrianto: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data included in article/supplementary material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

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