A COMBINATION ECONOMICS APPROACH, EQUITY, AND SCIENCE AND TECHNOLOGY CAPACITY FOR ESTABLISHING PROVINCIAL COMMODITY PRIORITIES FOR AGRICULTURAL RESEARCH: AN ALTERNATIVE FOR RESEARCH PRIORITY SETTING

Kombinasi Pendekatan Ekonomi, Pemerataan, dan Kapasitas IPTEK untuk Menetapkan Prioritas Komoditas Provinsi untuk Penelitian Pertanian: Alternatif Penetapan Prioritas Penelitian

Marhendro

Associate Faculty Member, Binus Business School, Bina Nusantara University
Jl. Raya Kb. Jeruk No. 27, Kebon Jeruk, Jakarta Barat, Jakarta, Indonesia
Telp. (021). 5435830, Fax. (021). 5435830
E-mail : marhendro@binus.ac.id

(Makalah diterima, 19 November 2021 – Disetujui, 03 Juni 2022)

ABSTRAK

Penelitian pertanian merupakan kunci dalam mendukung keberhasilan pembangunan pertanian. Meskipun penelitian mempunyai peranan yang penting, namun keterbasan sumberdaya institusi pertanian akan mendorong untuk hanya melaksanakan penelitian yang pririoritas saja yang dilaksanakan. Hal ini tidak saja terjadi di negara berkembang, namun terjadi juga di negara maju. Oleh karena itu, study ini bermaksud untuk memberikan alternatif dalam menyusunan prioritas komoditas untuk diteliti di tingkat provinsi, Hal ini mengingat Indonesia mempunyai wilayah yang sangat luas, sehingga sumberdaya alam dalam mendukung pengembangan komoditas juga berbeda-beda di masing-masing provinsi. Dalam, penyusunan prioritas komoditas untuk diteliti pada studi ini, ada tiga aspek yang menjadi pertimbangan yaitu pendedekatan ekonomi, keadilan, dan kapasitas ilmu dan teknologi. Untuk melaksanakan pengujian model ini dipilih Provinsi Jawa Barat dan Jawa Timur, dengan empat komoditas yaitu padi, jagung, kedelai dan ketela pohon.

Kata kunci: penyusunan prioritas, komoditas, padi, jagung, kedele, ketela pohon

ABSTRACT

Agricultural research is key in supporting the success of agricultural development. Although research has an important role, the limited resources of agricultural institutions will encourage only priority research to be carried out. This is not only happening in developing countries, but also in developed countries. Therefore, this study intends to provide an alternative in prioritizing commodities to be researched at the provincial level. This is because Indonesia has a very large area, so that natural resources in supporting commodity development are also different in each province. In setting commodity priorities for research in this study, there are three aspects to be considered, namely the economic approach, justice, and the capacity of science and technology. To carry out the testing of this model, West Java and East Java provinces were selected, with four commodities, namely rice, corn, soybean and cassava.

***Key words:** priority setting, commodity, rice, corn, soybean, casava*

INTRODUCTION

The agricultural research and development in Indonesia were used to be carried out by various institutions. Among others, these include the Agency for Agricultural Research and Development (IAARD) under the Ministry of Agriculture, Indonesian's Institute of Sciences (LIPI), Agency for Science and Technology Assessment (BPPT), Agency for Atomic Energy Research (BATAN), and Universities. Based on the Presidential Decree Presidential Decree No. 78/2021, The **National Research and Innovation Agency** (*Badan Riset dan Inovasi Nasional*, BRIN) was established, a new non-ministerial government agency directly under the President of Indonesia. Therefore, the agency will become the sole national research agency of Indonesia.

Up to now, the government investment still plays major role in agricultural research. There are some economic rationales behind this phenomenon. In general, Alston and Pardey (1996) stated that since those who invest in agricultural research cannot capture all benefits, while the others can "free ride" in agricultural research investment, private benefits to investors are less than social benefits of the investment and as a result some socially profitable investment opportunities remain unexploited. Therefore, if private returns are less than returns to society as whole, the private sector will under-invest in agricultural research.

Declining government budget for agricultural research has begun to appear (Just and Huffman, 1992). It was noted that federal funds provided to state agricultural experiment stations (SAES) in the United States have been declining over the past 15 years. For Indonesia, this can be seen from the trend declining budget allocated to research activities by IAARD. In fiscal year 2012 it was Rp. 191.8, Rp. 293.2 Billion in the year 2013 but declined to only Rp. 173.6 Billion in Year 2014, in 2015 (Rp. 204.1 Billion), 2016 (Rp. 273.2 Billion), 2017 (Rp. 180.5 Billion), 2018 (Rp. 259.3 Billion) and 2019 (Rp. 134.5 Billion (IAARD Statistics 2012-2019)

Declining budget in real terms, financial crisis and other economic and political problems faced by Indonesia now make it imperative for its agricultural research institutions to be more efficient in using their scarce resources. This phenomenon, as a matter of fact, is not true for developing countries alone, but also for developed countries (Norton, et al, 1992). Indeed, as stated by Anderson (1992), there is no area where the resources are not scarce.

Moreover, increasing demand for other economic research programs, such as the broad-based societal interest in protecting environmental quality in ensuring sustainability of natural resources and in improving the economic status of the underprivileged is a major challenge faced by agricultural research institutions (Sundquist, 1992). Another challenge is to create explicitly pro-poor research strategy for the public sector (Hazell and Haddad, 2001). Consequently, research administrators in both developed and developing countries are increasingly seeking priority-setting procedures to help in solving the often-conflicting demands of constituency groups to achieve optimal result of the investment (Norton, et al, 1992).

Resources for agricultural research are scarce. For the public research institutions, agricultural research administrators will finally be asked to provide evidence that the costs of their operation are justified by the benefits to the public. Therefore, only the prioritized research programs for the priority commodities of research institutions should be funded both at provincial and national levels. The main objective of this study was to develop a provincial commodity prioritization scheme for Indonesia that allows an improvement of measurement of research benefits.

RESEARCH METHODOLOGY

This study is intended to model the geo-politically provincial commodity priorities for agricultural research based on three criteria, namely, economic efficiency, equity and the science and technology capacity. The analysis of economic efficiency involved the calculation of economic surplus and benefit-cost analysis. Benefit-cost ratio of research program was calculated to project efficiency gain over the lifetime of the technology resulting from research for different commodities in each of the geo-political province.

Based on the study of Pingali and Pandey (2001), poverty alleviation and subsistence status are important equity issues for research prioritization. According to Braunschweig and Reyes (2000), another important issue that should be included in the setting of priorities of agricultural research is the science and technology capability of research institutions. Therefore, these issues were addressed by incorporating appropriate indicators in the setting of priorities.

The highest rank of priority is given to the commodity with the highest value of economic surplus as a result of the research-induced supply shift and the exogenous demand shift, equity and the science and technology capacity considerations.

The Model

The model developed for this study involves a partial equilibrium provincial market within which the economic benefits resulting from the research are measured in terms of the change in producer's surplus (PS), consumer's surplus (CS), and total economic surplus (TS). The demand for and supply of each commodity for each province within Java. as a sample location for the application of this model, were specified and shifted over time by the research and other factors. The assumptions used in this model are as follows:

- Linear demand and supply functions define a single commodity market framework with no linkages to other commodity markets via cross-price elasticities
- Trading activities are limited to the different geo-politically provincial markets within Indonesia, disregarding the export and import activities with other countries. This leads to a closed economy situation so that the quantities and prices are determined internally.
- Provincial markets are connected via price spillover effects. The selected commodities in this study are assumed to be traded in significant quantities and over the long distances across the provinces Therefore, research-induced changes in provincial production and prices will possibly affect the quantities and prices of other provinces.
- The dynamic elements of agricultural research are explained by the specific time profiles for technology generation and adoption, variable prices across the provincial markets, and multiple periods to aggregate annual economic gains over time (30 years). The time-bound of 30 years usually used by previous studies (Alston, *et al* 1995), Mills (1997), and Mills (1999) was corrected depending on the lifetime of the technology resulting from research.
- Exogenous demand and supply growth contributed by the increase of population and other non-research related factors that influence the production are incorporated in this study.

Based on the above assumptions, the algebraic presentation of the model is as follows:
General form of supply and demand for a single commodity (Alston, *et al* 1995):

Supply: $$Q_{i.t} = \alpha_{i.t} + \beta_i PP_{i.t} \quad (1.a)$$

Demand: $$C_{i.t} = \gamma_{i.t} + \delta_i PC_{i.t} \quad (1.b)$$

where $Q_{i.t}$ is the quantity produced in province *i* at year *t*, $PP_{i.t}$ is the producer price in province *i* at year *t*, $C_{i.t}$ is the quantity consumed in province *i* at year *t*, $PC_{i.t}$ is the consumer price in province *i* at year *t*.
For $t = 0$

Supply: $$Q_{i.0} = \alpha_{i.0} + \beta_i PP_{i.0} \quad (2.a)$$

Demand: $$C_{i.0} = \gamma_{i.0} + \delta_i PC_{i.0} \quad (2.b)$$

The initial intercepts and slopes of the supply and demand curves for province i above are:

$$\beta_{i.0} = \frac{\varepsilon_i Q_{i.0}}{PP_{i.0}} \quad (3.a)$$

$$\alpha_{i.0} = (1-\varepsilon_{i.0})Q_{i.0} \quad (3.b)$$

$$\delta_{i.0} = \frac{\varepsilon_i C_{i.0}}{PC_{i.0}} \quad (3.c)$$

$$\gamma_{i.0} = (1-\eta_{i.0})C_{i.0} \quad (3.d)$$

where $\varepsilon_{i.0}$ is the elasticity of supply in province *i* at $t = 0$, and $\eta_{i.0}$ is the elasticity of demand in province *i* at $t = 0$.

To incorporate the exogenous growth of supply because of growth in productivity or increase in area planted, and of demand because of the increase in population and income that is expected to occur regardless of whether or not the research program is undertaken, the intercepts of equation (1.a) and (1.b) can be stated as:

$$\alpha_{i.t} = \alpha_{i.t-1} + \pi_i^Q Q_{i.t} \quad (4.a)$$

$$\gamma_{i.t} = \gamma_{i.t-1} + \pi_i^C C_{i.t} \quad (4.b)$$

where π_i^Q is the growth rate of supply not attributable to research and π_j^C is the growth rate of demand (i.e. increase in population, income, etc.).

The important variable in determining research-induced supply shift, $K_{.t}$, is measured as the percentage change in cost per unit measurement of output. $K_{.t}$ can be obtained by dividing the absolute reduction in costs per unit measurement in output, k_t, with the current producer price $PP_{j.0}$.

k_i. can be calculated by using the following formula (Alston *et al*, 1995, p 360):

$$k_{j.t} = \left[\frac{E(Y_j)}{\varepsilon_j} - \frac{E(C_j)}{(1+E(Y_j))} - s_j E(F_j)\right] p_j A_{j.t} (1-d_j)^t PP_{j.0} \quad (5)$$

where for particular commodity *j*, $E(Y_j)$ is expected increase in value of output after the new technology has been adopted, ε_j is supply elasticity for commodity *j*, $E(C_j)$ is proportionate change in variable input cost per hectare to obtain the expected yield change, s_j is fraction of fixed costs to pre-research costs per ton, $E(F_j)$ is proportionate change in fixed costs, p_j is probability of research success to achieve the expected yield change, A_j is the adoption rate defined in relation to years, *t*, from commencement of research, and $(1-d_j)$ is depreciation factor.
Therefore,

$$K_{jt} = \frac{k_{j.t}}{PP_{j.0}} \quad (6)$$

One of the issues related to the economic surplus approach, as presented by Alston and Pardey (2001) is that the government activities in agricultural research can have positive impact on the private sector research activities. The study by Alfranca and Huffman (2001) shows that public agricultural research in the European countries competes with the private sector agricultural research. In other words, the public agricultural research crowds out private agricultural research. To address this, the measurement of benefits of public agricultural research should be modified to incorporate this issue.

There are three approaches for integrating the contribution of private sector research. The first approach assumes that there is no technology resulting from private sector research programs applied in the areas under the study. It means that all areas in the provinces under the study only apply technology resulting from public sector research. Therefore, the vertical supply curve shift is based on the research resulting from public sector research, *k*. All benefits from research, therefore, are attributed to the public sector research. In other words, the public sector research investment 'wins' in the competition with private sector research investment. This is true for rice, soybean, and cassava because the technologies applied to these commodities in Indonesia resulted from public sector research investment.

In this approach, by assuming a particular province as the "domestic" province (province A) and the other provinces in Indonesia as the "rest of provinces' (ROP) depicted in Figure 2, and following the presentation of Alston, *et al* (1995, pp 216-217), and by considering only a one-shot comparative static analysis on a particular commodity, the supply curves can be stated as follows:

Province A Supply: $Q_A = \alpha_A + \beta_A P$ (7.a)

Incorporating k in equation (5.7.a):

$$Q_A = \alpha_A + \beta_A(k + P) = \alpha_A + \beta_A k + \beta_A P \quad (7.b)$$

The second approach assumes that some parts of the area under study apply technology resulting from private sector research. This assumes further that there is no difference between imported or domestically generated technology. The estimated benefits of research, therefore, should be attributed to both public and private sector research. To calculate the benefit of public sector research, the vertical supply curve shift, k_i. of public sector research is subtracted by the vertical supply shift, Θ_t. , of private sector research. Θ_t is computed using equations 5 and 6. This implies that the public sector investment 'lose' in that area. This can be calculated through two possibilities.

The first possibility is based on the benefits approach. In order to get the supply curve shift Equation 7.a1 is modified to be:

$$Q_A = Q_{Apub} - Q_{Apriv}$$

Where: $Q_{Apub} = (\alpha_{Apub} + \beta_A k) + \beta_A P$ (7.a2)

$$Q_{Apriv} = (\alpha_{Apriv} + \beta_A \theta)) + \beta_A P$$

The second possibility which is the one adopted in this study is based on the area approach. This means that the areas dominated by private sector research are removed. The rest of the areas are used a basis for calculating the benefit of public sector research based on the Alston, *et al* (1995) model. This is true for the case of corn where the high yielding varieties resulting from private sector research are successfully and actively planted in some areas in the provinces under study. The equation 7a1 is modified to be:

$$Q_A^* = \alpha_A^* + \beta_A k + \beta_A P \quad (7.a3)$$

where $Q_A^* = A_A^*. Y_A^*$

$\alpha_A^* = \alpha_{Apublic} - \alpha_{Aprivate}$

A_A^* is the area dominated by public sector research

Y_A^* is average yield of the area dominated by public sector research.

Province A Demand:

$$C_A = \gamma_A - \delta_A P \quad (7.b)$$

Rest of Province (ROP) Supply:

$$Q_B = \alpha_B + \beta_B P \quad (7.c)$$

Rest of Province (ROP) Demand:

$$C_B = \gamma_B - \delta_B P \quad (7.d)$$

Since export and import are disregarded (closed-economy situation), therefore,

$$Q_A + Q_B = C_A + C_B \quad (8)$$

The formula is adopted from Alston et al 1995, p 217, Box 4.2. The original assumption of the formula is an "open-economy". However, in this study, the term "close- economy" is used to describe that the study is only confined in the Indonesian economy. Equation (8) shows that the quantity consumed is equal to quantity supplied. Suppose import or export is included, import/ export has to be added in both sides of equation (8) in order to ensure that the quantity consumed is equal to quantity supplied. Therefore, import/export can be canceled out.

$Q_A + Q_B + I/E = C_A + C_B + I/E$, since I/E is canceled out, then:

$Q_A + Q_B = C_A + C_B$

Solving for P:

$$P = \frac{\gamma_A + \gamma_B - \alpha_A - \alpha_B - \beta_A k}{\beta_A + \gamma_A + \beta_B + \delta_B} \quad (9)$$

For $k = 0$, equation (9) will be:

$$P = P_0 = \frac{\gamma_A + \gamma_B - \alpha_A - \alpha_B - \beta_A}{\beta_A + \gamma_A + \beta_B + \delta_B} \quad (10)$$

For $k = KP_0$, equation (9) will be:

$$P = P_1 = \frac{\gamma_A + \gamma_B - \alpha_A - \alpha_B - \beta_A KP_0}{\beta_A + \gamma_A + \beta_B + \delta_B} \quad (11)$$

Thus, the change in price is:

$$P_1 - P_0 = \frac{-\beta_A KP_0}{\beta_A + \gamma_A + \beta_B + \delta_B} \quad (12)$$

Dividing equation (12) by P_0 and multiplying through the numerator and denominator by P_0 / Q_{A0} and converting to elasticity, the result is

$$Z = -\frac{P_1 - P_0}{P_0} = \frac{\varepsilon_A K}{\varepsilon_A + s_A \eta_A + (1 - s_A)\eta_B^E} \quad (13)$$

where Z is the absolute value of the relative change in price, η_B^E is the elasticity of excess-demand curve of ROP defined as $\eta_B^E = \frac{(\beta_B + \delta_B)P_0}{C_{B.0} - Q_{B.0}}$ and used, considering the fact that the traded quantity, $QT_0 = C_{B.0} - Q_{B.0} = Q_{A.0} - C_{A.0}$.

Therefore, the welfare effects to Province A are:

- Province A consumer's surplus change is similar to the closed economy, so that
  $\Delta CS_A = P_o C_{A.0} Z (1 + 0.5 Z_\eta)$ (14.a)
- Province A producer's surplus change is:
  $\Delta PS_A = P_o Q_{A.0} (K - Z) (1 + 0.5 Z\varepsilon_A)$ (14.b)
- Total economic surplus change is
  $\Delta TS_A = \Delta CS_A + \Delta PS_A$ (14.c)
- For ROP, surplus change is:
  $\Delta TS_B = P_o QT_0 Z (1 + 0.5 Z\eta_B)$ (14.d)

Similar answers will be obtained by substituting Z for $E(P_{d.j}) = E(P_{s.j}) = Z$, where $E(P_{d.j})$ is expected demand price of commodity j, and $E(P_{s.j})$ is expected supply price of commodity j, and by defining $E(Q_{d.ij}) = Z\eta_i$ and $E(Q_{s.A}) = \varepsilon A (K - Z)$ and $E(Q_{s.B}) = Z\varepsilon_B$. The disaggregated ROP welfare effects would be as follows:

- The change of consumer's surplus of ROP is:
  $\Delta CS_B = P_o C_{B.0} Z (1 + 0.5 Z\eta_B)$ (15.a)
- The change of producer's surplus of ROP is
  $\Delta PS_B = P_o Q_{B.0} Z (1 + 0.5 Z\varepsilon_B)$ (15.b)

Using equation (15.a) and (15.b), the total change of surplus is:

$\Delta TS_B = \Delta CS_B + \Delta PS_B$
$= P_o QT_0 Z (1 + 0.5 Z\eta^E_B)$ (5.15.c)

Equation (14.c) and equation (15.c) were used to calculate the research benefits (ΔTS_i) over time of both province A, (the province where research program originated), and the rest of provinces. Given the projected cost of research for the same years, net benefit of research program on a commodity can be summarized using the Benefit-Cost Ratio (BCR). BCR is the ratio of all future benefits discounted to the present value to all costs discounted to the present value.

Sources of Data and Method of Data Collection

Sources of Data for Efficiency Criterion

Based on the model presented in the previous section, the following data are required:

- Research-induced supply shift by public research (K_t) and by private research (θ_t.) of each commodity for a province.
- Market-related data,
- Research costs and discount rate.

The term "province *i*" in this study refers to geo-political province *i* or province *i* within Indonesia, whereas the rest of province (ROP) refers to all provinces within Indonesia less province *i*. Therefore, the term province, geo-political province, and province were used interchangeably in this study.

The required data included both primary and secondary data. Primary data were gathered by interviewing the key persons from various levels within the Indonesian Agency for Agriculture Research and Development (IAARD), and private research sector. Primary data were used in determining the research-induced supply shift, which is a crucial variable in this study.

Secondary data, especially market-related data, were collected from the various publications of both government and private institutions. Among others, these include the Central Bureau of Statistics, Ministry of Agriculture, Ministry State of Research Technology, and other secondary data sources.

Sources of Data and Method of Data Collection on Equity and Science and Technology Capacity Criteria

The data required for equity and science and technology criteria are as follows:

- Poverty index,
- Subsistence-farming index,
- Existing capacity,
- Scientific potential.

Poverty index is needed for the equity criterion. This is to give more weight to the commodity that will help alleviate poverty. Highest index is given to the commodity with highest ratio to the poverty line. The data required for this are cost structure for each commodity and poverty line for each province. The sources of both data were Cost Structure of Paddy and Secondary Food Crops are available at the Central Bureau of Statistics.

Subsistence-farming index is also needed for the equity criterion. This index is to modify the efficiency criterion by distributing the investment of agricultural research to the commodity that is more subsistence-oriented. Therefore, the highest weight is given to the commodity that has the lowest ratio of area planted to high yielding variety. Data on the area planted to high yielding variety of each commodity were available at the Directorate of Seed, Directorate General of Food Crop, Ministry of Agriculture.

Information on the existing capacity and scientific potential are needed for incorporating the science and technology capacity criterion. Indicators used for this criterion are number of PhD level scientists and number of senior researchers of each AIATs and RIs. The assumption employed in this criterion is that PhD level scientists have the absorption capacity of the crop research program, whereas the senior researchers implement the current research activities. Therefore, for the potential capacity, the highest rank is given to the commodity with highest ratio of PhD level scientists, whereas for the existing capacity, the highest rank is given to the commodity with the highest ratio of senior researchers. Data on the number of PhD level scientists and number of senior researchers can be gathered agricultural from the Ranking Staff (DUK), Personnel Division of IAARD headquarters.

Method of Analysis

This study employed a two-step analysis. In the first step, the benefit-cost ratio (BCR) approach was used to calculate the benefits of research over the costs. In the second step, the results of the first step calculation were used to establish commodity priorities using the Analytical Hierarchy Process (AHP). Two levels of funding were used as the hierarchy criteria (Taha, 1997).

Benefit-Cost Ratio (BCR)

This study used a spreadsheet to calculate economic surplus measures of streams of benefits and costs given the data collected for the variables outlined in the foregoing discussions. Data analysis included the conversion of benefits and costs into summary statistics using BCR.

Mathematically, BCR for commodity j can be calculated using the following formula (adapted from Gittinger, 1982):

For Province A:

$$BCR_{A.j} = \frac{\sum_{t=1}^{t} \frac{\Delta TS_{A.j}}{(1+t)^t}}{\sum_{t=1}^{t} \frac{\Delta C_{A.j}}{(1+t)^t}} \qquad (20.a)$$

For ROP:

$$BCR_{B.j} = \frac{\sum_{t=1}^{t} \frac{\Delta TS_{B.j}}{(1+t)^t}}{\sum_{t=1}^{t} \frac{\Delta C_{B.j}}{(1+t)^t}} \qquad (20.b)$$

Where r is the discount rate, C_{Aj} is the annual research cost of province A for commodity j expended to t years in the future and $C_{B.j}$ is the national annual research cost for commodity j less annual research cost of provincial A for commodity j expended to t years in the future.

Discounted net economic benefits were calculated for the λ_T years by using methods detailed in the previous section, specifically equations (20.a) and (20.b). Using equation (5.20.a) for provincial level and (5.20.b) for national level, the benefits of research were computed. The results of the computation were used as input for determining the commodity priorities using the Analytic Hierarchy Process.

Analytical hierarchy process (AHP). The second step involves the determination of the commodity priorities. This step used the AHP approach. The explanation of AHP approach was drawn heavily from the presentation of Braunschweig and Reyes (2000). According to Braunschweig and Reyes (2000), the AHP procedure is based on three principal steps, namely; (1) decomposition of a complex unstructured problem; (2) comparative judgments about its components; and (3) synthesis of priorities derived from the judgments.

- *Step one*

  Step one consists of breaking down the decision problem into hierarchical structure. The top level is the ultimate goal, that is, selecting the commodity priority for agricultural research. The second level is the decision criteria that are considered relevant to the ultimate goal. The third level consists of sub-criteria of each criterion that are considered relevant to each criterion. The bottom level is the alternative.
- *Step two*

  This consists of evaluating the commodity alternatives and weighting the criteria. The criteria are compared in pairs to define their importance with respect to the ultimate goal. The verbal terms of fundamental scale is presented in Table 4.1 that are used to assess the intensity of preference or possibility between two criteria and sub-criteria. Using relative comparisons and verbal terms can assist in weighting the criteria since the criteria and sub-criteria used are non-quantifiable elements. Once the verbal judgments are made, they are translated into numbers using the fundamental scale presented in Table 15. The alternatives are compared to assess their relative importance with respect to the criteria and sub-criteria. TASC (2001) shows that the alternatives can be quantitative and qualitative data. For this study, quantitative data were used to determine the alternatives' relative importance with respect to the criteria and sub-criteria.

- *Step three*

  This step determines the ultimate goal, that is, to set commodity priorities for agricultural research. Since, in this study, there are three criteria and two sub-criteria of each criterion applied to evaluate the alternatives, the local priorities must be combined considering the criteria weights. This synthesis can be done by multiplying the relative priorities of each alternative with the corresponding criteria weight and adding the result up to obtain the final composite priorities with respect to ultimate goal. Equations 4.20 and 4.21 summarize this procedure.

  Three criteria, namely; (1) efficiency (V_1), (2) equity (V^2), and (3) science and technology capability (V_3) of research institutions were used as hierarchy. Issues on equity and enhancing the scientific and technological capability of research institutions were included in the study.

  To rank four alternative decisions relating to the selected four commodities: rice, corn, soybean, and cassava, two sub-criteria of each criterion were used. Since these criteria are uncertain, they were judged by the respondents using questionnaire to determine their relative importance using pairwise comparison. Since there are three criteria, there is a 3 x 3 comparison matrix. Based on this matrix, eigenvectors (V_m) can be computed (TASC, 2001).

  Indicators that were used for every criterion are as follows:

  1. Sub-criteria current (S_{11}) and proposed funding (S_{12}) were used based on the BCR calculation.
  2. Poverty alleviation (S_{21}) is the ratio of income from commodity j to poverty line for province i.
  3. Subsistence status (S_{22}) is the share of area grown to traditional variety relative to the total area of commodity *j*.
  4. Existing capacity (S_{31}) is the ratio of senior researchers engaged in the research activities to the researchers working at a commodity under the study.
  5. Scientific potential (S_{32}) is the ratio of researchers with advance training (PhD) engaged in the research activities to the researchers working at a commodity under study.

The four alternative decisions were determined based on the economic efficiency, equity and science and technology capability of research institutions criteria of each of the four alternative decisions. For each sub-criterion *n* in the criterion *m* and commodity *j*, the formula is as follows:

$$P_{jn} = \frac{BCR_{jn}}{\sum_{j=1}^{4} BCR_{jn}} \qquad (5.21)$$

Therefore, the final priorities of the commodity can be computed using the following formula:

Final commodity priority: $P_j = \sum_{m=1}^{3}\sum_{n=1}^{2} V_{mn} S_{mn} P_{jmn}$ (5.22)

Where:

$\sum_{m=1}^{3} V_m = 1$ For sub-criterion *m*: $\sum_{n=1}^{2} S_n = 1$, $\sum_{j=1}^{4} P_{jn} = 1$

P_j = *final priority of commodity j.*
V_m = *weight of criterion m or eigenvectors m.*
S_n = *sub-criterion in the criterion m.*
P_{jm} = *priority of commodity j with respect to criterion m.*
j = *rice, corn, soybean, and cassava.*
m = *criterion efficiency and equity.*
n_1 = *sub-criterion (1) current, and (2) proposed funding.*
n_2 = *sub-criterion (1) poverty alleviation and (2) subsistence status.*
n_3 = *sub-criterion (1) existing capacity, and (2) scientific potential capacity*

RESULT AND DISCUSSION

The model has been tested by Marhendro (2003) where the study areas were confined in four provinces in Java, Indonesia, comprising of West Java, Central Java, Special Province of Jogjakarta and East Java, and four commodities, namely, rice, corn, soybean, and cassava. This provides a comprehensive provincial priority ranking of commodities for research. By comprehensive is meant that priority ranking of commodities takes all criteria and sub-criteria in an integrated manner using the analytic hierarchy process (AHP). The core of AHP is the determination of relative weights of the different criteria and sub-criteria to rank the decision alternatives.

Two comprehensive priority ranking alternative decisions based on the composite weight of each commodity is presented for each province. The first is a comprehensive priority ranking based on the assumption that public sector research investment is able to cover all areas planted to rice, soybean, and cassava. For corn, it is based on the assumption that the public sector research excludes the production areas dominated by private sector research. It means that the public sector research investment complements with the private sector and the public sector focuses their research activities in the production areas where the private sector research is not dominant. The second is a comprehensive priority ranking based on the benefit to other provinces resulting from price spillover due to the research-induced supply shifts in province or province where the technology was generated.

As the result of the study, provincial commodity ranking for research for four commodities and four provinces is presented in Table 1.

The above results show that rice is the first priority commodity in West Java, Central Java, and East Java based on the benefit of research to the province and Central Java and East Java based on the benefit to other provinces. It ranks second in Special Region of Jogjakarta based on the benefit to the province and in Special Region of Jogjakarta and West Java based on the benefit (loss) to other provinces. This is consistent with the current and proposed research priorities.

This result is understandable considering that rice is a staple food that is economically and politically important. Java accounts for more than 50 percent of the rice harvested area and more than 58 percent of rice production in Indonesia. The dominant role of Java in rice is due to the fact that most of irrigated areas in Indonesia are located in Java. This is why various programs launched by the government centered in Java. Besides, substantial investments for improving and expanding irrigation and other infrastructure have been established. However, the potential problem in the future regarding rice is the limited production area because of land conversion to non-agricultural uses while high cost is required for opening new rice lands in off-Java Island, among others. Therefore, research on rice is high priority.

Cassava ranks first in the Special Region of Jogjakarta based on the benefit to the province and to other provinces. It ranks second in West Java, Central Java, and East Java based on the benefit to the province and Central Java and East Java based on the benefit to other provinces. Cassava is cultivable in a wide range of soil and climatic conditions and resistant to pests and diseases. Because of these characteristics, production can be easily increased even in the absence of improved technologies. Considering the high potential of cassava for domestic consumption and export, research on this commodity is very important.

Soybean ranks third in West Java, Central Java, and the Special Region of Jogjakarta and fourth in East Java based on the benefit of research to the province. Based on the benefit of research to other provinces, it ranks third in the Special Region of Jogjakarta and fourth in other provinces. These are consistent with the current and future research priorities. The low priority of soybean is due to its currently low productivity. It needs longer intensity of light to produce maximum yields.

Based on the benefit of research to the province, corn only ranks third in East Java and fourth in other the provinces. Based on the benefits (loss) to other provinces, it ranks third in West Java, Central Java, and East Java. These are not consistent with the future research priority where it ranks second. The remarkable increase in the production and productivity of corn, especially in Central Java, the Special Region of Jogjakarta, and East Java is due to technologies resulting from private sector research. The role of multinational corporations in the development of the corn industry in Indonesia is widely

Table 1. Priority ranking of four commodities in four Provinces, Indonesia

APPROACH/ COMMODITIES	RANKING IN THE PROVINCES			
	West Java	Central Java	Special Region of Jogjakarta	East Java
Public Sector Research Benefit to the Provinces				
Rice	1	1	2	1
Soybean	3	3	3	4
Corn*)	4	4	4	3
Cassava	2	2	1	2
Public Sector Research Benefit to other the Provinces				
Rice	2	1	2	1
Soybean	1	4	3	4
Corn*)	3	3	4	3
Cassava	4	2	1	2

**) adjusted for private sector research benefit* known. However, these corporations only focus their activities to the most favorable areas for corn. That is why average productivity in these areas is much higher, at 10-12 tons/ha, than the national average productivity, at 2-3 tons/ha.

CONCLUSION

The results indicate that the existence of technologies developed by the private sector research in Java lowers the benefit of public sector research. However, this does not affect the priority ranking of commodities in all provinces. For West Java and the Special Region of Jogjakarta where the share of HYVs of corn developed by private sector has been high, corn has been in the last rank, even though the benefit of research after adjustment for the private sector research is still socially profitable. For corn-dominant provinces such as East Java and Central Java, since the share of HYV is very small, the existence of private sector technology does not affect much the benefit of public sector research. Therefore, the priority ranking of commodities based on public sector research benefit does not change.

These results imply that, for public sector research, there is room for developing corn technologies in Java. Furthermore, the public sector can focus its research in production areas where private sector research is not dominant, meaning, that public and private sectors can complement rather than duplicate or compete in their research efforts.

Limitations of the Study

There are three limitations relating to the methodology employed in this study.

First, uncertainty is inevitable in the estimation of research parameter in the ex-ante analysis. Only net yield increase has explicitly incorporated uncertainty by constructing a probability of success, even though it finally ended as a deterministic parameter. This can create some problems. One of them leads to a complete loss of information regarding the uncertainty and riskiness of research. There might be a problem for decision maker to assess, control and reduce the uncertainty of research.

Second, setting priority based on the benefit-cost ratio (BCR) may discriminate against projects with relatively high returns and high costs, even though these may be shown to have greater wealth generating capacity compared to the one with high BCR ratio.

Third, this methodology only provides priority ranking of commodities. Specific research activities/areas, such as breeding, socio-economics, policy, crop protection, post harvest, crop production, are not derived from the study. Therefore, this aspect of research prioritization should be addressed. This methodology also assumes that a province is mutually exclusive to other provinces. The study to see the effect of research of a group of provinces to other provinces is required.

ACKNOLEDGEMENT

The author coveys his gratitude to all level of management and staff of Indonesian Agency for Agricultural Research and Development (IAARD) for the support in conducting this research. Sincere appreciations are also due for providing data to the Heads of: Indonesian Center for Rice Research Institute, Indonesian Legumes and Tuber Crops Research Institute, Indonesian Cereal Research Institute, West Java Assessment Institute for Agricultural Technology, Central Java Assessment Institute for Agricultural Technology, Special Region of Jogjakarta Assessment Institute for Agricultural Technology, East Java Assessment Institute for Agricultural Technology.

REFERENCES

ALFRANCA, O., & HUFFMAN, W. E. (2001). Impact of Institutions and Public Research on Private Agriculture Research. Agricultural Economics, Vol. 25 (2-3) pp, 191 - 198.

ALPHONCE, C. B. (1997). Application of the Analytic Hierarchy Process in Agriculture in Developing Countries. Agricultural Systems, Vol. 53, 97 - 112.

ALSTON, J., & PARDEY, P. (1996). Making Science Pay : The Economics of Agricultural R&D Policy. The AEI Press.

ALSTON, J., & PARDEY, P. (2001). Attibution and Other Problems in Assessing the Return to Agricultural R&D. Agricultural Economics, Vol. 25, 141 - 152.

ALSTON, J., NORTON , G., & PARDEY, P. (1995). Science Under Scarcity: Principle and Practice for Agricultural Research Evaluation and Priority Setting. Cornell University Press.

ANDERSON, J. R. (1992). Agricultural Research Institutions and Priorities in an Era of Resource Scarcity : Discussion. American Journal of Agricultural Economics, 74 (5), 1111 - 1113.

BRAUNSCHWEIG, T. (2000). Priority Setting in Agricultural Biotechnology Research : Supporting Public Decisions in Developing Countries with Alatytic Hierarcky Process. Research Report 16. July 2000. ISNAR.

BRAUNSCHWEIG, T., & REYES, J. C. (2000). Final Report: Integrating and Enhanching the Research Priority Setting in Agricultural Biotehnolgy in the Philippines. Laguna, the Phillipines: PCCARD, DA-BAR, UPLB, ISNAR.

HAZELL, P., & HADDAD, L. (2001). Agricultural Research and Poverty Reduction. Washington DC: IFPRI.

INDONESIAN AGENCY FOR AGRICULTURAL RESEARCH AND DEVELOPMENT (IAARD). (2012). Statistik Badan Litbang Pertanian (Yearbook of Statistic of Agricultural Research and Development). http:\\\www. litbang.pertanian.go id.

INDONESIAN AGENCY FOR AGRICULTURAL RESEARCH AND DEVELOPMENT (iAARD). (2013). Statitik Badan Litbang Pertanian (Yearbook of Statistic of Agricultural Research and Development). http.\\\www.litbang.pertanian.go id.

INDONESIAN AGENCY FOR AGRICULTURAL RESEARCH AND DEVELOPMENT (IAARD). (2014). Statistik Badan Litbang Pertanian (Yearbook of Statistic of Agricultural Research and Development). http:\\\www. litbang.pertanian.go id.

INDONESIAN AGENCY FOR AGRICULTURAL RESEARCH AND DEVELOPMENT (IAARD). (2015). Statistik Badan Litbang Pertanian (Yearbook of Statistic of Agricultural Research and DevelopmentI. http:\\\www. litbang.pertanian.go id.

INDONESIAN AGENCY FOR AGRICULTURAL RESEARCH AND DEVELOPMENT (IAARD). (2016). Statistik Badan Litbang Pertanian (Yearbook of Statistic of Agricultural Research and Development). http:\\\www. litbang.pertanian.go id.

INDONESIAN AGENCY FOR AGRICULTURAL RESEARCH AND DEVELOPMENT (IAARD). (2017). Statistik Badan Litbang Pertanian (Yearbook of Statistic of Agricultural Research and Development). http:\\\www. litbang.pertanian.go id.

INDONESIAN AGENCY FOR AGRICULTURAL RESEARCH AND DEVELOPMENT (IAARD). (2018). Statistik Badan Litbang Pertanian (Yearbook of Statistic of Agricultural Research and Development). http:\\\www. litbang.pertanian.go id.

INDONESIAN AGENCY FOR AGRICULTURAL RESEARCH AND DEVELOPMENT (IAARD). (2019). Statistik Badan Litbang Pertanian (Yearbook of Statistic of Agricultural Research and Development). http:\\\www. litbang.pertanian.go id.

JUST, R. E., & HUFFMAN, W. E. (1992). Economic Principles and incentives: Structure, Management, and Funding of Agricultural Research in The United Sates. American Journal of Agricultural Economics, 74 (5): 1101-1108.

MARHENDRO. (2003). An Economic Approach for Establishing Regional Commodities Priorities for Agricultural Research In Indonesia. Dissertation. Unpblished.

MILLS, B. F. (1997). Ex Ante Research Evaluation and Regional Trade Flows: Maize in Kenya. Journal of Agricultural Econiomics, Vol. 49 (3): 393-408.

MILLS, B. F. (1999). Agricultural Research and Priority Setting: Information Investment for The Improved use of Research Resources. ISNAR.

NORTON, G. W., PARDEY, P. G., & ALSTON, J. M. (1992). Economics Issues in Agricultural Research Priority Setting. American Journal of Agricultural Economics, 74 (5): 1089-1094 .

PINGALI, P. L., & PANDEY, S. (2000). Meeting World Maize needs: Technological Oppurtunities and Priorities for The Public Sector. In 2000 CYMMYT World Maize Facts and Trends. CYMMYT.

PRICE, G. J. (1982). Economic Analysis of Agricultural Projects. Baltimore and London: The John Hopkins University Press.

SUNDQUIST, B. W. (1992). Agricultural Research Instituions and Priorities in an Era of Resources Scarcity: Discussion. American Journal of Agricultural Economics., Vol. 74 (5): 1109-1110.

TAHA, H. A. (1997). Operation Research: An Introduction. Sicth Edition. Prentice Hall International Inc.

THE ANALYTIC SCIENCES CORPORATION (TASC). (2001). An Illustrated Guiide to Analytic Hieranchy Process. Retrieved from http:///www.expertchoice.com