The method on measuring utilization index of agricultural technology

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Abstract. Utilization of technology as a research result is the foremost indicator towards the success of R&D as well as the measure of the multiplier effect concerning the usage of R&D budgets. However, to define the indicators and measurement of technology benefits is less considered. This study was aimed to determine the scope, indicators, and comprehensive measurement methods on the utilization of technology in the form of an index to standardize the value. Through literature studies, benchmarking of previous models and Focus Group Discussions, the measurement indicators of technology utilization index include: the availability of technology at the user’s location, the distribution of technology adoption, technology benefits, technology accessibility and user acceptance. Every variable for each indicator was based on the type of technology. The method for measuring the level of technology utilization using a composite index of four variables and calculation was carried out by weighting the importance of each variables based on the eigenvectors value of Analytical Hierarchy Process. Three utilization categories were not utilized (index <1); underutilized (index 1 to 3); and high utilized (index> 3). As an example, the utilization index of a new superior varieties (VUB) of rice was high (3.75) with relatively good indicators on technology benefits and availability of VUB rice seed at the user’s location. Furthermore, the result implies that the method on measuring the utilization index is adequate to be widely applied for other types of technology.

1. Introduction
It is undeniable that technology is one of the main sources of growth in agricultural production. The role of technology to support sustainable production growth is increasingly important in accordance with population growth, limited quantity and quality of agricultural resources, climate change and changes in consumer preferences. Rehman, et al. [1] mentioned that agricultural technology is amongst the most innovative and impactful areas of modern technology since agricultural technology can substantially improve the agricultural production and sustainability. Agricultural technologies have contributed to feeding the world, reducing negative environmental impacts and mitigating climate change as well [2]. Technology has received much attention in recent years due to changing demand from consumers and producers of food and other goods as well as services provided by agriculture sector [3].

Further, technology can improve household food security as explained by Chanyalew [4] that households adopting agricultural technologies are more likely to have higher food security compared to non-users. Besides, studies in Ethiopia on the impact of improved agricultural technologies (corn and wheat varieties) revealed that households adopting these improved agricultural technologies had higher...
level of consumption, increased their food security and household welfare [5,6,7]. For this reason, the role of the Indonesian Agency for Agricultural Research and Development (Balitbangtan), Ministry of Agriculture as one of the institutions creating technological innovation become more strategic.

Up to date, Balitbangtan has produced more than 600 agricultural technologies, such as new high-yielding varieties (rice, corn, soybeans), superior livestock seeds (chicken, sheep/goats, ducks, chili pepper and shallot), fertilizers, vegetable pesticides, agricultural tools and machines and land maps. Some of these technologies have been mass-produced and disseminated to farmers. The role of procuring agricultural technology has also been optimized through adapting them to specific locations and users, providing information on these technological innovations and creating advanced and strategic agricultural innovations. However, the success of technology utilization is inadequate on the procurement of technological innovation (generating system) since it was very reliant on the innovation delivery subsystem and the innovation acceptance subsystem (receiving subsystem). These last two systems were often stated as bottlenecks in the process of adoption and diffusion of technological innovations [8] and hence, it affected the level of technology utilization by users at large scale [9].

Utilization of technology as a research result is the foremost indicator towards the success of research and development (R&D) as well as the measure of the multiplier effect concerning the usage of R&D budgets. The critical question is how much farmers use and how much benefit farmers have gained from using the technology. Balitbangtan has actually tried to measure the benefits of technology that has been adopted by the community, especially farmers. However, this measure is still partial and has not been standardized. How to define the indicators and measurement of the technology benefit is less considered. Therefore, this study was aimed to determine the scopes, indicators, and comprehensive measurement methods on the utilization of technology in the form of an index to standardize the value. The formulation of an index could be used as an evaluation tool to get the feedback from users and become input for technology improvement process as well.

2. Materials and methods

2.1. Materials

Agricultural technology provided by Balitbangtan was grouped into seven types of technology (following the technology group on the measurement of agricultural technology readiness level), namely: (i) plant varieties, (ii) livestock strains/clumps, (iii) test equipment, agricultural tools and machinery, (iv) pesticides (biopesticides, chemicals, attractants and PGR), (v) fertilizers (organic, inorganic, biological and soil enhancers), (vi) biopesticides and medicines, (vii) post-harvest and processing.

The characteristics of each type of technology were different, which allowed the variables and indicators in utilization index to be different. However, generic variables and indicators were able to be arranged and can be adjusted based on the specific characteristics of the technology.

Measuring the level of technology utilization, not only measuring technology adoption by farmers, but also the availability of technology and how easily the technology was accessed by users as well as how much benefit of technology usage in term of farmers’ income increase, production or quality increase and cost efficiency. As mentioned by Foster and Rosenzweig [10] and Carletto [11], there were two major drivers of successful agricultural technology in developing countries which were the availability and affordability of technologies; and farmer expectations that adoption will remain profitable.

Moreover, sustained adoption of agricultural technology was influenced by the profitability and prices for agricultural product [12]. Study by Keil [13] found that the awareness-raising campaigns for a particular technology also impacted the sustainability of technological adoption. Therefore, the availability of technology at the user's location, the distribution of adoption, technology access, and benefits are the main variables in the technology utilization index.
2.2. Methods

This study used the literature study, benchmarking against the currently developed index measurement model, focus group discussion (FGD), and applied testing. The literature study was carried out through a theoretical review, a study of the concepts of diffusion, dissemination, and development of agricultural technology relevant to the measurement of the technology utilization index. Derivation of variables and indicators of technology utilization index was conducted from interviews and focus group discussions (FGD) with experts, practitioners, and regulators involved in R&D and adoption of agricultural technology. Furthermore, applied testing were carried out to obtain measurement indicators and models in accordance with the facts in the field, accommodate the characteristics of technology and technology users.

There were four activities that need to be carried out to measure the index of technology utilization, namely (1) formulating variables and indicators of technology utilization, (2) formulating a formula for measuring utilization index, (3) collecting data and information through applied tests and measuring the technology utilization index, and (4) compiling procedures for measuring the level of technology utilization.

Formulation of variables and indicators for measuring the index of technology utilization was conducted through literature studies, benchmarking of measurement models that have been developed and Focus Group Discussions (FGD) involving researchers across R&D unit. Some indicators were measured by perception using a likert scale and the weighting of the importance of each variable were obtained from the Analytical Hierarchy Process.

The weighting of each variables of utilization index described how much influence of one variable has on the other variables. The weighting with AHP method was first developed by Saaty [14] in order to determine the importance level of the criteria or variable. The weighting on AHP was resulted from a pairwise comparison technique whereas each variable was paired with other variables and then compared how important these variables to other variables that were paired with the intensity of importance in Table 1. The weight was resulted by normalizing the eigenvectors on the ratio matrix.

### Table 1. Intensity of importance in the method of Analytical Hierarchy Process.

| Importance | Intensity of Importance |
|------------|------------------------|
| 1          | The two elements are equally important |
| 3          | One element is slightly more important than the other ones |
| 5          | One element is more important than the other ones |
| 7          | One element is much more important than the other ones |
| 9          | One element is absolutely more important that the other ones |
| 2, 4, 6, 8 | Scores between two other closed by scores |
| Reciprocal | If element i obtains 1 point compare to element j, then i will have the reciprocal point compare to j. |

3. Results and discussions

3.1. Formulating variable and indicators

Through literature studies, benchmarking of previous models and Focus Group Discussions, the measurement indicators of technology utilization index included four variables namely the technology adoption distribution, technology benefits, technology availability at the user's location and technology accessibility.

Indicators for the variable of the technology adoption distribution were distinguished by the type of technology. The adoption distribution for technology of variety, fertilizer and pesticide was the percentage or proportion of the area using technology to the total planted area per season at the sub-district level. Indicator for the adoption distribution of test equipment technology as well as agricultural tools and machinery was the proportion of the area using technology to the using capacity of agricultural tools and machinery. Based on the FGD with experts, the adoption distribution was divided into five groups, namely: <10%; 11-25%; 26-35%; 35-50%; and >50%.

The technology benefit indicator was the percentage or proportion of production increase after the use of technology to the average of production per sub-district. Meanwhile, the benefits of fertilizer...
technology, agricultural tools and machinery were calculated from the percentage of production costs decrease or production efficiency obtained due to the use of technology. The benefits of technology use were divided into five groups, which were: <5%; 5-10%; 11-15%; 16-20%; and > 20 %.

The variable of technology availability consist of three indicators namely amount of technology as needed, time of technology availability according to usage time and technology quality. Further, indicator of the variable of technology accessibility was the number of technology provider agents and the cost to acquire the technology. Those indicators were ordinal data of user perception using a Likert scale of 1 to 5. The scores of the technology availability and accessibility variable included in the formula were the average scores. Descriptions of variables, indicators and measurement scales in the technology utilization index are presented in Table 2.

### Table 2. Variables, indicators and measurement scale of technological utilization index.

| No | Variable | Group of technology | Indicators | Measurement scale |
|----|----------|---------------------|------------|------------------|
| 1. | Distribution of adoption (SA) | Plant varieties, livestock strains, fertilizer, biopesticides and medicines | 1.1. Percentage or proportion of the area that use technology to the total planted area per season at the sub-district level | Divided into 5 range:  
<10%; 11-25 %; 26-35 %; 35-50 %; and >50 %. |
| | Test equipment, agricultural tools and machinery | 1.2. Proportion of area using technology to the using capacity of agricultural tools and machinery | | |
| | Post-harvest and processing | 1.3. Number of farmers using post-harvest and processing technology | | |
| | | 1.4. Proportion of operation hours of tools to capacity of processing and post-harvest tools | | |
| 2. | Benefit of technology (MT) | Plant varieties, livestock strains, fertilizer, biopesticides and medicines | 2.1. Percentage of production increase after the use of technology to the average of production per sub-district | Divided into 5 range:  
<10%; 11-25%; 26-35%; 35-50%; and >50 %. |
| | Test equipment, agricultural tools and machinery | 2.2. Percentage of productivity changes compared to previous varieties | | |
| | Post-harvest and processing | Percentage of production costs decrease or production efficiency | | |
| 3. | Availability of technology in user location (KT) | Plant varieties, livestock strains, fertilizer, biopesticides and medicines | 1.1. Perception on amount of technology as needed | Ordinal data of farmers’ perceptions using a Likert scale of 1 to 5 |
| | Test equipment, agricultural tools and machinery | 1.2. Perception on time of technology availability according to usage time | | |
| | Post-harvest and processing | 1.3. Perception on quality of technology | | |
| 4. | Accessibility of technology (AT) | 4.1. Number of technology provider agents | Ordinal data of farmers’ perceptions using a Likert scale of 1 to 5 |
| | Post-harvest and processing | 4.2. The cost to acquire the technology | | |

Data required in measuring the utilization index of technology were primary and secondary data as presentes in Table 3. Primary data were collected through FGDs and interviews with extension workers, head of federated farmer groups (gapoktan), head of farmer group, and farmers who used technology in the last year of measurement. The primary data collection included aspects of the characteristics of farmers as recipients/users of technology, land area for technology use, productivity and production increase, efficiency of production costs obtained after using technology, availability of technology, and accessibility to technology.
Table 3. Data and source of data in technological utilization index measurement.

| No | Data                                                                 | Data source                                      |
|----|----------------------------------------------------------------------|--------------------------------------------------|
| 1  | Planted area, harvested area, productivity and production of agricultural commodities at provincial and district levels | Provincial agriculture service                    |
| 2  | Planted area, harvested area, productivity and production of agricultural commodities at sub-district levels   | Sample district agriculture office                |
| 3  | Number of seed breeders, seed producers, agricultural machinery, farmer institutions, and number of technologies at the sub-district level | Sample district agriculture office                |
| 4  | Planted area, harvested area, productivity and production of agricultural commodities at village levels          | Extension offices, extension workers and Mantri Tani in the sample sub-districts |
| 5  | Number of seed breeders, seed producers, agricultural machinery, farmer institutions, and number of technologies at the sub-district level | Extension offices, extension workers and Mantri Tani in the sample sub-districts |

Provincial distribution was required to represent the spread and diversity of technology use. Therefore, the sample province was selected purposely based on geographical distribution and characteristics of agroecosystems. Selection of sample districts in each province was also conducted by applying the purposive sampling methods. In one district, the sample of sub-districts were selected following the slovin index with the population is a sub-district that has an agro-ecosystem in accordance with the characteristics of technology that will be measured. Sub-district was the smallest unit of analysis whereas in one sub-district, two villages were selected representing high-production and low-production villages which have the most technology users. As a case study, Central Java and Aceh provinces were included in this study since they are one of Indonesia’s rice production center and have diversity pattern on the use of a new superior varieties (VUB) of rice.

3.2. Measuring utilization index
The technology object used to arrange technology utilization index was technology that had a technology readiness (TKT) level 9 (development stage and is ready to be applied by users). The formula for measuring the level of technology utilization is a composite index of four variables that were used after being weighted based on eigenvalue of the Analytical Hierarchy Process (AHP) result.

Formula of technological utilization index as follows:

$$TPT = \sum_{i=1}^{4} w_i X_i$$

which is translated into:

$$TPT = 0.12 \text{SA} + 0.35 \text{MT} + 0.43 \text{KT} + 0.10 \text{AT}$$

whereas:

TPT = utilization index of technology  
SA = distribution of technology adoption  
MT = technology benefit  
KT = technology availability  
AT = technology accessibility and affordability

With such weights, the value of utilization index obtained from the formula was divided into three groups, namely: (a) not utilized (TPT index below 1); (b) underutilized (TPT index 1 to 3); and (c) high utilization (TPT index above 3).

3.3. Application test of technology utilization index measurement
The applied test for measuring the technology utilization index was carried out for VUB technology of rice and simulation for measuring the technology utilization index was presented in Table 4.
Table 4. Measurement of the VUB rice technology utilization index based on applied test of formula.

| No | Variable | Group of technology | Indicators | Measurement result | Measurement Scale |
|----|----------|---------------------|------------|--------------------|-------------------|
| 1. | Distribution of adoption (SA) | Plant varieties, livestock strains, fertilizer, biopesticides and medicines | 1.1. Percentage or proportion of the area that use technology to the total planted area per season at the sub-district level | 11.8% | 2 |
| 2. | Benefit of technology (MT) | Plant varieties, livestock strains, fertilizer, biopesticides and medicines | 2.1. Percentage of production increase after the use of technology to the average of production per sub-district | 50% (3 ton/ha) | 4 |
| 3. | Availability of technology in user location (KT) | Plant varieties, livestock strains, fertilizer, biopesticides and medicines | 3.1. Perception on amount of technology as needed | 4.45 | 4.16 |
|   |          |                     | 3.2. Perception on time of technology availability according to usage time | 4.21 | |
|   |          |                     | 3.3. Perception on quality of technology | 3.82 | |
| 4. | Accessibility of technology (AT) | | 4.1. Number of technology provider agents | 3.2 | 3.8 |
|   |          |                     | 4.2. The cost to acquire the technology | 4.4 | |

The distribution of adoption as a percentage of the planting area of Balitbangtan rice varieties to the sub-district planting area gives a value of 11.8% and it belongs to measurement scale of 1.4. This finding corresponds with the study by Ruzzante et al. [15] that the size of farm are more likely to adopt improved technology, meaning that the smaller farm size reveals the low score of the index.

The average score of technology availability was 4.16 and it belongs to scale 4. Meanwhile, the average score of accessibility and affordability of technology of VUB rice was 3.75. It indicated that availability and accessibility of new superior varieties of rice has been going well since both variables had the highest score in the utilization index. Study by Lampach et al. [16] found that the access to affordable technology will bring the increased productivity that then lead to sustain the adoption.

Using the weighted variables by AHP as described previously, measuring results of the utilization index of rice variety technology were as follows:

\[
TPT = \sum_{i=1}^{4} w_i X_i
\]

\[
TPT = 0.12 \text{SA} + 0.35 \text{MT} + 0.43 \text{KT} + 0.10 \text{AT}
\]

\[
TPT = 0.12 (2) + 0.35 (4) + 0.43 (4.16) + 0.10(3.18)
\]

\[
TPT = 3.7468
\]

Thus, based on the categorization of technology utilization status from the index value, the technology utilization status of superior rice varieties was included in high utilization since the utilization index of this technology was at 3.7468.

4. Conclusions

Measurement of the level of technology utilization is important for research and development institutions, because the current assessment on the performance of research and development of agricultural technology does not only address the number of technology produced but also haves reached the number used and the magnitude of the benefits for agricultural development. Thus, efforts are needed to analyze the level of technology utilization from various types of technology that have been widely adopted and developed in society. Measurement of the utilization index of technology could be used as
an agenda for each R&D institution within the scope of Balitbangtan. For this reason, the results of these methods and procedures can be determined as an index instrument for the utilization of Balitbangtan technology. The application of the utilization index measurement method to other types of technology requires testing and validation process so that a policy to improve the procedure for measuring the level of technology utilization and its application is required, as well as establishing it as part of the process in preparing and applying agricultural technology.

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