Introducing technology of planting methods to increase rice production for sustainable farmers’ income [version 1; peer review: awaiting peer review]

Julian Witjaksono\textsuperscript{1,}, Rita Indrasti\textsuperscript{2,}, Bungati Bungati\textsuperscript{1,}, Jefny B Markus Rawung\textsuperscript{2,}, Siti Sehat Tan\textsuperscript{2,}, Abdul Gaffar\textsuperscript{1,}, Nandang Sunandar\textsuperscript{3,}, Enti Sirnawati\textsuperscript{3,}, Conny N Manoppo\textsuperscript{3,}, Muhammad Assagaf\textsuperscript{4,}, Wawan Sulistiono\textsuperscript{2,}, Donald Sihombing\textsuperscript{2,}, Wahyu Handayati\textsuperscript{2,}, Resmayati Purba\textsuperscript{5,}, Asmin Asmin\textsuperscript{5}

\textsuperscript{1}Research Center of Behavioral and Circular Economic, National Research and Innovation Agency, Indonesia, Indonesia
\textsuperscript{2}Research Center for Horticulture and Estate Crops, National Research and Innovation Agency, Jakarta, Indonesia
\textsuperscript{3}Agriculture Policy, Ministry of Agriculture, Jakarta, Indonesia
\textsuperscript{4}Research Center for Agroindustry, National Research and Innovation Agency, Indonesia, Indonesia
\textsuperscript{5}Research Center for Food Crops, National Research and Innovation Agency, Jakarta, Indonesia

Abstract

Background: Rice self-sufficiency is still a great concern in Indonesia; in order to feed the population of 270 million people, farmers must implement new technology to boost rice production. This study aimed to provide information on the differences between direct seed planting and its conventional counterpart in terms of productivity and farmer income. Secondly, we aimed to characterize the productivity and farmer income for two legowo planting systems (legowo 4:1 and legowo 2:1). Finally, farmers’ perceptions of the legowo implementation were evaluated.

Methods: This study was carried out in Konawe District at the farm level in Karandu Village, Anggota Sub District of Southeast Sulawesi Province, Indonesia. The research design was implemented to allow comparison between legowo 4:1 and legowo 2:1. 60 farmers who implemented legowo 2:1 and legowo 4:1 respectively, were selected. Moreover, 30 farmers who did not implement both 4:1 and 2:1 were selected as the conventional planting method. This research design was implemented in order to compare between legowo and non legowo planting systems, as mentioned above, 60 respondents will compare with 30 farmers in terms of yield and economic advantage. Lastly, in order to determine technological perceptions, a total of 150 farmers were interviewed.

Results: The study case results showed that direct seed planting is much more profitable than its conventional counterpart. The introduction of legowo 4:1 was highly significant in boosting rice
production compared to legowo 2:1. In terms of perception, we found that the low cost and the availability of legowo are the most important parameters for the adoption of this technology.

**Conclusions:** In summary, we recommend the implementation of the legowo 4:1 planting system to boost rice productivity. By reducing labor costs, the direct seeding method increased farmers’ income.

**Keywords**
legowo, rice, technological innovation, farmers, income

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Introduction
Rice, the main cash crop of farmers, is a strategic and important crop in Indonesia. This staple food is consumed by more than 90% of the population comprising 270 million people with rice consumption has reached 97.40 kg/capita/year. The Indonesian government has launched a program to increase the planting area for food security and rice self-sufficiency, which aims to not only increase the planting area but also boost rice production.1

Southeast Sulawesi Province is one of the rice production areas supporting this national program. One of the potential areas producing rice in Southeast Sulawesi is Konawe District, with the largest paddy planting area. It has been stated that the rice productivity of this region is still low compared to national productivity due to the low adoption of technological innovations.2 A research study3 unveiled a few procedures that could be executed to expand rice production. One planting design broadly used for rice development in Indonesia is jajar legowo, known as Jarwo Rice Planting System.

The Jarwo switches back and forth between at least two (usually two or four) crop lines and one free space column. Hence, this planting system makes ideal use of space for development and expands the yield to excess of 160,000 harvested plants per hectare.4 Changes in plant division are one of the most significant agronomic practices for expanding crop yield. Jajar legowo has been well received because of its benefits in crop upkeep and higher number of plants per area.5 Likewise,6 detailed that jajar legowo is a proper innovation that increases rice yield and farmer income compared with the conventional strategy.

The legowo planting system has been recognized as a technology to grow rice on paddies in a rice farming system. This technology has three patterns of planting: 2:1, 4:1, and 6:1. This study was carried out to determine the resulting productivity and farmer income due to the implementation of the legowo planting system. In this study, we determined and compared the economic advantages of the legowo 4:1 and 2:1 planting systems. Furthermore, to forgo the potentially high cost of the legowo planting system due to labor, we implemented direct seed planting. Thus, as part of the system design, direct seed planting is compared with its conventional counterpart. Lastly, to assess the performance of the legowo planting system, we evaluated perceptions of it among the farmers who implemented the legowo planting system. Information on sensitive attributes was identified in this study and can be used as a consideration for stakeholders in developing strategies to maximize rice productivity.

More specifically, Konawe district is the region which has implemented legowo planting system widely across the county and adopted rapidly by farmers particularly in Karandu Sub District. The overall goal of this examination was to survey mechanical advancement of the paddy cultivating framework in Karandu County, Anggota Sub Region, Konawe Region of the Southeast Sulawesi Province in Indonesia. Specific goals were as follows:

(1) To describe the introduction of direct seed planting technology and a transplanting method;

(2) To identify the economic advantages resulting from the introduction of the legowo 4:1 and 2:1 planting systems;

(3) To identify farmers’ perceptions of the legowo planting system.

This paper discusses the implementation of technological innovation in terms of transplanting as the conventional method and direct seed planting, the introduction of the 2:1 and 4:1 Legowo planting systems, and the perceptions of farmers who adopted the Legowo planting system. The study’s purpose is to prove that this technology significantly increases rice production and is highly profitable compared to its conventional counterpart.

Methods
Research design
An action research approach was implemented to deploy the innovative legowo planting system such that it may spread across the county. This research was designed as three study models: (1) a study to compare between direct seed planting and a transplanting method as its conventional counterpart; (2) an economic study comparing the Legowo 4:1 and Legowo 2:1 planting system; and (3) observations and interviews on farmers’ perceptions of the introduction of the Legowo planting system by open questions based on the interview guide (see extended data).

Sampling procedure and sample size
A purposive sampling was employed wherein 60 farmers were selected at the farm level in Karandu village as respondents who adopted legowo 4:1 and legowo 2:1 planting system, respectively. A total 120 farmers who live in Karandu village and implemented those planting system as the representative of the farmers population have been
selected as the respondents. As the comparison between legowo planting system and its counterpart 30 farmers were selected randomly. All the respondents have been interviewed through the questionnaire (see extended data) as the semi structured question.

Measurement of variables
The instrument for obtaining information was a semi structured open questionnaire for the proficient respondents, while interview schedules were utilized to help the non-instructed or uneducated respondents. The measured variables were rice production and productivity of the farming system when implementing the direct seeding method along with a farm business analysis of the rice farming system, consisting of variable costs such as fertilizer, pesticides, herbicides, and labor costs. Finally, for the third objective, we asked the study farmers about their perceptions of the introduction of the legowo planting system in terms of the profitability, productivity, technological implementation, availability, and cost associated with its introduction.

Data Analysis
Economic analysis of rice with different planting methods was calculated by adding the cost of all input parameters such as the cost of seeds, fertilizers, pesticides, fuel, labors, etc. and cost of operation machinery. Costs of fertilizers, seeds and pesticides were calculated on the basis of the available market price in the corresponding years. Net income (idr/ha) were worked out by subtracting the total cost of cultivation of each planting method from the gross income of respective planting systems that was calculated to ascertain economic viability of different planting method (legowo 2:1, legowo 4:1 and its conventional).

For this study we used qualitative and quantitative data. The quantitative data was tabulated using Microsoft Excel 2010 (14.0) then analyzed so that relevant inferences could be drawn. The data was analyzed using descriptive statistics. Descriptive analysis has been widely used among studies in various sciences, including economics and sociology. Moreover, profitability analysis was conducted to analyze production costs and revenues via quantitative analysis. Financial investigations were utilized to decide whether farmers would receive a greater and steady income from the use of innovation and was appraised as to whether the farmer had sufficient capital to adopt the innovations or not.

Ethical statement
This study was approved by the Ethics Board of The Provincial of Research and Development of Southeast Sulawesi (project number 13/2017) as the funding body that content its ethical statement. Written informed consent to participate was obtained before the interviewing process. This project is funded by the provincial government not by The National Research and Innovation Agency.

Results
The differences between direct seedling and its conventional counterpart
The direct seed planting system applied in rice paddies is a cultivation technique that does not require an initial nursery phase. This system is most widely used by Indonesian farmers in the cultivation of lowland rice. Direct seeding methods have several advantages over transplanting. In addition to their higher economic returns, directly cultivated crops are quicker and simpler to plant, less labor intensive, and require less water. In wet fields, direct cultivation should be possible through either transferring or penetrating seeds into the mud using a drum seeder. Drum seeders are utilized for quick planting, and this is broadly executed by farmers at the study site. This tool works best on a very much evened out, smooth, and wet seedbed. Seeders might be obstructed if the dirt is tacky or if there is inadequate planning.

Direct seed planting using equipment and pulling by human force is commonly used as an innovation to accelerate the planting season, especially in areas with fewer farm workers. Based on the survey at the field farm, study findings at the farm level in Karandu Village indicated that the conventional method of transplanting is commonly used by farmers. A comparison between direct seed planting and its conventional counterpart in terms of productivity and income can be seen in Table 1.

<table>
<thead>
<tr>
<th>Justification</th>
<th>Direct seeding method (drum seeder)</th>
<th>Transplanting method</th>
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</thead>
<tbody>
<tr>
<td>Rice productivity (kg/ha)</td>
<td>6347</td>
<td>5196</td>
</tr>
<tr>
<td>Farmer income (IDR/ha)</td>
<td>18,322,400</td>
<td>14,810,650</td>
</tr>
<tr>
<td>Expenditure (IDR/ha)</td>
<td>6,230,000</td>
<td>7,230,000</td>
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Table 1 show that the implementation of direct seeding in the farming system results in higher productivity for farmers compared to its conventional counterpart (transplanting method). Moreover, the direct seed method results in higher income in comparison to the transplanting method. The results of the farm business analysis showed that the expenditure in the paddy farming system using the conventional system (transplanting) is IDR 7,230,000 per ha, higher than that using direct seeding (IDR 6,230,000 per ha). Thus, the direct seeding system is able to reduce the cost by IDR 1,000,000 per ha. This fits with the study finding by\(^\text{16}\) that direct seeding is able to decrease the production cost and lower the labor cost,\(^\text{17,16}\) while the conventional system (transplanting) has high labor costs associated with the care of seedlings and their planting. Direct cultivation saves on work as it dispenses with the nursery raising and transplanting of seedlings. Further, the work is spread out over a more extended period in direct cultivation than in transplanting, where more work is needed at the time of transplant.\(^\text{1}\)

The study findings in Table 1 show that rice productivity using direct seeding (drum seeder) is higher than that of using transplanting (6347 and 5196 kg/ha, respectively). The higher grain yield of direct cultivation when contrasted with transplanting is primarily a result of higher panicle number, higher 1000 grain weight, and lower sterility rate.\(^\text{18}\) Additionally, the greatest overall gain was found for farmers utilizing a drum seeder (IDR 18,332,400) in contrast with transplanting (IDR 14,810,650). The impact of the planting framework on the grain yield, straw yield, cost of development, overall gain, and returns per rupee on resources put into rice developed on sandy dirt topsoil soil were assessed in Bangalore.\(^\text{3}\) The authors observed that direct cultivation using a drum seeder delivered a higher overall gain of 34,953 rupee per ha and higher returns per rupee (3.12) in contrast with a total compensation of 30,420 rupee per ha and returns per rupee (2.66) recorded in the transplant framework.\(^\text{19}\) A significant justification of the advantage of direct cultivation for farmers is the increasing expense of development and diminishing benefits with customary work (transplanting). A review of 77 studies in various locations showed that different techniques for direct cultivation have reduced the expense of production by USD 9–125 per ha and required only ordinary work to produce the increased revenue of direct cultivation, as compared with transplanting.\(^\text{19}\) Farmers probably lean toward more innovative methods that give higher benefits, notwithstanding comparable or somewhat lower yield.\(^\text{7}\)

### Economic advantages of the legowo planting system

To address the gap between rice production and demand, the use of innovations in farming is important as it is one of fundamental prerequisites of rural development.\(^\text{20}\) Without innovation, agrarian advancement will decline; then, individuals' requirements for food cannot be met on the grounds that, as per Malthus' hypothesis, the populace will expand exponentially.\(^\text{21}\)

In the legowo planting framework, clusters are considered. The legowo column design alternates between at least two lines of rice planting and one clear line. The objective of legowo planting is that the plant populace per hectare can be maintained and even improved.\(^\text{22,23}\) An investigation by\(^\text{24}\) discovered that the execution of the legowo planting framework could expand rice production by 35% compared with a non-legowo planting framework. The legowo planting framework is one part of a harvest incorporated into the board framework, which is a development strategy designed by organizing divisions among clusters and between columns so that bunches of rice are compacted in lines, with greater distance between the lines.\(^\text{25}\)

An analysis of the farming system (Table 2) was carried out to describe grain yield and farmer income when implementing the legowo planting systems, both 4:1 and 2:1, compared with the conventional counterpart. The study findings based on the legowo planting system showed that rice productivity under the 4:1 and 2:1 systems (6850 and 6120 kg/ha, respectively) was much higher than that under the conventional counterpart (5232 kg/ha).

More specifically, based on the second study model, the study results (Table 2) show that legowo 4:1 is significantly better than Legowo 2:1 based on the evaluated parameters. This is also supported by the study findings,\(^\text{7,26}\) due to the jajar legowo 2:1 (two lines) planting framework utilizes separation of 25 cm × 12.5 cm × 50 cm; this results in a lower plant number per hectare than that under jajar legowo 4:1 (four columns full), which has plant dispersal of

<table>
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<tr>
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<th>Legowo 4:1</th>
<th>Legowo 2:1</th>
<th>Conventional</th>
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<tr>
<td>Rice productivity (kg)</td>
<td>6850</td>
<td>6120</td>
<td>5232</td>
</tr>
<tr>
<td>Economic profitability (IDR)</td>
<td>17,258,850</td>
<td>15,375,000</td>
<td>11,265,335</td>
</tr>
</tbody>
</table>

Source: primary data (tabulated).
25 cm × 12.5 cm × 50 cm, resulting in a plant number of ±256,000 clusters/ha. In addition, legowo 4:1 increases the crop population by 60% compared to legowo 2:1 which, in turn, increases the population by 30% in comparison with the conventional method (25 cm × 25 cm). Both planting systems (legowo 2:1 and 4:1) affect the plant population per unit area and the number of productive tillers and could affect crop production. The reason for these changes is also linked to the effect of fringe plants that are expected to be productive, delivering better results. Moreover, in terms of economic advantages, the results show that rice was significantly more profitable for farmers who implemented legowo 4:1 instead of legowo 2:1 or the conventional counterpart (IDR 17,258,850, IDR 15,375,000 and IDR 11,265,335, respectively).

In addition, based on the financial analysis of the farming system, farmers who implemented the legowo planting system were directly able to increase their farming income and lower the cost of farming production compared with the conventional counterpart; this is in line with the results of research conducted by.23,27 Moreover, our study findings indicated that the legowo planting system was able to increase grain production and increase farmers’ income. This is in line with study results by.5 According to,22 the implementation of the legowo planting system is able to increase the productivity and income of paddy farmers, and it is recommended that it be widely implemented.28 Moreover, a legowo study by25 showed that the adoption of the legowo planting system resulted in an increase in farmer income from IDR 5,926,000 (before adoption) by IDR 912,000 (after adoption).

Farmers’ perceptions
A recent study assessed farmers’ perspectives on a given innovation regarding their perceived needs and related involvement.29 As indicated by,30 a new innovation should be altered to fit the local interest and specific considerations. Above all, the cost of the new innovation should be comparable to the costs of the currently accessible substitute advances to guarantee quick take-up and increasing use of the new farming innovation. Below, Table 3 portrays farmers’ insights into the legowo planting framework as a development innovation that has been broadly received.

The study findings (Table 3) show that the farmers’ stated main reason for implementing the legowo planting system is mostly that the technology is easy to implement (91.7%), feasible (80%), and results in high productivity (91.7%), and 100% indicated that the technology is available and cheap. In a study of the application of agricultural innovations, a measurement of farmers’ perceptions of technological innovations in jarwo super rice carried out in Gorontalo Regency indicated that most farmers (80%) agreed or strongly agreed that application of the legowo planting system could increase rice production. This was also evidenced by the average yield of rice with the application of the legowo planting system being higher than that using farmers’ existing technology28 and matches with the study findings that farmers prefer this technology (legowo planting system) due to its high grain yield. In terms of feasibility, the study findings are in line with research by that revealed that farmers mostly agree with the Legowo planting system technology because it is proven that this technology results in a higher income than compared with the planting system that was commonly practiced by farmers. Moreover, in terms of the legowo planting system’s ease of implementation, the results of our study are consistent with the results of research by25 Hutapea et al. (2017) and according to in terms of ease of application, farmers stated that the components of the legowo technology were easy to understand and easy to apply in the field.

Conclusions and recommendations
The first study model herein found that direct seeding using a drum seeder resulted in increased rice productivity compared with the transplanting model. This increases farmer income via a reduction in variable costs, particularly labor costs. In the adoption of the legowo planting system as a technological innovation, the findings were that legowo 4:1 is profitable, increasing farmer income significantly compared to legowo 2:1. Both systems increased farmers’ income and rice productivity compared to their conventional counterpart.

In the analysis of perceptions, firstly, most farmers adopted the technology due to the easy access of the technology, and it is also important that the implementation of new technology is not costly. Secondly, the technology adopted by farmers should not be complicated. Thirdly, the legowo planting system is able to increase rice production compared to its conventional counterpart.
Authors’ contribution
J. Witjaksono did conceptualization, funding acquisition, investigation, and writing-original draft preparation. R. Indrasti contributed conceptualization, visualization and writing-review and editing. N. Sunandar did conceptualization and visualization. S. S. Tan interpreted writing-review and editing. Jefny, B. M. Rawung, Conny, N. Manoppo, Donald. Sihombing, and Wahyu Handayati writing-review and editing. A. Gaffar, and E. Sirnawati designed methodology. M. Assagaf and W. Sulistiono conceptualization and writing-review and editing. All authors read and approved the final manuscript.

Data availability
Underlying data

This project contains the following extended data:
- KUISIONER PENELITIAN.doc (Research questionary of legowo planting system and its counterpart).
- Panduan Wawancara.doc (Points of question for interview guide).
- Data Legowo (Tabular Data)
- Ethic Clearance (Informed Consent of Respondent)
- Project Approval

Data is available under the terms of the: Creative Commons Attribution 4.0 International (CC BY 4.0)

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References

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