Strip cropping and monoculture pattern for maize development on a rainfed rice fields

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Abstract. South Sulawesi has 228,605 hectares of rainfed rice fields as potential for maize development. Increasing maize production in rainfed lowland land can be done through strip cropping and monoculture patterns. The purpose of the study was to see the effect of a maize-based dual cropping pattern on the production of strip cropping and monoculture maize, as well as the value of the land equivalence ratio of monoculture and strip cropping patterns. The dual cropping patterns studied were maize strip cropping with peanuts, maize strip cropping of mung beans, maize strip cropping with soybeans and maize strip cropping of sweet potatoes. The feasibility of applying the strip cropping systems can be seen from the Land Equivalence Ratio (LER) value of more than one. It means it is profitable. Maize strip cropping with peanut had the highest LER value of 1.38 and maize strip crop with mung bean had the lowest LER of 0.75.

1. Introduction
South Sulawesi Province is one of the national maize development centers in Eastern Indonesia. This area has an agroecosystem of rainfed rice fields covering an area of 228,605 hectares [1] as a potential for maize development. Maize can be grown up to 20-30 percent in rainfed lowland agroecosystems [2].

Optimizing the use of rainfed paddy fields in this area with maize commodity is still relatively low. In 2009, maize production in rainfed lowland was recorded at 1,395,742 tons with a harvested area of 299,669 hectares or a productivity level of 4.6 tons per hectare [3]. This productivity is still far below the potential yield of superior maize varieties which are at the level of 9-11 tons per hectare [4]. Statistical data showed that in this area there are still a number of fallow paddy fields. In the April-September planting season, the area of fallow paddy fields was recorded at 232,421 hectares, and in the October-March planting season, the fallow area was recorded at 167,000 hectares. Thus, in two growing seasons, there are a total area of 399,390 hectares of fallow paddy fields [5]. The growth of maize crop area in the dry season is wider than the rainy season [6]. After rice, the development of maize in the future will be more widespread in rainfed land compared with dry land.

Water as one of the limiting factors in the agroecosystem of rainfed paddy fields. So that, some farmers use rainfed paddy fields only once for rice and then harvest rice, some try to drill wells in the corner of the rice fields as a source of irrigation water so that they can be planted more than once. Farming on rainfed rice fields needs to be optimized because the area of this land is decreasing due to changes in land function. In 2008, the conversion of rainfed paddy fields in South Sulawesi was recorded at 16,526 hectares [3].
In order to increase food production in rainfed paddy fields, it is necessary to pursue a dual cropping pattern based on regional superior commodities. Maize is one of the leading commodities in South Sulawesi specially in Gowa Regency. So that, in the application of the double cropping pattern, maize is chosen as the commodity base. Strip cropping is a dual cropping model with the same or almost the same plot area between the main crop and the second crop. The dual cropping pattern applied was maize strip cropping with peanuts, maize strip cropping with mung beans, maize strip cropping with soybeans and maize strip cropping with sweet potatoes. The intercropping system of cereals with legumes commonly used by farmers does not always give good results due to the selection of inappropriate varieties [7].

The intercropping system of maize and beans increases the efficiency of land resource use, also the volume and frequency of harvesting compared to monoculture cropping system. Intercropping systems are more profitable than monoculture cropping systems because of higher land productivity, diverse commodity types, efficient use of production facilities, less risk of failure, and more secure soil fertility [8,9].

The advantage of applying the intercropping or strip cropping system can be seen from the Land Equity Ratio. If Land Equality Ratio of more than one, it means that the intercropping system is profitable [10]. Land Equivalent Ratio (LER) is a measure of the relative of land required to plant total monoculture production in order to provide yields equivalent to one hectare of intercropping production. The advantage of the intercropping pattern over the monoculture pattern is that in the strip cropping, the use of resources increases both in space and time [11,12].

The purpose of this study was to examine the effect of a maize-based dual cropping pattern on maize production and strip cropping production and the value of the Land Equity Ratio for strip cropping and monoculture cropping patterns.

2. Methods
The study was carried out on rainfed paddy fields owned by farmers in Gowa Regency, South Sulawesi Province from March to July 2020. The tools and materials used are wooden sticks, plant spacing ropes, organic and an-organic fertilizers, seeds (maize, peanuts, green beans, soybeans) and sweet potato cuttings and other supporting materials.

The study was arranged according to a randomized block design, four replications and five cropping patterns as treatment. The size of the monoculture treatment plot was 18.3 m x 5 m, while the maize strip cropping was legumes, the plot size was maize was 15.3 m x 5 m and beans was 3 m x 5 m. The maize varieties planted are HJ-37 and Devon soybean varieties, while green beans and sweet potatoes are local varieties commonly grown by farmers. The number of maize seeds per planting hole, peanuts, green beans and soybeans are two seeds and sweet potato cuttings per planting hole. Sweet potatoes were made into planting mounds with a width of 100 cm and a height of 30 cm and a spacing of 50 cm x 30 cm.

| Table 1. Planting distance treatment. |
|---------------------------------------|
| Treatments | Planting distance | Plant population/ha |
|            | Maize | Strip cropping | Maize | Strip cropping |
| A          | 75 cm x 40 cm | 40 cm x 20 cm | 66,667 | 250,000 |
| B          | 75 cm x 40 cm | 40 cm x 20 cm | 66,667 | 250,000 |
| C          | 75 cm x 40 cm | 40 cm x 20 cm | 66,667 | 250,000 |
| D          | 75 cm x 40 cm | 50 cm x 30 cm | 66,667 | 66,666 |
| E          | 75 cm x 40 cm | - | 66,667 | - |

Description: a). maize strip cropping with peanuts, b). maize strip cropping with green beans,
c). maize strip cropping with soybean, D). maize strip cropping with sweet potato, E). monoculture maize (control).

An-organic fertilization was carried out twice for maize plants, at the age of the plant 10 and 35 days after planting, while organic fertilization was carried out once at planting time to cover the planting hole. Types and doses of fertilizers per hectare used for maize are: 400 kilograms NPK (16:16:16); 124.2 kilograms N; 36.8 kilograms P; 25 kilograms of K and 2 tons of organic fertilizer. The first fertilization dose was 50 percent NPK, 40 percent N, 100 percent P2O5 and 0 percent K2O. The second fertilization dose: 50 percent NPK; 60 percent N; 0 percent P2O5 and 100 percent K2O. An-organic fertilizer is given by making holes with a wooden stick about 7-10 centimetres beside the maize plant. Types and doses of an-organic fertilizers used for the first and second fertilization of each commodity (Table 2).

| Strip cropping  | First fertilizer dose/Ha NPK (16:16:16) (kg) | Second fertilizer dose/Ha NPK (16:16:16) (kg) |
|-----------------|------------------------------------------|------------------------------------------|
| Maize           | 200                                      | 200                                      |
| Peanut          | 10                                       | 15                                       |
| Green bean      | 10                                       | 15                                       |
| Soybean         | 10                                       | 15                                       |
| Sweet potato    | 50                                       | 50                                       |
| Control         | 200                                      | 200                                      |

The first and second fertilization for peanut, green bean and soybean aged 7 and 30 days after planting and sweet potato aged 7 and 45 days after planting. Fertilizer holes for peanut, green bean, and soybean are made between two plants about 10 cm from the plants, while sweet potato fertilizers are given beside the planting holes as far as 7-10 cm.

Embroidery of plants that didn’t not grow is done one week after planting. Maize plant embroidery materials are planted in small poly backs that are planted with the first crop, so that the embroidery plants are as old as the first crop. Meanwhile, the embroidery of strip cropping (peanuts, green beans and soybeans) is done in the form of seeds. Before planting maize seeds, soak them in water for about half an hour, or seeds without soaking as long as the land is irrigated before planting, if the soil is muddy after watering, rest 1-2 days before planting.

If the maize seeds have not been treated with seed, it is better to give saromil at a dose of one gram for the one kilogram seed as a downy mildew control. As for the seeds of nuts before planting, they are given the insecticide sevin or furadan types to be safe from ant pests. Irrigation is carried out when the condition of the plant is dry, which is marked by drying of the soil and rolling the edges of the leaves of the maize plant. Irrigation is carried out 3-4 times until the plants are harvested. Irrigation is carried out by pumping using drilled wells at the edge of the location. Weed control is done chemically using the herbicide with the calaris type which is selective. For the control of the cob and stem borer, furadan is added to the top of the plant as much as 2 grams of planting at the age of 40-45 days of planting.

Observation Parameter
The parameters observed are:
- Maize plant height (cm)
- Height of maize cobs (cm)
- Age of maize anthesis 50 percent (days)
- Corn silking age 50 percent (days)
- Leaf Area Index (LAI)
- Maize straw (t/ha)
- Weight 1000 seeds (gram)
- Number of grains per kilogram of seeds (grains)
- Production of strip cropping and monoculture maize
- Production of strip cropping and monoculture beans
- Production of strip cropping and monoculture sweet potato
- Land Equivalence Value (LEV)

3. Results and discussion
Data on growth components of plant and cob height, tasselling and silking age of maize plants (Table 3). The five cropping patterns studied did not show significant differences in plant and cob height, tasselling and silking age of maize. This is because the competition that occurs between maize plants and strip cropping plants is not to a critical limit which affects the growth of maize plants. Strip cropping is shorter than the main crop so it does not reduce light intensity to maize plants as C₄ plants. Even underground competition such as nutrients and water occur but not to the critical limit of the plant because it is suspected that there are differences in the root form of maize and strip cropping plants. The height of the cornsobs is in three positions; in the middle of the stem, above the middle of the stem, and below the middle of the stem. Hybrid maize varieties HJ-37 position the location of the cob in the middle of the stem (Table 3).

Table 3. The effect of maize-based multiple cropping patterns on height of plants and cob location and age of tasselling and age of maize silking in rainfed paddy field agroecosystems.

| Treatments | Maize plant height (cm) | Maize cob height (cm) | Maize anthesis age 50% (day) | Maize silking age 50% (day) |
|------------|-------------------------|-----------------------|-------------------------------|----------------------------|
| A          | 218.97 a                | 119.62 a              | 48.75 a                       | 52.25 a                    |
| B          | 220.87 a                | 116.87 a              | 48.75 a                       | 52.75 a                    |
| C          | 228.95 a                | 121.05 a              | 48.25 a                       | 52.75 a                    |
| D          | 220.85 a                | 125.37 a              | 48.50 a                       | 53.00 a                    |
| E          | 220.47 a                | 118.60 a              | 48.75 a                       | 53.00 a                    |
| (%)        | 3.5                     | 5.6                   | 1.3                           | 1.2                        |

Description: a). maize strip cropping with peanuts, b). maize strip cropping with green beans, c). maize strip cropping with soybean, d). maize strip cropping sweet potato, e). monoculture maize (control)

Information on the position of the cob of a maize variety is necessary as an alternative to whether a variety can be developed or not in an area ecosystem that is endemic to dog and pig pests. All the multiple cropping patterns studied did not show a significant effect on the anthesis and silking age of maize (Table 3). This is because only one variety of maize is planted so that it is genetically the same with respect to the age of anthesis and age of silking. Besides that, strip cropping with short plant morphology does not hinder the intensity of sunlight on maize plants. The average age of anthesis in maize was 50% faster at 48-49 days than the silking age of 52-53 days (Table 3).

The generative or flowering phase begins at the age of 60 days after planting and takes 2-3 days to fertilize the hairs in one cob [13]. The time difference of more than four days between the appearance of male and female flowers is thought to affect the optimization of maize pollination. Treatment A (maize strip cropping with peanut) gave a denser maize leaf canopy and significantly different from treatment E on Leaf Area Index (Table 4).

Table 4. The influence of maize-based multiple cropping patterns on ild, straw, weight of 1000 seeds and number of grains/kg maize seeds in rainfed paddy field agroecosystems.

| Treatments | Maize area index | Maize straw (height/ha) | Weight of 1000 maize kernels (g) | Number of grains/kg maize kernels |
|------------|------------------|-------------------------|----------------------------------|----------------------------------|
| A          | 4.26 a           | 12.37 a                 | 291.17 a                         | 3437.5 a                        |
| B          | 4.07 ab          | 12.42 a                 | 302.50 a                         | 3313.0 a                        |
| C          | 4.14 ab          | 12.45 a                 | 305.62 a                         | 3278.5 a                        |
| D          | 3.74 ab          | 13.15 a                 | 293.60 a                         | 3413.3 a                        |
| E          | 3.56 b           | 12.70 a                 | 297.75 a                         | 3360.8 a                        |
| (%)        | 10.3             | 10.6                    | 4.2                              | 4.3                              |
The maize leaf canopy is wide and thick, causing many leaves to overlap in case the lower leaves are not productive in photosynthesis. The wider the leaves of maize plants, the more overlapping leaves and the lower leaves do not get optimal sunlight, thus affecting the photosynthetic activity of plants which have an impact on the production of plant dry matter as raw material for seed production [13,14]. The standard leaf area index for hybrid maize is 3.3 – 4.0 [15].

Maize straw can be used as animal feed, mulch and organic fertilizer. The advantages of using maize straw as ruminant feed, because maize straw contains 27.8 percent crude fiber; 1.5 percent fat; 7.4 percent protein; ash 10.8 percent and BETN 53.1 percent [15]. The benefits of straw as organic mulch, especially in the tropics, can lower the daily soil temperature, which is lower than the temperature of the open soil during the day. This is important because the temperature of open and dry soil can reach 40°C or more which affects plant root activity [16]. The five maize-based multiple cropping patterns studied did not show a significant effect on the weight of 1000 seeds and the number of grains per kilogram of maize kernels (Table 4). It is suspected that the dose of fertilizer used and the maize varieties planted are the same, as well as underground competition between the main and strip crop does not affect the critical limit of the plant so that there is no variation in growth.

The weight of a thousand seeds and the number of grains per kilogram of seeds are generally determined by the amount of fertilizer applied and the variety of maize planted. These two factors when combined with various doses of fertilizer in several varieties of maize will cause variations in the growth components and yield components. Peanuts, green beans, soybeans and sweet potatoes as strip crops provide insignificant competition for light, nutrients and water for maize plants. The maize-based multiple cropping pattern treatment gave an average weight of a thousand maize kernels 291 – 305 grams and the average number of grains per kilogram of maize kernels was 3278 – 3437 grains (Table 4).

Strip cropping consisted of four types of plants, three legumes and one sweet potato also maize as the main crop. The data showed that A treatment, strip cropping of peanuts gave the greatest land equivalence value of 1.38 but was not significantly different from D treatment (Table 5).

| Treatments | Maize | Peanut | Green bean | Soybean | Sweet potato | Land Equity Value |
|------------|-------|--------|------------|---------|--------------|------------------|
|            | monoculture | strip cropping | monoculture | strip cropping | monoculture | strip cropping | monoculture | strip cropping | monoculture | strip cropping | Value   |
| A          | -      | 5.92   | 2.07       | 1.33    | -            | -                | -            | -            | -            | -            | 1.38 a |
| B          | -      | 5.10   | -          | -       | 0.30         | 0.03             | -            | -            | -            | -            | 0.73 c |
| C          | -      | 5.62   | -          | -       | -            | 1.80             | 0.87         | -            | -            | -            | 1.18 b |
| D          | -      | 5.50   | -          | -       | -            | -                | -            | -            | 10.3        | 6.95        | 1.36 ab |
| E          | 7.97   | 0.00   | -          | -       | -            | -                | -            | -            | -            | -            | 0.00 d  |

Description: a). maize strip cropping with peanuts, b). maize strip cropping with green beans, c). maize strip cropping with soybean, d). maize strip cropping sweet potato, e). monoculture maize (control)

To produce 1.33 tons of peanuts and 5.92 tons of dry shelled maize, an area of 1.38 ha is needed for monoculture maize plantations. This shows that strip cropping maize with peanuts is more profitable than monoculture maize cropping systems because it is more efficient in land use. The land equivalence value in B treatment, strip cropping of green bean, was the lowest, not enough, only 0.73 and significantly different from the other four treatments. This indicates that the maize strip cropping system with green bean is only 0.73 percent of the monoculture maize cropping system. The land equivalence
value of less than one is not available for intercropping [17]. The low land equivalence value of maize strip cropping with green bean is due to the growth of green bean experiencing problems so that many do not grow which results in low production. Do two times of embroidery the results are still not growing a lot. Information from cooperating farmers that before the study was conducted, farmers had planted green beans in that location, but more did not grow than those that grew. This requires further specific study of the causes of the problem.

D treatment of strip cropping maize with sweet potato had land equivalence value of 1.36 and was not significantly different from C treatment (Table 5). The high land equivalence value in sweet potatoes is supported by high tuber production (6.95 tons). To produce 6.95 tons of sweet potatoes and 5.50 tons of dry shelled maize, 1.36 ha of land is needed for monoculture maize cultivation. This illustrates that the strip cropping pattern between maize and sweet potato is more efficient in land use than the monoculture maize cropping pattern. D and E treatment with a monoculture cropping pattern as a control did not have land equivalence value because farmers were not used to the dual cropping pattern due to the increased workload.

The Land Equivalence Ratio of all strip cropping pattern treatments gave a value of more than one except for B treatment which strip cropping of maize and green bean had land equivalence value of less than one (Table 5). This shows that strip cropping is more productive than monoculture. The strip cropping system of maize with legumes increases the efficiency of land resource use, increases the volume and frequency of harvesting compared to monoculture cropping systems [18]. The high land equivalence value strip cropping maize with peanuts as well as strip cropping maize with sweet potatoes is because these two commodities produce higher production than other strip crops (Table 5). All strip cropping treatments (A, C and D) with more than one Land Equity Ratio were favorable (Table 5). While the strip cropping pattern of maize with green beans has a land equivalence value of less than one, only 0.73. This indicates that the strip cropping pattern of maize with green beans only reached 0.73 percent of the yield of single cropping of green bean. So that, it was not profitable for strip cropping. The treatment of strip cropping with a Land Equity Ratio of less than one is not profitable [17].

4. Conclusion
The difference between the intercropping and the strip cropping pattern is that the strip cropping plot is wider than the intercropping plot. Maize strip cropping peanuts had the widest leaf area index of 4.26, but not significantly different from B, C and D treatments. Except for E treatment with the lowest leaf area index value of 3.56. Strip cropping maize with peanuts, maize with soybeans and maize with sweet potatoes was more efficient and more productive than monocultures with more than one land equivalence value. Meanwhile, the highest land equivalence value was peanuts strip cropping of 1.38, but not significantly different from sweet potato strip cropping of 1.36. Maize strip cropping with green bean had the lowest land equivalence value of 0.75 and was significantly different from the land equivalence value of other treatments. The low land equivalence value of maize strip cropping with green bean is due to the lack of growing mung bean population.

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