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DRY LAND MANAGEMENT SYSTEM THROUGH PLANTING PATTERNS IMPROVEMENT IN BERASTAGI, KARO REGENCY, INDONESIA

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ABSTRACT

The land in Berastagi has a high erosion potential caused the high intensity of rainfall, steep slopes, and the cropping pattern is not good. Long-lasting erosion has lowered soil fertility and even reduced or eliminated soil tillage. This study aimed to obtain the appropriate intercropping pattern in the Berastagi dry land of Karo Regency, Indonesia. This study conducted a non-factorial randomized block design method with 5 replications. The treatment is in the form of farmers planting patterns and improved cropping patterns, namely P1, P2, P3, P4, and P5. The results showed that improved cropping patterns yielded higher rice equivalent yields compared to farmers' cropping patterns. Improved cropping patterns of P4, P2, and P3 are economically feasible in the Berastagi Karo dry land because they have a marginal B/C ratio above two, while the farmers' cropping pattern, namely intercropping of upland rice/cassava has the lowest B/C ratio of 1.72.

KEYWORDS: Intercropping, upland paddy, cassava, corn, peanuts, green beans.

INTRODUCTION

Berastagi is one of the cities located in Karo Regency, North Sumatra, Indonesia. Geographically, this city is on a plateau or around 1300 m above sea level. The city, which has daily temperatures between 17-19 ˚C, is located about 10 km from the city of Kabanjahe, the capital of Karo Regency, towards the North. Meanwhile, if from the capital of North Sumatra, Medan, Berastagi City is located 78 km to the South. Viewed from the city of Medan, Berastagi which is in the highlands appears to be flanked by two active mountains, namely Mount Sibayak (2100 m asl) and Mount Sinabung (2400 m asl). Not only cool temperatures and fertile soil conditions, the city is famous for being productive in producing lots of vegetables and fruits. From this city, the supply of vegetables and fruits in the city of Medan or other major cities on the northern island of Sumatra can be fulfilled.[1] However, the land in Berastagi has a high erosion potential because the intensity of rainfall is quite high, steep slopes, and cropping patterns are not good. Long-lasting erosion has reduced soil fertility and even reduced or eliminated soil tillage,[2] so that the risk reduction requires plant development that is not only aimed at increasing crop production, but also must pay attention to the sustainability of agricultural.

One effort that can be done to minimize the risk of erosion on dry land with wet climatic conditions is to do a multiple cropping pattern. The multiple cropping pattern is one of the technologies for managing agricultural land that can minimize the risk of using dry land, especially for the development of food crops. The multiple cropping pattern is an agricultural land management system by combining intensification and crop diversification.[3]

The multiple cropping pattern that has generally been done by farmers is intercropping system, which is a system of planting using more than one type of early maturing plants in a regular planting row and carried out planting simultaneously on a plot of land.[3] In general, intercropping systems are more profitable than monoculture systems because the productivity of the land becomes high, the types of commodities produced are diverse, saving in the use of production facilities, and the risk of failure can be reduced.[4] In addition, the intercropping system can also reduce erosion and can even increase soil fertility.[5] According to,[6] in terms of the socio-economic aspects of intercropping systems, there are various benefits including increasing the ratio between income and capital, can reduce production costs if implemented intensively and systematically and increase land productivity. In addition, the production of plant stover will be more so that it can be returned to the soil to maintain and increase the content of soil organic matter or can be used as animal feed.

According to,[7] intercropping systems can increase the productivity of agricultural land if the types of plants combined in this system form mutually beneficial interactions, so that it requires determining the appropriate cropping pattern in order to increase crop production and land productivity. Based on the above, this study aims to obtain the appropriate intercropping cropping pattern in the Berastagi dry land of Karo Regency, Indonesia.

MATERIALS AND METHODS

The study was carried out on farmers land on Berastagi dry land in Karo Regency, North Sumatra, Indonesia with altitude of 1300 m above sea level and undulating topography from January 2015 to December 2016. This study using a non-factorial randomized block design with 5 replications. To compare between treatment groups using Orthogonal contrast, because of the treatment given is qualitative. Treatment in the form of farmers cropping patterns and improved cropping patterns. Farmer cropping pattern (P1): intercropping upland rice + cassava. Improved cropping pattern consists of P2: intercropping upland rice + corn/cassava - peanuts, P3: intercropping peanuts + corn/cassava - green beans, P4: intercropping green beans + corn/cassava - peanut, P5: intercropping green beans + corn/cassava - green beans.

The farmers cropping pattern uses upland rice of local varieties (Kartuna) and local varieties of cassava, then the following season the land is given up. The spacing of irregular upland rice is ± 22 cm x 22 cm, while the spacing of cassava is almost the same as the improved cropping pattern of 200 cm x 80 cm. Fertilizers are only given to upland rice with a dose of 350 kg Urea/ha and 145 kg TSP/ha. Urea fertilizer is given 3 times by placing it on the soil surface around the plant.

Improved cropping patterns using upland rice Dodokan varieties with a spacing of 20 cm x 20 cm, peanuts Macan varieties and green beans Merak varieties with a spacing of 50 cm x 10 cm, corn Arjuna varieties with spacing of 200 cm x 40 cm and cassava varieties local with a spacing of 200 cm x 80 cm. Corn is planted 2 seeds/holes and cassava 1 cuttings/holes in the same row. Fertilization is carried out on upland rice plants with a dose of 200 kg urea/ha, 100 kg TSP/ha, and 100 kg KCl/ha. Fertilizers and green bean plants are fertilized at a dose of 100 kg urea/ha, 100 kg TSP/ha, and 100 kg KCl/ha. Similarly, the corn plant was fertilized with a dose of 100 kg urea/ha, 50 kg TSP/ha, and 50 kg KCl/ha, while fertilization was not carried out on cassava plants. Fertilizing urea in upland rice is given 3 times by means of an array between rows of plants. Fertilizing time is 1/3 of the urea dose and all TSP and KCI doses are given at planting, while the remaining 2/3 urea 1/3 part is given at 35 days after planting and 1/3 at the time of flower primordia, while fertilization urea in corn is given twice by ditugal around the plant, namely 1/3 dose of urea and all TSP and KCI at planting, while 2/3 urea is given at the age of 30 days after planting.

The variables observed included plant growth, yields and yield components and plant wastes. Land productivity is based on a comparison of the total yield of rice equivalent, i.e:

$$\text{Total yield of rice equivalent} = \frac{(Y1\,x\,P1)+(Y2\,x\,P2)+(Y3\,x\,P3)+(Y4\,x\,P4)+(Y5\,x\,P5)}{P1}$$

Where: Y1,2,3,4,5: yields of upland rice, peanuts, green beans, corn, and cassava; P1,2,3,4,5: price of seeds or tubers upland rice, peanuts, green beans, corn, and cassava; P1: the price of rice (milled dry grain).

Farming analysis is based on the level of farm efficiency from the revenue and cost balance or B/C ratio analysis, followed by an analysis of economic feasibility of each planting pattern or marginal B/C ratio, through mathematical equations[8] as follows:

$$B/Cratio = \frac{(Yi/Yf)x\,\mathrm{Pr} - (Ci/Cf)}{Ci/Cf}$$

$$\text{Marginal } B/Cratio = \frac{\{(Yi\,x\,\mathrm{Pr}) - Ci\} - \{(Yf\,x\,Pr) - Cf\}}{Ci - Cf}$$

Where, Yi: yield of rice equivalent (milled dry grain) from improvement cropping pattern, Yf: yield of rice equivalent (milled dry grain) from farmers cropping pattern, Pr: price of rice (milled dry grain), Ci: price of improvement cropping pattern, Cf: price of farmers cropping pattern.

RESULTS AND DISCUSSION

Climate Conditions of Experimental Sites

At the time of the study, 2015 was the rainy season and 2015 was the dry season (Fig. 1). In 2015, the average rainfall was 140.8 mm/month, while in 2016, the average rainfall was 33.8 mm/month. Based on the Oldeman climate classification, the month classification is divided into two parts, namely the wet month and the dry month. A wet month is a month with an average rainfall greater than 200 mm and a dry month is a month with rainfall equal to or less than 100 mm. The 200 mm number is used by reasoning that the water needs of the wetland rice, including the perolation, are close to 200 mm, while the 100 mm number is used for reasons because the secondary crops will lack water if the rainfall is smaller than 100 mm.[9]

Figure 1 showed that in 2015 it was the rainy season and 2016 was the dry season in Berastagi. This can be seen from the very low rainfall in 2016, which is less than 100 mm, while in 2015, the rainfall is quite high in April, September, October, November and December, which is above 200 mm. Based on the Oldeman climate classification, then in 2015 is a year with wet months, humid months and dry months. Wet months consist of 5 months (April, September to December), humid months consist of 2 months (May and August), and dry months also consist of 5 months (January, February, March, June, July), while in 2016 is a year with a dry month throughout the year, because every rainy month is less than 100 mm.

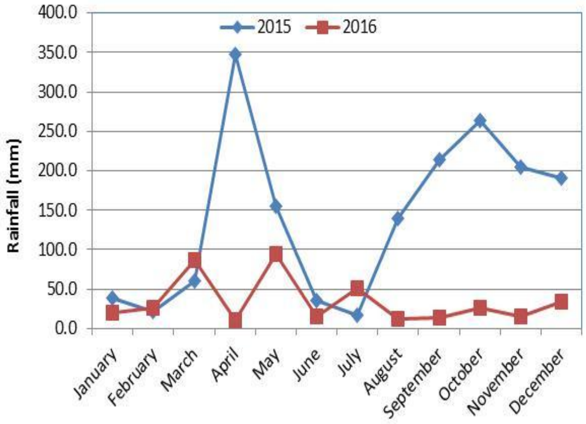
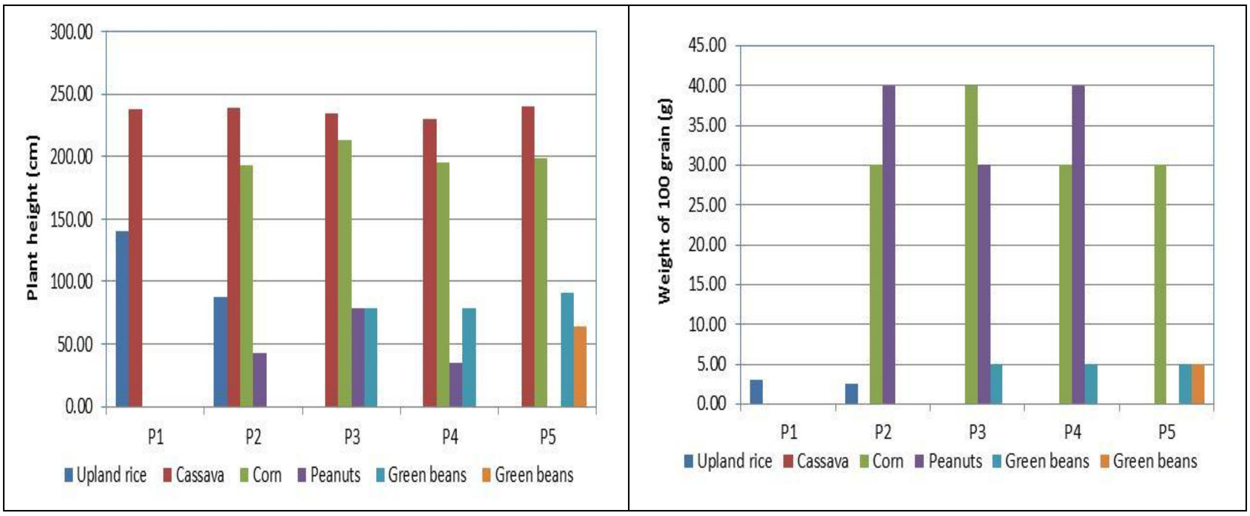


Figure 1: Monthly rainfall patterns in Berastagi Karo Regency in 2015 and 2016.

Plant Growth and Yield

Increasing cropping intensity through cropping patterns management affects growth and crop yields (Figures 2 and 3). Plant height and weight of 100 grains of rice filled with local varieties (Kartuna) are higher than Dodokan varieties, while the age of plants at harvest is almost the same. This is due to the genetic characteristics of upland rice varieties of local varieties which have a higher plant height than superior varieties of upland rice. In line with the research[10] which showed higher growth of upland rice in intercropping cropping patterns.

The highest dry weight of plant stover was found in P3 (peanut + corn/cassava - green bean cropping patterns), which was 11.54 t/ha (Figure 3, left). The high yield of dry stover can be used as mulch or can be used as animal feed. It is intended that the nutrients taken by plants for their growth and development can be returned to the soil, so that the nutrient cycle occurs sustainably. The results of the study of,[11] showed that plant residues can improve soil physical and chemical properties. Similarly, the results of the study of,[12;13] also showed that cover cover residues can increase nutrient content of N, P, K soil through their nutrient balance.



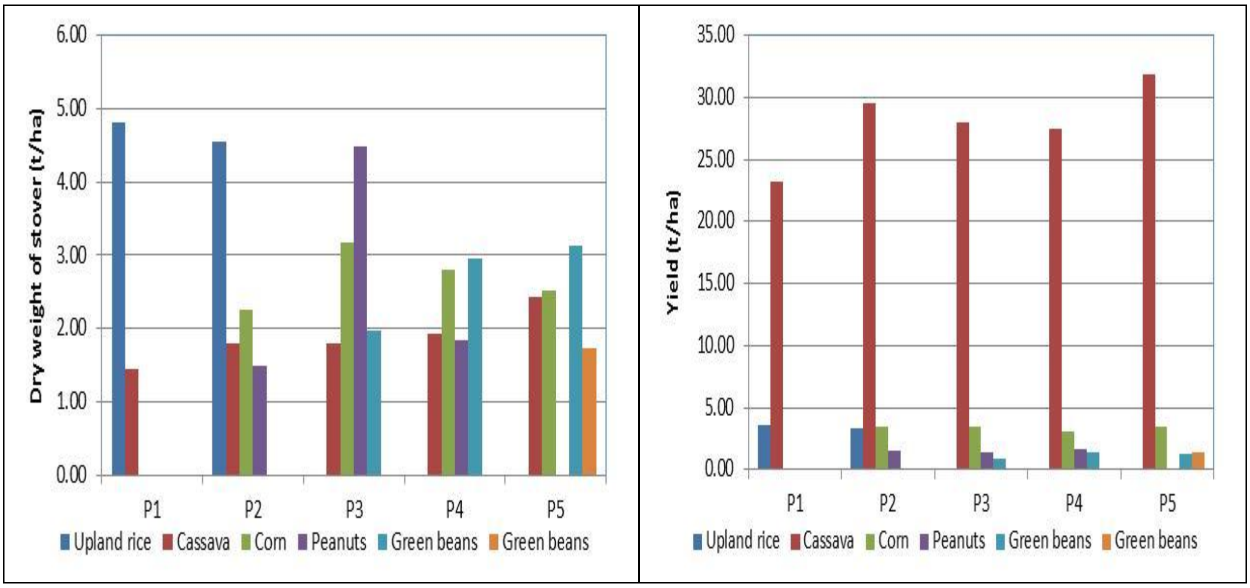
Note: P1: farmers cropping pattern intercropping upland rice + cassava; P2: improvement cropping patterns intercropping upland rice + corn/cassava – peanuts; P3: improvement cropping patterns intercropping peanuts

+ corn/cassava – green beans, P4: improvement cropping patterns intercropping green beans + corn/cassava - peanuts, P5: improvement cropping patterns intercropping green beans + corn/cassava –green beans.

Figure 2: Plant height (left) and weight of 100 grains (right) of each plant used in intercropping patterns.

Dried stover can also be used as animal feed. The daily food requirements for sheep and goats with a body weight of 20 kg require 2.6-2.9% of the amount of feed (dry ingredients) of body weight (0.52-0.58 kg of feed)[14]. If the average dry land ownership is 0.35 ha, then the application of P3 (intercropping peanuts + corn/cassava – green beans) with a dry weight of 4.04 t can accommodate 21 sheep or 19 goats for a year.[15]

The yield of local varieties of upland rice in the cropping pattern of farmers is higher than the yield of upland rice Dodokan varieties in the pattern of improved cropping which has a shorter harvest age of 10 days. This is due to the farmers cropping pattern, upland rice is only planted with cassava, while in the improved cropping pattern, upland rice is planted with corn, peanuts and cassava. In line with the results of research by[10] which also showed higher upland rice yields in monoculture crops than intercropping. According to,[16] seeds with a low planting density showed a more perfect seed filling rate. High levels of photosynthesis due to the optimum light intensity in the crop supported by sufficient water availability produce sufficient assimilates for seed filling which ultimately contributes to high yield. On the contrary, the results of fresh cassava on farmers' cropping patterns were lower than those of fresh cassava in the improved cropping pattern (Figure 3, right). This is because cassava in the improved cropping pattern gets nutrient supply through surface water flow and erosion from surrounding plants (upland rice, peanuts, green beans, and corn) which are given complete fertilizer with the right dosage. In line with the results of the study of[17] which shows that in the rainy season erosion will occur due to surface flow which will bring organic matter and nutrients with it.



Note: P1: farmers cropping pattern intercropping upland rice + cassava; P2: improvement cropping patterns intercropping upland rice + corn/cassava – peanuts; P3: improvement cropping patterns intercropping peanuts + corn/cassava – green beans, P4: improvement cropping patterns intercropping green beans + corn/cassava - peanuts, P5: improvement cropping patterns intercropping green beans + corn/cassava –green beans.

Figure 3: Dry weight of stover (left) and yield (right) of each plant used in intercropping patterns

Orthogonal Contrast Test between Treatments

Statistical analysis based on orthogonal contrast testing showed that cropping patterns have a significant effect on the growth and yield of food crops (Table 1).

Table 1 showed that improved cropping patterns have a very significant effect on farmers cropping patterns for all variables. The total height of food crops in the improved cropping pattern is higher than the total plant height in the farmers cropping pattern. This is due to the fact that only two types of food crops were planted, namely upland rice and cassava, while in the improved cropping pattern there were 4 types of food crops planted, namely upland rice, corn, cassava, peanuts, and green beans. Likewise in the variable weight of 100 grains, stover dry weight and crop yields showed that improved cropping patterns were better than farmers cropping patterns. This is due to the cropping pattern that improves more types of planted food so that it gives more yield and dry stover weight. This showed that the use of improved cropping patterns can increase the productivity of dry land by utilizing all land for planting food crops. In line with the results of the study by[2] which showed that cropping patterns improved by planting more types of food crops showed better growth and yield of food crops than using only 2 types of food crops.

Table 1: Total plant height, weight of 100 grains, dry weight of stover, and yield of food crops with farmers planting patterns and improved cropping pattern.

Treatments	Plant height (cm)	Weight of 100 grain (g)	Dry weight of stover (t/ha)	Yield (t/ha)
Cropping patternn (P)				
P1 vs P2 P3 P4 P5	**	**	**	**
P1	b	b	b	b
P2 P3 P4 P5	a	a	a	a
P2 vs P3	**	ns	ns	**
P2	b			a
P3	a			b
P2 vs P4	**	ns	ns	**
P2	a			a
P4	b			b
P2 vs P5	**	**	**	ns
P2	b	a	a	
P5	a	b	b	
P3 vs P4	**	ns	ns	ns
P3	a			
P4	b			
P3 vs P5	**	**	**	**
P3	a	a	a	b
P5	b	b	b	a
P4 vs P5	**	**	**	**
P4	b	a	a	b
P5	a	b	b	a

Note: **: very significant at the 1% level based on the LSD test

ns: not significant at the 1% level based on the LSD test

P1: farmers cropping pattern intercropping upland rice + cassava; P2: improvement cropping patterns intercropping upland rice + corn/cassava – peanuts; P3: improvement cropping patterns intercropping peanuts + corn/cassava – green beans, P4: improvement cropping patterns intercropping green beans + corn/cassava - peanuts, P5: improvement cropping patterns intercropping green beans + corn/cassava –green beans.

Farming Costs and Revenues

The application of improved cropping patterns by cultivating twice planting requires more labor than the cropping pattern of farmers who only cultivate one planting per year, so that there is an increase in labor requirements for each cropping pattern P2, P3, P4 and P5, which are respectively 94.26%, 83.25%, 85.89% and 77.03% (Table 2). Manpower cultivates during the rainy season more than in the dry season because the soil conditions are heavier including terrace improvements.

Table 2: Labor needs and materials for production of food crop per hectare with a farmers and improved cropping pattern in Berastagi Karo Regency, Indonesia.

Description	**Cropping Patterns (P)**				
	P1	**P2**	**P3**	**P4**	**P5**
	RS/DS	RS/DS	RS/DS	RS/DS	RS/DS
Labor (HOK)					
Tillage	72/0	72/43	72/43	72/43	73/43
Planting	57/0	81/58	81/58	81/58	81/58
Insertion	6/0	9/5	8/5	8/5	8/5
Fertilizing	76/0	108/40	56/40	56/40	56/40

Weeding	75/0	65/44	48/44	48/44	48/44
Pest control	-	-	-/4	12/-	-/4
Harvesting	92/0	100/70	138/57	120/70	125/57
Post harvest	40/0	62/55	82/30	65/55	65/33
Total	**418**	**812**	**766**	**777**	**740**
Materials					
Seed (kg)	60	70/70	100/35	65/70	65/35
Anorganic fertilizer:					
Urea (kg)	350/0	300/50	200/50	200/50	200/50
TSP (kg)	140/0	150/50	100/50	100/50	100/50
KCl (kg)	-	150/50	100/50	100/50	100/50
Pesticide (kg)	-	10/10	10/10	10/10	10/10

Note: P1: farmers cropping pattern intercropping upland rice + cassava; P2: improvement cropping patterns intercropping upland rice + corn/cassava – peanuts; P3: improvement cropping patterns intercropping peanuts + corn/cassava – green beans, P4: improvement cropping patterns intercropping green beans + corn/cassava - peanuts, P5: improvement cropping patterns intercropping green beans + corn/cassava –green beans.
RS: Rainy season; DS: Dry season.

Fertilizers given by farmers for upland rice in farmers' cropping patterns are urea and TSP with a high enough dose without balanced KCl fertilizer. In the improved cropping pattern, the fertilizer given is urea, TSP, and KCl which is intended for upland rice, corn, peanuts and green beans, while cassava is not given fertilizer specifically.

Improved cropping patterns require production costs of between Rp. 2,096,000 to Rp. 2,336,500 or an increase of 80.39% -101.16% compared to farmers' cropping patterns. The highest use of production costs is found in the P2 cropping pattern, which is the cropping pattern for improving upland rice + corn / cassava-peanuts intercropping. Although there was an increase in production costs in the improved cropping pattern compared to farmers cropping patterns, it was followed by an increase in farmers' income (Table 3).

Table 3: Rice equivalent yields and economic analysis of farmers and improved cropping patterns in Berastagi Karo Regency, Indonesia.

Cropping patterns	Rice equivalent yield (t/ha)	Revenue (Rp/ha)	Cost (Rp/ha)	Net Income (Rp/ha)	B/C ratio	Marginal B/C ratio
P1	7.89	3,154,400	1,161,500	1,992,900	1.72	-
P2	18.54	7,416,400	2,336,500	5,079,900	2.17	2.63
P3	16.39	6,556,800	2,218,500	4,338,300	1.95	2.22
P4	18.73	7,493,200	2,267,000	5,226,200	2.30	2.92
P5	14.49	5,794,400	2,096,000	3,698,400	1.76	1.82

Note: P1: farmers cropping pattern intercropping upland rice + cassava; P2: improvement cropping patterns intercropping upland rice + corn/cassava – peanuts; P3: improvement cropping patterns intercropping peanuts + corn/cassava – green beans, P4: improvement cropping patterns intercropping green beans + corn/cassava - peanuts, P5: improvement cropping patterns intercropping green beans + corn/cassava –green beans.

The application of improved cropping patterns (P2, P3, P4, and P5) gives an increase in total rice equivalent yields of 134.98%, 107.73%, 137.39%, and 83.65% compared to farmers cropping patterns, respectively. Increasing the total yield of equivalent rice in the improved cropping pattern is caused by an increase in cropping intensity, in addition to the use of superior varieties with regular spacing and appropriate and balanced fertilization doses.

Farming production costs of cropping patterns of farmers per hectare were Rp. 1,161,500 and in the improved cropping pattern ranged from Rp. 2,096,000 to Rp. 2,336,500 (Table 3). The fourth largest cost of an improved cropping pattern is for seed purchases, fertilization, maintenance, and labor costs.

Financially, the five researches for proper improvement cropping patterns are developed because it is seen from the benefits compared to the given giving, which is still greater than one and has a positive value of 1.72-2.92 (Table 3), with the contribution of net income of Rp. 1,992,900 in P1, Rp. 5,079,900 in P2, Rp. 4,338,300 in P3, Rp. 5,226,200 in P4, and Rp. 3,698,400 in P5 (Table 3).

The most financially profitable cropping pattern is P4, which is the cropping pattern of improved intercropping of green beans + corn/cassava-peanuts. With this cropping pattern, the net income obtained reaches Rp

5,226,200 and the B/C ratio is 2.92 per hectare of land. This is in line with the results of[18] which showed improved cropping patterns better than farmers cropping patterns. When examined further, the production costs of farmer cropping patterns are lower than those of improved cropping patterns (Table 3). However, because land use is not efficient because it only uses 2 types of food crops, as well as planting that is only done in the rainy season (dry season is fed), the yield of food crops obtained is also low, which affects farmers' income.

For farmers in general, each decision to implement a recommended technology package will be determined by the level of net income they will receive. Net income as a manager is the difference between the total value of production and the total cost, including family labor and land use costs. According to,[19] a farm will be able to survive or be feasible to be developed if the net income for managers reaches at least 20% of the costs incurred. Thus, in addition to the cropping patterns P4 and P2, the two other cropping patterns studied (P3 and P5) adequately represent the opportunity cost of farmers as farm managers if the cropping pattern is developed.

In Table 3, it is seen that based on the marginal value of B/C ratio obtained in the five cropping patterns studied shows that the planting patterns of P2, P3, and P4 have high B / C ratio marginal values, which are 2.63, 2.22, and 2.92 respectively. This means that the cropping pattern is profitable or feasible. This situation will be achieved if there are no changes in both farming costs (expenses) and sales of results (receipts). However, when the recommended technology package is developed, changes in costs and prices of production often occur.

A package of farming technology will be easier for the user/farmer to adopt if he has the ability to remain implemented under conditions of changes in costs and production prices. The results of economic analysis of farming of P2, P3, and P4 cropping patterns indicate that there is a high enough adaptation ability to increase farming costs and decrease in product selling prices (Table 3) indicated by marginal values of B/C above 2. According to[20], the application of a technology can be said to be economically feasible if it has a marginal minimum B/C ratio of 2.

CONCLUSION

Improved cropping patterns yield higher rice equivalent yields than farmers cropping patterns.

The application of improved cropping patterns (P2, P3, P4, and P5) increases production costs due to increased use of labor and production facilities, but the increase in production costs can be offset by increasing profits by 154.9% in P2, 117.69% at P3, 162.24% in P4, and 85.58% on P5 compared to the cropping pattern of farmers.

Cropping patterns of improved P4 (cropping patterns of improved intercropping of green beans + corn/cassava - peanuts) provide the highest B/C ratio and marginal B/C ratio, ie 2.30 and 2.92, followed by P2 (cropping patterns of improved intercropping of upland rice + corn/cassava – peanuts) for 2.17 and 2.63, and P3 (cropping patterns for intercropping of green beans + corn/cassava - peanuts) of 1.95 and 2.22. The three cropping patterns are economically feasible in the Berastagi Karo dry land because they have a marginal B/C ratio above two, whereas the farmers cropping pattern, namely intercropping of upland rice/cassava has the lowest B/C ratio of 1.72.

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