Profitability and Land Equivalent Ratio of Maize and Soybean Intercropping on Dryland Agroecosystem

by Ria Rustiana

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ABSTRACT
The provision of sufficient and sustainable food continues to increase as the population increases. A strategic effort to increase land productivity is the intercropping planting system. However, to what extent the profitability and land efficiency of the intercropping system, especially maize and soybeans in dryland, has not been thoroughly studied. This study aims to determine the profitability and efficiency of land use in various population combinations of soybean and maize in the intercropping systems in dryland. The experiment was arranged in a randomized block design involving five treatments of maize and soybean population, i.e., 1. maize monoculture (planting space: 40x35 cm); 2. 1 row of maize: 6 rows of soybeans (25%: 75%); 3. 2 rows of maize:4 soybean rows (50%:50%); 4. 3 rows of maize:2 rows of soybean (75%:25%) and 5. soybean monoculture (planting space 30x20 cm). All treatments were repeated 5 times. The experimental results showed land equivalent ratio (LER) of soybean and maize increased with the decrease in soybean population in the same land unit. However, the increase was moderate in the composition of soybean 2 rows of and 3 rows of maize. Thus, the optimum LER was obtained at the composition of 4 rows of soybeans and 2 rows of maize (land occupation of 50%:50%). Farmers income from intercropping soybean+maize was higher than the monoculture of soybean and maize in dryland. The most profitable combination of soybean+maize intercropping was at a composition of 50:50% or 4 rows of soybeans and 2 rows of maize. This is indicated by the optimum profit given by the combination population of soybean and maize intercropping with the B/C ratio of 1.92.

***Keywords:** dryland, intercropping, LER, Maize, population, soybean*

1. INTRODUCTION

The provision of sufficient and sustainable food is always in line with population growth which is always increasing. However, food supply is always faced with very serious problems such as scarcity of natural resources [1, 2], decreased quality of natural resources due to water and soil pollution, and excessive use of chemical fertilizers [3, 4], climate change [5], loss of biodiversity [6], and depletion of land suitable for food production [7, 8].

Expansion of planting area to increase cereal production increasingly difficult to be conducted continuously due to limited area of agricultural land suitability. Therefore, one of the most realistic efforts is through increasing productivity. The increase in land productivity can be achieved through the intercropping systems [9]. The intercropping system is carried out to obtain an increase in total production and reduce the risk of crop failure or loss of one of the plants as well as reduce production costs and increase farm income. In an intercropping system, it is necessary to regulate plant density and select plant species to obtain an optimal population without neglecting the carrying capacity of the land, so that the reduction in yield of each plant due to competition for nutrients, water and light will be compensated with the same population as the monoculture cropping system [10].

There are three main commodities strategic in Indonesia i.e., rice, maize and soybeans. Rice demand for consumption from 2017 to 2019 reached 33.47 million tons/year, while grain production reached 80.93 million tons or about 51.8 million tons of rice (64.02% unhulled rice conversion) [11]. Maize production is estimated to have a surplus of 2.25 million tons to 4.25 million tons in 2020 [12]. However, soybean commodity experienced an increasing deficit for 1.6 million tons in 2016 and the deficit is estimated to increase to 1.91 million tons in 2020 [13].

The challenge of supplying soybeans is getting tougher as the harvested area decreases. Soybean harvested area in 2014 was 615 thousand ha with a production of 955 thousand tons, and in 2017 it fell to 356 thousand ha with a production of 539 thousand tons [14]. The decline in soybean harvested area was mainly due to a decrease in farmers' interest in planting soybeans because profits were lower than planting other crops. The government seeks to meet soybean needs by increasing production through intensification and expansion of harvested areas. Agricultural intensification can be obtanied through improved management [15] and increased land use intensity [16]. The intensity of land use can be assessed based on the intensity of planting [17].

The application of the intercropping pattern is an effort to increase the intensity of land use [18]. Yield advantages exist if two crops are grown together due to the difference use of resoures [19]. A common instrument to measure the land productivity in intercropping crop systems is land equivalent ratio (LER) and it often used as an indicator to determine the efficacy of intercropping [20]. If a value of LER is morer than 1.0, it indiates that yield for that particular crop combination of intercropping is more than growing similar population of monoculture crops, and LER value of less than 1.0 indicates that beneficial yield of intercropping is lower than that monoculture crops [21]. Maize-soybean intercropping may also advantages in term of saving irrigation water, especially in the location of water scarcity [20, 21].

Intercropping has been practiced in many countries, such as China, India, Nigeria, Mali, Indonesia and Ethiopia [22–25], with a contribution of 15-20% of the world's food supply [28]. Intercropping of cereals with various bean crops in China and Africa is more profitable as yields increase [27, 28]. The pattern of intercropping with legumes also contributes to land sustainability by reducing soil erosion and improving the supply of nitrogen nutrients [31], as well as being ecologically, biologically, and socio-economically beneficial compared to growing non-legume crops in monoculture [32].

A number of crop intercropping studies have been conducted in Indonesia in terms of population, productivity, and land use efficiency [31–33]. However, most studies did not report the appropriate cropping pattern related to land use efficiency particularly in a maize-soybean intercrop in tropical dryland and semi-arid climate in Indonesia. Furthermore, there were not many study reports on profitability of maize and soybean intercropping. The purpose of this study was to determine the profitability and efficiency of land use in various population combinations of soybean and maize intercropping systems in dryland and semi-arid climate of Indonesia.

2. MATERIALS AND METHODS

2.1. Materials

The experiment was conducted through a participatory on-farm research approach, involving farmers and extension workers during research progress ranging from planning, implementation to evaluating the performance of technology applied. With this mechanism, farmers and extension workers understand the advantages and disadvantages of the technology applied [36]. Materials used were maize seed, soybean seed, fertilizers, pesticides. The use of materials is explained in detail at next section.

2.2. Methods

2.2.1. Experimental design

The experiment was carried out on a dry climate dry land agro-ecosystem of the Pototano District, West Sumbawa Regency. The most basic selection of the location is that the Pototano area is an area of dry land with a semi-arid climate zone. This is based on a low average annual rainfall of 1134 mm/year for 8 years. Most of the rainfall occurred from November to April, but there was rain spill out or rainfall fell on February

(Figure 3). This condition is enough to affect the growth of maize where in February the maize has entered the flowering phase or seed filling which really needs sufficient water in that phase.

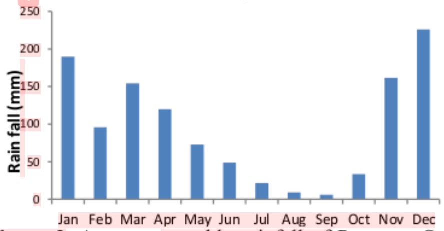

Figure 3. Average monthly rainfall of Pototano Sub-district for 8 years (2011-2018).

The experiment was arranged in a randomized completely block design with five treatments of maize and soybean populations, i.e 1. Maize monoculture (planting size 40x35 cm); 2. 1 row of maize and 6 rows of soybean (25%:75%) (Figure 1a); 3. 2 rows maize and 4 rows of soybean (50%:50%) (Figure 1b); 4. 3 rows of maize: 2 rows of soybean (75%:25%) (Figure 2) and 5. soybean monocultures (30x20 cm spacing). The treatments were repeated four times. Cultivation of maize and soybean were referred to integrated maize management technology [37] and soybean plant management technology [38].

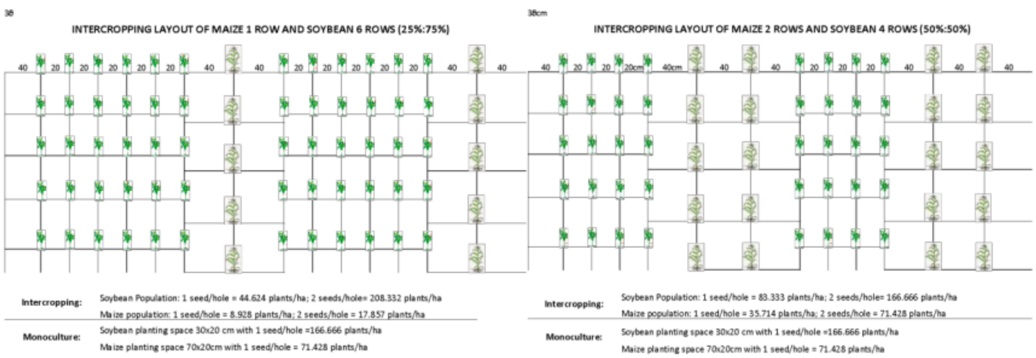

Figure 1. Intercropping arrangement of maize 1 row and soybean 6 rows (a) and maize 2 rows and soybean 4 rows (b)

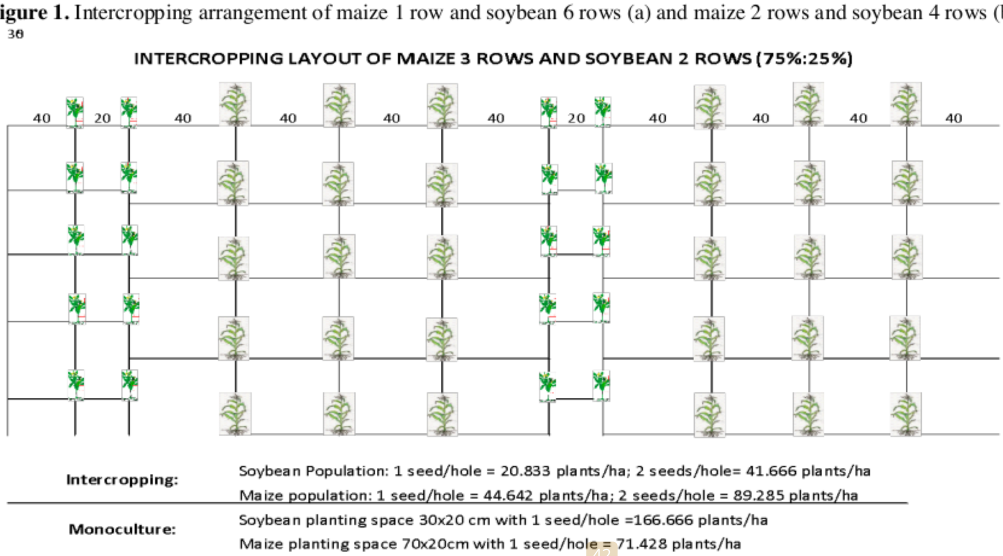

Figure 2. Intercropping arrangement of maize 3 rows and soybean 2 rows

Data of maize and soybean yields (tons.ha^{-1}) were obtained by sampling of each combination of intercropping plants, as follows: sampling was taken on each intercropped commodity by cutting all plants in the alley 4-5 meters long (depending on land), the wider the better. The sampling area (Lu) was measured and the sampling yield was weighed (Bu) then yield conversed to ton.ha^{-1} as follows:

$$H = \frac{Bu}{Lu} * 10 * P \quad (1)$$

Where H = Yield (ton.ha^{-1}); P= the percentage of land used with other commodities on the same land, for example, intercropping maize and soybean with a land use percentage of 50%:50%.

2.2.2. Land use efficiency

The efficiency of land use was determined through the land equivalence ratio (LER) approach using formulation [19]:

$$\text{LER} = \frac{KT}{KM} + \frac{JT}{JM} \quad (2)$$

KT = Yield of soybeans in intercropping (ton.ha^{-1}).
KM = Yield of solely soybean (ton.ha^{-1}).
JT = Yield of maize in intercropping (ton.ha^{-1}).
JM = Yield of solely maize (ton.ha^{-1}).

2.2.3. Economic analysis of soybean and maize intercropping

Economic analysis was conducted to obtain the financial benefit of composition combinations of intercropping. Data were analyzed based on cost and revenue structure analysis [39] using the formula:

$$I = \sum \quad (Y.Py) - (Xi.Pxi) \quad (3)$$

where:
I = Income (RP.ha^{-1})
Y = Production or yield (ton.ha^{-1})
Py = price of yield (RP.ton^{-1})
Xi = Type and amount of i input used in this experiment (i = seeds (maize and soybean), fertilizers, pesticides and labor)
Pxi = The unit price of i input.

The feasibility of soybean and maize intercropping was analysed using Benefit-Cost Ratio (BC ratio) using formulation:

$$\text{BC ratio} = \frac{Income\ (I)}{Total\ cost\ (C)} \quad (4)$$

2.2.4. Statistical analysis

Data in this experiment were collected and measured including on farm input and output data, yield, and financial analysis. Financial analysis was obtained from input and output data of farming that had been recorded during the experiment, including land preparation costs, planting costs, seed prices, fertilizers, pest control costs, and harvest costs. Most data were subjected to analyze statistically using analysis of variance (ANOVA) [40].

3. RESULTS AND DISCUSSION

3.1. Yield and LER variation of maize and soybean intercropping in dryland

Yield and land equivalent ratio (LER) of intercropping soybean and maize at various population combinations in dryland and semi-arid climate is presented in Table 1. It can be seen at the Table that soybean yields decreased in line with the decreasing population of soybeans intercropped with maize and same trend was also occurred in maize crop yields. This is understandable because the soybean population decreases in line with increasing maize population at the same land unit. Planting space have been recognized to determine the yield of soybean [39–41].

Table 1. Summary of soybean and maize intercropping on various plant population compositions in dry land Poto Tano.

Soybean and maize composition (%) and in (row)	Soybean (ton.ha^{-1})	Maize (ton.ha^{-1})	LER	Total yield	Yield reduction (%)	
				(ton.ha^{-1})	Soybean	Maize
100:0 (solely soybean)	1.630c	0		1.630		
75:25 (6:1)	1.200bc	4.033a	1.35	5.233	26.38	38.26
50:50 (4:2)	1.083b	5.467b	1.50	6.550	33.56	16.30
25:75 (2:3)	0.533a	5.733b	1.20	6.266	67.30	12.23
0:100 (solely maize)	0	6.532c		6.532		

Note: Values followed by the same letter within the same column are not significantly difference at p:0.05 according to duncan's multiple range test.

The highest yield was significantly obtained at soybean monoculture, followed by intercropped soybean with population of 75% with maize 25% and the lowest yield was at 25% soybean population with maize 75%. In the intercropping system, crop management is one of the determinants of intercropping commodity productivity [42–44], including line space that was significantly affects nutrients uptake, water use efficiency, growth and capitulation of plant [47]. Crop arrangement aimed to minimize the negative influence between the commodities involved in the intercropping pattern. Total plant population reduces by increasing the spacing but additional nourishment gives better individual plant stand and extra yield. Khan [47] reported that increasing or decreasing row spacing and plant population have clear-cut effect on yield. Furthermore, narrow rows (less than 50cm) mostly gave additional grain yield compared to wider row spacing (greater than 50cm) under different crop growing conditions [48].

Although yield of soybean decreased at intercropping with maize, LER increased and reached a peak at 4 rows of soybean and 2 rows of maize (with 50:50% of land planted). The value of LER then decreased at 25%:75% land composition of soybean and maize. This indicated that optimum composition of soybean and maize intercropped was 50%:50% land occupation (4 rows of soybean and 2 rows of maize). Yield of soybean and maize intercropped were decrease as each population decreased compared to sole yield of maize and soybean crops. The highest yield reduction was found at 25%:75% of land composition (2 rows of soybean and 3 rows of maize). Muoneke [49] reported that soybean yield decreased as maize population (plant.m^{-2}) increased at same land unit. However, total yield of intercropping 50%:50% land occupation (4 rows of soybean and 2 rows of maize) were higher compared to sole soybean and maize although this was not significant. This indicated that optimum intercropping composition of soybean and maize in the same unit land was 50%:50% of land occupation (4 rows of soybean and 2 rows of maize). Our results of experiment were in-line with reported by Yang [46]. Total intercrop yields were higher than those of sole crop maize and soybean, and the land equivalent ratios of the intercropping systems were above 1.3 [46].

3.2. Profitability of soybean and maize intercropping in dryland

Financial analysis of soybean and maize intercropping in dryland and semi-arid climate is presented in Table 2. In general, there was an increase in the income of soybean and maize intercropping compared to soybean monocultures. The highest cost of cultivation was obtained at labor with almost two times higher compared to input cost. Furthermore, the revenue from soybean decreases as yield decreases due to reduction of population, but this was conversely for maize. The lowest revenue was obtained from solely soybean and the highest revenue was obtained at intercropping soybean and maize for 50:50% land occupation (4 rows soybean and 2 rows maize).

The most profitable combination of soybean and maize intercropping was 50:50% composition or 2 rows of maize: 4 rows of soybeans. This is indicated by the highest profit given by the population combination for Rp. 15,762,000. Intercropping occupies greater land use and provides higher net returns [20]. It provides higher cash return than growing monoculture [30]. Ijoyah and Fanen [50] also reported that intercropping gave higher combined yields and profit net returns than those obtained from monoculture crop. Intercropping maize and cauliflower gave high net return compared to monoculture [51]. Sharma and Tiwari [52] also reported that maize intercropped with tomato increased total yields and obtained higher profit returns than those obtained from crops grown solely.

Table 2. Financial analysis of soybean+maize intercropping at various combinations of populations in dryland and semi-arid of Pototano.

	Components	Maize (M) monoculture (ha)	Soybean (S) monoculture (ha)	Intercropping S+M (ha): 6:1rows	Intercropping S+M (ha): 4:2 rows	Intercropping S+M (ha): 2:3 rows
A	**Input cost**	***2,995,000***	***1,895,000***	***2,320,000***	***3,020,000***	***3,495,000***
B	**Labour cost**	**6,250,000**	**4,150,000**	**4,950,000**	**5,200,000**	**6,000,000**
I	**Total A+B**	**9,245,000**	**6,045,000**	**7,270,000**	**8,220,000**	**9,495,000**
II.	**Yield**					
a	Maize yield ($kg.ha^{-1}$)	6,532		2,133	5,467	5,733
	Maize price ($RP.kg^{-1}$)	3,000		3,000	3,000	3,000
	Maize value ($RP.ha^{-1}$)	19,596,000	-	6,339,000	16,401,000	17,199,000
b	Soybean yield ($kg.ha^{-1}$)		1,630	1200	1083	533
	Soybean price ($RP.kg^{-1}$)	-	7,000	7,000	7,000	7,000
	Soybean value ($RP.ha^{-1}$)	-	11,410,000	8,400,000	7,581,000	3,731,000
III	**Total Revenue**	**19,596,000**	**11,410,000**	**14,799,000**	**23,982,000**	**20,930,000**
IV	**Total Benefit**	10,351,000	5,365,000	7,529,000	15,762,000	10,935,000
V	**B/C Ratio**	**1.12**	**0.89**	**1.04**	**1.92**	**1.20**

One of the indicators to determine the viability of intercropping is cost-benefit analysis. B/C ratio of various plant spacing of soybean and maize intercropping in dryland and semi-arid climate is presented in Figure 4. The lowest BC ratio was obtained at solely soybean for 0.89 while the highest B/C ratio was obtained at intercropped 4 rows of soybean and 2 rows of maize for 1.92. In general, it shows that the 50:50% population combination or 4:2 soybean + maize intercropping can be recommended to be applied in dryland and semi-arid climate. Thus, it can be summarized that the recommendation for the most profitable soybean-maize intercropping was the 50:50% land occupation or 4 rows of soybeans and 2 rows of maize.

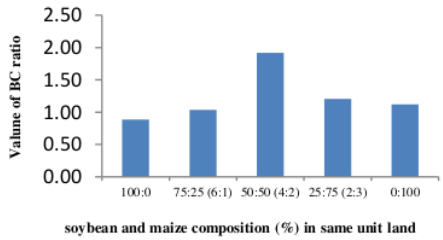

Figure 4. BC ratio of various plant combinations of soybean and maize intercropping on dryland and semi-arid climate NTB, Indonesia. Numbers in bracket indicate row of soybean : maize.

4. CONCLUSIONS

The most profitable combination of soybean and maize intercropping was at a composition of 50:50% or 2 rows of maize: 4 rows of soybeans. This was indicated by the high profit provided by the combination of the population with B/C ratio of 1.92 and the highest value of LER about 1.50. The income of soybean + maize intercropping was higher than that of monoculture of soybean and maize. The recommendation of the most profitable soybean-maize intercropping technology package was the 50:50% package or 4 rows of soybeans and 2 rows of maize in the dryland and semi-arid agroecology.

ACKNOWLEDGMENT

We thank the Indonesian Agency for Agricultural Research and Development for funding this research. We also thank Mr. M. Yunus for helping in crop management and observations in the field.

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