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ANALYSIS RISK AND RETURN OF CROPS PORTFOLIO

Rulianda Purnomo Wibowo[1], Dian Pebriyani[2]*
[1,2]Faculty of Agriculture, Universitas Sumatera Utara
Correspondence E-mail: dianpebriyani10@gmail.com

Abstract

Agricultural sector is exposed to risk especially risk in crop price or production volatility. The cropping pattern or mixed cropping is a diversification strategy which is considered as an approach to reduce the risk in agriculture farming. This research was conducted to analyze the combination of two plant types, namely vegetable crops and food crops. Portfolio combine longbean and spinach as vegetable crop portfolio and paddy and corn as food crop portfolio. The risk analysis method is used to calculate expected return, standard deviation and coefficient variation. This research also analyzes the choice of portfolio based on preference using Stochastic Efficiency with Respect to A Fuction (SERF). The results showed that with the aim of reducing the risks from farming, combination of spinach with longbean and paddy with corn can reduce risks and provide greater income. Moreover, at various levels of risk preference, the vegetable portfolio is more preferred than food crops portfolio. This study result implies a potential development for vegetable crops vertical farming in Medan.

Keywords: crop portfolio, risk, risk preference, SERF

1. INTRODUCTION

Farmer are expecting a large economic return from farming, however agricultural sector is exposed to risk especially risk in crop price or production. Those risk may influence farmers' decision in choosing crop or farm management. The risk may have a negative effect on agricultural business profitability. Farmers with risk averse preferences may prefer crops with low risk eventhough generate lower return. Thus farmers' preferences for risk are one of the important aspect that influence farmers' decisions (Wibowo et al., 2017; Wibowo, Rizaldi, et al., 2019; Wibowo, Sumono, et al., 2019).

There are two types of risk in agriculture, namely production and price risk. Production risk affect plant productivity due to weather uncertainty, pest, plant disease and other factors that not directly manage by farmer. On the other hand, price risk can be a result from price fluctuations in the commodity market which will further affect farmers' income (Patrick et al., 1985; Pebriyani et al., 2022). In the long term, the risks faced by farmers will affect farmers' decisions in allocating capital and land for farming (H. C. Limbong et al., 2022; Rosa et al., 2019; Wibowo et al., 2017).

The cropping pattern or mixed cropping is a diversification strategy which is considered as an approach to reduce the risk in agriculture farming. The cropping pattern or mixed cropping is carried out by combining two or more types of crops on a cultivated land. This cropping pattern concept is carried out by implementing the Modern Portfolio Theory (MPT) concept which is often used in the financial analysis model (Markowitz, 2010) in which a portfolio should be more than one type of asset in order to cover risks from other assets (Markowitz, 1952). MPT implementation in farming is expected to cover the revenue losses from one crop due to production risk or price risk by profits from other crops (Debertin, 2012). The MPT implementantion also may provide benefits for farmers in reducing the risk (Hastrianty et al., 2020; Pebriyani et al., 2022). In addition, cropping patterns offer a number of agronomic benefits such as increasing soil fertility and protecting plants from diseases, weeds and insects (Mandal & Maity, 2022; Ogundari, 2013).

The issue of risk is also faced by farmer who cultivated vegetable crop in which vegetable crops are very vulnerable exposed to risks, especially price risk. Previous studies have explained that horticultural crops are more vulnerable to price risk than food crops (Irawan, 2007). Vegetable farmers especially in Medan experience relatively high price fluctuations. Based on data from the

Central Beurau Statistics, it is known that the average price of crops from the lowest respectively is corn (IDR 3,392), spinach (IDR 4,132), long beans (IDR 4,546) and rice (IDR 5,061).

Table 1. Distribution of plant prices in one year per hectare in Medan 2010

Plants	Min	Max	Means	Standard Deviation	Coeff. Variation
Longbean	3,975	5,463	4,546	493.0	0.11
Spinach	3,288	5,046	4,132	652.7	0.16
Paddy	3,780	5,950	5,061	711.1	0.14
Corn	2,507	4,646	3,392	647.8	0.19

Based on coefficient variations, i.e risk indicator, estimation on table 1, corn and spinach are more prone to revenue risk compared to other crops. This indicates corn and spinach have higher price risk compared to paddy and long beans. Farmers in Medan supplies their vegetables to markets sorrounding the city. However, it is feared that the high price risk will affect farmers' income and farmer preferences on farming. In the long term, it may dismay farmers' decisions in allocating capital and converting their land for non-agricultural purpose, e.g converting land for residential or industrial use.

This research was conducted to analyze the combination of two plant types, namely vegetable crops and food crops. Those crop combination is based on the main crops planted by farmer in Medan City (BPS, 2022). The combination of these plants formed a portfolio in various land change proportion to the distribution of land areas. The vegetable portfolio will combine spinach and long bean, with the consideration that spinach is one of the high-risk plants (A. H. A. Limbong & Ayu, 2018; Pebriyani et al., 2022; Tampubolon et al., 2022). Furthermore, the analysis on food crops will combine corn and paddy crops where corn plants have a fairly high risk. Other studies state that we can reduce the risk if we manage suitable crops in the portfolio (Paut et al., 2019). It is hoped that this portfolio analysis can explain risk reduction and returns for farmer if spinach and corn which considered as high-risk crops, are combined with other crops. Furthermore, the research is expected to explain the decision of farmers in choosing the types of food crops or horticultural crops based on their risk preference.

2. LITERATURE REVIEW

Agricultural diversification is an attempt to replace or increase monoculture agricultural output towards multicrops or mixed-crops agriculture. Such diversification is called horizontal diversification, a combination between plants, livestock, fishery, or fish-livestock. In addition, there is vertical diversification, the strategy that promote the integration between farming and other related agricultural commodity processing industries (Mubyarto, 1989). The risks and returns faced by decision makers are moving in one direction, greater risk comes with greater income potential and vica versa (Hanafi, 2007; Tandelilin, 2001).

Modern portfolio theory explains more assets in a portfolio may lower the risk of the portfolio. There is also the concept of reducing risk as a result of adding securities to the portfolio. This concept is very important to understand the risk portfolio. This concept states that if we continuously add types of securities to our portfolio, then the risk reduction benefits will be greater until we reach a particular point where the reduction benefits begin to decrease (Tandelilin, 2001 (Tandelilin, 2001).The Modern Portfolio Theory motivated the portfolio design for different land proportion on this study.

3. IMPLEMENTATION METHOD

This research is a quantitative study conducted in Medan using secondary data on long beans, spinach, paddy and corn farming in 2012-2022. Research data were collected from related sources such as the Central Beureau of Statistic, Department Agriculture of Indonesia and other literature studies. The research was carried out with the aim to analyze the risks and income that

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farmers are likely to receive if they apply a different cropping pattern by combining more than one type of crop cultivated simultaneously on one area of land. Furthermore, this combination of plants will be referred as a portfolio. The proportion of farming area by crop is determined as the weight using the following formula:

$$F_{a,b} = \frac{farming\ area\ (a,b)}{farming\ area\ (a) + farming\ area\ (b)} \quad (1)$$

where *F* is the proportion of farming area or weight of each crops in portfolio; *a* and *b* is the type of plant; total farming area is 1 hectare of land; the total of weight is equal to one (F_a+F_b=*1*). The distribution of plant weight in portfolio is as follows:

Table 2. Plant weight in the vegetable crop portfolio and food crop portfolio

Portfolio	Combination	Weight	Portfolio	Combination	Weight
1	Long bean : Spinach	0.1 : 0.9	**10**	Paddy : Corn	0.1 : 0.9
2	Long bean : Spinach	0.2 : 0.8	**11**	Paddy : Corn	0.2 : 0.8
3	Long bean : Spinach	0.3 : 0.7	**12**	Paddy : Corn	0.3 : 0.7
4	Long bean : Spinach	0.4 : 0.6	**13**	Paddy : Corn	0.4 : 0.6
5	Long bean : Spinach	0.5 : 0.5	**14**	Paddy : Corn	0.5 : 0.5
6	Long bean : Spinach	0.6 : 0.4	**15**	Paddy : Corn	0.6 : 0.4
7	Long bean : Spinach	0.7 : 0.3	**16**	Paddy : Corn	0.7 : 0.3
8	Long bean : Spinach	0.8 : 0.2	**17**	Paddy : Corn	0.8 : 0.2
9	Long bean : Spinach	0.9 : 0.1	**18**	Paddy : Corn	0.9 : 0.1

Furthermore, the expected return and risk for a particular portfolio is estimated to measure the expected income and the risk for different cropping patterns. Expected return is the sum of the return values expected to occur from the probability of each event. In this study, the expected return is the amount of farmer's return that obtained for one year harvest time at one hectare of land. The model of expected return for monoculture farming and expected return for portfolio can be seen below (Ahmad, 2004; Elton & Gruber, 1977) :

$$E(Ri) = \sum_{i=1}^{n} P_i \,.\, R_i \quad (2)$$

$$E(R_p) = [E(R_a)\, F_a] + [E(R_b)\, F_b] \quad (3)$$

where $E(R_i)$ is expected return of monoculture farming, $E(R_p)$ is expected return of portfolio, R_i is Return, P_i is Probability, $F_{a,b}$ is weight of crops in portfolio, *a* and *b* is type of crop a. Variance of return is the sum of the squared difference between the return and the expected return multiplied by the probability of each event. Coefficient variation is measured from the ratio of the standard deviation to expected return. Smaller coefficient variation in farm return shows lower agriculture risk faced by farmer. Calculation of variance and coefficient variation for monoculture farming can be seen in equation as below (Ahmad, 2004; Elton & Gruber, 1977) :

$$\sigma^2 = \sum_{i=1}^{n} P_i\ (R_i - E(R_i))^2 \quad (4)$$

$$\sigma = \sqrt{\sigma^2} \quad (5)$$

$$CV = {}^{\sigma}/_{ER_i} \quad (6)$$

$$\sigma^2(R)p = {F_a}^2 {\sigma_a}^2(R_a) + {F_b}^2 {\sigma_b}^2(R_b) + 2F_a F_b\, covar\,(R_a, R_b) \quad (7)$$

where σ^2 is variance of return, σ is standard deviation and *CV* is coefficient variation; $\sigma^2(R)_p$ is variance of portfolio; $\sigma_{a,b}{}^2\ (R_{a,b})$ is variance of each crop; $F_{a,b}$ is weight for crop *a* and crop *b* in portfolio; $covar\ (R_a, R_b)$ is covariance of crop *a* and crop *b*.

There is basic assumption and limitation of certainty equivalent and risk estimation that are applied to this study in which the risk that is taken into account is price risk. The variability in farm revenue based on changing values of product price and input prices over the last 10 years. Meanwhile, production variability is not taken into account or crop production is considered constant for the last 10 years.

Farmers' decisions on portfolio selection are analyzed using Stochastic Efficiency with Respect to a Function (SERF). This method is useful and easily understood on problems involving agricultural risk and farmer risk preference (Fathelrahman et al., 2011; Wibowo, Rizaldi, et al., 2019). This analysis uses the certainty equivalent (CE) value as the value of return that is willing to be accepted for risky choices according to farmer risk preferences. Farmer risk preferences is projected by the Absolute risk averse coefficient (ARAC). Farmer preferences are in the range 0-4 where greater ARAC value describes more risk averse preference, while a value of 0 describes a neutral risk preference. Calculation of certainty equivalent can be seen in equation as below (Hardaker & Lien, 2010) :

$$\max EU_{(Er,r)} = Maxx\ \{EU\ ([h\ (F)(f\ (ER_i, f) - cti, r) \quad (8)$$

$$s.t$$

$$CE(RAC) = \ln(1 - E[u(ER_i)])^{-1/ARAC} \quad (9)$$

$$CE = E(Ri) - (\mathrm{ARAC}\,.\,\sigma) \quad (10)$$

where *CE* is certainty equivalent of each portfolio, h is price volatility, cti is input cost and *ARAC* is risk preference coefficient. Furthermore, the certainty equivalent value will be depicted in a graph where the horizontal axis is the ARAC value and the vertical axis is the Certainty Equivalent. SERF graphs can show the selection of portfolio types at different levels of farmer preference (Hardaker & Lien, 2010; Lien et al., 2007; Rosa et al., 2019; Wibowo, 2019).

4. RESULTS AND DISCUSSION

The results of this study show return variability that may be received by farmers if farming is cultivated on one hectare of land in one harvest year. The expected return shows as a projection of income from monoculture farming, while the risk can be explained by the value of the coefficient variation. Greater coefficent variation value indicates the plant has higher risk. The expected return and risk from cultivating long beans, spinach, paddy and corn can be seen in table 2 below

Table 3. Expected Return and Coefficient Variation of Crops

Plants	Expected Return	Coeff. Variations
Longbeans	75,771,198	0.137
Spinach	143,874,262	0.217
Paddy	83,391,002	0.155
Corn	56,493,471	0.267

The results showed that the plant with the greatest risk was corn with a coefficient variation of 0.267. The expected return value of corn shows the lowest value compared to other crops (IDR 56,493,471/Ha). The high risk of corn farming is due to the relatively high price fluctuations of corn crop (see table 1). The plant with the lowest risk compared to other crops is long bean with a coeff variation value of 0.137. The expected return value of long beans shows the second lowest value.

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The plant with the greatest expected return is spinach with an expected return value of IDR 143,874,262/Ha. However, a large potential income is also followed by a large risk, in accordance with the risk management theory which states "high risk high return and vica versa". Previous research also explained that spinach is one of the plants with the greatest risk exposure (Pebriyani et al., 2022; Tampubolon et al., 2022).

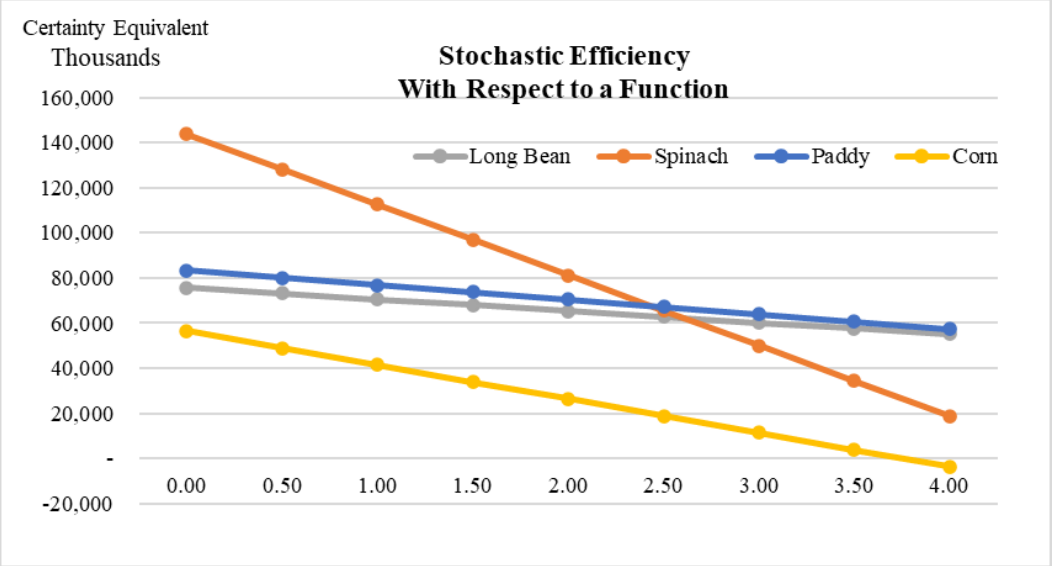

Figure 1. Graph of SERF on plants cultivated in monoculture

The selection of plants grown in monoculture can be seen in the SERF chart in Figure 1. Spinach is a plant selected at a neutral risk preference of "0" up to an ARAC value of 2.5. This is because spinach are plants with the greatest returns compared to other plants. In line with a large income, the risk of growing spinach is also quite high so that when farmers' preferences change to become more risk averse, farmers will choose to cultivate paddy with a lower risk than spinach.

It can be seen that regardless the level of risk preference, corn is a plant that was not selected. This is because corn is a type of plant with high risks and low-income potential. Based on the preferences of farmers at various levels of risk preference, corn is one of the crops that is not preferred to be cultivated (see figure 1). In fact, based on BPS (2022) data, the corn area in Medan is only 0.14% compared to the corn planted area in North Sumatra.

The risk from spinach and corn plants can be reduced by carrying out portfolio by combining high-risk plants with other plants. The expected return and risk values estimation of the portfolio can be seen in table 4 below.

Table 4. Return and Risk Portfolio of combinations of long bean, spinach, rice and corn crops

Portfolio	Expected Return	Coefficient Variation	Portfolio	Expected Return	Coefficient Variation
1	137,063,955	0.211	**10**	59,183,224	0.246
2	130,253,649	0.204	**11**	61,872,977	0.229
3	123,443,343	0.196	**12**	64,562,730	0.214
4	116,633,036	0.188	**13**	67,252,483	0.200
5	109,822,730	0.179	**14**	69,942,236	0.189
6	103,012,424	0.170	**15**	72,631,989	0.179
7	96,202,117	0.160	**16**	75,321,743	0.171

8	89,391,811	0.151	**17**	78,011,496	0.165
9	82,581,505	0.142	**18**	80,701,249	0.159

It can be seen that portfolios 1-9 is a combination portfolio of long bean and spinach plants. Sequentially portfolios 1-9 provide an increasing proportion of long bean land area. The results showed that the combination of spinach and long bean plants can reduce the risk of spinach farming while increasing the income received by farmers. These results indicate that long bean crops can cover losses from spinach farming. The results also showed that the combination of spinach and long bean plants had a lower risk value than if spinach was cultivated in monoculture farming. Portfolio 10-18 is a combination portfolio of paddy and corn. Sequentially portfolios 10-18 provide a larger proportion to paddy fields. The research results show that when combined with corn, paddy crop can reduce the risk of corn farming while at the same time increasing the income received by farmers. This shows that the paddy crop can cover losses due to risks from the corn crop.

The selection of plant species that farmers seek can be analyzed using the SERF graph where this graph illustrates the type of portfolio preferred by farmers at different levels of risk preference. The SERF graph for vegetable and food crop portfolios can be seen in Figure 2 below.

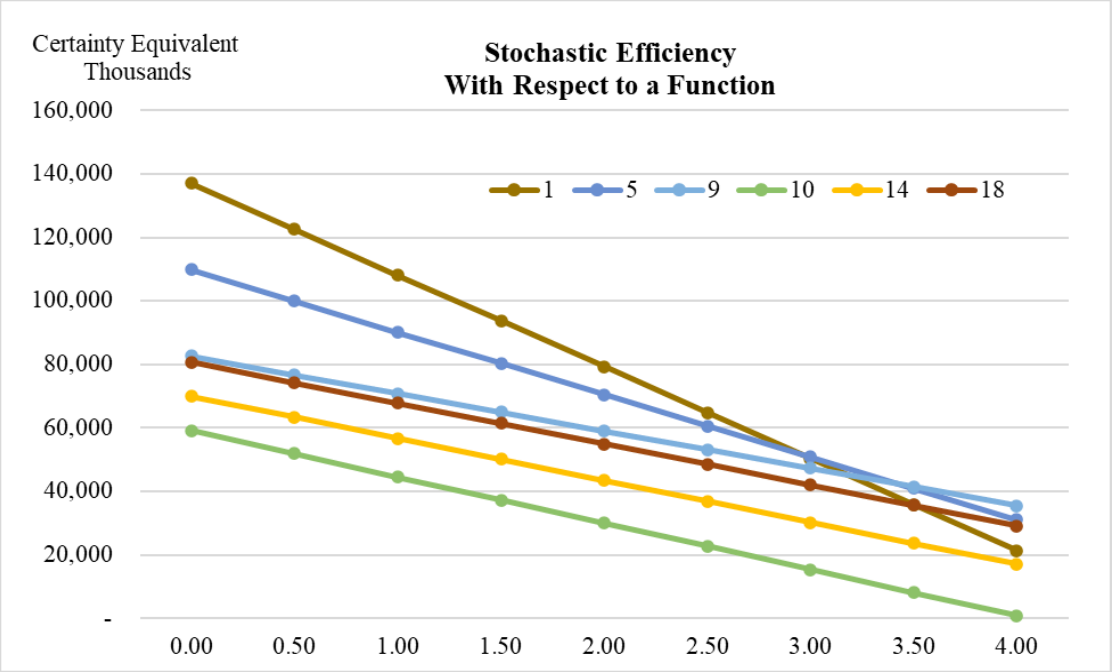

Figure 2. Graph SERF on Vegetables and Food Crops Portfolio

The results of the analysis using Stochatic Efficency with Respect to A Function show that the preferred portfolio is portfolio 1, which is a combination of spinach and long bean plants, at the level of risk preference 0 (neutral) – 3 (more risk averse). Portfolio 1 is a portfolio with a weight proportion of long beans 0.1 and spinach 0.9. Portfolio 1 provides greater expected income than other portfolios despite the higher risks. The portfolio decision is changing when risk preference is changing into more risk averse behavior. Farmers with more risk averse behavior will change their portfolio choices to portfolio 5 which has a lower risk value than portfolio 1. Portfolio 5 is a portfolio with a weight proportion of 0.5 long beans and 0.5 spinach. Furthermore, when farmer preferences change to risk averse (ARAC value 4), portfolio selection changes to the portfolio with the lowest risk value, namely portfolio 9. This result is in line with other studies that farmers who are more risk averse are more likely to choose assets or investments with lower risk (Liontakis & Tzouramani, 2016).

SERF results show that at any level of risk preference, the type of portfolio that will be choosen by farmers is vegetable portfolio. The food crop portfolio is not selected at any ARAC values. These results implies that agricultural development in urban areas in Medan should be focused on the development of vegetable crops. Other possibility is to develop urban and vertical farming for holticulture plantation in Medan.

4. CONCLUSION

The results showed that with the aim of reducing the risks from farming, the combination of spinach with long beans and paddy and corn can reduce risks and provide greater income opportunities. The results also show that at various levels of risk preference, the vegetable portfolio is more preferred than food crops portfolio. This research has not included production risk, so that further research is expected to be able to analyze production risk on the selection of farmer portfolios. In addition, it is hoped that further research will analyze the compatibility of plant combinations that will be combined in one portfolio from an agronomic perspective.

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