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Determining Risk-Efficient Tree-Crop Planting Strategies Using Stochastic Dominance Analysis

by

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ABSTRACT

Stochastic dominance analysis (SDA) is a non-parametric risk analysis tool, which partially ranks risky strategies to determine risk-efficient strategies that will be preferred by decision makers with similar risk attitudes. Four stochastic efficiency criteria which may be used to identify risk-efficient strategies, are (1) First Degree Stochastic Dominance (FSD), (2) Second Degree-Stochastic Dominance (SSD), (3) Stochastic Dominance with Respect to a Function (SDWRF), and (4) Stochastic Efficiency with Respect to a Function (SERF).

We are applying SDA to tree-crop planting strategies through the analysis of the cumulative distribution functions (CDF) of corresponding net returns. FSD and SSD are initially applied to eliminate FSD- and SSD- dominated strategies. SDWRF and SERF, which have higher discriminating power than the first two criteria, are then applied to the remaining strategies in order to identify risk-efficient strategies that will be preferred by decision makers with different degrees of risk-aversion. Planting rice alone was assessed to be the most-risk efficient, while planting corn with tomato, and banana with coconut and corn, were assessed to be acceptable to risk-averse decision makers. Three application softwares are used to facilitate the application of SDA, namely, (1) Stochastic Dominance Spreadsheet, (2) DOS-based SDRF Model, and (3) SIMETAR. A scenario analysis on the selling price of Gmelina is performed to determine which tree-crop planting strategies according to the price of timber are most acceptable to risk-averse decision makers.

Keywords: Stochastic dominance analysis, scenario analysis, risk analysis, risk aversion

I. Introduction

A. Background

Risk Analysis

Researchers are faced with the problem of identifying improved technologies to handle risk. Risk analysis considers the assessment of these technologies, which we will refer to as strategies or alternatives, in the presence of risk and uncertainty.

Decision makers have disparate ways of dealing with risk, and they are often classified according to their attitudes towards risk as either risk-preferring, risk-averse and risk-neutral. A risk- preferring decision maker prefers a strategy that will give high returns even if there's a possibility of low returns or even loss. A risk-averse decision maker, on the

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other hand, prefers a strategy that reduces the possibility of loss even if it does not necessarily give high returns. lastly, a risk-neutral individual tends to choose a strategy that maximizes the expected outcomes of the corresponding utility, regardless of the distribution of the outco mes (Patindol, 1997).

The concept of risk analysis involves the selection of risk-efficient strategies from a set of possible strategies that can be derived from a given scenario, such as crop management strategies (Lansigan et al., 1997), through the use of risk-efficiency criteria. A strategy is risk-efficient if it will be acceptable to risk-averse decision makers. A *risk-efficiency criterion* is a decision rule that reduces the set of all strategies by elimination of the ones that imply higher risk, without an increased return (Moss, 2001). A selected strategy is said to be risk-efficient if it will be preferred by all decision makers under a particular risk-aversion class.

The basic requirements of risk analysis include (1) the probability distributions of the outcomes, and (2) the utility function. The probability distribution of the outcomes provides a measure of the risk while the utility function provides a measure of the risk-attitude of the decision maker (Lansigan et.al,, 1997).

There are several approaches used in risk analysis. According to Markowitz (1952), and Heikkinen and Kousmaen (2003) as referred to in Benitez et.al. (2004), the *Mean Variance Method* is the classical approach to risk analysis, however its application is limited only to situations where the outcomes are normally distributed or if the utility function is quadratic. Another common approach is the expected utility model, but likewise, this approach has many detractors (Moss, 2001) and one of the reasons is because it requires that the utility function and probability distribution of the outcomes be precisely known (Lansigan et al., 1997). Since precise knowledge of the utility function is not always available, thus the significance of the stochastic dominance analysis becomes apparent since it requires only limited assumptions on the utility function, and it can also be applied for any distribution of the outcomes.

Stochastic Dominance Analysis

Stochastic dominance analysis is a non-parametric statistical tool used to partially rank alternatives or strategies according to their risk characteristics (Hien et al., 1997).

Generally, it groups the strategies into the "risk efficient" and "dominated" sets through the use of *stochastic efficiency rules.* These rules are implemented by pair wise comparison of the cumulative distribution functions of the outcomes resulting from different actions (Lansigan et al., 1997).

The most commonly used stochastic efficiency rules are the First Degree Stochastic Dominance (FSD) and the Second-Degree Stochastic Dominance (SSD). FSD is basically applicable when the only assumption regarding the utility function is that "more" is preferred to "less" (Lansigan, 1997). It can be implemented simply by direct observation of the position of the curves of two non-intersecting cumulative distribution functions (CDF). The CDF of the strategy lying to the right of the other dominates the other strategy, thus making it more risk-efficient. However, in reality, CDFs tend to intersect. This is where SSD becomes useful because dominance in this criterion is indicated by comparison of the areas under the CDF curves. SSD has a higher discriminating power and selects strategies that will be acceptable to risk averse decision makers. FSD and SSD, when used sequentially, classifies the different strategies into 3 groups, namely, (1) the dominated strategies, (2) strategies that could be acceptable to risk-neutral decision makers, and (3) those that could be used by risk-averse decision makers (Hien et al., 1997).

Another criterion developed, which is considered to have a higher discriminating power, is the Stochastic Dominance with Respect to a Function (SDWRF) criterion. This criterion ranks the different alternatives for decision makers with different degrees of risk-aversion by the use of bounds on the risk aversion coefficient within an SSD analysis. A newly developed criterion is the Stochastic Efficiency With Respect to a Function (SERF). Unlike the previously discussed stochastic dominance criterion, SERF works by selecting the risk-efficient strategies instead of finding a subset of dominated alternatives (Hardaker et al., 2004). It makes use of the Certainty Equivalents, instead of the CDFs, of each strategy. It is also claimed that SERF shows to have a higher discriminating power than SDWRF. The above-mentioned stochastic efficiency rules will further be discussed in the Theoretical Framework section of this paper.

Agroforestry and SAFODS

Agroforestry is an integration of agriculture and forestry; the two major disciplines of utilizing and managing the land. It is considered as a farming system that combines the production of trees with agricultural crops, animals and/or other resources (PCARRD). The integration of trees with crops or animals will provide economic benefits and ecological benefits (Palijon, 1999). Economically, it is helpful because it increases the system components, leading to an increase in labor requirements. Also, selection of the suitable combination of tree species and crop to be planted can result to a good production and in turn, a beneficial profit.

PCARRD (www.pcarrd.dost.gov.ph) states that one of the reasons of the destruction of the upland resources is the migration of lowland farmers to the uplands. They tend to apply lowland farming techniques, which is damaging to the upland resources. Ecologically, tree-based farming is helpful because trees help recycle nutrients, protect soils and provide numerous products such as fruits, vegetables, fodder, medicine, timber, fuel and others.

A project called smallholder agroforestry options for degraded soils (SAFODS) aims to improve the understanding of tree-crop systems to design more productive and sustainable agroforestry systems, and enhance the environmental and economic benefits of agroforestry to smallholder farmers (SAFODS, 2002). The ongoing implementation of the project's objectives is based on five work packages which deals with the following: (1) establishment of farmer typology of management objectives, (2) tree-by-site matching, and development of tree database for modeling, (3) on-farm-trial with the tree-soil-crop interactions, (4) study consequences of a broad array of management options based on model simulations, and lastly (5) risk and profitability analysis and information dissemination (SAFODS, 2002). The focus of this study is on the 5th working package.

B. Statement of the Problem

The transition into tree-based farming is gradual so it can cater for short-term financial and food security needs (SAFODS, 2002), therefore it is also important that planting strategies beneficial to farmers, especially in terms of minimizing risks of profit loss will be selected. SDA has been a useful risk analysis approach in the selection of risk-efficient cropping strategies (Patindol, 2001). Similarly, SDA is applied to tree-crop agroforestry data in order to analyze risk to select risk-efficient tree-crop planting strategies. The study also performs a scenario analysis to assess at which selling price of timber will a tree-crop planting strategy with Gmelina be risk-efficient.

C. Objectives of the Study

The objective of this study is to apply stochastic dominance analysis to identify risk-efficient tree-crop planting strategies in Claveria, Misamis Oriental.

Specifically, its aims are to:

(1) classify tree-crop planting strategies that will be acceptable to decision makers with different degrees of risk-aversion;

(2) compare the results of Stochastic Efficiency with Respect to a Function (SERF) and Stochastic Dominance with Respect to a Function (SDWRF); and

(3) perform a scenario analysis on the selling price of Gmelina.

D. Significance of the Study

Researchers explained that the main reason why farmers do not adopt tree-based farming is because they do not want to risk their income from the traditional farming system with the projected income from trees. However, planting trees together with crops provide ecological and other advantages. Results of the study will be useful in the promotion of tree-based farming to smallholder farmers. It will be specifically beneficial to the SAFODS' fifth work package, on the analysis of risk and profitability of tree-based farming.

It is important for farmers to choose a tree-and-crop combination that will provide risk-efficiency in terms of profits. Stochastic dominance analysis will be useful in selecting and partially-ranking tree-crop planting strategies that will project risk-efficiency in terms of net profitability. The results also show whether risk-efficient outcomes are acceptable for practical application. Results of the scenario analysis will show the price at which a tree-crop planting strategy with Gmelina will be assessed risk-efficient.

II. METHODOLOGY

A. Background of the Data

The data used in this study is acquired from the SAFODS database of farmers' tree-crop planting information in Claveria, Misamis Occidental. Each parcel of land was categorized into different tree-crop planting strategies. A tree-crop planting strategy is categorized according to the combined trees and crops planted in a certain parcel, and wherein net returns from each tree and crop planted can be computed in one year.

The trees and crops considered in the classification of farms are: *Gmelina*, *banana, coconut, coffee, corn, rice, and tomato.* Among the different timber trees planted in the area, only Gmelina is considered in this study due to limited availability of data on the market value of other timber trees. Banana and coconut are fruit trees, but only the fruit harvest for coconut is considered in the computation of the net returns. Coffee, corn, rice and tomato are the dominant crops, wherein corn is the most dominant crop planted. The tree-crop planting strategies and the number of plots available can be found on Table1.

Table 1 Tree Crop Planting Strategies Included in the Study

Strategy	**# of parcels**	**Strategy**	**# of parcels**
Coffee	4	Banana-Gmelina	4
Coconut-Corn	4	Banana-Coffee	4
Banana-Coffee-Corn-Gmelina	5	Corn-Gmelina	5
Corn-Rice	6	Tomato	6
Coffee-Corn	7	Rice	7
Banana-Coconut-Corn	8	Banana-Coffee-Corn	10
Banana-Corn-Gmelina	12	Banana-Coconut	13
Corn-Tomato	17	Banana-Corn	37
Banana	29	Corn	77

B. Estimation of Net Returns and Breakeven Point

The expected net return of each tree-crop combination is computed for seven years in order to take into account the benefits from the Gmelina trees, which are harvested after at least seven years. The Net Present Value (NPV) per hectare is computed to estimate the net profits, with a discount rate of 10% and it is computed as follows:

$$NPV = \Sigma_{t=0}^{7} \frac{(B_t-C_t)}{(1+r)^t}$$

Where Bt = benefits in year t

Ct = cost in year t

r = discount rate (10%)

t = year

Based on the SAFODS-Philippines 2003 Annual Report, Gmelina trees yield an average of 56 board feet per tree and are sold at an average price of PhP4.00 per board feet. The NPV for the Gmelina trees were computed separately from the fruit trees and crops because its production cost C_t varies each year. The details of these cost variables are specified in Table 2.

Table 2. *Cost Variables Accounted for in the Calculation of NPV of Gmelina*

Cost Variables	Cost in Pesos (PhP) per tree	Year Included
Seedlings	PhP 61.00/seedling	1
Planting (approx. 5.51 min/tree)	PhP 1.00/tree[1]	1
Pruning (approx. 21 min/tree) twice a year	PhP 7.00 /tree[1]	2 3 4
Ring weeding (approx. 5 min/tree) twice/year	PhP 2.00/tree[1]	1 2 3
Harvesting (approx. 18 min/tree)	Php 3.00/tree [1]	7
Postharvesting (approx. 21 min/tree)	PhP 3.50/tree[1]	7

[1]Computed at PhP80.00/MD, where MD=man-day at 8 hours/MD

This study assumes that the cost and benefits for the production of fruits and crops are constant every year for seven years thus the same formula as above is used for the computation of the NPV of fruits and crops, wherein benefits, $B_{t,}$ and cost, C_t, are constant for every year. Thus, the net returns for a specific plot of a specific strategy is the sum of the NPV of Gmelina and the NPV of fruits and crops in 7 years.

The cumulative distribution functions (CDFs) for each strategy are computed. Since the different tree-crop planting strategies have unequal points, solving for the slope of the line connecting two points helps to determine the net returns for a corresponding probability in order to obtain equal number of data for all the strategies.

Based on the recorded costs of production of trees and crops, the corresponding breakeven points were also obtained.

C. Identification of Risk Efficient Strategies

This study uses three application softwares, namely, SDRF Program, Stochastic Dominance Spreadsheet, and SIMETAR, for stochastic dominance analysis of the different tree-crop planting strategies.

The SDRF Program is a DOS-based program that performs Quasi-FSD, Quasi-SSD and Stochastic Dominance with Respect to a Function. Data can be manually entered into the program window during implementation of the criterion or a data text file can be created in a specified format as input file. In this study, a data text file is created because of the large amount of numbers that needs to be inputted.

The other software used is the Stochastic Dominance Spreadsheet in Microsoft Excel, which was created by Lowenberg-Deboer (1999) of Purdue University. The spreadsheet performs the FSD and SSD criterion. Data input are in columns and the user manually compares each pair of strategies and the result simply specifies the dominating strategy between the two.

The last software is called SIMETAR, which is the acronym for SIMulation for Excel To Analyze Risk. It is a Microsoft Excel Add-in which consists of both Menu-Driven and User-Defined Functions. It has more than 150 functions that can be categorized into seven groups, namely (a) simulating random variables, (b)statistical analyses and tests, (c) graphical analysis, (d) ranking risky alternatives, (e) data manipulation and analysis, (f) econometric modeling, and (g) time series analysis (Richardson et al., 2004). Particularly for this study, SIMETAR is used to perform SDWRF and SERF.

First Degree Stochastic Dominance (FSD) is initially applied to the dataset in order to eliminate dominated strategies. The remaining strategies are called the FSD-efficient set. The FSD-efficient set is then subjected to Second-Degree Stochastic Dominance (SSD) to determine the SSD-efficient set. The SSD-efficient set is then subjected to Stochastic Dominance with Respect to a Function (SDWRF) and Stochastic Efficiency with Respect to a Function (SERF) to assess strategies that will be acceptable to the different levels of risk aversion. The three softwares discussed above are used to facilitate stochastic dominance analysis on the 18 tree-crop planting strategies.

III. Results and Discussion

A. Estimation of Net Returns and Breakeven Points

The net returns (NPV) and Breakeven Points are computed for seven years. CORN-TOMATO is observed to have the highest net returns and breakeven point among all the strategies, while monocropping of COFFEE showed the lowest net returns and breakeven point, and BANANA-CORN-GMELINA has almost equal net returns and breakeven point. It can also be observed in Figure 1 that five strategies have higher breakeven points than net returns, whereas TOMATO, and COCONUT-CORN only gained approximately half the value of the breakeven point.

B. Results of the Three Application Softwares

SDRF Program

Stochastic dominance analysis using the SDRF Program resulted to six FSD-efficient strategies, namely, BANANA, TOMATO, CORN, RICE, CORN-TOMATO, and BANANA-COCONUT-CORN, and three SSD-efficient strategies, namely, RICE, CORN-TOMATO, and BANANA-COCONUT-CORN. Application of SDWRF shows that RICE and CORN-TOMATO are risk-efficient at a low level of risk aversion ($0 \leq r \leq 0.0001$), while only RICE is risk-efficient at both medium ($0.0001 \leq r \leq 0.001$) and high ($0.001 \leq r \leq 0.01$) levels of risk aversion. Table 3 shows a summary of the results of stochastic dominance analysis using SDRF Program.

A pairwise comparison of the 18 strategies is done which resulted to 153 pairs. By process of elimination of the dominated strategies, the procedure resulted to six FSD-efficient strategies, namely, BANANA, RICE, TOMATO, CORN-TOMATO, CORN-GMELINA, and BANANA-COCONUT-CORN, and three SSD-efficient strategies, namely, RICE, CORN-TOMATO and BANANA-COCONUT-CORN.

Figure 1 Mean Net Returns and Mean Breakeven Point of Each Strategy

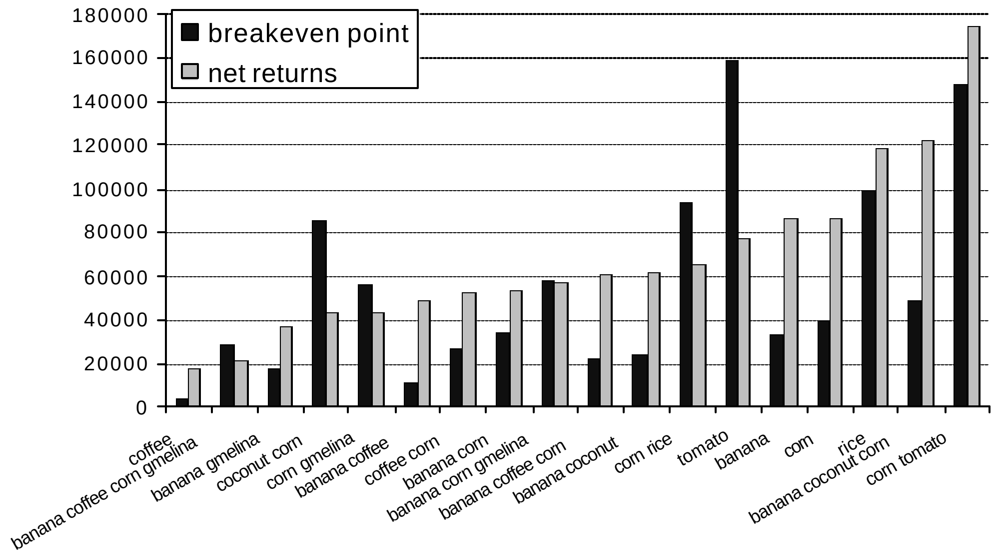


Table 3 Summa ry of SDRF Program Results

Stochastic Dominance Criteria		**Risk-Efficient Strategies**	**Range of r***	
			Lower Limit	**Upper Limit**
FSD		BANANA, CORN, RICE, TOMATO, CORN-TOMATO, BANANA-COCONUT-CORN	-0.000062	+0.000062
SSD		RICE, CORN-TOMATO, BANANA-COCONUT-CORN	0	+0.000062
SDWRF	Low Level Risk Aversion	RICE, CORN-TOMATO, BANANA-COCONUT-CORN	0	0.0001
	Medium Level	RICE	0.0001	0.001
	High Level	RICE	0.001	0.01

* r = Risk Aversion Coefficient

Stochastic Dominance Spreadsheet Results

A pairwise comparison of the 18 strategies is performed, resulting to 153 pairs. By process of elimination of the dominated strategies, the procedure resulted to six FSD-efficient strategies, namely, BANANA, RICE, TOMATO, CORN-TOMATO, CORN-GMELINA, and BANANA-COCONUT-CORN, and three SSD-efficient strategies, namely, RICE, CORN-TOMATO and BANANA-COCONUT-CORN.

SIMETAR Results

The SSD-efficient set, composed of RICE, CORN-TOMATO, and BANANA-COCONUT-CORN, are subjected to SDWRF and SERF under different levels of risk-aversion. RICE and CORN-TOMATO are both risk-efficient at low level of risk-aversion, while RICE is the only risk-efficient strategy at both medium and high levels of risk-aversion. Part of the output of SIMETAR for SDWRF at a low level of risk-aversion is shown in Table 4. Application of the SERF criterion also resulted to the same risk-efficient strategies for each level of risk-aversion.

Table 4 SIMETAR Output for Stochastic Dominance With Respect to a Function at Low Level of Risk Aversion

Analysis of Stochastic Dominance with Respect to a Function (SDRF)						
© 2004						
	Efficient Set Based on SDRF at			Efficient Set Based on SDRF at		
	Lower RAC	**0**		Upper RAC	**0.0001**	
	Name	Level of Preference		Name	Level of Preference	
1	Corn -tomato	Most Preferred	1	Rice	Most Preferred	
2	Banana-Coconut-Corn	2nd Most Preferred	2	Banana-Coconut-Corn	2nd Most Preferred	
3	Rice	3rd Most Preferred	3	Corn-tomato	3rd Most Preferred	
*The efficient sets are not the same for both RAC values. This result suggests that the efficient set changes between the two RACs. Use SERF analysis to determine the RAC(s) where the efficient set changes.						

C. Identification of Risk Efficient Strategies

Upon the application of FSD, the set of strategies are narrowed down to six FSD-efficient strategies. This shows the usefulness of FSD in rapidly eliminating dominated strategies despite its weak discriminating power. SDRF Program and the Stochastic Dominance Spreadsheet came up with different sets of FSD-efficient strategies. Results of SDRF Program and Stochastic Dominance Spreadsheet both show 6 FSD-efficient strategies, however, the set of strategies are not similar. Table 5 shows the different strategies assessed as FSD-efficient by the two application softwares. This study uses the FSD-efficient strategies generated by the spreadsheet since it shows evidence of CORN being dominated by RICE, thus eliminating CORN from the FSD-efficient set (Figure 2). It can be observed that the efficient strategies are applied to very few parcels only, wherein CORN-TOMATO and BANANA have the highest number of parcels applied to, at 17 and 29 parcels, respectively (Table 1).

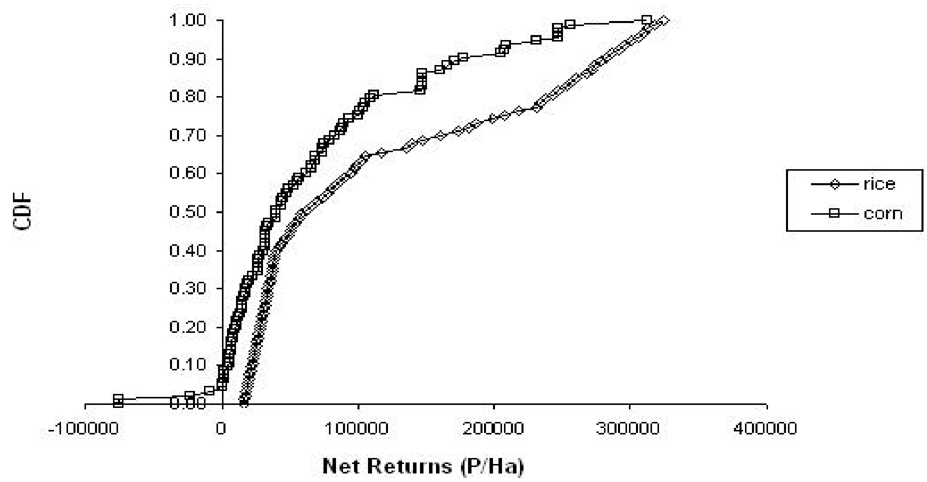
Table 5 Strategies Assessed as FSD-Efficient

Strategy	FSD-Efficient in SDRF Program?	FSD-efficient in the spreadsheet?
BANANA*	YES	YES
RICE*	YES	YES
TOMATO*	YES	YES
CORN-TOMATO*	YES	YES
BANANA-COCONUT-CORN*	YES	YES
CORN	YES	NO
CORN-GMELINA	NO	YES

* Strategy is assessed as FSD-efficient by both application softwares

The set of FSD-efficient strategies is then subjected to Second Degree Stochastic Dominance (SSD) criterion. This further narrows down the number of risk-efficient tree-crop planting strategies into the SSD-efficient set. Both SDRF Program and Stochastic Dominance Spreadsheet came up with the same SSD-efficient set, which consists of three (3) strategies namely, BANANA-COCONUT-CORN, CORN-TOMATO and RICE. The graph of the cumulative probabilities of the three strategies is shown in Figure 3.

Figure 2 Graph Showing Corn is Dominated in FSD-Sense



Looking at the properties of the SSD-efficient set, all strategies have the highest mean returns among all the other strategies. Likewise, the mean returns of all three strategies are more than their corresponding breakeven points.

In order to determine risk-efficient strategies for different degrees of risk-aversion, the SSD-efficient set is subjected to the Stochastic Dominance with Respect to a Function (SDWRF) criterion at levels of risk-aversion. For low levels of risk aversion ($0 < r < 0.0001$), the risk-efficient strategies are CORN-TOMATO and RICE, and for both medium ($0.0001 < r < 0.001$), and high ($0.001 < r < 0.01$) levels of risk-aversion, only RICE is found to be risk-efficient.

D. SDWRF and SERF

The most recently developed stochastic dominance criterion is the Stochastic Efficiency with Respect to a Function (SERF). This criterion is likewise applied to this study, particularly to the SSD-efficient set. The same levels of risk-aversion used in SDWRF are used, and the results are similar. The risk-efficient strategies for low levels of risk aversion ($0<r< 0.0001$) are CORN-TOMATO and RICE, and RICE is the only risk-efficient tree-crop planting strategy for both medium ($0.0001<r<0.001$), and high ($0.001 < r < 0.01$) levels of risk-aversion. Figures 3 and 4 shows the graph of the CDF and Certainty Equivalents of the three strategies, respectively.

The risk-efficient strategy can be directly observed from the graph of the certainty equivalents, such that only the strategy with its curve above the others for a certain range of risk-aversion coefficient is considered risk-efficient. As shown in Figure 4, CORN-TOMATO dominates the other two strategies at a certain range of ARAC (absolute risk aversion coefficient) but at a certain point, RICE becomes the dominating strategy. So we conclude that the risk-efficient strategies for 0<u><</u>ARAC<u><</u>0.0001 are CORN-TOMATO and RICE.

Figure 3 CDF Curves of the SSD-efficient strategies

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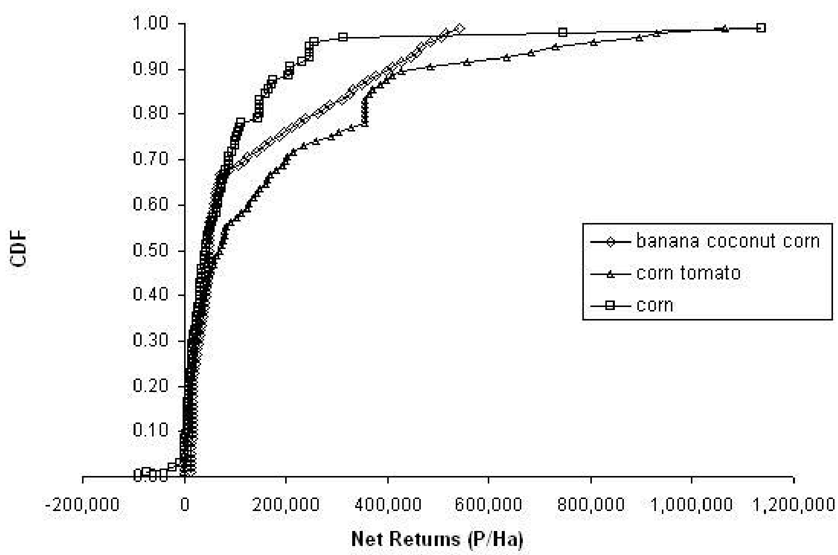
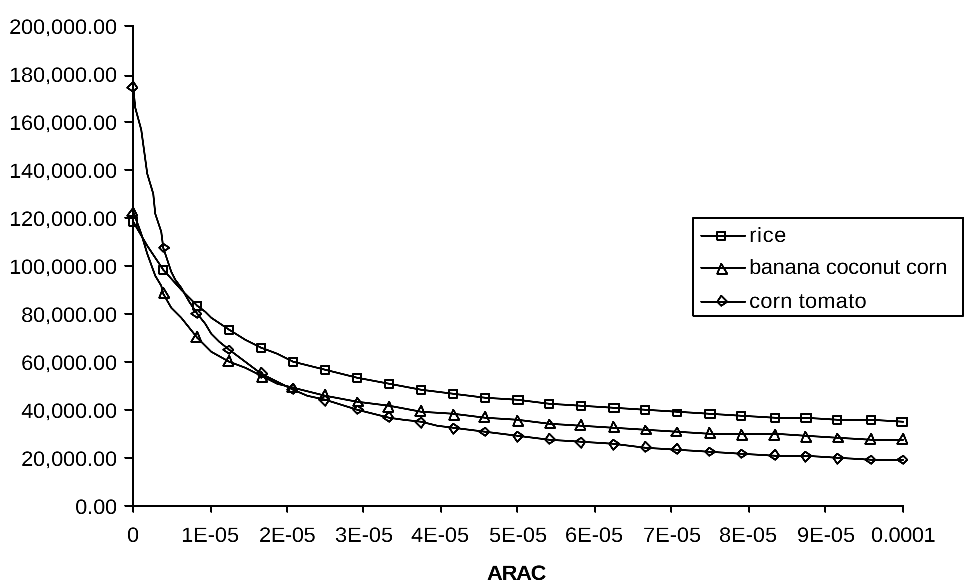
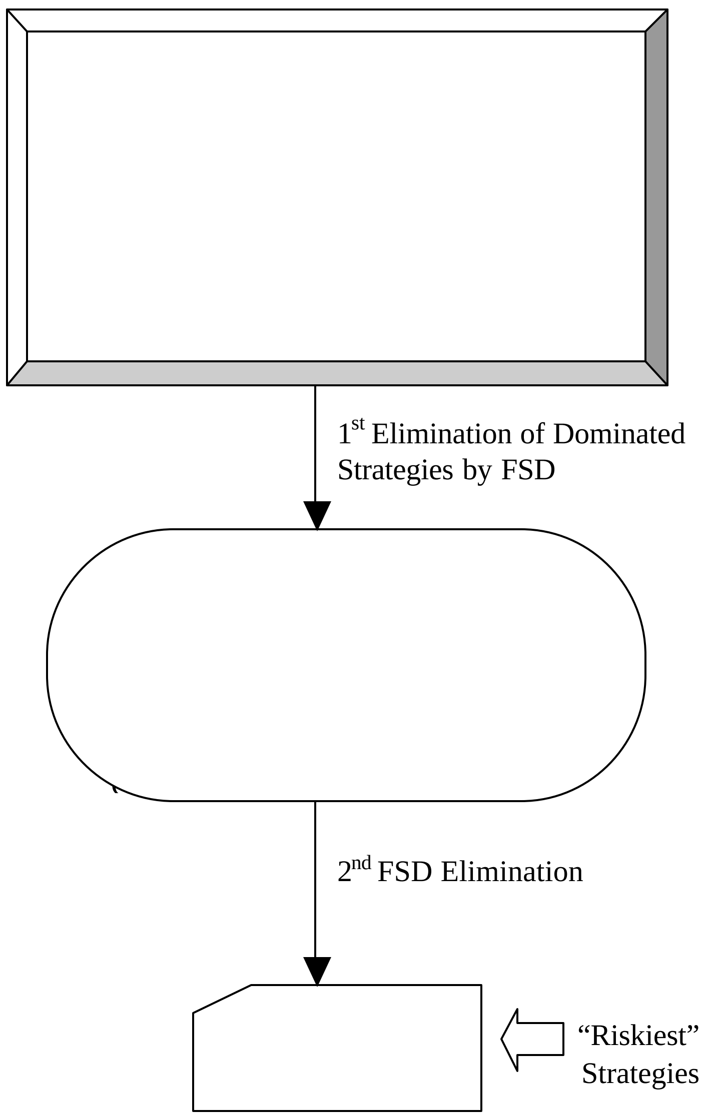




E. Identification of the "Riskiest" Strategy

The "riskiest" strategy, or the strategy with the highest risk, is also determined through successive elimination of the remaining strategies after using the FSD criterion. After three successive eliminations, COFFEE and BANANA-CORN-GMELINA turned out to be the "riskiest" among all the other strategies. Figure 7 shows a flowchart of the elimination process..

Looking at the properties of the two "riskiest strategies" we will notice that COFFEE has the lowest value of mean returns and breakeven point (Figure3), while BANANA-CORN-GMELINA has approximately the same values for both mean returns and breakeven point.



Out of the 300 farmers surveyed, Table 6 shows that only 2.33% of the farmers practice the most risk-efficient strategy, which is the monocropping of rice, while 5.33% practice the next risk-efficient strategy, CORN-TOMATO. Likewise, it also shows that only 1.33% of the farmers plant coffee. But majority of the farmers, 23.33% plant corn throughout the year.

Table 6 Relative Frequency of Farmers Practicing the Different Tree-Crop Planting Strategies

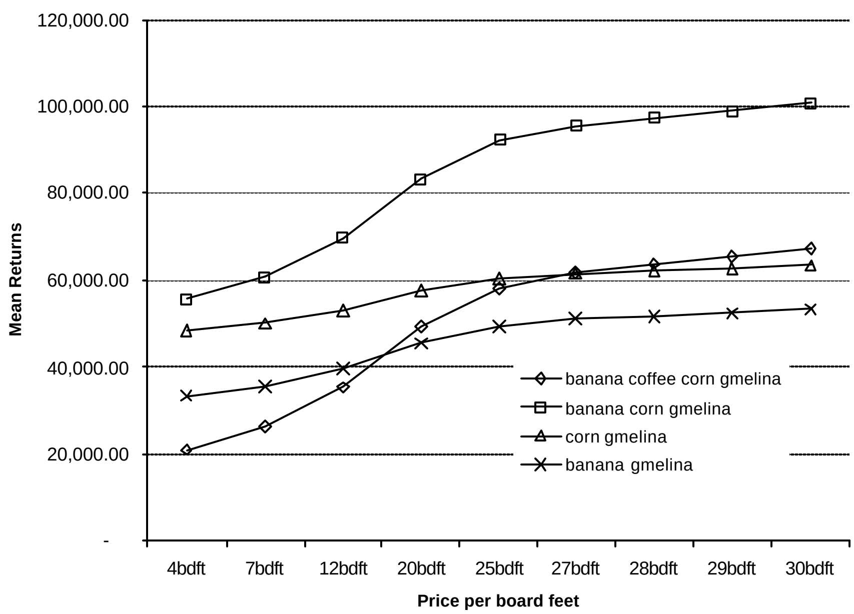
Strategy	No. of Farmers	Relative Frequency
BANANA-COFFEE	4	1.33%
BANANA-GMELINA	4	1.33%
COCONUT-CORN	4	1.33%
COFFEE	4	1.33%
BANANA-COFFEE-CORN-GMELINA	5	1.67%
CORN-RICE	5	1.67%
CORN-GMELINA	6	2.00%
TOMATO	6	2.00%
BANANA-COCONUT-CORN	7	2.33%
COFFEE-CORN	7	2.33%
RICE	7	2.33%
BANANA-COFFEE-CORN	10	3.33%
BANANA-COCONUT	12	4.00%
BANANA-CORN-GMELINA	13	4.33%
CORN-TOMATO	16	5.33%
BANANA	24	8.00%
BANANA-CORN	37	12.33%
CORN	70	23.33%
Other tree-crop combinations	59	19.67%

F. Scenario Analysis of Gmelina Selling Price

Based on the standard selling price of Gmelina trees, which is P4.00/board feet, results show that all strategies with Gmelina are dominated. Thus a scenario analysis on the selling price of Gmelina timber is evaluated. The NPV of strategies with Gmelina trees are recalculated at different prices of Gmelina timber, namely at, P7.00, P12, P20, P25, P28 and P30 per board feet (see Appendix Tables 2 to 5).

Results show that at P20/bdft and P25/bdft, BANANA-CORN-GMELINA and CORN-GMELINA, belong to the FSD-efficient set but are still eliminated when SSD is applied. At P28/bdft, BANANA-GMELINA is added to both the FSD- and SSD-efficient set. Also at P28/bdft, BANANA-GMELINA becomes risk-efficient at low, medium and high levels of risk aversion. Figure 8 shows the behavior of the mean net returns as the selling price of Gmelina timber increases.

Figure 8 Mean Net Returns of Strategies at Different Selling Prices of Gmelina timber



IV. Summary and Conclusions

Stochastic Dominance Analysis (SDA) is a risk analysis tool that partially ranks risky strategies. This approach to risk analysis is useful since it requires limited assumptions on the risk-aversion characteristics of the decision-makers. Also, it does not require that the utility function be precisely known. Application of the stochastic dominance criteria in comparing the probability distributions of different strategies resulted to the selection of risk-efficient strategies.

Application of the First Degree Stochastic Dominance provided for the elimination of a fairly large number of dominated strategies. This demonstrates the usefulness of FSD despite its weak discriminating power. Also, repeated application of FSD to the dominated strategies could be done to identify the “riskiest” or “least risk-efficient” strategy.

After consequent application of FSD and SSD, the different strategies can be classified further into three groups, as indicated in Hien et al., (1997). These groups are: (a) dominated strategies, (b) strategies that could be acceptable to risk-neutral decision maker, and (c) strategies that can be used by risk-averse decision makers. The strategies that can be considered acceptable to risk-neutral decision makers are those that are not dominated by FSD but are dominated by SSD. In this study, the strategies that belong to the second group are CORN, BANANA-CORN-GMELINA, and BANANA. The strategies that belong to the third group are simply the SSD-efficient strategies, which are CORN-TOMATO, RICE and BANANA-COCONUT-CORN. Therefore, the remaining strategies belong to the first group, which is the group of dominated strategies.

The application of SDRF Program and the stochastic dominance spreadsheet in Excel yielded different sets of FSD-efficient strategies. Results from the spreadsheet were used since it provided evidence of dominance.

Stochastic Efficiency with Respect to a Function (SERF) yielded the same risk-efficient strategies for the three levels of risk aversion as compared to the results of SDWRF. However, it appears that it is easier to use SERF because it provides for direct identification of the risk-efficient strategies by simply looking at the curves of the certainty equivalents for a specific range of risk-aversion coefficient.

The study applied stochastic dominance analysis in determining risk-efficient tree-crop planting strategies by analysis of the cumulative distributions of the net returns of each tree-crop planting strategy. Upon application of the procedure, based on the available data on costs and benefits on the production of the included trees and crops, and disregarding the farming systems applied, the monocropping of rice was assessed the most risk-efficient among the other strategies.

However, planting rice alone, is not applicable to all types of land or farming system, therefore we consider the next risk-efficient strategy which is the combined planting of corn and tomat. This can be explained by the high market value of tomatoes and planting corn after the harvest of tomato is considered to be less costly. The production of corn and tomato becomes less costly since farmers provide less input of fertilizers during the planting of corn because it is believed that corn still benefits from the input residues during the planting of tomato.

A scenario analysis on the price of Gmelina timber is also conducted. Different selling prices of Gmelina timber are considered in the recalculation of the net returns of each strategy with Gmelina. Application of stochastic dominance analysis shows that a tree-crop planting strategy with Gmelina will only be at least preferred by risk-neutral decision makers when the selling price is at least P20/bdft, and it will be preferred by risk-averse decision makers when the selling prices becomes at least P28/bdft. These prices are however, relatively very high. This can be explained by the high cost of Gmelina seedlings.

V. Recommendations

There are other trees and crops that are not included in this study due to insufficient number of data points available. The only timber tree considered is Gmelina since it is the only one with available market value during the time this paper was done. A wider selection of planting strategies with more timber tree species can also be considered in the analysis of risk. Likewise, the same procedure can be done with a lower price of Gmelina seedlings, since they are now only sold for P5/seedling, as compared to the previous price of P61/seedling. Since the difference is very large, there is a possibility that tree-crop planting strategies with Gmelina would be risk-efficient at a much lower price (lower than P28/bdft).

Likewise, forecasting analysis may also be incorporated with SDA, in order to take into account projected values of different factors affecting the net returns gained from the planting strategies. The ecological benefits from the different tree-crop planting strategies can also be included in the risk analysis.

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