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Risk and Economic Analysis of Greenhouse Cucumber and Tomato Cropping Systems in Oman

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Abstract

The agriculture investment decision affected by risk of capital and operation cost, yield and sale price of planted crops. This study examined risk of investment in green-house cucumber and tomato production and optimum mix of crop pattern at Al Batinah, Al Sharqiya Regions of Oman. The net present value with Monte Carlo simulation models are used to test risk efficiency and project viability. The result indicated that investment in two green-houses and growing one tomato crop and two cucumber crops (Tom1Cuc2) per year is more profitable and risk aversion. Stochastic Efficiency with Respect to a Function (SERF) performed and confirmed that (Tom1Cuc2) is the most risk efficient cropping system and got a positive NPV with 62% probability followed by growing tomato crop in two seasons with a positive NPV with probability of 58%. The study concluded tomato and cucumber producers are faced with different production and financial situations and their risk preferences play an important role in determining their production decisions. Risk premium analysis shows that greenhouse tomato growers need to be paid up to RO 2 847 to keep growing tomato instead of (Tom1Cuc2) cropping system. Greenhouse cucumber growers can sacrifices of RO 5 373 to justify not to switch from planting cucumber to grow (Tom1Cuc2) cropping system. Government subsidy should be given to farmers to construct new greenhouses to maximize their resource use efficiency, benefit from extended cropping season, protect their crops from adverse environmental conditions and increase food security.

Keywords: stochastic efficiency with respect to a function, risk simulation model, green-house cropping systems, risk aversion

1. Introduction

The vegetable crops cultivation area in Oman in 2017 recorded 52.9 thousand (acres) with a total vegetables production of 815 thousand tons. The vegetable cultivated area increased by 28% in 2017 compared to 2016 and total production is increased by 85% on the same period. The gap between demand and supply is still high and recorded 32% during summer season, (Ishag, 2017). The introduction of new technologies and green-houses will improve vegetable production growth and reduce import during summer season.

Green-house tomato production consist about 2%-5% of total Oman tomato production whereas green-house cucumber production cover about 61%-73% of total Oman cucumber production. Tomato is planted two to three times a year in green-houses and it benefits from a large harvesting period. Green-house cucumber is planted three to four times during the year and it takes short time for fruit maturity and harvesting. Although green-house technology offer fresh cucumber and tomato off-season and contributes in food security, risk of yields and price variability and profit sustainability need to be tested and investigated.

The agricultural activities development and excessive use of land and water at coastal areas in Al Batinah, Al Sharqiya and Al Dhahira Regions' caused water table dropped to a low level, and water salinity of the wells had increased and reduced water quality. That was mainly due to excessive underground water depletion and over pumping by new turbine power full water pumps introduced recently in Oman. The sea water intrusion Oman costal area is mixed with fresh underground water. The continuous irrigation with brackish water increased soil and water salinity and affected crop yields and cropping systems.

The Government authority recently announced that the underground water reserve and ground water recharge is 1295 millions m^3 per year, which is less than water consumption of about (25%). This unbalance underground water reserve is one of the most challenges factor facing agriculture sector development in the country.

As a result, cucumber producers and open field vegetable grower are searching for alternative to overcome water shortage and salinity problems and mitigate risk of yield and price variation loss.

1.1 Literature Review

The green house farming technology use is increasing in Oman and around the world due to continues resources and environmental pressure such as land, water and disease on open filed farming. A vertical farming gives a good environmental solution to areas interested to be self-sustainable, (Kumar et.al 2018). Eihab et.al (2017), used minimization of total absolute deviations (MOTAD) approach to investigate risk of water and environmental constrain on green house crop mix and crop risk efficiency.

Green house cropping system viability and sustainability refer to system ability to generate profit in spite of major constrains and disturbance. The system resilience and ability to continue in the future in term of financial viability and natural resources degradation can be taken as a tool to choice between alternative greenhouse cropping systems, Lien G. et.al (2007). Stochastic and dynamic nature of the cropping systems can be model to estimate positive return for each alternative green house cropping system.

Monte Carlo Simulation Dynamic Model can be used for project viability and was addressed by Savvakis C. Savvides in (1994). He argued that this integrated analysis provided a range of outcomes that can reduce the risk of uncertainty inputs parameters and generate reliable results for decision makers and investor. Additional information related to simulation dynamic model and policies analysis can be found in Blumenfeld et al. (2009); Carpenter, Brock and Hanson (1999); Chen et al. (2009); Folkes et al (2002), MA (2005); Sanders and Lewis (2003).

Monte Carlo Simulation models were used in this study to quantify risk and uncertainty associated with green house cucumber and tomato cropping system. The quantitative risk analysis of optimum crop mix will provide decision makers cropping system viability and probability by estimating NPVs for each model. The model will also help in improving green-house management and help policy makers to form accurate policy and maintain national food security and preserving the environment. S. Quiroga (2010) used Monte Carlo simulations to estimate crop yield risk to water variability.

The stochastic efficiency of alternative green-house cropping system can rank risky alternative over a range of risk aversion. This technique developed by Hardaker et al. (2004) and called stochastic efficiency with respect to a function (SERF). SERF is based on the notion that ranking risky alternatives in terms of utility is the same as ranking alternatives with certainty equivalents (CE). CE is defined as a granted return the farmers except with the same utility as the expected utility of the risky prospect (Hardaker et al., 2004). (Lien et al., 2006) used Stochastic Efficiency with Respect to a Function (SERF) to supplement sustainability criterion. In this study, the (SERF) technique is applied to assess a set of alternative risky crop optimum mix and cropping systems. The SERF method ranks alternative risky green-house cropping systems in terms of the CE of cropping system return over a range of risk aversion levels. SERF can compare any level of decision makers‟ preferences including risk-averse, risk neutral and risk loving. The green house cucumber and tomato data collected from excremental data from Plant Production Research Center at Director General of Agriculture and Livestock Research. The stochastic simulation models were employed to examine NPV distribution for four cropping system alternatives. The main objective of this paper is to investigate optimum crop mix, sustainability and risk efficiency over a range of risk aversion level.

2. Materials and Methods

The study evaluated the investment in green-house to grow cucumber and tomato crops through estimating and calculating future costs and revenues of the project. The net present values (NPV) of cash flows are calculated by multiplying the predicted net cash flows by a discounted rate of 10%, which is similar to commercial Bank interest rate. The inputs data, yield and price were collected from Agriculture Research Station experimental date and farmers' survey.

The study used dynamic simulation model to evaluate investment in two green houses and calculate Net Present Value (NPV) of four cropping systems to evaluate risk and economics sustainability. The stochastic budgeting data of green-house cucumber and tomato cropping systems were used to consider risk and uncertainty of yield and price for each green-house cropping system. The study used (@Risk 7.5) program to account for the stochastic nature of key cropping system variables in the Monte Carlo simulation model. Parameters of input distribution were used in the model and cash flow for each cropping system estimated for 10 years and presented in Table 1. A range of NPVs were obtained by using stochastic inputs variables in below formula.

$$NPV = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n}$$

Where,

Cn = the net cash flow in year n (n = 0, 1, 2, …. n), represented by farm income in this study.

n = the planning period which equals ten years in the current analysis.

r = the discount rate.

2.1 Net Present Value and Simulation Models

The study first identified the main key inputs variables and yield to estimate the best fit of variable probability distribution function which describes the range of the uncertainty around the expected variables. A historical data from Agriculture Research Station experimental data were used in the model to generate value for each greenhouse cropping systems. Monte Carlo Simulation analysis were used to incorporate stochastic variables main inputs cost, crop yield and price in the model. The probability distributions of each risky input variable i.e. (triangle – normal - binomials) were used to estimate Cumulative Distribution Function (CDF) of the model output (NPV) for each cropping system.

To investigate green-house cropping system risk efficiency and sustainability, the study performed Stochastic Efficiency with Respect to a Function (SERF) Analysis for different cropping system. The data were collected and calculated to generate Certainty Equivalent (CEs) and rank green house cropping system alternatives according to their risk efficiency and economic sustainability. The data for each green house cropping system model in this study is grouped to two categories (Table 1):

Table 1. Input used seasonally and capital fixed materials used in the models

Inputs used seasonally	Capital fixed materials replaced each 5 years
– Seeds	– Fans
– Fertilizers and Insecticides	– Cooling pads
– Plastic sheets	– Polyethylene sheets
– Hanging ropes	– Irrigation system
– Pruning scissors	– Tractors
– Insect yellow traps	– Car (Van)
– Packing boxes	– Planting trays
– Planting soil	

2.2 Stochastic Efficiency with Respect to a Function (SERF)

Simulation model is used to investigate risk management tool that can be used to improve sustainability of green house cropping systems and obtain the best sustainable cropping system. The model is run for (10,000) times for 10 years in the future to estimate Cumulative Distribution Function (CDF) of the model output (NPV) for each cropping system and assess the economic sustainability of different alternatives. The model failure measured in financial terms of getting a lowest or negative NPV, Hansen and Jones, (1996).

Stochastic efficiency with respect to a function (SERF) is used to rank the risky cropping systems alternatives simultaneously for decision makers with different risk aversion preferences. Risk Premium is also calculated by subtracting CE Certainty equivalent for less preferred alternative from dominant alternative. The certainty equivalent equation used in the study is presented below and include a utility function u (·), a random wealth variable X, and an initial level of wealth w0, the certainty equivalent is :

$$CE = u-1\{E[u(X + w0)]\} - w0,$$

The risk premium measure the minimum amount that would have to be paid to a farmers and decision maker to justify a switch from alternative present green house cropping system to other less risky cropping system. An analysis of four greenhouses cropping systems was conducted using a ten years experimental data and simulation model. Each green house cropping system is represented by two green house and yield, price, investment and operation cost data are collected from experiments data. Four models simulated the costs and returns of the four cropping systems to obtain the NPV probability distributions generated by the simulation model and used to rank the best alternative green house cropping system across a full range of Risk Aversion Coefficients -RACs.

2.3 Model Structure

The modeling structure represents Al Batinah and Al Sharqiya Regions with hot temperature and high humidity, began by defining inputs and parameters effecting crop cultivation income and return. The purpose of the study is to provide a high level of understanding of risks of growing green house cucumber and tomato in Oman. The main risk and uncertainty variables identified in the models were :

- Variable cost increase and it is effect on NPV.
- Cucumber and tomato selling price volatility and their effect on NPV.
- Cost of production per ton for each cropping system and it is effects on NPV.
- Annual increase in sales price and unit cost.
- Total sale volume for each cropping system.
- Probability of competitor entry to the market from year one.
- Cucumber and tomato yield variation at four cropping systems.

The quantitative risk analysis is performed after selecting key parameters and estimated inputs probability distribution for four green house cropping systems grown in two green houses as follows :

- One tomato crop and two cucumber crops per year in two greenhouses (Tom1Cuc2).
- Three cucumber crops in one greenhouse and mixed crops in second greenhouses (Cuc&Mix).
- Two tomato crops per year in two greenhouses (Tomato).
- Three cucumber crops per year in two greenhouses (Cucumber).

The model estimate individuals risk parameters affecting the combination of greenhouse cropping system in term of financial performance and cash flows. The probability distributions of the parameters are incorporated in to Monte Carlo Simulation Model which allows evaluation and quantified risks range of each parameters.

Four models were formed to represent four greenhouse cropping systems. Investment capital cost, crop yield, total sale volume, sale price and per unit cost of production for each cropping system is estimated. The estimation of each input variable and probability distribution at each cropping systems identified and incorporated in the analysis and shown by below Table (2).

Table 2. Input parameters distribution range used in greenhouse MCS for Tomato Models

Risk	Affects	Distribution	Absolut/ percentage	Impacts		
				Min	Most likely	Max
1st year tomato yield2 houses	Revenue	Normal	Absolut	15		16
Increase in yield ton	Revenue	Triangular	Percentage	1%	2%	3%
Sale Price/ton	Revenue	Triangular	Absolut	300	333	450
1st year unit cost/ton	Cost	Triangular	Percentage	35%	37%	45%
Increase in sales price	Revenue	Triangular	Percentage	0.5%	1%	1.5%
Increase in cost	Cost	Triangular	Percentage	0.5%	1%	1.5%

The study runs four greenhouse cucumber and tomato models tests and scenarios. The Stochastic Monte Carlo Simulation Models and Stochastic Efficiency with Respect to a Function (SERF) were used to evaluate and compare greenhouse cucumber traditional popular model (Basic Model) with other three cropping system models. The Stochastic Efficiency with Respect to a Function (SERF) performed to select the risk-efficient greenhouse cucumber and tomato cropping system in Oman.

A Latin hypercube sampling procedure with @Risk software from Palisade Corporation (7.5.0 Version) was used to calculate NPVs and statistic results with 10,000 number of iterations. In the simulation, values of parameters entering into the model were chosen from their respective probability distributions by Latin hypercube sampling technics and were combined according to functional relationships in the model to determine cropping system outcome and return i.e. NPV. The process was repeated a large number of times to give estimates of the output distributions of the performance measure which was expressed as cumulative distribution functions (CDFs) and Probability Density function PDF. The StopLight function analysis is also performed to develop probability of positive NPV and ranking graphs.

3. Results and Discussion

3.1 Monte Carlo Simulation Models Run Results

The study investigated the green house cropping system economic performance and sustainability and calculates NPV by using experimental data. Model (1) cropping system which grows tomato for one season and cucumber for two times (Tom1Cuc2) achieved the highest NPV i.e. RO 7 106 followed by (Tomato) model with RO 4 258 NPV, and (Cucu&Mix) model with RO 3 792. The net present value figure indicates and measures investment viability and economic performance of the cropping systems. The Stander Deviation SD for Model (1) is highest i.e. 24 348 and for Model (4) is lowest i.e. 17 754 and indicates low variation of cucumber outputs cropping system.

The Coefficient on of Variation of the probability distribution of NPVs was low for Model (1) and (3) and record 3.43% and 5.07% respectively and indicates that growing one tomato crop and two cucumber crops is most sustainable cropping systems with a risk efficient Net Present Value. The result also shows that Model (1) will get a positive NPV with 62% probability and Model (4) will get positive NPV with 58% probability. Table 3 below summarized the statistical results of four green-house cropping systems models.

Table 3. Green house cucumber and tomato cropping system statistics for NPVs for each model

Models	Model (1)	Model (2)	Model (3)	Model (4)
Cropping system	Tom1Cucu2	Cucu&Mix	Tomato	Cucumber
Mean RO	7 106	3 792	4 258	1 732
SD	24 348	20 737	21 599	17 754
CV	3.43%	5.47%	5.07%	10.25%
Skewness	-0.077	0.247	-0.027	-0.035
Kurtosis	-0.201	0.614	0.099	0.272
Min	(63 203)	(58 191)	(61 919)	(63 929)
Max	90 140	79 277	80 328	58 442
Range	153 343	137 468	142 247	122 371

The probability density function analysis for four cropping systems was estimated to consider a full range of possible outputs of cropping systems NPVs. It gives all possible outputs result and cover a range of (ARAC) level and shows Cucumber is most preferred model at upper risk aversion coefficient (URAC).

3.2 Cumulative Distribution Function

The Cumulative Distribution Function (CDF) chart for four green-house cucumber and tomato cropping systems is drown by using Simetar Program and displayed below in Figure 1. The CDF graph shows that the (Tom1Cuc2) cropping system lies more to the right than the other three alternatives cropping systems. This result suggests that growing one tomato rotation in August and two cucumbers rotation scenario (Tom1Cuc2) is preferred and risk aversion over the others scenarios because at each probability level of this scenario is associated with higher NPV. The cultivation and growing of three cucumber rotations (Cucumber) Scenarios lies further to the left than the others and it is the least preferred cropping system for the same reason. Although the CDF Graph procedure is superior to the other ranking methods it does not always result in an unambiguous ranking of the cropping system strategies.

When the CDF lines cross each other's there will be no clear ranking and the cropping systems need to be ranked based on expected utility principles such as stochastic dominance i.e. first and second degree stochastic dominance, certainty equivalents, stochastic efficiency with respect to a function (SERF), and risk premiums analysis.

3.3 Stochastic Dominance with Respect to a Function (SDRF)

The Stochastic Dominance with Respect to a Function (SDRF) analysis and certainty equivalent is performed under alternative utility for each cropping system and is used to rank greenhouses cropping systems scenarios. The preferred risky alternative is also calculated for the lower risk aversion coefficient (LRAC) and upper risk aversion coefficient (URAC) level. Table number 4 and 5 below shows and rank the risky alternative according to certain equivalent figures (CE) and shows model (Tom1Cuc2) cropping system is preferred for lower RACs level and considered to be the risk efficient cropping system followed by (Tomato) model. (Cucumber) model is preferred for upper RAC level as its price is more stable than tomato crop. Eihab F. et.al (2017), found that risk is reduced as greenhouse cucumber production increases due to the high level of tomato price volatility as the alternative to cucumber. The Stochastic Dominance with Respect to Function (SDRF) criteria is useful for ranking risky alternatives cropping system which CDFs are crossed.

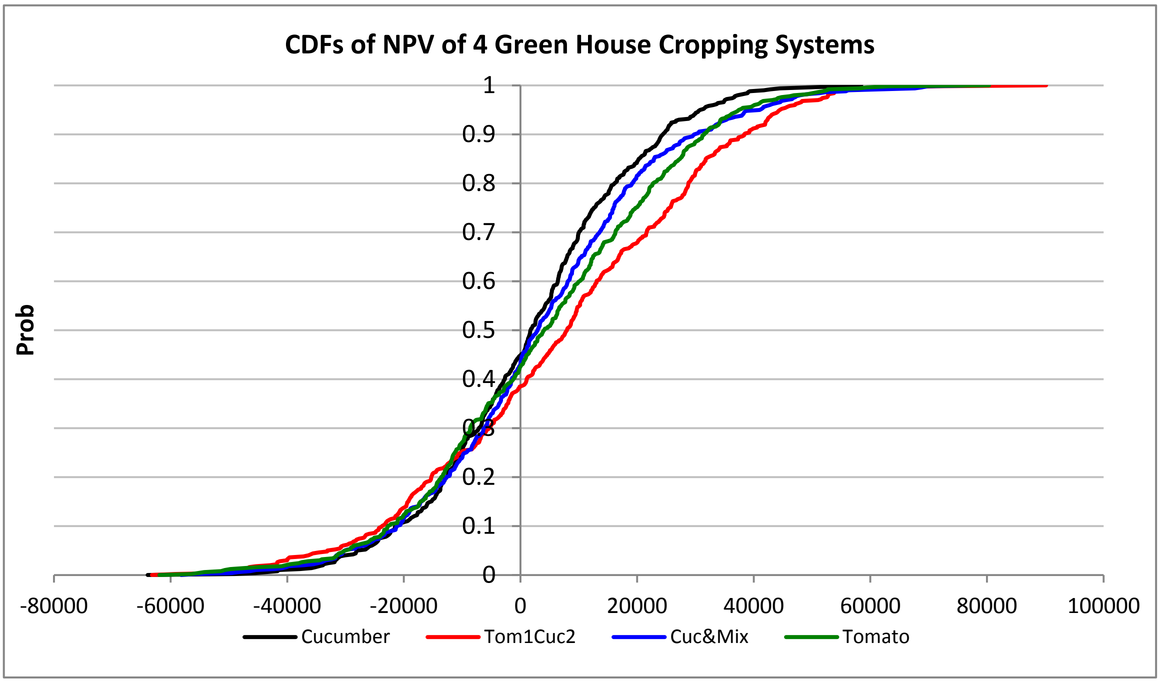

Figure 1. Cumulative Distribution Function of four green-house cucumber and tomato cropping systems

Table 4. Stochastic Dominance with Respect to a Function (SDRF) Analysis :

	Efficient Set Based on SDRF at			Efficient Set Based on SDRF at	
	Lower RAC	0.000		Upper RAC	0.0001
	Model	Level of Preference		Name	Level of Preference
1	Tom1Cuc2	Most Preferred	1	Cucumber	Most Preferred
2	Tomato	2nd Most Preferred	2	Cuc&Mix	2nd Most Preferred
3	Cuc&Mix	3rd Most Preferred	3	Tomato	3rd Most Preferred
4	Cucumber	Least Preferred	4	Tom1Cuc2	Least Preferred

The main limitation of Stochastic Dominance with Respect to a Function (SDRF) is that this technique it is a pairwise ranking of risky alternatives and not a simultaneous ranking of all alternatives. Another limitation is that if the LRAC and URAC are set to far apart the procedure will not result in a consistent ranking at both RACs level and only one alternative in the efficient set. However, the incentive in setting RACs for SDRF is to set them as far apart as possible to include a larger class of decision makers.

Table 5. Certainty Equivalents Under Alternative Utility Functions

	Model	CE Under Exponential Utility		CE Under Power Utility	
		Lower	Upper	Lower	Upper
1	Cucumber	1,731.67	-15,692.63	1,731.67	2,136.83
2	Tom1Cuc2	7,105.53	-20,194.13	7,105.53	25,315.57
3	Cuc&Mix	3,792.39	-16,502.69	3,792.39	3,645.92
4	Tomato	4,258.16	-19,270.94	4,258.16	22,501.94

3.4 The StopLight Function Analysis

The StopLight function analysis is performed by using Simetar program to develop probability ranking graphs. The StopLight graph summarizes the probabilities of NPV for each cropping system scenarios with lower and higher decision maker target. The study identified the NPV of less than zero NPVs which showed in red color. The graph also shows the probabilities that the risky alternatives exceed a maximum target of NPV of RO 15,000 and shows in green color. The probability of each scenario falling between the two targets is reported in the graph in a yellow color. StopLight analysis performed in this study and shows that green house cropping system (Tom1Cuc2) model got a positive NPV with a probability of 62% and (Tomato) model got a positive NPV with a probability of 58%. Figure (2) below displayed the probabilities of a risky alternative exceeding an upper target of RO 15,000 and falling below a lower target of (zero) NPV. This analysis is a powerful tool and help farmers and decision makers to rank risky alternatives and cropping systems according to their NPV profitability.

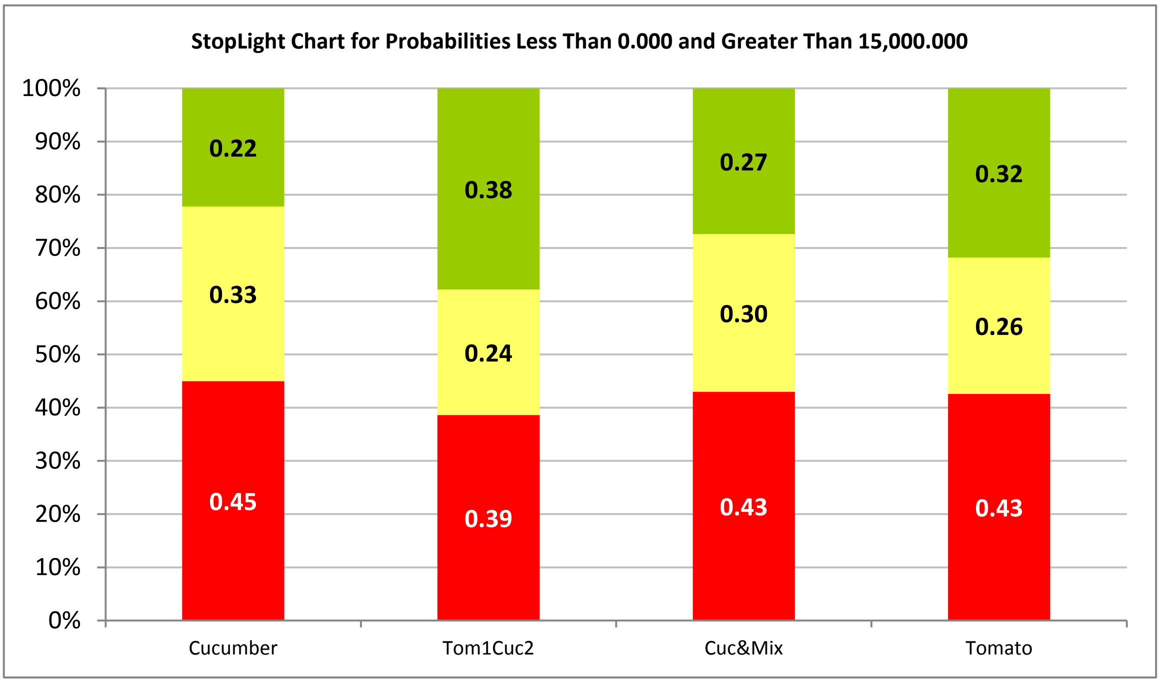

Figure 2. Cumulative Distribution Function of four green-house cucumber and tomato cropping systems

3.5 Stochastic Efficiency Respect to a Function (SERF)

The Stochastic Efficiency with Respect to a Function (SERF) analysis used a utility function with a range of risk aversion instead of evaluating CEs at the two extreme absolute risk aversion coefficients ARACs levels. The (SERF) analysis evaluates CEs for a range of ARACs and between the lower risk aversion coefficient (LRAC) and the upper risk aversion coefficient (URAC). The ARAC represents a decision maker's degree of risk aversion. The stochastic efficiency with respect to a function (SERF) ranking analysis is performed in this study to test green-house cropping systems risky efficient alternatives simultaneously.

The study performed Stochastic Efficiency with Respect to a Function (SERF) analysis between (0.000) ARAC which represent risk neutral decision makers and (0.0001) ARAC which represent extremely risk averse decision makers. The analysis ranked model (Tom1Cuc2) as the first and model (Tomato) as the second cropping system alternatives at risk neutral ARAC. Farmers at extremely risk averse ARAC degree, ranked model (Cucumber) as the first choice and model (Cuc&Mix) as the second cropping system alternative followed by model (Tomato) as shown in Figure (3) below.

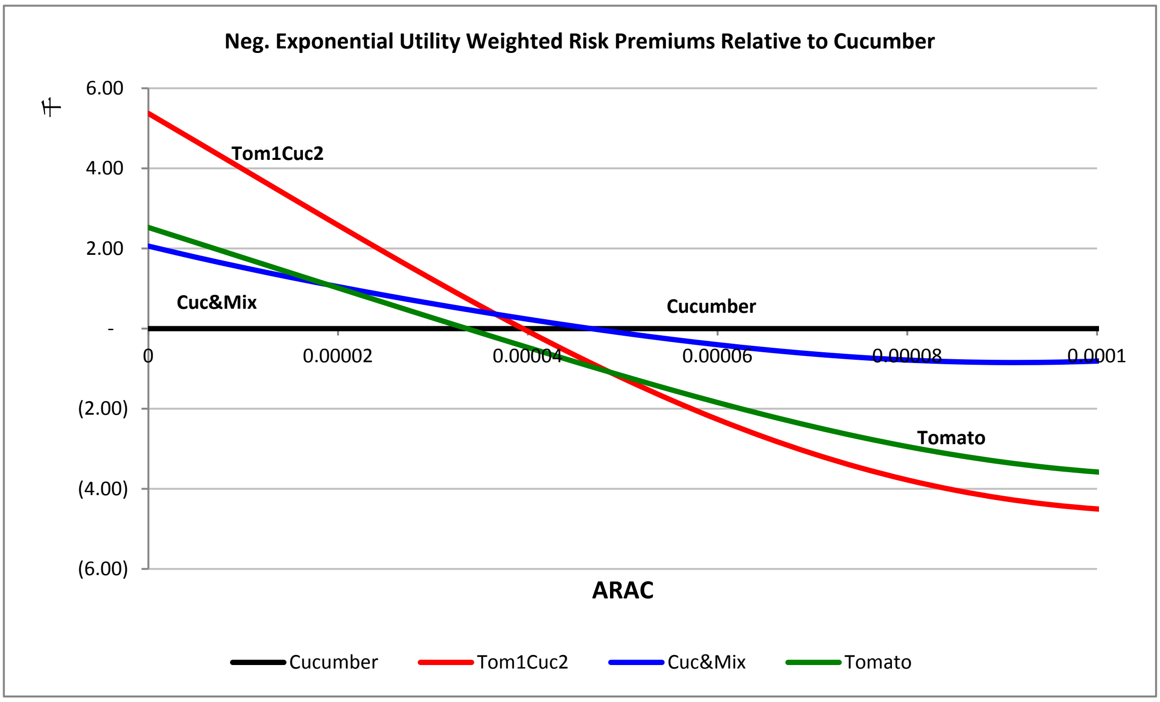

Figure 3. Cumulative Distribution Function of four green-house cucumber and tomato cropping systems

3.6 Probability Density Function (PDF) and Price Volatility Analysis

The historical data analysis of cucumber and tomato market prices showed a large price variation during the year due to crop cultivation seasonality. The gap between local tomato supply and demand increased during the summer and recover through imports from Jordan and other Gulf Cooperation Council Countries. While Jordan open field tomato grower and tomato import agency try to keep tomato at high prices, local greenhouse tomato grower try to benefit from October and November tomato high market price as shown in Figure 4 below. The investment in greenhouse technology will increase yield and reduce risk and offer tomato in lower compatible price. The investment in new greenhouse technology needs an appropriate cropping systems practices and mitigate price risk competition between local greenhouse tomato producer and tomato import agency during summer season.

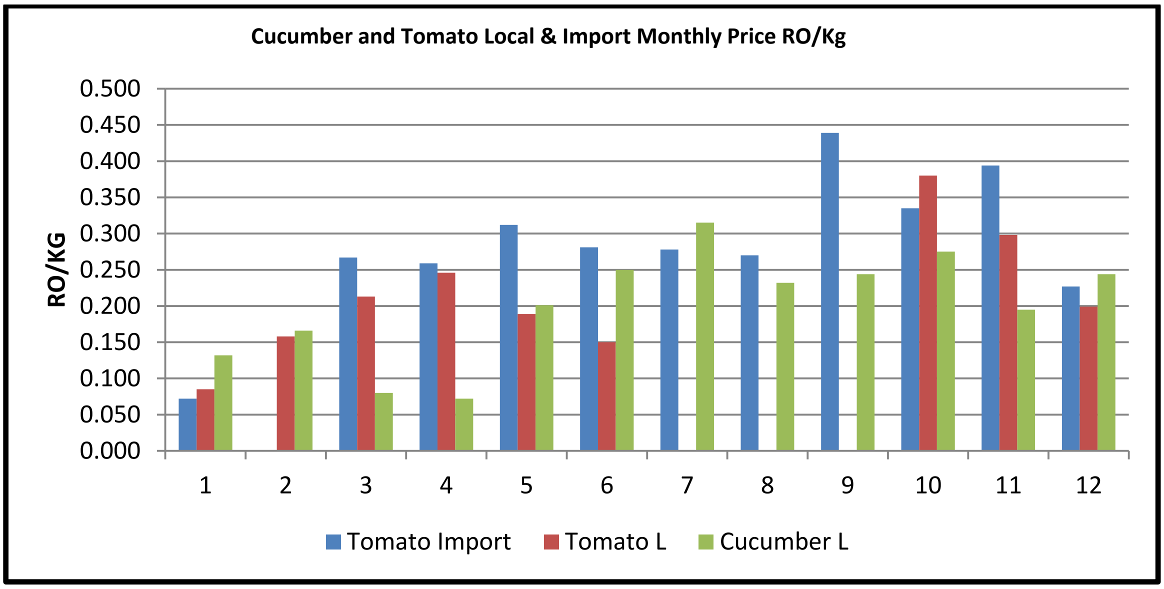

Figure 4. Cucumber and Tomato local and import monthly price RO/Kg

The NPV Probability Distribution Function analysis is performed and shows model (Tom1Cuc2) and model (Tomato) as negatively skewed distribution and have a great potential of downside risk management cropping system alternatives. The analysis shows that model (Cucumber) NPV Probability Distribution Function have a lower upside potential and downside risk and more appropriate and attractive to risk aversion decision makers as per Figure (5). The risk premium of this cropping systems scenario is high and account for R.O. 5 373 to justify not to switch from planting cucumber to grow more risky cropping system such as (Tom1Cuc2). Green-house cucumber growers are not willing to trade less profit model (Cucumber) with additional risky model (Tom1Cuc2).

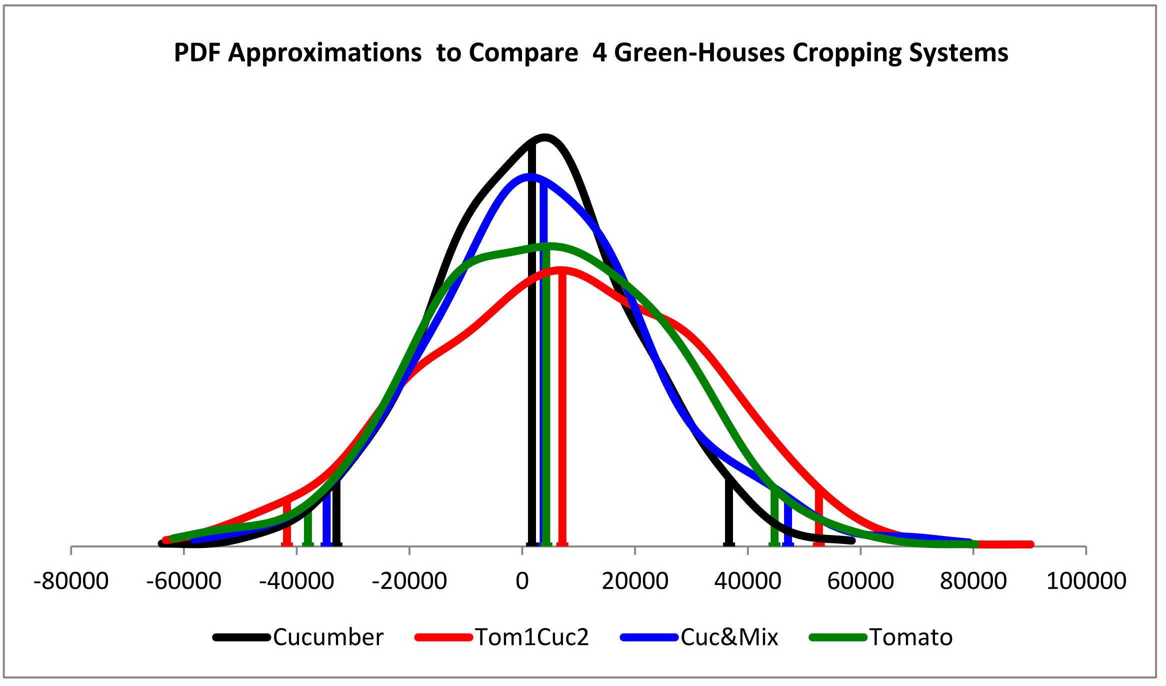

Figure 5. NPV Probability Density Function of four green-house cucumber and tomato cropping systems

4. Conclusion

The main task of this paper is to investigate green house cucumber and tomato cropping system sustainability and ranked them over the range of risk aversion levels. The study also evaluated the economic sustainability and optimum mix of cucumber and tomato crop growing in two green houses. Four stochastic simulation models were identified by using excremental and historical data from Plant Production Research Center at Director General of Agriculture and Livestock Research. The net present value of each greenhouse cucumber and tomato combination models are estimated and calculated. The risk of yield and price seasonal volatility for each cropping system incorporated in the models by identifying probability distribution for each uncertain variable.

The Stochastic Dominance with Respect to a Function (SDRF) analysis and certainty equivalent (CE) is performed under alternative utility function and deferent level of (ARAC). Model (Tom1Cuc2) cropping system is most preferred for lower RACs level and considered to be the risk efficient cropping system followed by (Tomato) model and (Cuc&Mix) model. (Cucumber) model is most preferred for upper RAC level due to yields and price stability compared to tomato crop.

Stochastic efficiency with respect to a function (SERF) and risk premiums analysis is performed for risk neutral decision makers and extremely risk aversion decision makers. Model (Tom1Cuc2) identified as the most risk efficient cropping system and got a positive NPV with 62% probability followed by tomato model cropping system with a positive NPV with probability of 58% for risk neutral farmers. Farmers at extremely risk averse ARAC degree, ranked model (Cucumber) as the first choice and model (Cuc&Mix) as the second cropping system alternative followed by model (Tomato) and model (Tom1Cuc2).

The study indicates tomato and cucumber producers are faced with different production and financial situations. Their risk preferences play an important role in determining their production decisions and Government supporting policy are required. The risk premium (RP) analysis shows that greenhouse tomato growers need to be paid up to RO 2 847 to keep growing tomato model instead of (Tom1Cuc2) cropping system and cucumber growers can sacrifices of RO 5 373 to justify not to switch from cucumber model to (Tom1Cuc2) cropping system model. The Government authority should subsidized farmers to construct additional new greenhouse to grow (Tom1Cuc2) cropping system and maximize their resource use efficiency, benefit from extended cropping season, protect their crops from adverse environmental conditions and increase food security.

Competing interests

The authors declares that he has no competing interest and declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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