Available online at www.sciencedirect.com

ScienceDirect

Agriculture and Agricultural Science Procedia 11 (2016) 105 – 111

Agriculture and Agricultural Science Procedia

International Conference on Inventions & Innovations for Sustainable Agriculture 2016, ICIISA 2016

Evaluation Models for Decision Support in the Context of Organic Farming System

Boonyong Punantapong[a,]*

[a]*Department of Industrial Physics and Medical Instrumentation, Faculty of Applied Science, King Mongkut's University of Technology North Bangkok, Bangkok 10800, Thailand*

Abstract

This paper presents the application of the combination of simulation model and multi-criteria decision models for evaluating investment in agricultural processing. The simulated alternatives are evaluated with multi-attribute decision tools expert system. The simulation system consists of deterministic production simulation models that enable different types of costs calculations for organic production and on farm food processing in the framework of supplementary activities. Simulation models were further evaluate by a qualitative multi-attribute decision modelling methodology using the software tool DEX-I and quantitative analytical hierarchical process (AHP). The simulation model was also evaluated by the standard financial analysis (i.e., cost benefit analysis). These results show that there was the difference before and after investment into specific processing equipment of three organic products with respect to positive financial values. The financial analysis reveals that after 10 years the farm had constant annual cash flow with an investment return at 9.43%. This showed that investments into organic farm was feasible financially. The integrated simulation model as the discount cash flow and multi-criteria decision analysis are the suitable methodological tool for decision support system on organic farms. The system takes into consideration different independent criteria and enables ranking of farm business alternatives. The model is useful in minimizing risk and inappropriate decision in investment.

Peer-review under responsibility of the Faculty of Animal Sciences and Agricultural Technology, Silpakorn University

Keywords: Decision model; risk in agri-farm; farming system

* Corresponding author. Tel.: +662 5552000; fax: +662 5878253.
E-mail address: bpp@kmutnb.ac.th

Peer-review under responsibility of the Faculty of Animal Sciences and Agricultural Technology, Silpakorn University
doi:10.1016/j.aaspro.2016.12.018

1. Introduction

The managerial tasks in agriculture are currently shifting to a new paradigm, requiring more attention on the interaction with the surroundings, namely environmental impact terms of delivery and documentation of quality and growing conditions (Dalgaard et al., 2006; Riezebos et al., 2009). This managerial changes is caused by external entities (such as government, public). This changes have been enforced by provisions and restrictions in the use of production input (e.g. fertilizers, agro-chemicals) and with a change of emphasis for subsidies to an incentive for the farmer to engage in a sustainable production rather than based solely on production (Kaufmann et al., 2009; Saysel et al., 2002). There are many factors such as farm type and soil quality, which might influence farmers' decisions. However, it is attempted to consider the complex interactions of all factors (Shi et al., 2005). Some researchers have adopted the approach of isolating parts of a system. In their research, the diffusion of organic farming practices is modeled by a generic agent model based on the theory of planned behavior for understanding and modeling the farmer's decision making process.

However, farmers constantly face decisions about whether to invest a new production process with increased risks and uncertainties or to maintain the current system without new risks and uncertainties. The possible method to evaluate a new investment opportunity is to use traditional discounted cash flow methods. Although the Net Present Value (NPV) methodology is widely used by project decision making process, a disadvantage of the NPV is that the method does not include the flexibility or uncertainty (Tegen et al., 1999; Wang et al., 2010). In fact, not all agricultural venture capital projects could make a profit immediately, because the sustainable development needs to be considered. For example, if the agricultural project of seed-improvement, as a long-term project, succeeds, it will greatly improve the food production and increase farmer's income (Skraba et al., 2003). Then a real option is defined as the value of being able to choose some characteristic of a decision with irreversible consequences, which affects especially on a financial income. Real options use a flexible approach to uncertainty identifying its sources, developing future business alternatives, and constructing decision rules.

Besides econometric modeling and mathematical programming, other approaches can also be used for the modeling of agricultural systems. System dynamics methodology can be used an alternative for modeling policy scenarios (Hadelan et al., 2009; Rozman et al., 2013). This paper presents application of simulation model for evaluating investments and combination with multi-criteria decision models in agricultural processing. The simulated alternatives are evaluated with multi-attribute decision tools as expert system.

2. Methods

The goals of this research is to develop a computer-based decision support system for the assessment of financial, technological and market impact with special emphasis on supplementary activities on organic farms. The relationships between system elements (i.e. input material, human labor) are expressed with a series of technological equations that are used for calculation of input usage and outputs produced the simulation model and decision model are used in analysis system as shown in Fig. 1.

Fig. 1 shows the processing of investment alternatives, which are further evaluated with multi-attribute decision model. A multi-attribute model is a hierarchical structure that represents the decomposition of the decision problem into sub-problems, which are smaller, less complex and possibly easier to solve than the complete model. The variants are decomposed in specific parameters (criterion, attribute, objective) and evaluated separately for each single parameter. The final variant evaluation is provided with the combine proceeding. However, the amounts of inputs are calculated as a function of given production intensity, while fruit 1 production costs are calculated as products between the models estimated input usage and their prices. For evaluation of simulated alternatives two methodological tools are applied: DEX-I expert system and AHP based expert choice. DEX-I is an expert system shell for multi-attribute decision making that combines the traditional multi-attribute decision making with some elements of expert systems and machine learning. This is traditionally carried out in a numerical way, using weights or similar indicators of attributes' importance. At the same time, attributes are organized hierarchically and connected by utility functions that evaluate them with respect to their immediate descendants in the hierarchy.

So if the net present value is negative then the alternative is unacceptable or if the labour usage in the investment project is low then the alternative is excellent. In contrast, in DEX-I modeling this can also be carried out in a numerical way, using weights or similar indicators of the attributes' importance. After each attribute has been assigned with its scales (qualitative value), the utility functions are defined. The utility function is conducted for each level in the hierarchy (capital utility function for aggregate attributes and overall utility function for the whole model except for the lowest level in the hierarchy). Furthermore, based on enterprise budgets cash flow projections can be conducted together with the investment costs for each business alternative. Then the NPV can be calculated. For an investment of t periods the formula is

$$NPV_t = -I + \sum_{i=1}^{n} \frac{TR - TC}{(1+r)^t} \tag{1}$$

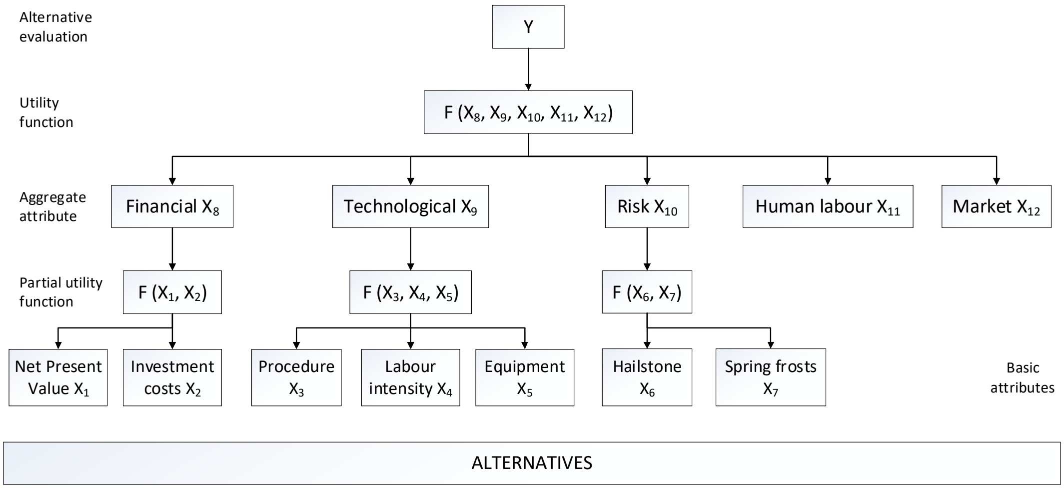

Fig. 1. Structure of model for organic farm planning (modified from Kaufmann et al., 2009; Rozman et al., 2013).

Where NPV_t = standard Net Present Value
I = investment costs
TR = total revenue
TC = total costs
r = discount rate (%)
t = time (years)

Normally, it was presumed that the maximization of NPV_t of the project investment used market prices for expenditures and commodities and describes the financial feasibility. From equation 1, the aggregate benefits, TR and the aggregate costs, TC are annually summed and discounted to the present with selected discount rate, r. Thus if the sum is positive, investment generates more benefits than costs to the project manager (farmer) and vice versa if the sum is negative.

In the real options methodology, the binomial model (i.e. lattice) is widely used real options valuation method (Hadelan et al., 2009; Musshoff, 2012). Fig. 2 represents the binomial process through a decision tree. According to Fig. 2, a node of value $C = NPV_t$ can lead to two nodes with their values being given by $C = NPV_t$ with probability $1 + d = d_1 = C_g$ and $1 - d = d_2 = C_d$, respectively.

However, binomial option is done by asset and option value tree project, using all maintained elements. The option valuation begins solving the tree's node value at the latest year and work back to the beginning year through backward induction (Tegen et al., 1999). The option on the node resulted by the *n* price increase (u^n) and can be calculated by

$$OV(u^n) \quad = \quad \max(V_s(u^n) - X) \tag{2}$$

Value of the option in the node *dn* can be formulated as:

$$OV(d^n) \quad = \quad \max(V_s(d^n) - X) \tag{3}$$

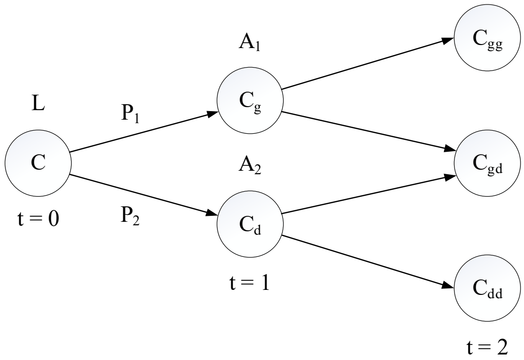

Fig. 2. Binomial lattice structure for real options.

Thus the calculation of the option value in previous steps is

$$OV(u^{n-1}) \quad = \quad \frac{P \cdot OV(\,u^n\,) + (1-P) \cdot OV(u^{n-1}d)}{1+r} \tag{4}$$

Where X = investment's value
OV = option value of project
r = annual risk free continuously compounded rate (%)
σ = annual variance (risk) of the investment's project
P = asset price
V_s = next period underlying asset price

Therefore, the strategic real options of the investment project are calculated (Musshoff, 2012):

$$NPV_s \quad = \quad NPV_t + OV \tag{5}$$

Where NPV_s = strategic real option

Fig. 2 shows an example of the symbolic representation of described elements, in which R_{in} is input flow, R_{out} is output flow, L is the stock, P_1 and P_2 are some arbitrary parameters.

So the conservation of mass principle for the above model could be described with the dynamic equation in the form of difference equation (Hadelan, 2009; Olholm et al., 2015).

$$L(k+1) \quad = \quad L(k) + \Delta t[R_{in}(k) - R_{out}(k)] \,\ldots\ldots k = 0,1,2,\ldots n \tag{6}$$

Where k is discrete time and Δt is the time interval of computation.

We can be calculated in eqn. 6 and are found that the value of level element $L(k+1)$ will be increased if $R_{in}(k) > R_{out}(k)$; it is unchanged if $R_{in}(k) = R_{out}(k)$; and it will be decreased, but if $R_{in}(k) < R_{out}(k)$. Thus eqn. 6 is to use for problem solving with the use of system dynamics methodology to that used with the system approach.

3. Results

Table 1 shows the results on a sample organic farm production and processing. These results showed that on a sample organic farm before and after investment into specific processing equipment of products. The results with the positive financial value 31.92x1,000 ฿/year and is economical by feasible (Ce = 1.02). The product 3 results with the lowest financial value (-312.24x1,000 ฿/year). This result could be explained by labour intensity of the branch (compared to presented production) and consequent higher production costs.

At the same time, the analysis showed the importance of variety and share of specific product selection (see table 1). From the economic point of view the most suitable is product 3 (Ce = 1.32) follow by product 1 (Ce = 0.92). Thus the production product 2 results with lower economic parameters, which can be explained by low production quantity and high labour intensity of the production process.

Table 1. The simulation model results for sample farm.

	Sample farm: before investment				Sample farm: after investment			
	Product 1	Product 2	Product 3	Total	Product 1	Product 2	Product 3	Total
Product quantity	4,850	325	18,370		1,872	98	5,224	
Total revenue ($x10^3$ ฿/yr)	381.78	75.35	155.48	612.61	589.54	455.25	20,815.35	21,860.14
Financial result($x10^3$ ฿/yr)	31.92	-57.68	-312.24	-338	-255.75	-115.35	17,822.30	17,451.20
Coefficient of economics (Ce)	1.02	0.72	0.48		0.92	0.48	1.32	
Labour (hour/yr)	45	19	1,520	1,584	60	43	3,872	3,975

Table 2 shows the financial analysis results for sample farm. It was after 10 year with constant annual cash flow and 8% discount rate a positive value (912.15%). Internal Rate of Return at investment return period is 9.43%. The analysis shows that the investment into analyzed business alternative on farm level is financially feasible.

Table 2. Financial analysis results for sample farm.

Year	Estimated annual cash flow (total/yr)
1	-18,955.32
2	-16,045.92
3	-13,455.98
4	-9,375.72
5	-5,211.73
6	-2,835.90
7	320.78
8	4,225.94
9	7,125.87
10	10,451.54

Investment costs: 25,324.71x10^3 ฿

Investment return period: 10 years at 8% discount rate; NPV=912.15 ฿

IRR at investment return period: 9.43%

Table 3. Asset valuation lattice for product 1 production by binomial model (for first 5 years of production).

Time (yr)	0	1	2	3	4	5
OV (x10³ ฿)	3,349.33	4,521.12	6,102.88	8,238.03	11,120.17	15,010.66
		2,481.25	3,349.33	4,521.13	6,102.88	8,238.03
			1,838.15	2,481.25	3,349.33	4,521.13
				1,361.74	1,838.15	2,481.25
					1,008.80	1,361.74
						747.34

Table 4. Option value assessments for product 1 production by binomial model (for first 5 years of production).

Time (yr)	0	1	2	3	4	5
OV (x10³ ฿)	221.48	426.68	821.99	1,583.56	3,050.73	5,877.23
		0.00	0.00	0.00	0.00	0.00
			0.00	0.00	0.00	0.00
				0.00	0.00	0.00
					0.00	0.00
						0.00

Table 3 and 4 show the details of the binomial lattice calculations, where binomial models comprise two underlying lattice generation as asset and option value lattice. Thus table 3 indicated that the possible project value after 5 years of production can be ranged from 747.34x1,000 ฿ to 15,010.66x1,000 ฿ depend on favorable or unfavorable business circumstances. Furthermore, option value assessments for product 1 by binomial model for first 5 years of production result with value 0.00 as shown in table 4.

Table 5. Project evaluation of business alternatives evaluation for the sample organic farm.

	Financial objective	Labour intensity	Technological objective	Market objective	Risk objective		Ranking
Weight	0.448	0.083	0.025	0.323	0.121		
Alternative priority						ΣWa	
Alternative 1	0.425	0.310	0.323	0.494	0.333	0.442	1
Alternative 2	0.222	0.521	0.333	0.210	0.333	0.317	2
Alternative 3	0.353	0.169	0.333	0.296	0.333	0.241	3

ΣWa is alternative priority with respect to individual objective (objectives with no sub-levels are assed directly from pair wise comparison matrices).

Table 5 shows the simulation result was further evaluated with multi-attribute decision model (DEX-I and AHP). Since the main results from a simulation model are numerical (investment financial indicators and labour input) the qualitative value must be assigned to each quantitative parameter in order to enable further analysis in DEX-IO decision model. Thus the applied AHP methodology should bring unequivocal clarity to the decision which business alternative should be favored and implemental on a sample part time organic farm.

4. Conclusions

The integrated simulation model combined with multi-criteria decision analysis present the suitable methodological tool for decision support system on organic farms. In the paper, an attempt was made to employ a real options approach to evaluate the fruit processing business alternatives on a farm. The system takes into consideration different independent criteria and enables ranking of farm business alternatives. The general implication from this empirical analysis is that uncertainty and risk attributes play an important role in farmers' decision to adopt a new business. Thus the presented methodological framework for cost analysis and decision support on conventional and organic farms could provide additional information support, bring additional clarity to the decision and could therefore play an important role in further development of organic farming systems. The system takes into consideration different independent criteria and enables ranking of farm business alternatives. Then the model results are useful in practice and helpful in setting up hedges in the correct proportions to minimize risk.

Acknowledgements

This work was partially supported the equipment and tools from Department of Industrial Physics and Medical Instrumentation, Faculty of Applied Science, King Mongkut's University of Technology North Bangkok.

References

Dalgaard, R., Halberg, N., Kristensen, I.S., Larsen, L., 2006. Modelling Representative and Coherent Danish farms Types Based on Farm Accountancy Data for Use in Environmental Assessments. Agriculture, Ecosystems and Environment 117(4), 223-237.

Hadelan, L., Njavro, M., Par, V., 2009. Plum Plantation Value Based on Real Option Contribution. Poljoprivreda 15(1), 51-56.

Kaufmann, P., Stagl., Franks, D.W., 2009. Simulating the Diffusion of Organic Farming Practices in Two New EU Member States. Ecological Economics 68(10), 2580-2593.

Musshoff, O., 2012. Growing Short Rotation Coppice on Agricultural Land in Germany: A Real Options Approach. Biomass and Bioenergy 41, 73-85.

Olholm, A.M., Kidholm, K., Birk-Olsen, M., Christensen, J.B., 2015. Hospital Managers' Need for Information Health Technology Investments. International Journal of technology Assessment Health Care 31(6), 414-425.

Riezebos, J., Klingenberg, W., Hicks, C., 2009. Lean Production and Information Technology: Connection or Contradiction. Computers in Industry 60(4), 237-247.

Rozman, C., Pazek, K., Kljajic, M., Bavec, M., Turk, J., Bavec, F., Skraba, A., 2013. The Dynamic Simulation of Organic Farming Development Scenarios: A Case Study in Slovenia. Computers and Electronics in Agriculture 96, 163-172.

Saysel, A.K., Barlas, Y., Enigun, Y.O., 2002. Environmental Sustainability in an Agricultural Development Project: A System Dynamic Approach. Journal of Environmental Management 64, 247-260.

Shi, T., Gill, R., 2005. Developing Effective Policies for the Sustainable Development of Ecological Agriculture in China: The Case Study of Jinshan Country with a System Dynamics Model. Ecological Economics 53(2), 223-246.

Skraba, A., Kljajic, M., Leskovar, R., 2003. Group Exploration of System Dynamics Models: Is there a Place for a Feedback Loop in the Decision Process. System Dynamics Review 19(3), 243-263.

Tegen, A., Wiebe, K., Kuhn, B., 1999. Irreversible Investment under Uncertainty: Conservation easements and the Option to Develop Agricultural Land. Journal of Agricultural Economics 50(2), 203-219.

Wang, Z., tang, X., 2010. Research of Investment Evaluation of Agricultural Venture Capital Project on Real Options Approach. Agriculture and Agricultural Science Procedia 1, 449-455.