doi: 10.14355/ijast.2014.0302.01

Role of Risk-Related Latent Factors in the Adoption of New Production Technology

The Case of Japanese Greenhouse Vegetable Farmers

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Received 8 Jan, 2014; Revised 20 Feb, 2014; Accepted 1 Mar, 2014; Published 10 May, 2014

Abstract

Most food safety and consumer trust measures focus on information management in preparation for accidents and system structures focused on inspection records for hygiene management. Recognizing the provision of safe produce coupled to preventative rather than reactive measures as being more important, this research uses covariance structure analysis to explore decision making associated with the adoption of new technology by farmers. Survey items range from standard farm characteristics (such as scale of operation and volume of sales) to social psychological constructs (such as attitudes about various farm operational risks). Data drawn from greenhouse vegetable farmers (185 mail survey responses) are used to estimate our causal models. Overall, large farms tended to be more progressive in the adoption of new technology, even when they perceived high operational risks. In the future, assuming Japan will participate in the Trans-Pacific Partnership (TPP), regulations associated with vegetable imports will be eased and Japan's greenhouse vegetable farmers will face fierce international competition. Food safety regulations will also likely be subjected to TPP guidelines. Under these circumstances, production technology for heightened food safety will be indispensable in order for Japan's greenhouse vegetable farmers to continue to thrive. Government support to encourage the adoption of new technology will also be necessary. The results of this analysis contribute fundamental knowledge to the formulation of measures designed to encourage adoption.

Keywords

Greenhouse Vegetable Farmers; New Production Technology; Food Safety; Perception of Operational Risks; Structural Equation Model (SEM)

Introduction

Recently, various measures have designed to ensure food safety and gain consumer trusts have been undertaken in Japan. However, most of these measures focus on distribution information in the case of accidents and on system structures for hygiene centered on the management of inspection records. More weight needs to be placed on the production of safe produce, or what we refer to as preventative measures rather than on such measures to resolve incidents after their occurrence.

Crop yield and demand for agricultural produce are easily affected by the weather; moreover, farm households are exposed to a host of risks. Despite these core facts, production factors, such as labor and land, are not easily manipulated for the dominant family-run farms that are the backbone of Japanese agriculture. Because of this inherent lack of flexibility to respond to risks as they arise, farm decision making tends to be conservative, especially around issues related to the adoption of newly developed technology. Further, at the national level, agricultural budgets continue to face major cuts as a result of the prolonged stagnation of the economy. As a result, cost-effectiveness has become the key operational measure of all new technologies. Understanding the adoption intention of different kinds of farm households about various technologies is critical for the development of effective measures that further the adoption of new food safety protocols.

This study provides an empirical investigation of how social psychological factors, such as farmer attitudes and perspectives, as well as operational characteristics of the farm influence decision making regarding the selection of technologies. A nationwide survey of greenhouse vegetable farmers investigated attitudes about the operational risks of the adoption of new technology such as reduced chemical use. A hypothesis of causal structure is tested through the analysis of covariance structure.

Hypothesis Formulation

Decision Making Factors for the Adoption of New Technology

Farm operation decision making involves a complexity of intertwined factors. The analysis of covariance structure, which has gained increased attention in recent years, enables tests of between-variable causal structure hypotheses with relative ease through an estimation of the Structural Equation Model (SEM). However, serious critiques of the arbitrariness of the modeling process necessitate ample caution to ensure the formulation of an objective hypothesis. This section reviews the existing literature and the justifications for the hypothesis about the latent and observed variables in our SEM.

A review of past research on the social psychological bases for farmers' operational decisions reveals that despite the increasing volume of research on consumer behavior, especially in the field of food safety, little work has focused on farmers. Willock *et al.*'s (1999) is one of a few studies conducted using SEM. Their study of farmers in Scotland revealed that variables based on subjective evaluations (social psychological factors) such as quality of life had a significant influence on various decision making processes. However, no analysis has yet been conducted on the management risks. On the other hand, Kurihara *et al*. used SEM and showed the aggressiveness and progressiveness of Japanese dairy farmers as important factors in the adoption of new technology (Kurihara, 2006; Kurihara *et al.*, 2008). Further, Asai and Yamaguchi (1998) found the psychological (mental) factor "Seeking Mental Composure" led to the adoption of new cultivars of rice through a principal component analysis.

In contrast, Yamamoto *et al.* (2005) identified perceived risks of environmental change within and without the operation as decision making factors for the adoption of new technology in their meta-analysis. Perceptions of investment risks regarding the effects of the new technology actually served to inhibit adoption. In light of such findings, the present study recognizes farmer (or operators) aggressiveness and perceptions of the various risks regarding their operation to be particularly important social psychological factors of the adoption of new technology and used these factors as the latent variables in the SEM.

Other work recognized strong links between the scale of the operation and their state of adoption of new technology (Miyatake, 2001; Konya *et al.*, 2002; Naka and Fujimoto, 2002; Kawasaki, 2010). Thus, farm scale was selected out of the many operation characteristics as a factor for adoption. In addition to these three factors (Aggressiveness, Risk Perception, Farm Scale), the adoption rate of new technology was entered as an outcome variable to assess their effect. The four were classified and then used as the latent variables in this SEM.

Risks of Agricultural Operations

Risks of agricultural operations, one of the factors for adoption, have been previously reviewed (Harwood *et al.*, 1999; Nanseki, 2011). Despite inconsistencies in the classification of risks, and in perception measurements across countries, these reviews have found common risks that heavily influence family-operated businesses. Apart from fluctuations in prices and yields, these include risks such as changes in government policies and laws as well as injuries and illnesses. While focused on irrigation technology, Koundouri *et al.* (2006) and Baerenklau and Knapp (2007) who studied Greek and Californian farms, respectively, found that those farms facing risks of altered crop yields were most likely to adopt new technology. Using these findings to guide our framework, seven indices (observed variables) were employed for the latent variable "Risk Perception" using the following questions and answer choices (Observed variables are annotated with an (*O*), latent variables with an (*L*)):

- Price Fluctuation Risk (*O*): Fluctuations in market prices for agricultural produce were operationalized with the question, "how do you feel about the yearly price fluctuations of the primary commercial crop in your greenhouse operation?" (5-point Likert scale, 5= Large, 4=Rather large, 3= Neither, 2=Rather small, 1=Small)
- Yield Fluctuation Risk (*O*): Likewise operationalized with a question on the perceived risks of

fluctuations in yields per unit area on a five-point Likert scale.

- Employment Risk (*O*): Risks pertaining to employment was operationalized with 4-choice questions (5=Large, 4=Rather large, 3=Rather small, 2=Small) on topics such as the employment of incompetent employees, decrease in rate of employee retention, expenses of discharging employees, risks of using trainees. “Unrelated” was included as an additional option for these questions, and “neither” was omitted to conserve page width. Since “unrelated” was assigned a code (1) for the SEM analysis, these questions were 5-point Likerts like the questions on Price and Yield Fluctuation Risks.
- Health Risk (*O*): Perceived health risks, such as of injuries, illnesses, and deaths of farm workers (5-point Likert scale with “unrelated”).
- Contract Risk (*O*): Perceived risks pertaining to contracts, such as of penalties of not reaching target yields, loss-incurring prices, and illegal maneuvers of a partnering firm were operationalized with 5-point Likert questions (with “unrelated”).
- Policy Risk (*O*): Perceived risks pertaining to agricultural policies such as cuts in governmental subsidies and losses resulting from international trade negotiations such as the Trans-Pacific Partnership (TPP) was operationalized with 5-point Likert questions (with “unrelated”).
- Investment (in new technology) Risk (*O*): Risks regarding the adoption of new technology, such as of suboptimal performance of the new technology, was operationalized with a 5-point Likert scale (with “unrelated”).

New Technologies in the Production of Greenhouse Vegetables

Regarding the new technologies in food safety, expert opinion was gained from Dr. Toru Maruo (Professor at Chiba University), the leading authority on greenhouse vegetable production in Japan. As a result, four indices (observed variables) were added as constituents of each of the four classifications of new technology (latent variables; total of 16 indices). Respondents were asked to indicate their adoption status or intention regarding the following practices on a 6-point scale (5=Adopted, 4=Strongly wish to adopt, 3=Would like to adopt, 2=Neither, 1=Not very interested in adopting 0: Do not want to adopt (incl. Unrelated)). Here, technologies for food safety were those with implications for the consumers' perceived safety, such as decreased use of chemicals and tests. They do not imply danger in conventional methods:

- Technology for the Reduction of Pesticides (*L*): Insect Net (*O*), Microbial Formulation (*O*), Reflective Mulch (*O*), Predator Insects (*O*).
- Technology for the Reduction of Disease Prevention Chemicals including Soil Disinfectants (*L*): Steam Disinfection (*O*), Hydrothermal Disinfection (*O*), Ethanol Disinfection (*O*), Plant Defense Activator(*O*).
- Post-Harvest Technology and Testing Technology(L): Residual Chemical Testing (*O*), Traceability (system adoption)(*O*), Test Outsourcing to Third Parties (*O*), Certifications (e.g. HACCP, GAP) (*O*).
- Technology for the Reduction of Artificial Fertilizers and Other New Technology (*L*): Nutriculture (*O*), Drip fertilization (*O*), Enclosed (using artificial light) Plant Factories (*O*), Pollinating Insects (*O*).

Overview of the Survey and Descriptive Analyses

Survey Overview

In September 2012, a one-shot mail survey was sent to 608 greenhouse vegetable farms throughout Japan. The addresses included operations and farms outside of the target population and were acquired from Teikoku Databank, Ltd., a private data management company, and a national organization of producers (Zenkoku Yasai Engei Gijutsu Kenkyukai). The actual survey was conducted through Intage Research Inc., a private survey company.

Following this mailing, 334 surveys were returned (RR 54.9%). However, perhaps reflecting the large number of questions, many farmers only partially completed the form. In addition, while this survey targeted fruit vegetable producers who tended to have greater capacity for the selection of technology, many responses were from mushroom and leaf vegetable farmers. These farms were omitted from the analysis, resulting in a sample size of 185 responses (80% of these were tomato and cucumber farms).

The survey consisted of three parts. One group of questions focused on characteristics and demographics of the farm operator and operation, another, on the perceived risks of operations, and yet another focused on social psychological attitudes regarding the adoption of new technology.

Operation Characteristics

TABLE 1 FARM OPERATION AND OPERATOR CHARACTERISTICS

Latent Var.	Index (Observed Var.)	Category	Analysis code	Cases (n=185)	%
Farming Scale	Annual Sales (Millions of Japanese yen)	<5	1	13	7.0
		5 - 9.99	2	42	22.7
		10 - 19.99	3	60	32.4
		20 - 29.99	4	22	11.9
		30 - 39.99	5	11	5.9
		40 - 49.99	6	3	1.6
		50 - 59.99	7	6	3.2
		60<	8	28	15.1
	Cultivated Land Area in Operation (a)		M=71.9, SD=98.1		
	Regular Employees		M=3.4, SD=7.1		
	Temporary Employees		M=2.6, SD=7.6		
Aggressiveness	Age	Younger than 30	6	1	0.5
		30 - 39 years old	5	17	9.2
		40 - 49 years old	4	27	14.6
		50 - 59 years old	3	57	30.8
		60 - 69 years old	2	76	41.1
		Older than 70	1	7	3.8
	Plans for Farming Scale	Scale-down	1	27	14.6
		Maintain scale	2	106	57.3
		Expansion	3	52	28.1
	Succeeding Operator	Undecided	1	61	33.0
		Has prospect	2	58	31.4
		Decided	3	66	35.7
	Attitude towards Technology Seminars	Rather passive	1	10	5.4
		Neither	2	35	18.9
		Rather aggressive	3	77	41.6
		Aggressive	4	63	34.1

Note: The code for analysis is the value used for the observed variables in the SEM.

Table 1 shows the characteristics of the greenhouse vegetable farms in the analysis. Farms with annual greenhouse vegetable sales of 10 million to 19.99 million yen were most common and comprised a third of the sample. An additional 15% were large scaled farms with sales of more than 60 million yen. Cultivated land (greenhouse) area averaged 72 acres, labor averaged 3.4 regular employees and 2.6 temporary employees. The principal operator was most commonly 60 - 69 years old (41%), followed by those 50 - 59 years old (31%). When asked about future operation scale, 57% expected to maintain their present conditions. And, when asked about succession, 36% had determined a successor while a third indicated that this had not been decided. Finally, 76% of the farmers indicated they participated aggressively in seminars on new technology.

To assess this sample's representativeness, it was compared to data drawn from the 2010 Census of Agriculture and Forestry, a complete enumeration by the Ministry of Agriculture, Forestry and Fisheries of Japan. There were 21,806 farm households that relied primarily on the sales of greenhouse (fruit) vegetables across Japan. Their annual sales averaged almost 4 million yen, and the average cultivated area 24.1 was acres. These farms averaged 0.17 regular employees and 2.4 temporary employees. The national average age of the principal operator was 62.7 years old, and 62.8% had a determined successor. While this study's sample farms were larger than the nationwide average, it should be noted that the census included a large number of small scale farmers (with sales above 500 thousand yen). This sample is therefore likely representative of self-sustaining farms such as those targeted in this analysis.

Risk Perception

TABLE 2 DEGREES OF PERCEIVED RISKS IN MANAGEMENT

Index (Observed variable)	Category	Analysis code	Cases (n=185)	%
Price Fluctuations	High	5	17	9.2
	Rather high	4	57	30.8
	Neither	3	57	30.8
	Rather low	2	33	17.8
	Low	1	21	11.4
Yield Fluctuations	High	5	4	2.2
	Rather high	4	30	16.2
	Neither	3	75	40.5
	Rather low	2	47	25.4
	Low	1	29	15.7
Risks of Employing	High	5	20	10.8
	Rather high	4	59	31.9
	Rather low	3	27	14.6
	Low	2	36	19.5
	Unrelated	1	43	23.2
Health Risks	High	5	53	28.6
	Rather high	4	58	31.4
	Rather low	3	31	16.8
	Low	2	36	19.5
	Unrelated	1	7	3.8
Contract Risks	High	5	6	3.2
	Rather high	4	16	8.6
	Rather low	3	19	10.3
	Low	2	51	27.6
	Unrelated	1	93	50.3
Policy Risks	High	5	44	23.8
	Rather high	4	60	32.4
	Rather low	3	31	16.8
	Low	2	36	19.5
	Unrelated	1	14	7.6
Investment Risks	High	5	24	13.0
	Rather high	4	88	47.6
	Rather low	3	43	23.2
	Low	2	21	11.4
	Unrelated	1	9	4.9

Note: Due to space limitations on the survey, "Unrelated" was not included in the answer options for Price Fluctuations and Yield Fluctuations. "Neither" was not included for the other indices.

Table 2 displays the perceived degrees of the seven risks of farm operation. For the risks associated with production and the market, the perceived risks of Yield Fluctuations were low ("(rather) high" is 18%), while those for Price Fluctuations were high ("(rather) high" is 40%). This may be because while greenhouse vegetable production is possible to plan, its share in the market is small relative to that of outdoor-grown vegetables. When the volume of outdoor-grown vegetables is high, market prices are strongly impacted by the state of outdoor vegetable production.

For the other five risks, Health had the highest perception, with 29% indicating "high." For aging family-run operations, injuries and illnesses of working family members, including the principal operator, were a major concern. Policy Risks of changes in agricultural policies had the next highest perception (24% "high"). Japan's participation in the TPP appeared to be of great concern to these farmers.

In contrast, Contract Risks had the lowest perceived risk, with 28% responding "low." Close to half responded "unrelated." This may reflect the large role oral contracts play in Japan, and that penalties for not being able to fulfill the contract (e.g., target yields) rarely occurred.

Attitudes about the Adoption of New Technology

Table 3 shows the state of adoption and attitudes toward the adoption of new technology. Respondents were asked to respond on a five-point scale in the actual survey (from not interested in adopting to adopted). Beginning with technologies to reduce pesticide use, many farms had already adopted several strategies, such as using insect nets and microbial formulations, and the rest indicated high levels of adoption intention. This well reflects the relatively low cost of adopting such technologies and their widespread availability in the marketplace.

In contrast, adoption rates were low for the technologies associated with reducing the use of soil disinfection chemicals and illness prevention chemicals. Further, adoption intention was not very high. Using new technologies for soil disinfection is labor intensive, and the techniques have yet to be verified in applied contexts. As for the plant defense activator, the short duration of its effectiveness appeared to be a considerable inhibitor.

Adoption rates were high for post-harvest technologies and various tests, perhaps reflecting heightened consumer consciousness about food safety. Of these, tests for residual chemicals and traceability (systems) were used by about 60% of the responding farmers and received high levels of adoption intention from other farms. However, adoption intentions for outsourcing testing to third parties and for various certifications were low, perhaps due to the associated costs.

TABLE 3 ADOPTION INTENTION OF FOOD SAFETY TECHNOLOGY

Latent Var.	Index (Observed Variable)		Cases (n=185)	%
Reduction of Pesticides	Insect Nets	Adopted	144	77.8
		Wish to adopt	21	11.3
	Microbial Formulation	Adopted	86	46.5
		Wish to adopt	38	20.5
	Reflective Much	Adopted	40	21.6
		Wish to adopt	36	19.5
	Predator Insects	Adopted	38	20.5
		Wish to adopt	54	29.2
Reduction of Soil Disinfectants	Steam Disinfection	Adopted	8	4.3
		Wish to adopt	35	18.9
	Hydrothermal Disinfection	Adopted	7	3.8
		Wish to adopt	36	19.4
	Ethanol Disinfetion	Adopted	3	1.6
		Wish to adopt	25	13.5
	Plant Defense Activator	Adopted	5	2.7
		Wish to adopt	28	15.2
Post-Harvest Technology	Residual Chemical Testing	Adopted	116	62.7
		Wish to adopt	38	20.5
	Traceability	Adopted	107	57.8
		Wish to adopt	31	16.8
	Test Outsourcing to Third Parties	Adopted	87	47.0
		Wish to adopt	23	12.4
	Certifications	Adopted	65	35.1
		Wish to adopt	46	24.8
Reduction of Artificial Fertilizers	Nutriculture	Adopted	47	25.4
		Wish to adopt	19	10.3
	Drip Fertilization	Adopted	44	23.8
		Wish to adopt	21	11.4
	Enclosed Plant Facdtories	Adopted	11	5.9
		Wish to adopt	19	10.3
	Pollinating Insects	Adopted	99	53.5
		Wish to adopt	9	4.9

Note: Codes for analyses were 5: Adopted 4: Strongly wish to adopt 3: Would like to adopt 2: Neither 1: Not very interested in adopting 0: Do not want to adopt (incl. Unrelated). "Wish to adopt" in the table includes 4 and 3.

The final group was the adoption intention for technologies for reducing the use of artificial (chemically synthesized) fertilizers, plant factories, and other new technology. While adoption rates and intention were low for the enclosed plant factories that are particularly expensive to implement, a quarter of the farms had already adopted nutriculture and drip fertilization. Further, over half of the farms were already using pollinizing insects, indicating this to be common technology in the field of greenhouse horticulture (especially for fruit vegetables).

The following section structurally examines the adoption process for new technology by using the attitudes and operation characteristics of operators including their risk perceptions.

Covariance Structure Analysis

A covariance structure analysis is conducted here to investigate the causal structure of the decision making process behind farmers' adoption of new technology. Of the seven latent variables considered above, the SEM was assumed with the three farm and farmer characteristic variables, "Farming Scale (*L*)," "Aggressiveness (*L*)," and "Risk Perception (*L*)" as the causal indicators (higher-order factors). Four latent variables aggregating the farmers' adoption intention for new technology was assumed as the first-order factor. First, an exploratory model was assessed to eliminate as much noise as possible in the estimation process. This second-order factor model contained paths from the three latent variables on farm and farmer characteristics to each of the four latent variables on new technology. As the coefficient of the path from "Farming Scale (*L*)" to "Reduction of Pesticides (*L*)" and to "Reduction of Soil Disinfectants (*L*)" did not match the hypothesis, a more complex, third-order factor model using "Farming Scale" as an exogenous latent variable was used for further assessment. However, as the causal relationship between the second-order factors (from "Risk Perception (*L*)" to"Aggressiveness (*L*)") was also taken into consideration, the structure differed slightly from a typical third-order factor model with an independent higher-order factor. Furthermore, taking Wald test results into account, the model was improved by eliminating the paths that considerably lowered the model's goodness of fit. This resulted in a validation model as shown in Figure 1.

In assessing this model with the maximum-likelihood method using AMOS, the large number of observed variables and the small sample size resulted in a low Goodness of Fit Index (GFI) of 0.79. The AGFI, or GFI after adjusting the degrees of freedom, was 0.76. However, the RMSEA (Root Mean Square Error of Approximation) that considers the small sample size is low, at 0.06. Further, all between-latent variable path coefficients were statistically significant ($p<0.05$). Therefore, these test results were evaluated as indicating that the model could be used to assess a causal structure.

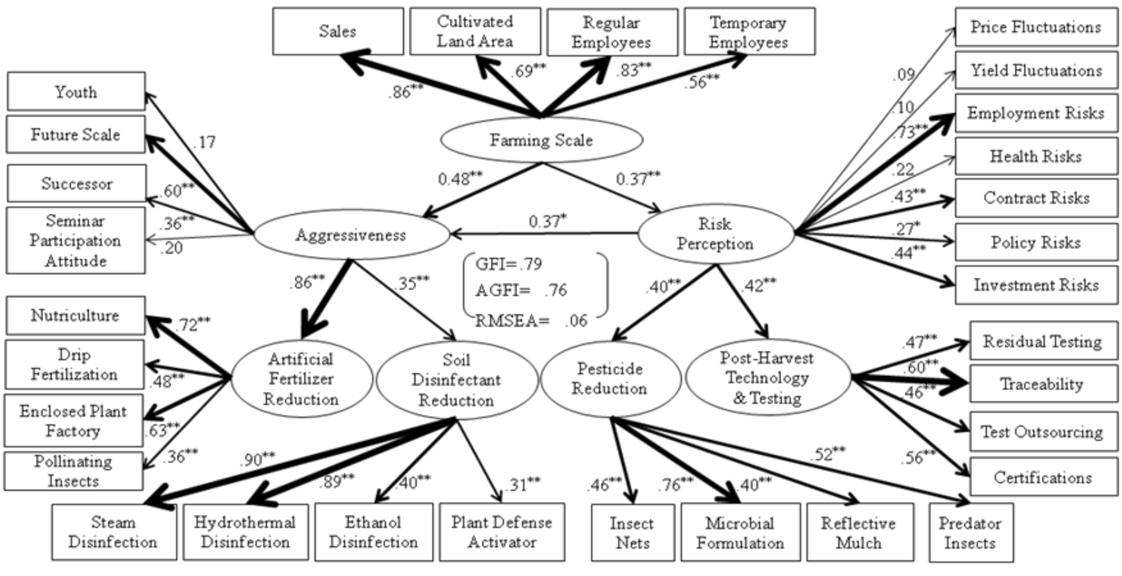

FIG. 1 CAUSAL STRUCTURE OF GREENHOUSE VEGETALBE FARMERS' ADOPTION PROCESS FOR NEW TECHNOLOGY

Note : 1) Ovals indicate latent variables; rectangles indicate observed variables. Error terms were omitted for simplicity.
2) Arrows indicate the direction of causality and their values indicate the standardized path coefficient. The thickness of the lines correspond with the coefficient values.
3) The statistical significance of the paths are indicated as ** for $p \leq .01$ and * for $p \leq .05$.

Test results are next considered, beginning with the relationships between the three latent variables for the farm characteristics and the observed variables that make them up. In Figure 1, the boldness of the paths is used to help show the key influencing factors. "Future Scale (*O*)" and "Successor (determined) (*O*)" were the main observed variables for "Aggressiveness (*L*)." "Employment (Risks) (*O*)," "Contract (Risks) (*O*)," and "Investment (Risks) (*O*)" were the main observed variables for "Risk Perception (*L*)." Additionally, "Farming Scale (*L*)" determines both "Aggressiveness (*L*)" and "Risk Perception (*L*)." Combined, these results reveal a causal structure in which larger farmers are more aggressive but also exposed to greater risks. Further, the positive and significant path coefficient from "Risk Perception (*L*)" to "Aggressiveness (*L*)" indicates that the heightened levels of perceived risk do not inhibit the expansion in farm scale.

Next, the relationship between farm characteristics and the intention to adopt new technology shows the direct influences of "Risk Perception (*L*)" on the adoption of "Technology for the Reduction of Pesticides (*L*)" and "Post-Harvest Technology and Testing Technology (*L*)," and of "Aggressiveness (*L*)" on the adoption of "Technology for the Reduction of Artificial Fertilizers (*L*)" and "Technology for the Reduction of Soil Disinfectants (*L*)." Farms that perceived high operational risks were more likely to adopt intangible, soft technologies to gain consumer trust, and farms with more aggressive management approaches were more likely to adopt advanced and expensive hard technologies (i.e., equipment).

Overall, the covariance structure analysis confirmed the hypotheses that large-scale farms and those that perceived operational risks were more progressive in the adoption of new technology.

Conclusion

This study quantitatively revealed farmers' selection of new technologies for safety such as the reduction in pesticide use with a focus on social psychological aspects. More specifically, a survey of greenhouse vegetable farms (mostly of fruit vegetables) throughout Japan inquired farmers' adoption intention for new technology. An SEM revealed farm operation characteristics and farmers' social psychological attributes as latent variables influencing farmers' adoption of new technology.

The following were the most important findings drawn from the descriptive analyses:

- Greenhouse vegetable farmers perceived high risks for price fluctuations, injuries and illnesses, and policy changes;
- Adoption rates of technologies to reduce pesticides and artificial fertilizers, as well as for post-harvest tests, were already high.

The subsequent covariance structure analysis found the following:

- Decision making factors for the selection of new technologies included exogenous factors such as Farming Scale as well as social psychological factors such as Aggressiveness and Risk Perception.
- While Farming Scale and Risk Perception were associated with the selection process for new technologies in general, the effect of Aggressiveness was more narrowly focused on the selection of technology for the reduction of artificial fertilizers such as nutriculture.

Given Japan's participation in the negotiations of TPP, the outlook is for the easement of various policies that protect Japan's vegetable production from international competition. The significance of this is that Japan's vegetable farmers will soon face fierce international competition on pricing. As food safety policies such as those related to residue chemicals are also likely to be eased, consumer interest in food safety is likely to increase even more. In this context, technologies that reduce the use of pesticides and that ensure food safety will likely enhance the competitive edge of Japan's vegetable farmers. However, to encourage the adoption of such new technologies, it is necessary to provide government support, perhaps through subsidy programs and promotion. Taking into account the results of this analysis in this process will likely enable the development of more efficient measures that support the adoption of new technology.

ACKNOWLEDGMENT

This work was supported by JSPS KAKENHI Grant Numbers 21380133, 24580314.

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doi: 10.14355/ijast.2014.0302.02

Assessment of Landuse Change and Its Impact on Watershed Hydrology Using Remote Sensing and SWAT Modeling Techniques

A Case of Rawal Watershed in Pakistan

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Received 5 Aug, 2013; Revised 20 Oct, 2013; Accepted 1 Mar, 2014; Published 10 May, 2014

Abstract

Assessment of hydrological effects of the landuse transformations on both water yield and flow regimes is an imperative aspect in watershed management. Dealing with water management issues requires analyzing of different elements of hydrologic processes taking place in a watershed area. In the present study, hydrological response of the Rawal watershed (located in the sub-Himalayan region) was studied to historical landuse evolution and variable landuse change scenarios using SWAT -Soil and Water Assessment Tool model. The temporal analysis of LANDSAT TM (1992) and LANDSAT ETM plus (2010) image data revealed a decrease of over 16% in the scrub forest coverage while built-up land increased three folds during 1992-2010 period. Major part of the scrub forest had converted into agriculture and built-up land besides rangeland in some areas. The landuse changes resulted in an increase of about 6.0% in the water yield and 14.3% in the surface runoff of the watershed. The scenario of extreme deforestation likely due to growth in urbanization, exhibited a decrease of about 0.4% in the water yield and an increase of about 122% in the sediment yield from base conditions of 2010 period. In case of an afforestation scenario (e.g. increase of scrub coverage to about 76%), the sediment yield decreased by about 11.4%. Appropriate soil conservation measures based on suitable afforestation techniques can prove influential in mitigating the risk of soil erosion in this fragile mountain ecosystem of the Himalayan region.

Keywords

Landuse Change; Watershed Hydrology; Remote Sensing; SWAT Model; Rawal Watershed

Introduction

Pakistan is facing acute problem of forest resource scarcity coupled with the deteriorating natural environment. The meagre forest cover i.e. about 4.8 percent of the total country area is further deteriorating due to heavy demands of rapidly growing urbanization. The surface runoff particularly in the mountainous terrain has been affected by the cutting of trees and addition of paved surfaces under urban development. Tube-wells cater to about 50 percent of the present water demand in Rawalpindi city and almost 40 percent demand in Islamabad are being met by abstraction from the aquifer which is recharged by the flow from the surrounding hills of Margalla and Murree. These factors need to be quantified for their likely downstream impacts. Understanding controls over the water cycle is important in evaluating the potential impact of landuse/landcover change on the water cycle (Keese *et al.* 2005). Landcover plays a key role in controlling the hydrologic response of watersheds in a number of important ways (Schilling *et al.* 2008; Mao and Cherkauer, 2009; Elfert and Bormann, 2010; Ghaffari *et al.* 2010). Changes in landcover can lead to significant changes in leaf area index, evapotranspiration (Mao and Cherkauer, 2009), soil moisture content and infiltration capacity (Costa *et al.* 2003), surface and subsurface flow regimes including baseflow contributions to streams (Tu, 2009) and recharge, surface roughness (Feddema *et al.* 2005), runoff (Ashraf, 2013) as well as soil erosion through complex interactions among vegetation, soils, geology, terrain and climate processes. Furthermore, land use modifications can also affect flood frequency and magnitude (Ward *et al.* 2008; Remo *et al.* 2009; Benito *et al.* 2010; Qiu *et al.* 2010) and regional climate (Kueppers *et al.* 2007; Paeth *et al.* 2010). An analysis of changes occurred in the hydrological regime can provide basis for estimating the impacts of landuse and climate changes on water resources. It can also be used as a tool to recommend changes in the water management regimes. One can formulate water conservation strategies only after understanding the spatial and temporal variation in landuse and the interaction of various hydrologic components. Since the hydrologic processes are very complex, their proper comprehension is essential, for which watershed models are being widely used.

The present work focuses on evaluating surface runoff generation and quantifies the water balance of a Himalayan watershed in Pakistan under variable landuse conditions and future scenarios through hydrological modelling. The SWAT model, developed by United State Department of Agriculture, has been used for hydrological response analysis. The model is being applied worldwide for evaluation of the impact of landuse and landcover changes on the hydrology of catchments (Odira, 2010) besides other applications. The study may help in developing effective adaptation strategies related to changing water management regimes issues in future.

Study Area

Rawal watershed lies within longitudes 73º 03′ - 73º 24′ E and latitudes 33° 41′ - 33° 54′ N covering an area of about 272 sq km in southern Himalayas mountains of Pakistan (Fig. 1). The Rawal dam was constructed on the Korang - the main river flowing in the east of the capital city Islamabad, which supplies on an average 22 million gallons of water per day for households' needs of Rawalpindi and Islamabad area. The elevation in the watershed ranges within 523-2145 meters above mean sea level (masl). The climate is sub-humid to humid sub-tropical where rainfall is highly erratic both in space and time. The mean annual rainfall is about 1220 mm. There are two types of natural forests found in the mountains e.g. scrub forests (xerophytic forests of thorny and small-leaved evergreen species) up to 1000 to 1200 m elevation and coniferous forests, pure and mixed with hardwood species, from 1200 m elevation to the tree limit (Amjad *et al.* 1996).

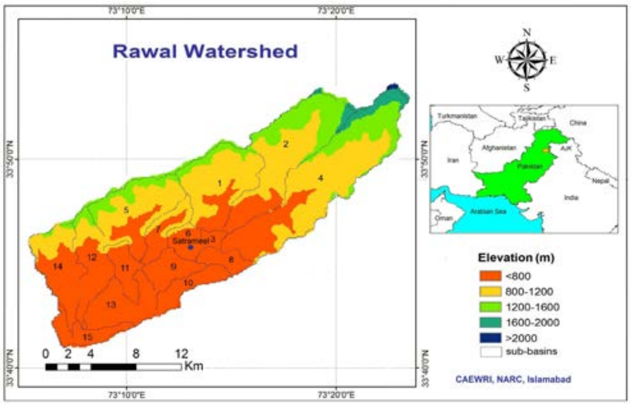

FIG. 1 LOCATION MAP OF THE STUDY AREA

The dominant plant species are *Dodonaea viscose, Carissa spinarum and Olea ferruginea* (Hijazi, 1984). The factors like rapid urban development, ill-legal cutting due to high market value of forest wood and intensive use of forest wood for household needs, ineffective forest management and forest diseases are accelerating deforestation rate in the watershed area (IUCN, 2005; Tanvir *et al.* 2006). The removal of forest cover from steep slopes has lead to accelerated surface erosion besides increase in the surface runoff. The storage of the Rawal dam (capacity of 47,230 acre-ft) has been reduced almost by 34 percent since its development in 1960 due to human induced and natural factors of sedimentation in the catchment (IUCN, 2005). There is no systematic study carried out yet to document the landuse variability and its impact on the hydrology of the watershed area.

Materials and Methods

An integrated hydrological, spatial modeling and field investigations approach was adopted in the present study to achieve the study output. In order to analyse the temporal changes in the watershed landuse, satellite image data of LANDSAT-5 TM (period 1992) and LANDSAT-7 ETM+ (2010 period) (Path-Row: 150-37) with spatial resolution of 30m were used. The images were georectified using Universal Transverse Mercator (UTM) coordinate system (Zone 43 North). The image analysis was performed using visual and digital interpretation techniques to observe landuse variability both spatially and temporally. Visual interpretation was performed for qualitative while digital interpretation for quantitative analysis of the landuse/landcover in the watershed. Supervised method was applied following maximum likelihood rule for quantitative analysis. The spatial modeling functions of ERDAS Imagine 9.2 software were utilized for detection of landuse/landcover changes in the watershed area.

The basic input data used for SWAT 2005 model were digital elevation model (DEM), hydrology, soil and landuse distribution extracted from image data. SWAT is a process-based continuous daily time-step model that offers distributed parameter and continuous time simulation, and flexible watershed configuration (Arnold *et al.* 1994). It is capable of predicting the impact of land management practices on water, sediment yield and agricultural chemical yield (Neitsch *et al.* 2005). The boundaries of the watershed and its sub basins were generated using Aster 30m DEM in the model. The hydro-meteorological data used includes: temperature (max& min) and precipitation data from 1991-2010 of Satrameel observatory lying within the watershed area (see Fig. 1) and discharge data of the Korang River (1991-2010 period). The SCS – Soil conservation services curve number method has been used in this study for surface runoff estimation. The importance of land uses lies mainly in the computation of surface runoff with the help of SCS curve during the model operation (Arnold *et al.* 1994). The subcomponents of the water balance analyzed were water yield, surface runoff, lateral and base flows, soil water recharge and actual evapotranspiration, expressed in terms of average annual depth of water in millimeters over the total watershed area. The main basin was divided into 15 sub basins which were further divided into 73 hydrologic response units (HRUs) composed of homogeneous landuse, soil types, relevant hydrological components and management practices.

Model Calibration

The model was run for calibration period of 1991-2006. The first 6 years of the simulated output were discarded from the calibration process, since they were required by the model as a warm-up period. Validation of the model was performed using monthly river flows data of 2007-2010 period. The accuracies of the model calibration and validation were evaluated by calculating indexes like Nash & Sutcliffe coefficient (*NTD*), Root Mean Square Error (*RMSE*) and correlation coefficient R^2 of the time series. The Nash & Sutcliffe coefficient (Nash and Sutcliffe 1970) is an estimate of the variation of a time series from another as given by the equation 1:

$$NTD = 1 - \frac{\sum_{i=1}^{n}\left(Q_{obs,i} - Q_{sim,i}\right)^2}{\sum_{i=1}^{n}\left(Q_{obs,i} - \bar{Q}_{sim,i}\right)^2} \quad (1)$$

And root mean square error- *RMSE* was computed using the equation 2:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left[Wi\left(Q_{sim,i} - Q_{obs,i}\right)\right]^2} \quad (2)$$

Where, Q_{sim} = simulated time series, Q_{obs} = observed time series, $\bar{Q}_{sim}$ = numerical mean for the simulated time series, W = weight and n = total number of measurements. A Nash & Sutcliffe coefficient approaching unity indicates that the estimated time series is close to the observed one. The *NTD* index value of 0.78 was estimated signifying a quite precise calibration (Table 1).

TABLE 1 EVALUATING THE ACCURACY OF THE MODEL CALIBRATION AND VALIDATION PROCESSES

Index	Calibrated period	Validated period
NTD	0.78	0.90
RMSE (mm)	1.1	1.6
R^2	0.78	0.93

Later the model was validated using the same indexes, for the period of January 2007 to December 2010, which indicated a Nash Sutcliff efficiency value of 0.90 for this process. Time series of simulated and observed monthly discharges indicated a good matching for the calibration period 1/1997-12/2006 and validation period 1/2007-12/2010 (Fig. 2a and Fig. 2b). RMS error was obtained within range of 1-1.6 for calibration and validation processes. The coefficient of correlation R^2 value was calculated about 0.78 for calibrated period while 0.93 for validated period which are reasonable for model prediction. The curve numbers selected for various landuse for model calibration (shown in Table 2) were based on landuse characteristics defined by SCS Engineering Division (1986). The conifer and scrub forest classes were assigned 30 and 32 CN values while agriculture and rangeland as 65 and 49 values. The input value of 0.01 was used for soil evaporation compensation factor – ESCO during model calibration. The factor modifies the depth distribution to meet the soil evaporative demand to account for the effect of capillary action, crusting and cracks.

The baseflow alpha factor - ALPHA_BF which is the number of days for base flow recession to decline through one log cycle was adjusted to 0.5 day during calibration. The baseflow recession constant, α_{gw}, is a direct index of groundwater flow response to changes in recharge (Smedema and Rycroft, 1983).

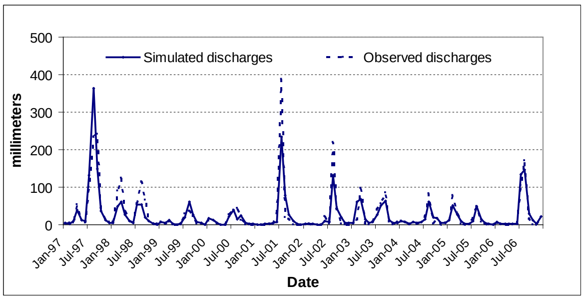

FIG. 2A TIME SERIES OF SIMULATED AND OBSERVED MONTHLY DISCHARGE DATA FOR THE PERIOD 1/1997-12/2006 (MODEL CALIBRATION)

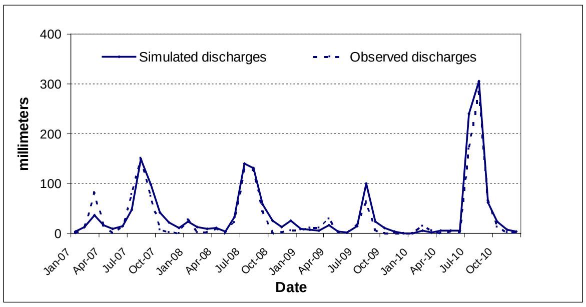

FIG. 2B TIME SERIES OF SIMULATED AND OBSERVED MONTHLY DISCHARGE DATA FOR THE PERIOD 1/2007-12/2010 (MODEL VALIDATION)

TABLE 2 CN VALUES ADJUSTED FOR HYDROLOGICAL MODELING OF RAWAL WATERSHED

S.No.	Landuse/landcover	CN2
1	Conifer forest	30
2	Scrub forest	32
3	Agriculture land	65
4	Rangeland	49
5	Soil/Rocks	58
6	Built-up land	61
7	Water	92

Results and Discussion

Hydrological Response Analysis

The landuse/landcover change had been detected in about 53% of the Rawal watershed area. About 20% of the scrub forest cover had converted into rangeland besides agriculture and built-up land during 1992-2010 period. This is supported by the findings of Arfan (2008) and Shafiq et al. (1997) according to which extensive grazing and wood cutting have deformed the plants into bushes. The built-up land had shown a rapid growth in its coverage i.e. from 2.6% in 1992 to 8.7% in year 2010. The rate of decline in conifer coverage was estimated over 2.1% y^{-1} during the last two decades, which is higher than deforestation rate of about 1.5% annually in the country reported by FAO (2005) due to high urban development in the watershed. A comparison of the landuse/landcover of 1992 and 2010 periods are shown in Fig. 3.

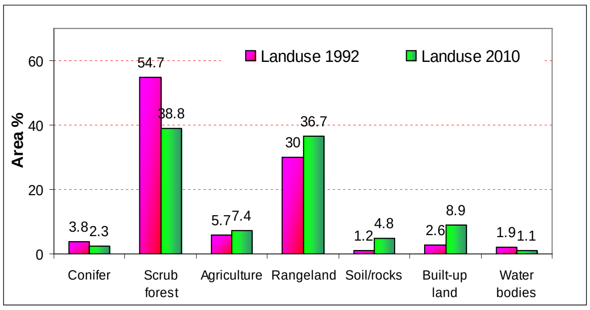

FIG. 3 COMPARISION OF 1992 AND 2010 LANDUSE CONDITIONS IN RAWAL WATERSHED

Major conversion of the agriculture land class was observed from scrub forest followed by rangeland class. The conversion of conifer class to agriculture was very low. The conversion of landuse into built-up land class was high from rangeland class i.e. about 2.6% of the area followed by the scrub forest class which indicated transfer of 2.4% area into the built-up land class. The changes in landuse between 1992 and 2010 period resulted in an increase in the water yield from 356mm to 379mm in the Rawal watershed (Fig. 4). The surface runoff increased by 14.3% while lateral flow had shown a decrease of about 3.7% due to the landuse changes within the last two decades. The water yield had shown an overall 6% increase while sediment yield increased by 17.4% due to combining effect of landuse and hydrological variations in the watershed. The increase in surface runoff was found higher during monsoon months i.e. July, August and September. A similar increase had been observed for the water yield of watershed during these months under 2010 landuse condition. The average soil loss was estimated over 17 tons per hectare annually in the watershed, which is close to the average erosion rate of 19.1 tons ha^{-1} y^{-1} estimated by Nasir *et al.* (2006) for a small sub-catchment lying in the center of the watershed area. The sediment yields between 5 and 10 tons ha^{-1} y^{-1} range and greater than 15 tons ha^{-1} y^{-1} range indicated an increase in the southeastern sub-basins while less than 5 tons ha^{-1} y^{-1} range had shown a decrease here during 1992-2010 period. Similarly, surface runoff exhibited an increase in the southern sub basins while lateral discharge had shown a declining trend due to prevailing urban development (impervious condition) in the watershed area.

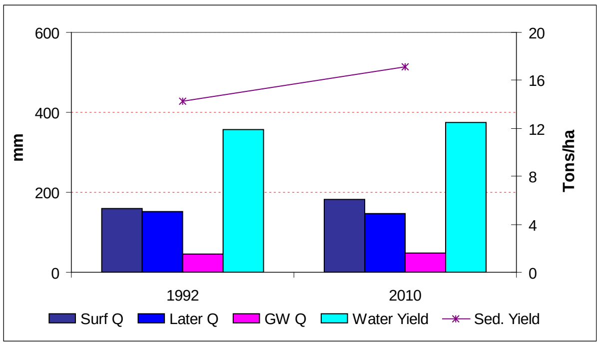

FIG. 4 HYDROLOGICAL COMPONANTS OF RAWAL WATERSHED IN 1992 AND 2010 PERIODS

Landuse Change Scenarios

The response of various hydrological parameters was studied under probable changes in landuse/landcover in the watershed in future. The conversion of various land covers within 1992-2010 period formed the basis for developing these scenarios. The scenarios 2 to 4 are related to different cases of deforestation while scenario 5 pertains to an afforestaion case. These scenarios are based on our field experience that most of the urbanization is occurring on the expense of scrub forest and rangeland while agriculture land is being transformed from rangeland and scrub forest in the lower elevation areas (below 1200m) of the watershed. Also extensive wood cutting is resulting in degradation of the forest cover into range bushes and shrubs. The scenarios 1 to 4 also depict probable conditions of urbanization besides variable deforestation conditions in the watershed area. The percentage coverage of the landuse/landcover under various scenarios is shown graphically in Fig. 5 and in map form in Fig. 6.

In scenario-1, all the agriculture land is assumed to be converted into built-up land (built-up land increases to about 16%) keeping other landuse conditions same as of the base year 2010. The scenario indicates an increase of about 0.3% in the surface runoff and about 0.6% in the sediment yield from that of the base year 2010 (Table 3).

In scenario-2, all the rangeland under scenario-1 is assumed to be converted into agriculture land (about 37% increase in agriculture land) while the scrub forest is converted into rangeland (About 39% increase in rangeland). The situation indicates an increase of about 1.8% in the water yield and about 16% in the sediment yield from the base year. The surface runoff had increased by 3.5% while lateral discharge decreased by 3.3% due to decrease in the scrub forest coverage.

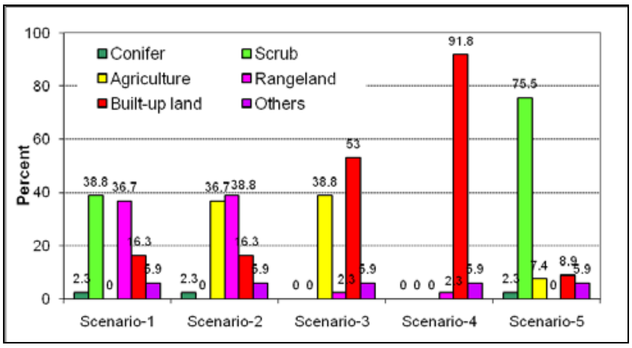

FIG.5 PERCENTAGE COVERAGE OF LANDUSE IN DIFFERENT SCENARIOS

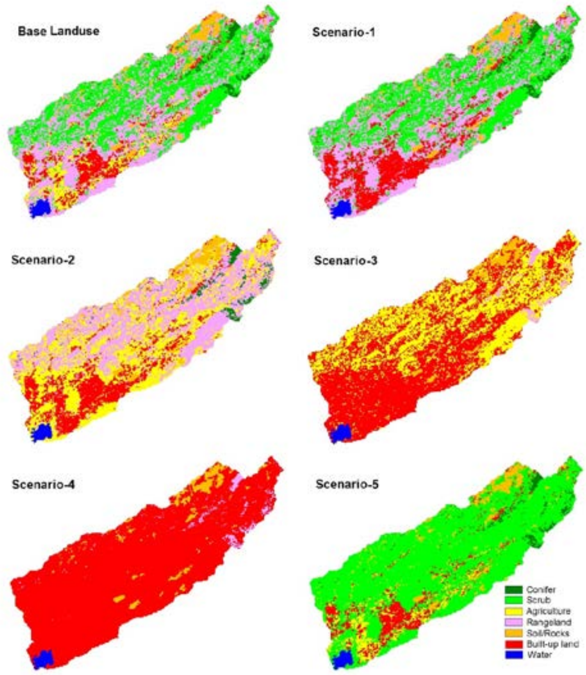

FIG. 6 LANDUSE DISTRIBUTION IN BASE YEAR 2010 AND DIFFERENT SCENARIOS

In scenario-3, all the conifer forest cover (about 2.3%) under scenario-2 is assumed to be converted into rangeland, the rangeland into agriculture land (agriculture land increases to about 39%) and the agriculture land into built-up land (built-up land increases to about 53%). In fact, this scenario exhibits an extreme deforestation case under which forest cover has degraded into bushes and shrubs due to over cutting. The scenario has shown an increase of about 1.3% in the water yield and about 4.3% in the sediment yield from the base year. The surface runoff increases by 5% while lateral discharge decreases by 2.9% due to decrease in the scrub coverage.

The scenario-4 also represents a deforestation case under which all the agriculture land under scenario-3 is converted into built-up land (built-up land increases to about 92%, an extreme situation of urbanization). In contrary to the previous scenario, water yield has shown a decrease of about 0.4% under this scenario. The construction of roads, pavements and other structures reduce the infiltration area that will ultimately affect the recharging of the aquifer of the twin cities of Islamabad and Rawalpindi. There is also a significant increase in the sediment yield from that of base year likely due to high growth of urbanization with absence of any forest coverage.

The last scenario-5 represents an afforestation case under which the rangeland in base landuse of 2010 is assumed to be converted into scrub forest (scrub coverage increases to about 76%). This scenario indicates a decrease in the water yield besides a significant decrease of about 11.4% in the sediment yield. Therefore appropriate soil conservation measures based on suitable afforestation techniques can be highly influential in risk mitigation of soil erosion in this part of the Himalayan region in future.

Conclusions

Rapid degradation of natural vegetation due to human and climatic induced factors has highly influenced the water balance of the watershed resulting in reduction of average annual water yield of the area. The change in landuse during the last two decades resulted in an increase in the water yield and surface runoff while decrease in the lateral flows. Major causative factors of these changes may include deforestation and high growth in urbanization in the watershed area. Integrated approach of remote sensing and hydrological modeling has proved helpful in investigating the environmental changes and their impact on the watershed yield. High resolution remote sensing data coupled with in-situ information can provide base for undertaking accurate assessment and characterization of deforestation and sedimentation risk in the mountain watersheds. It is essential to regulate the urban development properly and undertake an extensive community based reforestation programme in the watershed area.

The study would help evaluate better management options for sustainable development of land and water resources in the Himalayan watersheds in future.

TABLE 3 PERCENTAGE CHANGES PROJECTED FOR VARIOUS HYDROLOGICAL COMPONANTS UNDER DIFFERENT LANDUSE SCENARIOS USING BASE LANDUSE OF 2010

No.	Scenarios	Surf. Runoff %	Lateral Q %	Water Yield %	Sediment Yield %
1	Conversion of all agriculture land into built-up land	0.3	-0.1	0.0	0.6
2	Scenario-1 plus conversion of all scrub forest to rangeland and rangeland to agriculture land	3.5	-3.3	1.8	16.3
3	Conversion of all confer of senario-2 into rangeland, agriculture land increases to about 39% and built-up land to about 53%	5.0	-2.9	1.3	4.3
4	Scenario-3 plus conversion of all agriculture land into built-up land	1.5	-0.8	-0.4	122.5
5	Conversion of all rangeland of base landuse into scrub forest cover	-3.5	2.1	-3.3	-11.4

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doi: 10.14355/ijast.2014.0302.03

Suitability Analysis for Urban Agriculture Using GIS and Multi-Criteria Evaluation

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Received 1 Nov, 2013; Accepted 10 Mar, 2014; Published 10 May, 2014

Abstract

As known by all, urbanization and urban expansion are common global phenomena; in 2011 world urban population accounted for 53% of the total population (United Nations, 2011). Another important feature of this trend is that half the population in the developing countries being considered as urban. Its ultimate result is indicated by the conversion of agricultural land to built environment. As a result, cities are unable to survive on their own fresh vegetables like in the past. City population creates a huge demand for fresh vegetables and leaves in the developing countries' context. Therefore upgrading agricultural activities in the cities and surrounding areas is more prominent. Conventional agriculture cannot be promoted in the urban areas. Therefore urban agriculture methods could be made popular in the urban areas. For this matter, Identification of suitable land for best agricultural practices is needed. In this case, stakeholders' evaluation about spatial variations is vital. Present GIS analytical functions provide better facilities for that whereas integration of multi-criteria evaluation and AHP provide better insights for that. This research develops a methodology to amalgamate stakeholders' perceptions to spatial analysis, integrating MCE and AHP with GIS. Final classification is developed based on the result map of the above application. Further, using a simple regression model, a study on the driving factors affecting the urban agriculture has been done. It provides a better guideline for different urban agriculture suitability in the study area.

Keywords

Suitability Analysis; Urban Agriculture; Multi-criteria Evaluation; Analytic Hierarchy Process

Introduction

In the 21st Century the urban expansions in Asia pushed up the overspill population in the wilderness areas and the rural hinterland. Above urban transition caused high land demand and it exerted pressure on agriculture and wetlands in the immediate surroundings of urban centers. It has the further effect to balance sustainable urban development (Allen, 2003). Land is an essential ingredient in the urban growth. Therefore land utilization necessitates fulfilling sustainable development. As a consequence of high demand, development pressure on agricultural lands and wetlands in immediate surroundings of urban centers has been increased. It has threatened the environment and also resulted in loss of agricultural lands, loss of investment in agricultural infrastructure, destruction of natural landscape and unsustainable exploitation of ground water. Therefore peri-urban agriculture land conversion threatened the loss of urban food production. From the long history of the urban age, farms and forests have been integrated within cities and it was given a hand to promote their sustenance (Thapa and Murayama, 2008). With the rapid increase of population in Asian countries a very high demand has been created for a continuous supply of food; especially fresh and nutrient-rich food.

Currently, development trends are paying less attention to this, because the economies are mainly diverting throughout market mechanism. It is about time that significant attention is paid to overcome this situation. Otherwise, it will create critical pollution and nutritional problems.

Urban Agriculture

In the context of sustainable living, agriculture areas play a major role in the lungs of the urban areas. It provides an evergreen sustainable life for the masses who live in the congested urban areas. But, urbanization results in the replacement of these green agriculture features such as the built matter for residential, commercial, roadways etc. Along with these structural changes, cities influence the negative consequences, such as, loss of fresh vegetables and leafs, nutritional problems etc. Increase of the vegetated surfaces in the urban landscape helps to minimize negative effects of structural changes (Simon, 2008). A healthy natural ecosystem is supported to prevent a lifelong system of the urban community. Hence the present fast urban system requires to be changed with natural ecosystems not only focusing on parks and walkways but also urban agriculture practices. Present city planners concern the urban agriculture and urban forestry combination with the urban environment as green spaces. Foster and Rosenzweig (2007) stated "the first time in modern history there is an understanding by global thinkers and city managers of the important role that agriculture and forestry can play in the creation of modern, dynamic, ecologically, sustainable cities" (Foster and Rosenzweig, 2007). Further he stated that the indigenous socioeconomic and ethnic structures of an urban area are the foundation stones upon which a strategic superstructure of urban agriculture and urban forestry can be created.

Although urban agriculture is a relatively simple solution, in many cities, formal recognition and integration of agriculture into city planning and city growth has hardly changed. In the city planning, urban agriculture can be recorded as one of the best models for sustainable urban growth to take place. At present, developed countries have included this concept in their city plans. But, in the context of Asian countries, an absence of this concept can be seen due to differences in their urban scenario.

The urban agriculture has played an important role in the sustainable exploitation of urban environments and makes a substantial contribution to many cities for self-reliance in food. Foster in 2007 defined that, Urban Agriculture is any and all enterprises, commercial and non-commercial, related to the production, distribution, sale or other consumption of agricultural and horticultural produce or commodities in a metropolitan / major urban center. The amount of land available for urban agriculture is continuing to minimize but the need of food in the cities is becoming more pressing due to the large-scale migration. On the other hand, urban agriculture contributes to local economic development, poverty alleviation and social inclusion of the urban poor. However, land scarcity is one of the major obstacles for the growth of this sector. Hence, finding possible agriculture developments for different parts of the city is important because it will add value to sustain the cities. With limited land, urban agriculture practices cannot be done in the traditional way and different alternative methods need to be identified for different regions of the city, not only fringe congested areas. Hence the city needs to consider different urban agriculture practices. It cannot be done through observation of the field and it should be done through spatial analysis. However, some decision support systems need to be integrated with spatial analysis in order to do that. GIS and multi criteria decision making are better tools for that purpose. GIS provides a tool for integrating and analyzing land resources to assure the suitability of a land use or several land uses (Jankowski and Richard 1994).

GIS and Multi Criteria Decision Making

GIS is a better tool for spatial data analysis. Spatial data analysis is the process of extraction of useful information distributed over the space. Therefore it is seeking out patterns and associations on maps that help to characterize, understand and predict spatial phenomena. It includes "a variety of activities that serves in the descriptions, understanding, and prediction of patterns and associations along the map" (Carter, 1994). Land suitability analysis is one of the important components of spatial data analysis. It can be described as a process to determine suitability factors for some specific uses to determine its suitability level (Hopkins 1977; Steiner 1983). Land suitability is mostly related to different criteria like physical, socioeconomic and environmental. The evaluation result of those multiple criteria assists to take better decisions about the suitable areas and it is named as multi-criteria evaluation.

Multi-criteria Evaluation is primarily concerned with how to combine the information from several criteria for decision making purposes. It is numerical algorithms that define the suitability of a particular solution on the basis of the input criteria and a weight together (Pereira and Duckstein, 1993) with some mathematical or logical means of determining trade-offs when conflicts arise (Heywood et al., 2002). The combination of GIS and MCE process transforms geographical data (input) into a result decision (output) (Carver, 1991; Heywood et.al., 1995; Malczewski, 1996). In the earlier stages GIS techniques played a major role, while in the later stages, MCE techniques became a major importance. In this combination GIS facilitates the analysis of data to obtain information for making decisions (because GIS has limited capacity to examine the value structure), whereas the MCE techniques provide the tools for aggregating the geographical data and the decision maker's preferences into the usefulness of alternative decisions. Over the last 10 years or so, researchers attempted to find solutions for land-use suitability problems using GIS-based multi-criteria evaluation procedures. (e.g. Sui, 1992; Banai, 1993; Jankowski and Richard,1994; Malczewski, 1999;2004; Mohamed et al., 2000; Pereira and Duckstein, 1993; Joerin et al., 2001). Within this MCE process, determination of criterion weights have become an important task and Analytic Hierarchy Process is one of the best methodologies to be used.

Analytic Hierarchy Process (AHP)

The AHP is a powerful and flexible decision making process to help people set priorities and make the best decision when both qualitative and quantitative aspects of decisions need to be considered. AHP was developed in the 1970's by Thomas Saaty as the most highly regarded and widely used decision-making theory. The most prominent character of this theory is using the pair-wise comparison matrix to value judgements. The criteria pair-wise comparison matrix takes the pair-wise comparisons as an input and produces the relative weights as output and the AHP provides a mathematical method for translating this matrix into a vector of relative weights for the criteria (Malczewski, 1994; 1996; 2004, Eastman et al., 1995). It is the procedure by which criteria are combined to arrive at a particular evaluation and by which evaluations are compared and acted upon (Eastman et al., 1995). The following table shows the pairwise comparison scales in the AHP defined by Saaty.

TABLE 1 THE AHP SCALES FOR PAIRED COMPARISONS

Intensity of Importance	Definition
1	Equal importance
2	Equal to Moderate importance
3	Moderate importance
4	Moderate to strong importance.
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very to Extremely strong importance
9	Extreme importance

Source: Adapted by Saaty

In the recent years many researchers used multi-criteria evaluation in various disciplines. In 2003, Sharifi, et.al, (demarcation boundary in the city and National Park), 2001, Merwe et. al., (public decision making for buffer zone demarcation), 1999, Kralidis, (find the best location for housing), Kangas, et. al ((2002) (Multi-functional forestry), ui(1994); Weerakoon, (2002) (Urban land evaluation), Sadek (1999) (root alignments developments), Bannai, (1995) (flood vulnerability analysis)

Study Problem

Colombo urban area plays a major role in the urbanization in Sri Lanka. During the last two decades, following characteristics have become prominent in the Colombo urban areas, such as,

- Most of the agricultural land uses are converted to built-up uses.
- Most of the paddy lands are under-utilized due to surrounding land activities.

Therefore, loss of agriculture lands in the urban area is more prominent. As a result of that Colombo and surrounding suburban areas have to depend on other cities in the country to meet their food requirements like vegetables, fruits and meats. To overcome the above issues it is proposed to discourage fragmentation of the agricultural lands and filling low lying lands but not a proper solution for avoiding loss of agriculture lands. Although there are several agricultural lands, those cannot be used for agricultural purposes. The other land areas which are suitable for urban agriculture are still vacant or underutilized. Urban agriculture can be promoted as a major land use/function and commercial activity for these lands. Several studies have been concerned about the urban agriculture in Sri Lanka but never paid attention on how to combine that with urban land uses. As a developing country with less technology, attention needs to be paid to improve technology with ways to maximize the use of our limited resources. Identification of suitable land for suitable urban agriculture practices is a significant task and this research intends to provide a basic guideline for that.

Objectives of the study

The main objective of this study is to develop a methodology for identification of land for different urban agriculture activities in the Colombo Urban Area. To achieve this main objective following specific objectives were outlined.

- To identify possible agriculture practices suitable for Colombo urban area.
- To combine these different practices in a GIS platform and evaluate it based on stakeholder analysis integrated with MCE and AHP methods.
- To identify different agriculture suitability and their relationship with different factors in the case study area.

Methodology

Identify Suitable Agriculture Practices

Stakeholder analysis highlighted that following factors affect the underutilization of agricultural lands.

- Cultivation cost is high
- Land blocks are Small for mass agriculture like paddy
- Less harvest
- Difficulties of find labors
- High demand for urban and suburban lands
- Insect infection
- Affection of government policies and rules
- Busyness
- Natural disasters

Due to the above reasons stakeholder analysis suggests that above reasons are involved in decreasing the traditional agriculture practices in the case study area and they suggest that some of the urban agriculture practices are possible for that area. According to that a preference table was created and the following practices received priority.

Agriculture products	%
Vegetable & leafs	23.31
Fruits	19.55
Flora & Fauna	9.02
Livestock	12.03
Aquarium	7.52
Compost production	10.53
Dairy farms	18.05
Total	100.00

Apart from the above, agriculture stakeholders suggest the following urban agriculture practices for these areas, such as organic farming practices, home business gardens and low cost agriculture practices for highly congested areas. The next important task is to find areas for these different agriculture practices. Researchers have developed some methodologies using GIS and MCE. AHP method is used to give priority weights.

Data

Data was collected from several primary and secondary sources. Two types of primary sources were used for that. At first thematic maps were used as primary data and obtained 1:2000 scale digital maps prepared by the survey department of Sri Lanka. A second category of data includes agriculture experts' and farmers' opinions obtained from unstructured interviews. It was used for decision making stage of the research; AHP weights were calculated based on this outcome.

Methodological process of identifying the suitable land areas for urban agriculture is based on four steps. First, the factors affecting the agricultural uses were set up as criterion maps. Secondly all of the factors were scored in the suitability range based on expert opinion. Third, the weights of all factors were determined using the Analytic Hierarchy Process through experts' and farmer's opinions. Finally GIS operations are used to generate the final urban agricultural suitability map. After that a spatial sample is developed in the area.

Criterion Maps

Different criterion maps were developed based on primary and secondary sources such as Land use, slope, water table depth, flood retention areas, land value, environmental sensitive areas, and population density and housing density. All criterion maps were converted to 10 X 10 raster maps and composite weights were assigned to these grid cells. Each criterion map consists of main criteria and sub criteria. Using pair-wise comparison matrix, priority weights were given and composite weights were calculated based on these weights assigned to main criteria and sub criteria. Final map is an outcome of the overlaying of this composite weight map.

Raster map is shown like a matrix and weights were assigned to each grid cell. Each grid cell is assigned a composite weight. The cartographic modeling procedure, which is a process of overlaying multiple data layers in GIS where Bj is the j-th grid cell in the result data layer and "x" represents the operator when performing cartographic modeling.

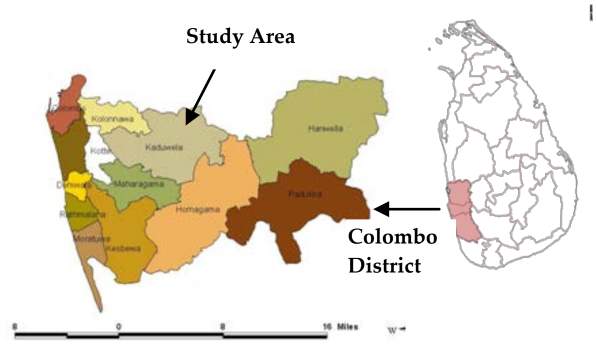
The following algebraic multiplication operator is used in this paper:

$$Bj = \sum_{i=1}^{n} Wi * rijk$$

After that, using simple multiple regression, significant driving factors were identified.

Case Study Area

Kaduwela Municipal Council Area (KMCA) is one of the MC areas located in the Colombo District, Sri Lanka. (see figure 1) It is situated 11 miles away from the city of Colombo. The area of the KMC is 87.69 sq.km. It is located within the Wet Zone, which experiences a rainy, humid and hot climate. The topography of it is a gradual slope from high elevation in the south to low elevation in the north. The Kelani River flows from East to West along the Northern boundary of the KMC Area. There are highly valued resources, which can be added in terms of density of ecosystems along with their flora and fauna in the KMC. During the two decades from 1981 –2001 average annual growth rate is 2.6 %. Thus an increasing trend of population growth could be seen in the KMC for the last two decades and it is still continuing.



Source: Urban Development Authority, Sri Lanka

FIGURE 1 LOCATION OF STUDY AREA

When taken into consideration the land use of the study area, 28% of the area was found to be non built-up area. Most of the area is underutilized. Other areas are suitable for some kind of agriculture practices.

Results and Discussion

Using AHP rankings composite weights were given to criterion maps. After analyzing the composite weights of six criterion maps final map were developed. It is shown in Figure 2. Final map is classified under 4 categories and those are named as Type1, Type 11, Type 111 and Type 1V. Each type of these categories was identified for different agriculture practices. These four types were identified based on the stakeholder analysis.

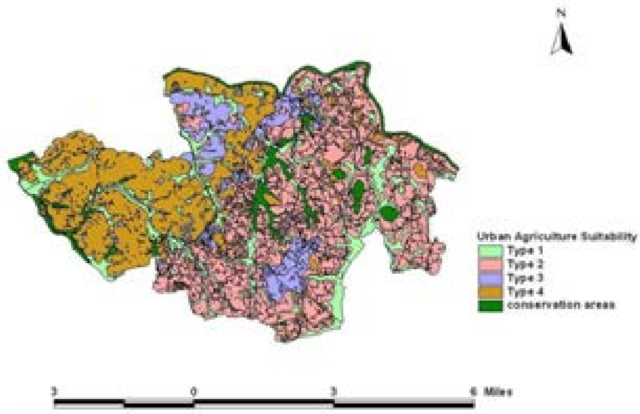


FIGURE 2 FINAL SUITABILITY MAP

Percentages of different types of agriculture practices are indicated in table 2.

TABLE 2 RESULT MAP CLASSIFICATION

Land classification type	% of the land
Type 1	13%
Type 11	41%
Type 111	15%
Type 1V	25%
Protected areas	6%

Different land classifications indicated different uses of urban agriculture and it can be classified as follows.

Type 1 - Areas Suitable for Leafy Vegetables

These areas consist most of the paddy fields and marshes and presently most paddy fields are not used for paddy or any type of agriculture. Most of these areas are water logging areas. Some of the areas close to the city are already identified as green recreation areas. Other suitable areas far from the city can pay attention to growing leafy vegetables. At present there is high demand for leafy vegetables from urban dwellers and it has become difficult to meet the existing demand. Therefore uplifting these areas is important.

Type 11 – Areas Suitable for Organic Farming Practices

These areas are not low lands. They consist of agriculture like coconut and other agriculture. To avoid fragmentation of that land for profitable purposes more profitable way of organic farming practices can be introduced. The organic agriculture is one of the best solutions for minimizing the negative consequences of agriculture. These products have a strong demand due to high consumer preference. Hence it will result in the uplift of income of the people who are engaging in agriculture. Thus, these more suitable areas can be used for that and can be proposed some subsidies for farmers for uplift that.

Type 111 - Areas Suitable for Home Business Gardens

These areas suitable for introduce home business gardens (HGB). The concept allows urban people to work on environmental and/or commercial agriculture with a viable mix of resource utilization and sustainable management at the homestead level. The main theme of the concept of the HBG is to stress the need in converting simple form of home gardening or kitchen gardening into the entrepreneurship development venture on the long-term basis.

Type 1V – Cultivation Towers

These areas are suitable to develop some agriculture using vertical space. Family nutrition gives high priority so as to address issues of imbalance in food intake by advocating cultivating some important nutritious crops (earth-beds or pots) for urban communities. For instance, use of vertical space of the homestead by adopting low cost methods such as "cultivation tower", cultivations in empty containers, plastic bottles and tires are also can be advocated for that.

Conservation Areas

These areas not suitable for urban agriculture practices and they should be protected as conservation areas for maintaining green spaces in the city.

Relationship Among Agricultural Types and Driving Factors

Further a spatial sample has been developed and the most influential driving factors for different agriculture practices have been evaluated using a regression model. In this case, land use is concerned as a dependent variable. Other factors such as slope, water table depth, flood retention areas, land value, environmental sensitive areas, population density and housing density concerned as independent variables. Regression model can be developed as follows

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X_6+\beta_7X_7$$

$$Y=12.056 -0.005X_1+(- 0.231X_2)+2.34X_3+1.245X_4 (-0.243X_5) +2.056X_6+1.321X_7$$

Where,

X_1= Slope
X_2= Water table depth
X_3= food retention areas
X_4= Land value
X_5= Environmentally sensitive areas
X_6= population density
X_7 = Housing Density

According to the regression model, population density, housing density, flood retention areas and land value has most significant driving factors with different land use types and slope, environmentally sensitive areas and water table depth has not significant driving factors. It indicates that urban agriculture practices mainly depend on the land uses in the urban environment and natural factors are not significant with urban agriculture practices.

Conclusions

This research aimed to develop a suitable methodology to identify suitable land for different urban agricultural practices in a scientific manner. GIS and a multi-criteria integrated methodology have been used for finding out different agriculture practices. In the context of application, the analysis indicates that 4 different urban agriculture practices like Type 1, Type11, Type 111 and Type 1V/ Final analysis map, illustrates 13% of the area consist of type 1 category. Presently these areas are under-utilized water logged areas and it need to focus on development with active participation of farmers in the particular area without harming green environment. This is the imperative point to extract from this study to consider agriculture experts to fulfill the present demand. Also urban planners have to pay attention this area to preparation of their development plans. They can reflect on these areas as green areas for survive urban environment. Type 11 areas indicated large area and development potential areas with high population growth. Hence this area is most suitable for organic farming. The multi-criteria analysis method successfully used for demarcation of each types of urban agriculture practices.

When the analysis used in other urban areas it can be formed in different forms depend on its local features by limiting the user's requirements, differentiations the rules used in the criteria and weighted parameters. Urban agriculture connected with different driving factors small regression analysis used for that and it shows significant driving factors affect to that. In this way, the analysis can be a useful tool in an active approach to urban pattern control.

In general GIS based analysis offer a powerful tool for suitability analysis due its capability to process and analyze different layers of spatial data. Also statistical analysis used for identify different influential factors affect to that.

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doi: 10.14355/ijast.2014.0302.04

Developing an Organic Farming System in Maluku

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Received 18 Nov, 2013; Accepted 10 Feb, 2014; Published 10 May, 2014

Abstract

Organic farming is a system used to increase long-term soil fertility in Maluku. The aim of our experiment was to develop continuous agricultural production to improve the sustainability of food supply in Maluku. The experiment was important in attempting to provide long-term benefits to the environment, making use of local bio resources, namely sago waste and city organic waste as compost, in order to improve and cultivate local plants and nutritious food. The experiment conducted in Waisamu and Passo, consisted of two treatments, i.e. making compost from sago waste and city organic waste, and then applied to local corn. Each treatment consists of two factors and three replications, using Randomized Complete Block Design; the first of which is types of compost, i.e. from sago waste and city organic waste; while the second factor is compost dosage, onsisting of five levels, i.e. 0 ton per hectare, 7, 5 ton per hectare, 10 ton per hectare, 12, 5 ton per hectare, 15 ton per hectare. The variables observed for compost quality are C/N ratio, mineral content N, P, K, Ca, Mg, Fe. Height and leaf area of plant, weigh, diameter and amount of stem on an ear were observed for growth and production of plant. The results proved that the higher dosage the 15 ton per hectare of the compost is, the higher of growth and production of the corn, 250 g compost from organic city waste is which improves the higher growth and production of pakchoy (*Brassica chinensis*). Composts from sago waste and city organic waste contain macro and micro nutrient that increases the nutrient content of soil, improving plant growth and corn production.

Keywords

Compost; Sago Waste; City Organic Waste

Introduction

Organic farming system is a method of farming system to provide the consumer with fresh, tasty and authentic food while respecting natural life-cycle systems and to increase long-term soil fertility.To achieve this, organic farming relies on a number of objectives and principles, as well as common practices designed to minimize the human impact on the environment, while ensuring the agricultural system operates as naturally as possible.

Maluku is islands province, consisting of small islands and 90% sea area. Small islands according to the 'land area' category is a relative concept, specially, the size is less than 10.000 km^2 (BPSMaluku, 2008). Depending on many small islands, greater amount of fertilizer and pesticides are needed to produce the same yields of crop, which is challenging. On the other hand, fertilizer and pesticides inorganic are expensive to poor farmer, and artificial chemicals destroy soil micro-organisms resulting in poor soil structure and aeration as well as decreasing nutrient availability, Pests and diseases become more difficult to control as they become resistant to artificial pesticides. Maluku has a greater amount of bio resources such as sago palm and many crops for example nutmeg, clove, *Aegle Marrmelos*, betel, soursop, etc that used to make pesticides. It has been estimated that about two tones of sago starch, extracted from sago palms are produced per day at villages in Maluku and about 4 to 5 tons of sago waste are produced. Most of the factories are built near river sides as sago waste is likely to be discarded into rivers, a practice which may cause water pollution. On the other hand, it ihas been estimated that about 2 tones of city organic waste are produced a day. Sago waste and city organic waste can be used for composting on soil and water conservation, and management practices that restore, maintain and enhance ratio low under 20%.

Organic fertilizers are better for plants and healthier for human than chemical fertilizer, due to no harmful chemicals, and they boost the growth of beneficial soil organisms and promote healthier root development., provide better balanced nutrition in forms more readily available to plants and add organic material, keeping soil friable, helping it hold moisture, oxygen and nutrients. Fertilizers made from plants generally have low to moderate N-P-K (nitrogen, phosphorus, potassium) values, but their nutrients quickly become available in the soil for plants to use. Some of them even provide an extra dose of trace minerals and micro nutrients. Residual effects of manure or compost application can maintain crop yield level for several years after manure or compost application ceases since only a fraction of the N and other nutrients in manure or compost become plant available in the first year after application (Motavalli *et al*., 1989; Eghball *et al*., 2002). Residual effects of N- or P-based manure or compost application increased corn production for one year and influenced soil properties for several years (Bahman Eghball, Ginting, and John E. Gilley, 2004).

The aim of our experiment was to develop continuous agricultural production to improve the sustainability of food supply in Maluku. The benefit of our experiment were to renewable soil and water conservation, management practices that restore, maintain and enhance ecological balance and allow people to consume nutritious food.

Experimental

Materials

Materials that used in the research were sago waste, grass, kitchen scraps, leaves, dolomite lime, molasses, effective microorganism-4, cow manure. Local seed corn, i.e. pulut corn and delima corn were collected from Kisar, one villages in Maluku South West. The research was conducted in Waisamu, West of Seram regency and Passo, centre of Maluku regency since May until October 2012.

Composting Methods

Sago waste chopped with machine and put it on the

Floor. Begin the pile with 2″ layer of sago waste and add a 1″ layer of cow manure, dolomite lime (500 g) and pour with an effective microorganism 4 which mixed with molasses as bioactivator. Repeat the layers until the pile is about 4 high. Add just enough water to moisten the pile, then cover it with a black plastic. Turn the pile every the fourth day until the compost is finished. Using the same methods to composting city organic waste (leaves, fresh grass clipping, kitchen scraps, etc). The compost should be finished in about four weeks. Finished compost is dark brown, crumbly, and has an earthy odor.

Field Preparation and Planting

The field was tilled twice at a depth of 25 cm. Once each plot received the assigned amount of compost, the field was tilled to incorporate the compost into the top 15 cm of the soil. Seed local corn was planted in 5 cm deep. Plant distance of seed corn was 70 x 50 cm. *Brassica chinensis* seed was planted in polybag

Plot Layout and Experimental Design

Each corn seed was planted in a 336 m² plot (15 x 21 m²). Each plot was divided into 3 blocks, each was 20 m² (5 x 4 m). The research using a randomized block design with one factor. There are two treatments: The compost of sago waste applied on corn plant in Waisamu consisting of five levels: 0 t ha^{-1}; 7,5 t ha^{-1}; 10 t ha^{-1}; 12,5 t ha^{-1}; 15 t ha^{-1}. The compost of city organic waste applied on *Brassica chinens*is at integrated waste city installation in Passo. Pakchoy were planted in polybag. There are five levels compost per polybag, i.e. 0g; 150g, 200g, 250g and 300g. Each of the two treatments replicated three times. This meant that each of the two treatments consisted of 15 plots. Each of two treatment consisted of 525 seeds corn (141 corn crop/ plot and 141 polybag to planting pakchoy).

Data collection and analyses

Soil

Samples of soil were taken from each plot before planting for analysis of macro and micro nutrient, pH, cation change capacity at Soil Research Centre.

Compost

Samples of all types of compost were analyzed before application in order to quantify the amounts of macro and micro nutrient, cation cxhange capacity, moisture content, pH..

Sampling

Samples were taken from the plants at growth stages and at harvest. Five corn plants per plot were randomly selected for sampling, while each pakchoy per polybag.

Maintenance

Local corn and pakchoy were sprayed with organic pesticides for insect/pest and disease control. Crop watered two times a day.

Variables

Variables of corn that measured at optimum growth stages were plant height, leaf number, leaf area. The plant height, leaf number of the pakchoy was measured every week. At harvest, the corn ears and were collected and weighed. Variables of corn that measure after harvest were length, diameter and weight of corn ears, dry weight shelled grain. Leaf area was measured using formula by Pearce *et al* (1988)

LD (cm^2) = (p x ℓ x K)

LD = leaf area (cm2)

p = length of leaf sample (cm)

ℓ = width of leaf sample(cm)

K = correction factor

$$K = \frac{\frac{C}{B} \times A}{p \times l}$$

A = paper area to draw leaf sample (cm^2)

B = paper weight (g)

C = weight of each replica (g)

P = leaf length

ℓ = leaf width

Statistical analyses

The analysis of variance (ANOVA) procedure of the SAS system software, Version 9.2, (SAS Institute Inc., Cory, NJ, USA) was used to evaluate effect of treatments. Means values of the plant height, leaf number, leaf area, ear length, ear diameter, ear weighy, weight of dry shelled grain with different levels of compost were compared using Duncan, s test.

Results and Discussion

Variable of Compost

The compost variables from sago waste and city organic waste are reported in Table 1.

Compost from city organic waste had a lower N, P, K, C-organic, Cu , Mg content compared to that from sago waste, but other content were higher in compost from city organic waste. This meant that nutrient content of compost depending on compost material. Dependency on value soil chemistry criteria of Soil Research Centre Bogor (1983) *cit* Sarwono (2007), C-organic, N-total, P_2O_5, K_2O and pH of research area soil in Passo were 2,57%, (low), 0,25% (low), 19 mg/kg (moderate), 0,14 cmol(+)/kg (moderate), 5,7 (acid), respectively (Tatipata and Jacob, 2012 a), while C-organic, N-total, P_2O_5,, K_2O of soil in Waisamu were 1,63% (low), 0,15% (low), 19 mg/kg (moderate), 0,42 cmol(+)/kg (moderate), respectively (Tatipata and Jacob, 2012b). Compost from sago waste and city organic waste that applied on soil can adds nutrients and organic matter, so these provide nutrients for growth corn and pakchoy.

TABLE 1 THE VARIABLE OF THE COMPOST FROM SAGO WASTE AND CITY ORGANIC WASTE

Variable	Sago waste compost	Organic city waste compost
N -total (%)	1,14	1,08
P (%)	1,11	0,50
K (%)	4,32	0,29
Ca (%)	0,85	6,54
Mg (%)	2,58	0,65
Co (ppm)	95,46	-
Zn (%)	0,03	140 ppm
S (%)	1,97	-
Fe (%)	1,06	5596 ppm
Mn (%)	0,08	324 ppm
Na (%)	0,06	-
C/N	14	12
C-organic (%)	15.58	14,50
N- organic (%)	-	1,08
N-NH_4 (%)	-	0,14
N-NO_3 (%)	-	0,04
Water content (%)	27.52	45,46
Cation Exchange capacity	30.41	32,23

Source: Tatipata and Jacob, 2012

Note: - is not analyzed

Plant Growth

The effects of compost on growth performance of the plants as measured by the plant height, leaf number, leaf area of the corn and the pakchoy are reported in Table 2, Tabel 3 and Table 4, respectively. The analysis of plant height, leaf number, leaf area both of sticky white corn and leaf number and leaf area of pomegranate corn were significant at the 5% level. 15 t ha^{-1} sago waste compost provide higher corn growth, while 250 compost from city organic waste provide higher of pakchoy growth.

TABLE 2 THE EFFECT OF COMPOST DOSAGE ON HEIGHT PLANT, LEAF NUMBER, LEAF AREA ON PULUT COR

Compost dosage(t ha^{-1})	Pulut Corn		
	Plant Height (cm)	Leaf Number	Leaf Area (cm^2)
0	58.96 a	6.25 a	263.36 a
7,5	100.08 ab	7.17 a	344.28ab
10	104.33 b	7.33 a	372.80 ab
12,5	110.25 b	7.42 a	419.33 ab
15	123.18 b	9.08 b	524.80 b

1,ab,b,b means number followed by the same letter within the same column did not different significantly at 5% of DMRT

TABLE 3 THE EFFECT OF COMPOST DOSAGE ON HEIGHT PLANT, LEAF NUMBER, LEAF AREA ON DELIMA CORN

Compost dosage (t ha^{-1})	Delima Corn		
	Plant Height (cm)	Leaf Number	Leaf Area (cm^2)
0	130,00 a	8,83 a	285,87 a
7,5	133,08 a	9,92 ab	356,93ab
10	153,33 a	10,17 ab	377,17 ab
12,5	154,50 a	10,33 ab	427,63 ab
15	158,25 a	10,92 b	529,13 b

1,ab,b,b means number followed by the same letter within the same column did not different significantly at 5% of DMRT

TABLE 4 THE EFFECT PF CITY ORGANIC COMPOST ON HEIGHT PLANT, LEAF NUMBER, LEAF AREA ON PAKCHOY

Compost dosage (g polybag^{-1})	Plant Height (cm)	Leaf Number	Leaf Area (cm^2)
0	17.50 d	4.00 e	273.8 e
100	28.17 c	5.00 d	503.7 d
150	31.00 b	5.33 c	670.2 c
200	32.17 b	6.00 b	789.4 b
250	40.00 a	7.00 a	995.3 a

1,ab,b,b means number followed by the same letter within the same column did not different significantly at 5% of DMRT

Nutrients in organic matter must be released by soil microorganisms through a decaying process called mineralization. This biological process is affected by variations in moisture, temperature, and the microbial species and populations present in the soil. Therefore, organic materials are far less predictable in nutrient content, nutrient release, and nutrient-use efficiency than commercial grade fertilizers. Organic materials can serve as effective and environmentally sound fertilizer materials only if their nutrient contents are known and their mineralization rates are estimated closely. The soil is a living system. as well as the particles that make up the soil, it contains millions of different creatures. These creatures are very important for recycling nutrients. C-organic of compost from sago waste and city organic waste were 15,58% and 14,50% can increase C-organic soils that generally low (Kartini, 2000). Higher C-organik of soil can improves the structure of soil. This allows more air into the soil, improves drainage and reduces erosion.and improve soil's ability to hold water (Lingga and Marsono, 2006). Feeding the soil with manure or compost feeds the whole variety of life in the soil which then turns this material into food for plant growth. Organic amendments are often applied to soils to increase crop productivity, crop quality (Bresson et al. 2001; Edmeades 2003; Risse et al. 2001).Composted manure increased corn crop growth rate (CGR) leaf -N concentration, leaf area index (LAI), and, in one of two years, net assimilation rate (NAR). Composting swine hoop manure before field application appears to be an effective alternative to fresh-manure application for corn production (Terrance et al., 2004) Application of manure or composted manure can increased soil concentrations of nutrients and organic matter (Chang et al., 1991; Eghball, 2002). Soil organic matter can improving root plant uptake of water and nutrients, and can dissolve minerals within the soil, leaving them available for plant roots. It also helps make a good environment for all the soil microbes and organisms that work with and enhance a plant's health and growth. N-mineralization from organic matter depend on C/N ratio. The lower C/N ratio, the higher nutrients and mineral dissolved. C/N ratio of compost from sago waste and city organic waste were 14 and 12, respectively. It was optimum C/N ratio. Plant height, leaf number and leaf area of the two corn and pakchoy that applied with 15 t ha^{-1} of sago waste compost and 250 g per polybag of city organic waste were resulted in high content of nutrition. More or less nutrients available for plant through root absorption reflected the increase in cation exchange capacity (CEC). CEC suggests high amount of available minerals in the compost. Available minerals are very essential for plant growth and development. The higher the CEC, the higher the negative charge and the more cations that can be held. The. CEC of sago waste and city organic waste were 30,41 and 32,23, respectively. Organic matter can improve the structure of all types of soils, from loose structure to crumbs structure and increase soil aeration. Residual effects of compost application can maintain crop yield level for several years after manure or compost application ceases since only a fraction of the N and other nutrients in compost become plant available in the first year after application (Motavalli et al., 1989; Eghball et al., 2002). Power (1999) found that 40% of beef cattle feedlot manure N and 20% of compost N were plant available in the first year after application, indicating that about 60% of manure N and 80% of compost -N became plant available in the succeeding years, assuming little or no loss of N due to NO_3–N leaching or denitrification. Residual effects of organic materials on soil properties can contribute to improvement in soil quality for several years after application ceases (Ginting et al., 2003). According to Sunarto and Suwardi (2010), The higher of corn plant was improved after add 1.5 t ha^{-1} and 1,0 t ha^{-1} of chicken manure. On the other hand, add 6,06 ml water^{-1} liquid compost can increase the highest of pakchoy (Barus, 2011). Increased N, P, K, pH, and C levels in the soil can increase crop yield.

Plant Production

The effect of compost on corn ears per plot, length and diameter of ear, and dry grain shelled weight of the corn plant are reported in Table 5 and Table 6, while the effect of compost on pakchoy fresh weight is reported in Table 7.

TABLE 5 EFFECT OF SAGO WASTE COMPOST ON LENGTH, DIAMETER, WEIGHT OF EAR AND WEIGHT OF DRY SHELLED GRAIN ON PULUT CORN

Compost dosage (t ha^{-1})	Pulut Corn			
	Ear Length (cm)	Ear Diameter (cm)	Ear Weight (g)	Weight of Dry Shelled Grain (g)
0	13,49 a	2,74 a	44,23 a	40,28 a
7,5	15,36 ab	3,09 a	53,15 a	41,72 a
10	15,58 ab	3,28 a	58,87 a	46,17 a
12,5	16,87 b	3,50 a	61,83 a	47,76 a
15	17,28 b	4,14 a	62,14 a	52,63 a

1,ab,b,b means number followed by the same letter within the same column did not different significantly at 5% of DMRT

TABLE 6 EFFECT OF SAGO WASTE COMPOST ON LENGTH, DIAMETER, WEIGHT OF EAR AND WEIGHT OF DRY SHELLED GRAIN OF THE PULUT CORN

Compost dosage (t ha^{-1})	Delima Corn			
	Ear Length (cm)	Ear Diameter (cm)	Ear Weight (g)	Weight of Dry Shelled Grain (g)
0	14,94 a	2,99 a	44,23 a	41,67 a
7,5	16,61 ab	3,42 a	53,15 a	42,42 a
10	16,86 ab	3,55 a	58,87 a	47,19 a
12,5	17,82 b	3,75 a	61,83 a	48,68 a
15	18,18 b	4,90 a	62,14 a	53,56 a

1,ab,b,b means number followed by the same letter within the same column did not different significantly at 5% of DMRT

TABLE 7 EFFECT OF CITY ORGANIC COMPOST ON FRESH WEIGH OF THE PAKCHOY

Compost dosage(g $polybag^{-1}$)	Fresh Weight (g)
0	18.87 e
100	67.78 d
150	81.11 c
200	90.00 b
250	100.00 a

1,ab,b,b means number followed by the same letter within the same column did not different significantly at 5% of DMRT

The analysis of ear length of pulut corn and delima corn and the fresh weight were significant at the 5% level. The other variables were not significant. However, increasing the compost dosage (15 t ha^{-1} for corn plant and 250 g for pakchoy), increase both growth and production of the two plants. *Brassica sinensis* that applied with compost was higher than that not applied with compost (Pratomo dan Rohin, 2011). Green manures are manure from plants with high nitrogen content and the nitrogen of green manure adds nitrogen in soil. Nitrogen in soil organic matter becomes available to plants through mineralization. Conditions that favor high yields also favor the activity of soil microorganisms that are responsible for mineralization. Therefore, estimated for N released from organic matter are related to expected yields. Vermicompost tea can positively influence plant yield and quality of pakchoy and increase soil biological activity in multiple soil types (Pant et al., 2011).

Compost amendment increased corn whole-plant P and K uptake 19 and 21%, averaged across 2 years. No-tillage increased whole-plant P uptake 1 year compared to MP and CT (113 vs. 65 kg ha^{-1}) and increased grain P concentration (3.1 vs. 1.5 g kg^{-1}) (Singer et al, 2007). 0.5 NPK + 0.5 MSW1 gave the best plant growth, health and yield for potato and corn

Nitrogen (N) is important for growth and development of plant, and of the macronutrients, is often the one that is most limiting. Soil nitrate (NO_3^-) and ammonium (NH_4^+) are both forms of inorganic nitrogen that are readily available for use by plants. They are formed from the mineralization (by microorganisms) of organic forms of N such as soil organic matter, crop residue, and manures. The content of plant available nitrogen is important to assure that the crop has enough for adequate growth. Nitrogen is a major part of chlorophyll and the green color of plants. It is responsible for lush, vigorous growth and the development of a dense, attractive lawn. (Burke, 2011). Chlorophyll is a pigment which function in photosynthesis. Increasing of nitrogen in soil, increased photosynthesis, so plant produced many assimilate. The assimilate can improve plant growth and production. Nitrogen is building block amino acid, amide and nucleoproteins which function in divide, enlargement and differentiation of cell, so improve plant growth. Plant growth is a increase size, volume, weight and cell number (Salisbury and Ross, 1995).

Phosphorus is a component of the complex nucleic acid structure of plants, which regulates protein synthesis. Phosphorus is, therefore, important in cell division and development of new tissue. Phosphorus is also associated with complex energy transformations in the plant.(USDA NIFA, 2013). Barber at Purdue University indicates phosphorus uptake is largely a function of size and nature of the root system, rate of water absorption, amount of phosphorus in the soil, and ability of the soil to supply phosphorus to the soil solution.

Potassium (K) is an essential plant nutrient, because it is required in large amounts by plants. Potassium is a vital component of numerous plant functions, including nutrient absorption, respiration, transpiration, and enzyme activity (USDA, 2013).

Other nutrients such as magnesium (Mg), calcium (Ca) contributed to growth and production of corn and pakchoy. Mg is a component of chlorophyll, while Ca can straighten up cell permeability.

Conclusions

Organic farming system can develop in Maluku through using local bio resources such as sago waste and city organic waste to compost. The compost can applied on local plant such as sticky white corn (pulut corn) and pomegranate corn (delima corn) as well as pakchoy to increase growth and production. Organic farming entails an emphasis on biodiversity of the agricultural system and the surrounding environment, reduction of external and off-farm inputs and elimination of synthetic pesticides and fertilizers and other materials, renewable resources, soil and water conservation, and management practices that restore, maintain and enhance ecological balance, human consume healthy food.

ACKNOWLEDGEMENTS

The research was funded by Direktorat Penelitian dan Pengabdian Kepada Masyarakat (DP2M) DIKTI Jakarta, Indonesia.

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doi: 10.14355/ijast.2014.0302.05

Optimization of the Process of Osmo-Vacuum Drying of Pear Slices

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Received 19 Nov, 2013; Revised 20 Dec, 2013; Accepted 1 Mar, 2014; Published 10 May, 2014

Abstract

Response surface methodology was used for optimizing vacuum dried pear slices by osmotic pretreatment. The effect of drying temperature (70-50 ° C), pressure vacuum (30-10 kPa) and drying time (300-180 min) as independent variables were evaluated on the moisture content, the percentage of shrinkage and *rehydration ratio* pear slices as dependent variables (responses). The optimum conditions for minimum moisture content and shrinkage and *maximum rehydration ratio* include: Temperature 56 ° C, vacuum pressure of 10 kPa and the drying time of 250 minutes. The optimum conditions obtained moisture content, shrinkage and and the percentage of rehydration ratio were found to be 23%, 67% and 1.45, respectively.

Keywords

Osmotic; Rehydration Ratio; Vacuum Pressure; Shrinkage; Drying

Introduction

Payrvs and pear fruit of the genus belongs to the family of rosacea. Are planted in temperate regions. Its origin goes back to the Asian region. Pearing is a good source of Dietary Fiber, Vitamin C, Copper and vitamin K. Processing means further including pear compote, yogurts and fruit and juice in the sauce and drying. Dried pears can be in different forms such as bakery products, consumers face different Bgvshthay nuts used. Diabetics is to eat dried pears, the elderly and children is (Park et al; 2003). According to FAO (2008), Iran produced 115,812 tons of the fruit is pear growers in twentieth place (FAO, 2011). Osmotic dehydration of fruits and vegetables by immersing them in liquid water activity lower than the food is done. Osmotic dehydration pretreatment can be used as food, water content of 30 to 70% of its initial reduced. Among the advantages of osmotic dehydration secondary drying stage can shorten the time to 60% savings in energy consumption as much as 20% (Martinez, 2006). An alternative to conventional methods of drying, vacuum drying atmosphere. This procedure is carried out at low pressure and moisture content of the product. There is a vacuum of air and water vapor expands in food, the food made in the structural floor and bloated, heat and mass transfer surface to volume ratio is higher. As a result, the use of vacuum drying, drying speed can be higher or lower ambient temperature drying process is achieved with less oxygen (Lee and kim, 2009). Oxidation reactions are minimized due to the lack of air and color, flavor and texture of dried products is maintained to some extent (Madamba and Liboon, 2001). Response surface methodology is a useful technique to assess the number of input variables or characteristics of performance measures that affect product quality or processing. In this study, response surface method for optimization of drying conditions Osmosis -Pear vacuum was used.

Material and method

Sample Preparation and Osmotic Dehydration

Pears required in this study were obtained from a local market cover. Out of IMC used Glabyhay 3/1 ± 85%, respectively. Glabyhay used in the experiments using the skin of a woman's hand cutting and die cuts with a thickness of 9 mm and a diameter of 35 mm cut-participants design. In order to prevent enzymatic browning reaction prepared sections for 5 min in a solution of 1% ascorbic acid and 2/0% citric acid were placed. Osmotic sucrose solutions were prepared at a concentration of 50%. Pear slices in a 1- liter glass beaker immersed in the osmotic solution and osmotic dehydration was carried out for 114 minutes. During osmotic dehydration temperature using a magnetic stirrer at 55 ° C and a stirring speed of 300 rpm was maintained. After looking over the water samples were removed from the osmotic solution. Osmotic solution in order to remove surface residue and washed with distilled water, dried by filter paper and then weighed.

Vacuum Drying

Pear samples were pretreated by osmotic drying using a vacuum dryer at the Department of Agriculture, Shahrood University was built. Prior to testing, the device was turned on for an hour to reach a stable temperature. After reaching the desired temperature devices as osmotically pre-treated pear slices on a tray and placed within a layer were tested. Vacuum drying at temperatures of 50, 60 and 70 ° C, vacuum pressures of 10, 20 and 30 kPa and at 180, 240 and 300 min were performed. Pear slices during the drying out of the machine, they were weighed.

Humidity Measurement

AOAC 931.04 method and moisture content dried samples were measured using Equation 1 (Noshad et al; 2011).

$$X_i = \frac{M_i - M_d}{M_d} \quad (1)$$

At this time M_i, i sample weight and the dry weight is M_d.

Measuring the Percentage Shrink

For measuring shrinkage, changes in sample size were calculated using the fluid displacement method (Equation 2). In this study, to reduce the liquid all titles and author details must be in single-column format and must be left-justified. Absorbed by the sample of water was used instead of toluene (Noshad et al; 2011).

$$Sh = \frac{V_0 - V}{V_0} \quad (2)$$

In this regard V_0 and V, respectively, were the original volume of the sample.

Measurement of Rehydration Ratio

For the measurement of rehydration, samples were then removed from the dryer and weighed (W_d) were immersed in water at 50 degrees Celsius. After 30 min, the samples were removed and the surface dried with filter paper and weighed again (W_r). Rehydration ratio (RR) was calculated using Equation 3 (Noshad et al; 2011).

$$RR = \frac{W_r}{W_d} \quad (3)$$

Design of Experiments

Response surface methodology for predicting the influence of process variables on the moisture experimental design with a quadratic center was filled with three levels for each variable (chauhan and srivastava, 2009). Response surface methodology using Design Expert content, the percentage of shrinkage and rehydrated pear slices were used. The central composite experimental design with a quadratic center was filled with three levels for each variable (chauhan and srivastava, 2009). Response surface methodology using Design Expert software version 6.0.2 was used in the experimental data.

Conclusion

Analysis of variance to assess the effects of process variables on each response was significant. With multiple regression analysis, the quadratic polynomial models for the prediction of the response obtained. Fitting the data obtained for moisture content, percentage of shrinkage and water re quadratic polynomial model was based. As a result of moisture in the ANOVA tables (Table 1), the second intake (Table 2) and percent shrink (Table 3) is observed, all regression models are statistically significant at the 99% confidence level. The lack of response surface fitted to all models in the 95 per cent level was meaningless. Statistically, all process variables were found to be linear for all the replies In addition, the second vacuum pressure and relative humidity in this impounding and quadratic terms were significant drying time on moisture. The optimal conditions for drying osmosis - as vacuum drying at 56°C, vacuum pressure of 10 kPa and the drying time was 250 minutes. Dried pears obtained in optimal conditions to produce a product with 23% moisture content, shrinkage of 67%, and the ratio of water intake 45/1. The results show that the optimized drying osmosis - Pear vacuum in the temperature range 70-50°C, vacuum pressure of 30-10 kPa, and 300 to 180 minutes drying time of response surface methodology was an efficient way.

TABLE 1 ANALYSIS OF VARIANCE (ANOVA) MODELS ARE THE COEFFICIENTS OF MOISTURE

Source	Coefficient	Degrees of freedom	Sum of squares	The probability P
Model	0.47	5	0.32	<0.0001 **
A vacuum	0.11	1	0.12	<0.0001 **
B tempreture	-0.072	1	0.052	0.0007 *
C time	-0.092	1	0.084	<0.001 **
A^2	-0.14	1	0.064	0.0003 **
C^2	0.80	1	0.020	0.0160 *
Error		5	9.48×10^{-3}	
Weakness		9	0.029	0.293 ns
Fitting				

* Significant at 99% level, * significant at 95%, ns insignificant at 95%

TABLE 2 ANALYSIS OF VARIANCE (ANOVA) MODELS ARE THE COEFFICIENTS OF THE REHYDRATION RATIO

Source	Coefficient	Degrees of freedom	Sum of squares	The probability P
Model	1.33	4	0.25	<0.0001 **
A vacuum	-0.092	1	0.085	<0.0001 **
B tempreture	0.088	1	0.077	<0.0001 **
C time	0.089	1	0.078	<0.0001 **
A^2	0.050	1	0.013	0.0159 *
Error		5	2.99×10^{-3}	
Weakness		10	0.023	0.077 ns
Fitting				

* Significant at 99% level, * significant at 95%, ns insignificant at 95%

TABLE 3 ANALYSIS OF VARIANCE (ANOVA) AND THE COEFFICIENTS OF THE MODELS ARE SHRINKAGE

Source	Coefficient	Degrees of freedom	Sum of squares	The probability P
Model	0.67	3	0.070	<0/0001**
A vacuum	-0.023	1	5.54 ×10-3	0/0392*
B tempreture	0.058	1	0.034	<0/0001**
C time	0.055	1	0.031	<0/0001**
Error		5	6.27 ×10-3	
Weakness		11	0.011	0/649ns
Fitting				

* Significant at 99% level, * significant at 95%, ns insignificant at 95%

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