Tropentag 2012, Göttingen, Germany
September 19-21, 2012

Conference on International Research on Food Security, Natural Resource Management and Rural Development organised by:
Georg-August Universität Göttingen and University of Kassel-Witzenhausen

Integrated Economic, Environmental and Multi-criteria Risk Analysis to Compare the Performance of Pest Management Systems in Tomato Production in Chiang Mai Province, Thailand

Benjamin Blum[a], Pepijn Schreinemachers[a], Christian Grovermann[a], Thomas Berger[a], Jirawan Kitchaicharoen[b]

[a]University of Hohenheim, Institute of Agricultural Economics and Social Sciences in the Tropics and Subtropics, Germany
[b]Chiang Mai University, Department of Agricultural Economics, Faculty of Agriculture, Thailand

Introduction

Pest management practiced in commercial small-scale agriculture has widely been criticized due to the associated negative effects of heavy and unsafe use of pesticides (Mwanthi and Kimani, 1990; Okello, 2005; Thrupp et al., 1995). Also in northern Thailand highland farmers, who had previously been involved in subsistence rice production, have become increasingly dependent on synthetic pesticides as they adopted cash crop production (Schreinemachers et al., 2011). In the region these issues have received increasing attention and alternatives to conventional production systems have evolved. Still, there is a lack of quantitative studies comparing these new approaches to conventional practices. In the context of sustainable development of mountainous areas, it is important to assess the performance of different pest management systems in an integrated manner. Therefore this study presents a comparative profitability analysis together with an environmental impact assessment, which is further complemented by a multi-criteria analysis (MCA) of specific risks linked to tomato production.

Farmers, like most other people, place greater weight on potential negative outcomes of risk and they are generally willing to sacrifice potential income to avoid either risk or uncertainty (Ahsan, 2009; Ghadim and Pannell, 2003). The issue of risk is especially relevant for northern Thailand, since there is much uncertainty about yields and prices due to the fact that farmers have only recently adopted fresh market vegetable production systems. It is thus important to explicitly consider the effects of this uncertainty, while taking into account individual farmer's ranking of different risk categories.

The research questions for this study are: How do different tomato production systems compare in terms of profits? How do different pest management schemes in tomato production compare in terms of environmental impact? How do different tomato production systems compare in terms of four ranked risk criteria? By answering these questions we aim at identifying best practices in contrast to conventional tomato production.

Materials and Methods

Data for this study were collected using a structured questionnaire survey, which was carried out at four sites in Chiang Mai province from December 2011 to March 2012. Data was acquired from 71 farms in Chiang Mai province and covered the 2008/2009, 2009/2010 and 2010/2011 tomato cropping seasons. The sample was stratified in four small-scale tomato producer groups according to different types of pest management strategies.

In calculating profits, the fixed costs plus variable costs equal total production costs. The variable costs comprise all inputs such as costs of labor, fertilizer, pesticide, seedling and seed, transport costs, electricity, etc. Opportunity costs for family labor and opportunity costs for land are also considered. Total costs are subtracted from total revenues to calculate the profit (per tomato production system, *i)*. Total revenue is the sum of sales of the harvested crop.

$$(Profit)_i = (Total\ revenue)_i - (Total\ cost)_i$$

where;

$$(Total\ cost)_i = (Variable\ cost)_i + (Fixed\ cost)_i$$

Further we analyze the environmental sustainability of pest control in each tomato production system in terms of the potential environmental impact of the applied pesticides using the Environmental Impact Quotient (EIQ) method (Kovach et al., 1992; Levitan et al., 1995). The method is a holistic approach to quantify the hazard potential of a pesticide. The so-called average EIQ field use rating for tomatoes is determined as:

$$(Av. EIQfield\ use\ rating)_i = \sum_{p=1}^{m} \sum_{n=1}^{3} \frac{(A_p \times p\_active_p \times EIQ_{p,n})}{3}$$

in which A_p is the application rate (kg/ton) of a pesticide (p) for a total of m pesticides, *p_active* is the proportion of active ingredients, and EIQ is the EIQ base value of the active ingredients, with the subscript n describing the total impact of a given pesticide on farm workers, consumers and the local ecology.

Besides economic performance and environmental impact, we assess different aspects of risk. For this purpose we use a MCA framework in order to take account of farmer risk perceptions. Normally, the primary purpose of multi-criteria analyses is the search for a compromise solution, satisfying to the decision maker, rather than the optimum (Guitouni, 1998). In our study, tomato producers were asked to rank the pre-identified risks. The results of the individual rankings were then brought to bear in the MCA. For the analysis of the risk perceptions, a ranking of risks was performed in line with the Carnegie Mellon Risk-Ranking Method (Florig et al., 2001). The selected criteria and alternative production systems are displayed in the evaluation matrix (Table 1).

Table 1: Multi-criteria evaluation matrix

Production system	C1: Financial risk	C2: Market risk	C3: Production risk	C4: Health risk
P1: Hydroponics	Debt/asset ratio (%) *Ranking	Price variability (%) * Ranking	Yield variability (%) * Income distribution * Ranking	Toxicity (%) * Handling (%) * Ranking
P2: Under roof				
P3: Open field (alt.)				
P4: Open field (conv.)				

The presented criteria for the financial risk, market risk, production risk and health risk are the product of the calculated values for the standard risk indicators and the producers' individual perceived importance of the respective risk.

The assessment of risks follows the rationale of the release assessment (Covello, 1993). This type of assessment involves quantifying the extent to which a risk source releases or otherwise introduces risk agents into the human environment. To analyze the financial risk, the debt-to-asset ratio is calculated. It measures the level of debt held by outside sources through dividing total liabilities by total assets. The financial risk for each tomato producer is calculated as follows:

$$(Debt\ to\ asset\ ratio)_i = \frac{(Total\ liabilities)_i}{(Total\ assets)_i}$$

where;

$$(Total\ assets)_i = (Total\ current\ farm\ assets)_i + (Total\ fixed\ farm\ assets)_i$$

For the MCA the weighted financial risk per tomato production system is:

$$(Weighted\ financial\ risk)_i \ = \bar{x} \times \tilde{y}$$

where x is the debt-to-asset ratio and y represents the weight that ranks financial risk in comparison with the other risk attributes.

For the assessment of market risk the approach of the Economic Research Service (ERS) of the United States Department of Agriculture (USDA) (Harwood et al., 1999) is used, which involves analyzing output price variability. To determine the variability of the tomato prices throughout the previous three tomato production seasons, we calculated the absolute value of the coefficient of variation (CV) of the arithmetic mean of the tomato prices. For the MCA the weighted market risk decision criterion per tomato production system is:

$$(Weighted\ market\ risk)_i = \left(\frac{\sigma_w \times 100}{\bar{w}}\right) \times \tilde{u}$$

where w is the per kilogram price of tomatoes and u represents the weight that ranks the market risk in comparison with the other risk attributes. We use yield variability for estimating production risk by calculating the Relative Standard Deviation. Additionally, the proportion of the income generated from tomato production is considered. For the MCA the weighted production risk per tomato production system is:

$$(Weighted\ production\ risk)_i = \left(\frac{\sigma_s \times 100}{\bar{s}}\right) \times \left(\frac{k_t \times 100}{k_{total}}\right) \times \tilde{z}$$

where s is the yield per hectare per month and k is the proportion of income; z represents the ranking of the single risk attribute in comparison with the other risk attributes. The evaluation of the health risk is based on the toxicity of the applied substances and on the frequencies of behavior avoiding pesticide exposure (e.g., use of protective devices) as well as of exposure mitigating strategies (e.g. hand-washing and following the pesticide handling and application). For the MCA the weighted health risk per tomato production system is:

$$(Weighted\ health\ risk)_i = \left(\frac{\sigma_r \times 100}{\bar{r}}\right) \times \tilde{g}$$

where r is the amount of applied pesticides, which are classified as ‘highly hazardous’ and ‘moderately hazardous’ by WHO, and g represents the percentage of tomato producers that always use protective gear while handling pesticides, which we consider a suitable weight for this particular risk criteria.

Results and Discussion

Table 2 summarizes the general technical characteristics of the different types of tomato production systems. The hydroponic tomato production system presents the most refined mechanical crop protection with fine mesh to inhibit insect pests to reach the tomato crop. In the under roof RPF production system the plastic roof protects the tomato crop against direct rainfall.

Table 2: Technical characteristics of four alternative tomato production systems in Chiang Mai province, Thailand, 2011

Production system	Substrates	Irrigation	Fertilizers	Enclosures
Hydroponics	Coconut fiber	Drippers	Synthetic formula	Closed nethouse with fine mesh walls
Under roof	Soil	Sprinklers	Synthetic, biologic and cow manure	Transparent plastic roof
Open field (alt.)	Soil	Sprinklers	Synthetic, biologic and chicken manure	None
Open field (conv.)	Soil	Water hose	Synthetic and manure mix	None

The conventional open field tomato production system produced the lowest positive median value for profits constituting 9,886 baht per hectare per month (Fig.1). The alternative open field and the under roof tomato production systems resulted in comparably high median values of 42,297 and 38,188 baht per hectare per month respectively. These two systems present relatively low inputs coupled with stable markets and extension services provided by Thailand’s Royal Project Foundation. The hydroponic tomato production system produced negative profits of -29,369 baht per hectare per month. In this tomato production system the high fixed and fertilizer inputs compromise the profitability.

In terms of the active ingredients (AI) of applied pesticides we calculated the highest average field use rating (EIQ) for conventional open field tomato producers, constituting 14.7/ha/month (Fig.2). For all other tomato producer groups the values are significantly lower. The alternative open field tomato production system presents a median value of 4.2/ha/month; the under roof tomato production system presents a median of 4.4 /ha/month and the hydroponic production system has the least impact with 4.0/ha/month. These results indicate that the influence of the extension services, in place in the three systems, contribute to a significantly lower average field use rating than that of the conventional tomato production system. For reference, van der Velden et al. (2004) report an average AI use of 0.298 kg/per ton in tomato production in Spain. In the hydroponic production system, which has the lowest average field use rating, the average amount of AI is 0.287 kg/ton of output.

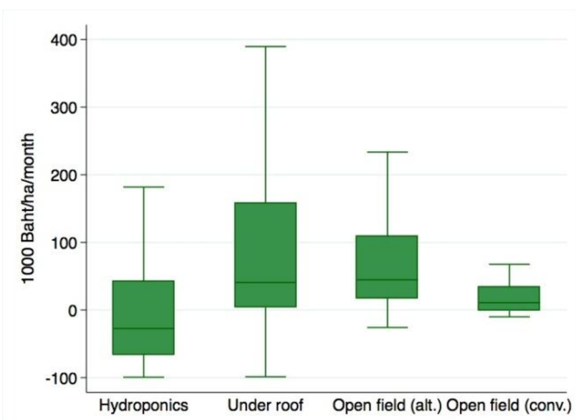

Fig. 1: Median for profit per hectare per month in tomato production in Chiang Mai province, Thailand 2008-2011

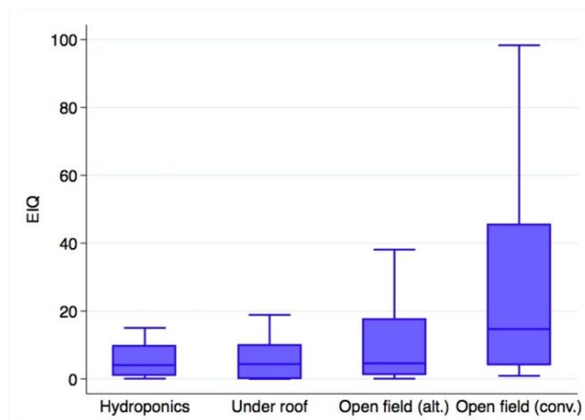

Fig. 2: Average field use ratings (EIQ) per ha per month in tomato production in Chiang Mai province, Thailand 2008-2011

Fig. 3 shows the outcomes of the MCA graphically. The MCA outcome values in the graph are relative, as a standardized index is calculated for the range of tomato production systems, before creating the graph. The employment of this so-called dimension index facilitates the (relative) comparison of the tomato production systems. However, this also means that the lowest value of 0 for any of the decision criteria only indicates that the respective tomato production system presents the lowest values for this criterion among the tomato production systems analyzed. Thus a low value on the dimension index in the graph does not necessarily imply zero or even low risk. There might very well be a high actual risk associated with this production system. The lines in red connect the values calculated for the dimension index for each criterion.

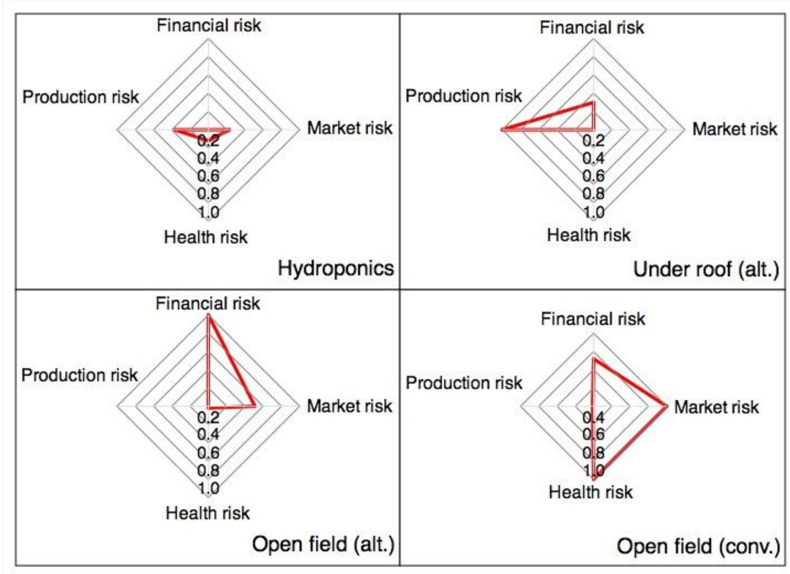

Fig. 3: Graphical comparison of the results of the MCA on tomato producers in Chiang Mai province, Thailand 2008-2011

The figure shows that the conventional open field tomato production system scores high on most criteria except for production risk whereas the hydroponic system scores relatively low on all criteria. The hydroponic and under roof systems present the highest specialization on tomato crops, which is important for the calculation of the production risk. The hydroponic producers rank the production risk significantly lower than the producers of all other groups.

Conclusion

The research results show three alternatives to conventional tomato production with similarly reduced environmental impact. The under roof tomato production system is the most efficient system in combining economically feasible pest management with reduced environmental impact and other associated risks. The system can be further improved by controlling for relatively high yield variability. The hydroponic production system presents the lowest values for risks and environmental impact. However the negative values for the profit indicate a system that cannot be economically sustained. Improved monitoring and on farm assessment need to clarify whether production inputs can be efficiently reduced in the hydroponic tomato production system.

References

Ahsan, D.A., 2009. Farmers' motivations, risk perceptions and risk management strategies in a developing economy: Bangladesh experience. Journal of Risk Research 14, 325-349.

Covello, V.T., Miley W. Merkhofer, 1993. Risk Assessment Methods: Approaches for Assessing Health and Environmental Risks. Springer.

Florig, H.K., M. Granger Morgan, Kara M. Morgan, Karen E. Jenni, Baruch Fischhoff, Paul S. Fischbeck, DeKay, M.L., 2001. A Deliberative Method for Ranking Risks (I): Overview and Test Bed Development. Risk Analysis 21.

Ghadim, A.A., Pannell, D.J., 2003. Risk attitudes and risk perceptions of crop producers in Western Australia, in: Babcock, B.A., Fraser, R.W. andLekakis, J.N. (Ed.), Risk management and the environment: Agriculture in perspective. Kluwer Press, Dordrecht, pp. 114-133.

Guitouni, A.a.M., J-M, 1998. Tentative Guidelines to Help Choosing an Appropriate MCDA Method. European Journal of Operational Research 109, 501-521.

Harwood, J., Richard Heifner, Keith Coble, Janet Perry, Somwaru, A., 1999. Managing Risk in Farming: Concepts, Research, and Analysis, Agricultural Economics Report No. (AER774) p. 136.

Kovach, J., Petzoldt, C., Degni, J., Tette, J., 1992. A Method to Measure the Environmental Impact of Pesticides, New York's Food and Life Science Bulletin. New York Agricultural Experiment Station. Cornell University, Ithaca, NY.

Levitan, L., Merwin, I., Kovach, J., 1995. Assessing the relative environmental impacts of agricultural pesticides: the quest for a holistic method. Agriculture, Ecosystems & Environment 55, 153-168.

Mwanthi, M.A.a., Kimani, V.N., 1990. Agrochemicals: A potential health hazard among Kenya's small-scale farmers, in: G. Forget, T.G., and A. d. Villiers (Ed.), Impact of Pesticides on Health in Developing Countries. IDRC, Ottawa.

Okello, J.J., 2005. Compliance With International Food Safety Standards: The Case Of Green Bean Production In Kenyan Family Farms. Michigan State University.

Schreinemachers, P., Sringarm, S., Sirijinda, A., 2011. The role of synthetic pesticides in the intensification of highland agriculture in Thailand. Crop Protection 30, 1430-1437.

Thrupp, L.A., G. Bergeron, a., Waters., W.F., 1995. Bittersweet Harvest For Global Supermarkets: Challenges In Latin America's Export Boom. NRI.

van der Velden, N.J.A., Janse, J., Kaarsemaker,, R.C., M., R.H.M., 2004. Duurzaamheid van vruchtgroenten in Spanje. Proeve van monitoring. Landbouw Economisch Instituut (LEI), Den Haag.