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

Sustainability Assessment by Fuzzy Evaluation: Case study in Urban Vegetable Cultivation Systems in Red River Delta, Vietnam

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1. Introduction

There are a number of challenges facing humanity such as: increasing demographics, increasing pollution, decline of readily available fossil fuels, decline of freshwater supply, challenges of climate change, soil erosion, biodiversity loss, and social inequality. This situation requires finding out the necessary activities in order to organize the agro-food systems for sustainable development. Sustainability is a prominent concept at the present time. In developing countries, the right attention and attitude to address the future challenge in agricultural production is essential to contribute to sustainable development. To increase productivity in agriculture and horticulture, often higher intensification and increasing amount of fertilizers and pesticides were used by the farmers in order to increase the yield. However, chemical fertilizer, pesticides have direct and indirect negative health effects for the actors directly or indirectly involved in the food supply chain. The living standard of the Vietnamese people has increased significantly, and the demand for fresh vegetables has increased in line with the standard of living. Nevertheless, most of the vegetable farmers in Vietnam often become trapped in a cycle of ever-higher chemical usage (Laodong, 2007). Therefore, research in order to assess the sustainability of vegetable cultivation systems are of highly importance.

There are 73 sustainability assessment methods, tool and procedures listed in the BEQUEST project including some rating system (cited by Poveda and Lipsett, 2011). Approaches commonly known by researchers in monitoring sustainability include environmental or extended cost-benefit analysis, multi criteria decision making and sustainability indicator analysis (Muller, 1997). The concept of Fuzzy logic was conceived by Lotfi Zadeh (1965) and presented not as a control methodology, but as a way of processing data by allowing partial set membership rather than crisp set membership or non-membership. Fuzzy logic is a scientific tool that permits to simulate the dynamics of a system without a detailed mathematical description. Fuzzy logic is a departure from classical two-valued sets and logic, that uses "soft" linguistic system variables and a continuous range of truth values in the interval [0, 1], rather than strict binary (True or False) decisions and assignments (Kaehler 1998). Andriantiatsaholiniaina and Phillis (2000) proposed the sustainability assessment by fuzzy evaluation method as a methodology to measure sustainability development using the example of seven selected economies: Australia, China, Greece, Japan, Madagascar, Switzerland, and the United States of America. The major advantage of fuzzy logic is it can be used

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both as compensatory and non-compensatory in a single model at different context, by using inferences through rules extracted from the experts.

This study is empirical research; the aim of this research is to investigate the characteristics of the urban vegetable cultivation systems in Red River Delta, Vietnam, and to evaluate the sustainability of those systems by using fuzzy evaluation method based on three aspects of sustainable agriculture such as environment, economic, and social.

2. Research methods

Case study: The case studies were conducted in three selected communes in urban areas of Ha Dong district in Hanoi in Red River Delta, Vietnam. The farms in those communes are small-scale vegetable and/or mixed vegetable-rice farms, using high inputs of soil amendments and pesticides for diversified cropping systems. The mean annual rainfall in this region, near to Hanoi, is 1733 mm, with more than 50% occurring in the period July to September. The mean temperature varies between 16.7-29.9°C, with the warmest period during June to August and the coldest during December and February. The relative humidity is between 74-82.5% (HSO, 2010). The soils are classified as Alluvial soil (Hoc, 2001).

Data analysis: To achieve the objective of the study, fuzzy evaluation method were used to assess the suitability based on ecological (ECOLsus), economic (ECONsus), ecological, and social sustainability (SOCsus) (Figure 1).

Twelve indicators were used such as financial return (FR), index of yield trend (IYT), efficiency of market channel (EMC), use of chemical fertilizer (UCF), use of organic fertilizer (UOF), cultivation of legume crop (CLC), use of chemical control (UCC), human health (HH), input self sufficiency (ISS), employment (EPL), access to credit (AC), and access to agricultural extension (AAE).

Instead of using the raw data for each indicator directly, the data were normalized to obtain a common scale and allow statistical aggregation (adopted from Allard et al., 2004). With this approach, the raw values were converted to common membership grades (from 0 to 1.0).

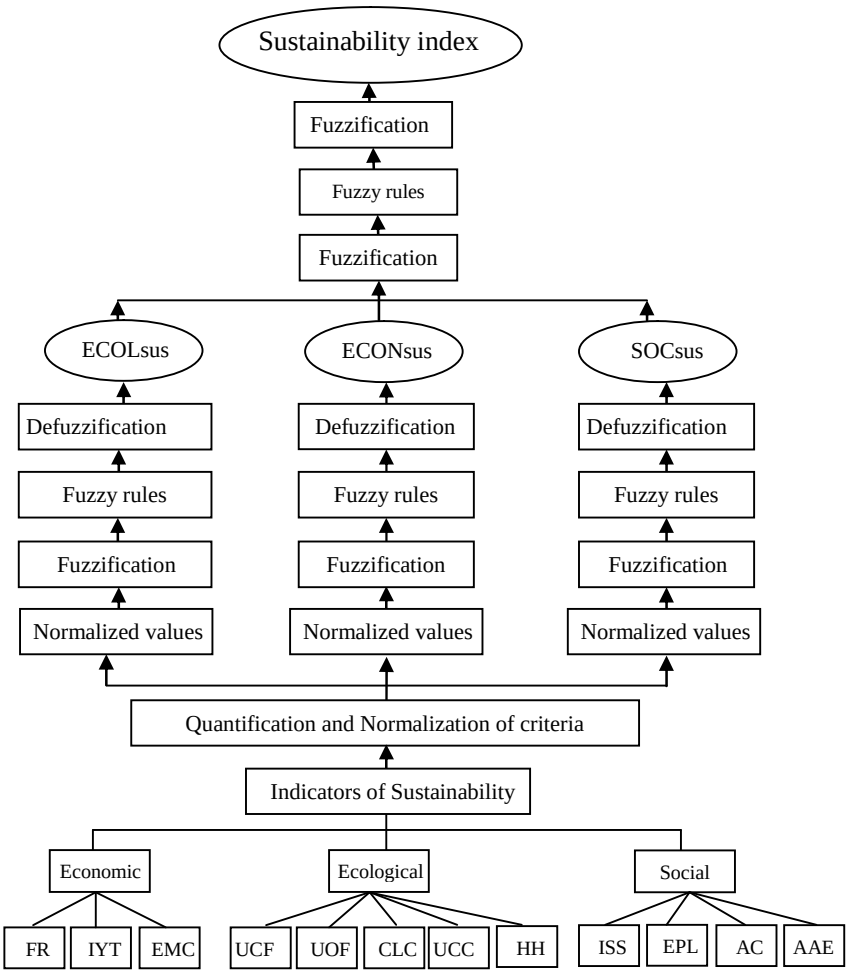

Figure1: The framework for the sustainability assessment

The fuzification method:

• For primary variables: ECOLsus, ECONsus and SOCsus, and Osus were assigned with Gaussian curve built-in membership function "gaussmf". Gaussian membership functions are most adequate in representing uncertainty in measurement (Kreinovich *et al.* 2011) and it has been found that Gaussian

function is performing better than the trapezoidal function, as it demonstrates a smoother transition in its intervals, and the achieved results were closer to the actual effort (Reddy and Raju 2009). A trapezoidal membership function adopted from Mathworks 2009a.

• For secondary variables: FR, IYT, EMC, ISS, EPL, AC, AAE, UCF, UOF, CLC, UCC, and HH were assigned with Trapezoidal-shaped built-in membership function "trapmf". Trapezoidal membership function were chosen because they seemed to be more appropriate for representing membership degree of the linguistic values which have a certain range of the normalized crisp values. Besides, they are also commonly used in practical applications (Berkan and Trubatch 1997, Pedrycz 1994). A trapezoidal membership function adopted from Mathworks 2009.

Aggregation process: The implication process evaluates individual rule over fuzzified grades and generates an output grade and output class. Now the Aggregation does two things. First it truncates the Consequent Fuzzy Set according to the grade obtained and secondly it does the Union of all these fuzzy sets. This aggregation process is done by Fuzzy Inference System (FIS) type Mamdani in MATLAB 7.1 program, fuzzy logic toolbox (Figure 2).

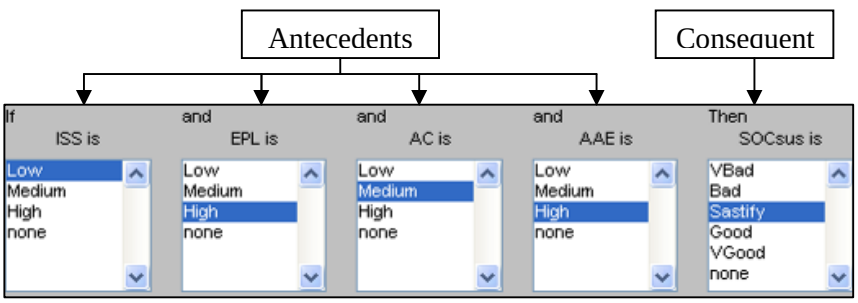

Figure 2. Fuzzy inference over indicator ISS, EPL, AC and AAE for aggregation

The defuzzification process: Defuzzification is the final operation that converts membership grades into a single crisp value. Several defuzzification methods have been presented in the literature (Driankov, Hellendoorn and Reinfrank 1996). After fuzzy reasoning we have a linguistic output variable which needs to be translated into a crisp value. The objective is to derive a single crisp numeric value that best represents the inferred fuzzy values of the linguistic output variable. Defuzzification is such inverse transformation which maps the output from the fuzzy domain back into the crisp domain. In this study the center-of-gravity was chosen because it conforms to the weighted-mean method that we use before fuzzification of the input which is the most frequently referenced in the literature.

3. Results

The farms in those communes are small-scale vegetable and/or mixed vegetable-rice farms. Vegetables grown in the study area included head cabbage, bean, cucumber, leafy cabbage, cauliflower, tomato, kohlrabi, cauliflower, and water morning glory. The average farm size was 0.107 hectares out of which 0.089 hectares were used for vegetable production; the number of plots was 4.52 and average plot size was 0.025 hectares.

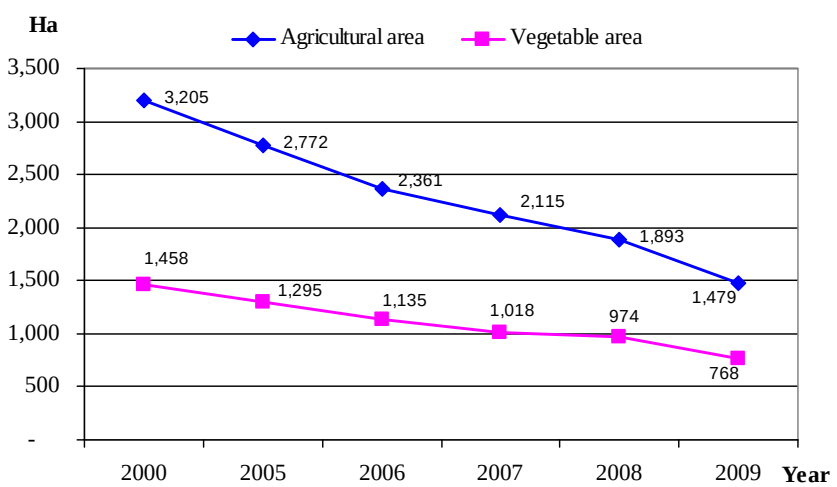

Figure 3. The agricultural and vegetable land area in Ha Dong district
Sources: Ha Dong Statistical Department, 2010

The agricultural and vegetable land area in the study area had significantly changed from 2000 to 2009. The agricultural land decreased by 53.85% (3205 hectares in 2000 and 1,479 hectares in 2009, respectively). The vegetable land area in 2009 was 1,458 hectares, a decrease of 690 hectares (47.33%) compared with the year 2000 (Figure 3). The agricultural land has been moved to other land use purposes, e.g. residential land, land for business premises, and land for public works.

Primary data was collected and standardized and its values are constructed in 0 to 1 scale and the higher the value, the better performance in sustainability. It can be observed in table 1.

Table 1: Normalization of sustainability indicators in the study area

Indic.	Unit	min(s)	max(s)	T(v)	data (v)	N (v)
FR	Million VND/ha	0	max	50	40.21	0.80
IYT	Yield trend	-1	+1	max(s)	-0.33	0.33
ECM	Market channel trend	-1	+1	max(s)	-0.03	0.48
ISS	Input self sufficiency (ratio of local inputs cost to the total inputs cost)	0	1	max(s)	0.55	0.55
EPL	Labor involved trend	-1	+1	max(s)	-0.61	0.20
AC	Access to credit	0	0.5	max(s)	0.50	0.50
AAE	Access to agricultural extension	0	0.5	max(s)	0.09	0.09
UCF	Use of chemical fertilizers trend	-1	+1	min(s)	0.55	0.23
UOF	Use of organic fertilizers trend	-1	+1	max(s)	-0.64	0.18
CLC	Cultivation of legume crop	0	5,022	max(s)	1,476	0.42
UCC	Use of chemical control trend	-1	+1	max(s)	0.06	0.53
HH	Household health status trend	-1	+1	max(s)	0.21	0.61

Note: min(s) = minimum values, max(s) = maximum values T (v) = target values, data (v) = data values, and N (*v*) = normalized value. 1 USD = 19,700 VND (June, 2010)

The results in the table 1 shows the access to agricultural extension indicator (AAE) is the lowest sustainability index, and the financial return indicator (FR) is the highest sustainability index among the indicators. Total 476 rules were gathered based on twelve indicators by using farmers' perceptions as well as their preferences into the decision making process. The fuzzification and defuzzification processes have done by using fuzzy tool box in MATLAB software. The results show that the value for environmental sustainability indicators is 0.33, the social sustainability indicator is lowest (0.25), and economic sustainability is highest (0.50). The overall sustainability of vegetable cultivation systems in the study area is characterised with a very low sustainability index (0.31) (Table 2). The results indicate that the overall sustainability for vegetable cultivation systems in urban area in Red River Delta, Vietnam is not sustainable; therefore further strategies are necessary in order to improve the sustainability of vegetable growing.

Table 2: Summary of sustainability index

Environmental	Social	Economic	Overall sustainability
0.33	0.25	0.50	0.31

4. Conclusion

- The study result is an evidence to prove the unsustainable agricultural issues in Red River Delta, Vietnam as it is stated in literatures.
- Twelve indicators in this research have been successfully used in evaluating the sustainability of vegetable cultivation systems and easy to quantify, regionally specific adapted, and based on acquirable data in the study area.
- Sustainability assessment by fuzzy evaluation approach appears to be well suited to provide quantitative answers pertaining to sustainability
- The urban vegetable cultivation systems in Hanoi, Red River Delta, Vietnam is not sustainable.

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