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Sustainability Assessment of Peri-urban Vegetable Cultivation Systems in Red River Delta, Vietnam

Nguyen Tien Long*, Michael H. Böhme
Department of Horticultural Plant Systems, Faculty of Agriculture and Horticulture, Humboldt University of Berlin, Germany

1. Introduction

Urbanization and industrialization leads to rapid changing environmental conditions along urban-rural interfaces. In some places in Vietnam was found contamination of water, soils and agricultural products due to heavy or inappropriate use of fertilizers, pesticides. The research of Uga et al, 2009 revealed that the vegetables purchased at a suburban market in Hanoi were highly contaminated with parasite eggs. A study has done by the Institute for Ecology and Biology Resources in 1998-1999 found nitrate levels from fertilizer use much higher than maximum residue levels. Toxic pesticides have caused many food poisoning scandals in Vietnam. From 2006 to 2010 more than 944 cases of food poisoning from direct and indirect exposure to pesticides do not include the numerous cases of ‘silent’ casualties by pesticides from pesticide residues (involving 33,168 people) were reported, causing 259 deaths (National Institute of Nutrition - United Nations Children's Fund, 2011). Specially, in peri-urban areas such as Hanoi where the majority of vegetables are produced, over-use of chemical fertilizers and pesticides as well as toxic waste from large industries has resulted in severe soil contamination and environmental pollution (Anh et al, 2004). The aim of this research is to investigate the characteristics of the existing vegetable cultivation systems, and to evaluate the sustainability of those systems in terms of economic, social, and environment. The results from this research will support for farmer and policymaker to achieve the goal of increasing vegetable production without polluting and destroying the natural resource base.

2. Research methods

Case study: The case studies were conducted in three selected communes in peri-urban areas of Thanh Tri 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 Hanoi from 2000 to 2008 is 1733 mm, with more than 50% of the rainfall 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).

* *Corresponding author:* nguyentienlong@huaf.edu.vn

Data analysis: To achieve the objective of the study, multi-criteria were used to evaluate the suitability based on economic, ecological, and social sustainability (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).

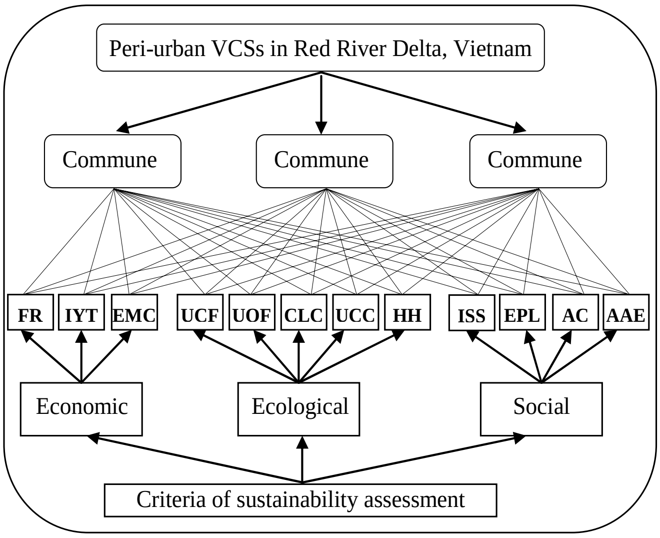

Figure 1: The framework for suitability assessment in this study

Instead of using the raw data for each indicator directly, the data were normalized to obtain a common scale and allow statistical aggregation. Normalize function were used to a common scale and allow statistical aggregation. Let v_i be the data value of indicator i. Then its normalized value N(v_i) is calculated as in equations 1, 2, 3, 4, and 5 (adopted from Allard et al., 2004). With this approach, the raw values were converted to common membership grades (from 0 to 1.0).

If the target value T(*vi*) corresponds to maximum: $$N(v_i) = \begin{cases} \dfrac{v_i - \min(s)}{T(v_i) - \min(s)} \text{ for } v_i \le T(v_i), \text{ and} \\ 1 \text{ for } v_i \ge T(v_i) \end{cases} \quad (1)$$

If the target value T(*vi*) corresponds to minimum: $$N(v_i) = \begin{cases} 1 \text{ for } v_i \le T(v_i), \text{ and} \\ \dfrac{\max(s) - v_i}{\max(s) - T(v_i)} \text{ for } v_i \ge T(v_i) \end{cases} \quad (2)$$

If the target value T(*vi*) corresponds to an interval: $$N(v_i) = \begin{cases} \dfrac{v_i - \min(s)}{T(v_i) - \min(s)} \text{ for } v_i \le \min T(v_i), \text{ and} \\ 1 \text{ for } v_i \in [\min T(v_i), \max T(v_i)], \text{ and} \\ \dfrac{\max(s) - v_i}{\max(s) - T(v_i)} \text{ for } v_i \ge \max T(v_i) \end{cases} \quad (3)$$

If the target value T(*vi*) corresponds to "yes" or "no" statement: $$N(v_i) = \begin{cases} 0.5 \text{ for } v_i = T(v_i), \text{ and} \\ 0 \text{ for } v_i \ne T(v_i) \end{cases} \quad (4)$$

and the value of each linguistic variable is given by the average aggregation: $$T = \frac{\sum_i N(v_i)}{n_i} \quad (5)$$

where: n_i = total number of indicators, min(s) = minimum values, max(s) = maximum values, T(*v*) = target values, data(*v*) = data values, and N(*v*) = normalized value.

The method for aggregation of all indicators and the set of weights in multi-criteria decision analysis problem to assess the overall sustainability was chosen as proposed by Allard et al., 2004.

$$I_{sus} = \sum_{i=1}^{n} I_i * w_i \quad (6)$$

where: the overall sustainability indicator (I_{sus}) is the result of the weighing average of all the normalized indicators I_i. w_i represents the weight of the ith indicator

3. Results

The agricultural land and vegetable area in the study area had significant changed from 2000 to 2009 (Figure 2). The agricultural land decreased by 36.7% (3815 hectares in 2000 with 2416 hectares in 2009 in comparison). The vegetable area in 2009 was 1027 hectares, decreased by 549 hectares (34.8%) compared with the year 2000. The agricultural land have been moved to other land use purposes, e.g. residential land, land for business premises, land for public works.

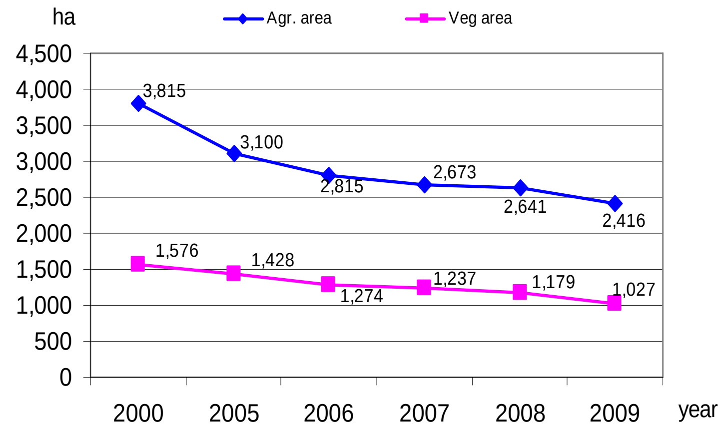

Figure 2: The agricultural area and vegetable area in Thanh Tri district

Vegetables grown in the study area included headed cabbage, bean, cucumber, leafy cabbage, cauliflower, tomato, kohlrabi, cauliflower, and water morning glory. The average of farm size was 0.152 hectares in which 0.1 hectares for vegetable production, the number of plot was 5.7 and plot size was 0.027 hectares (Table 1).

Table1: Land holding size, plot size, vegetable cultivation, and standard deviations (within parentheses) in the study area.

Characteristics	Unit	Value	
Farm size	ha	0.152	(0.035)
Number of plots	number	5.697	(1.130)
Plot size	ha	0.027	(0.003)
Vegetable cultivated area	ha	0.100	(0.025)

Table 2: 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	55.872	1.00
IYT	Yield trend	-1	+1	max(s)	0.1818	0.59
ECM	Market channel trend	-1	+1	max(s)	0.5455	0.77
ISS	Input self sufficiency (ratio of local inputs cost to the total inputs cost)	0	1	max(s)	0.6034	0.60
EPL	Labor involved trend	-1	+1	max(s)	-0.2121	0.39
AC	Access to credit	0	0.5	max(s)	0.44	0.44
AAE	Access to agricultural extension	0	0.5	max(s)	0.24	0.24
UCF	Use of chemical fertilizers trend	-1	+1	min(s)	0.2727	0.36
UOF	Use of organic fertilizers trend	-1	+1	max(s)	-0.4242	0.29
CLC	Cultivation of legume crop	0	5,022	max(s)	1,908	0.38
UCC	Use of chemical control trend	-1	+1	max(s)	-0.2727	0.36
HH	Household health status trend	-1	+1	max(s)	0.1818	0.59

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 showed the access to agricultural extension indicator (AAE) was the lowest sustainability index, and the financial return indicator (FR) was the highest sustainability index among the indicators. The sustainability index of EPL, AC, UCF, UOF, CLC, UCC were low as 0.39, 0.44, 0.36, 0.29, 0.38, and 0.36 respectively (Table 2).

The weight factor was estimated by pair-wise comparison method (Saaty, 1980) based on a number of indicators. After structuring the problem as a hierarchy, workshops were organized and the matrix of pair-wise comparisons was established, checking consistency and ranking the weight of the factors were done. The aggregate of normalized value of all indicators and its weight were done and represented in table 3.

Table 3: Summary of Sustainability Index

Environmental	Social	Economic	Overall sustainability
0.42	0.37	0.74	0.52

The aggregate value for environmental sustainability indicators was 0.42, the social sustainability indicator was lowest (0.37), and economic sustainability was highest (0.74). The overall sustainability was (0.52) then we can conclude that the overall sustainability for this cropping system is acceptable, but should be improved.

4. Conclusion

The agricultural land and vegetable area of the farm household in peri-urban Hanoi were small and fragmented and threatened by urbanization.

The trend of organic fertilizer usage declined and the trend of chemical fertilizer usage increased, farmer's usage of pesticide are in unsustainable manners, farmer's concern just is the income from their farm and has limitation access to the credit and also limitation access to agricultural extension service.

The overall sustainability of peri-urban vegetable cultivation systems in Hanoi was assessed and it was conditional sustainability.

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