GREEN PRODUCTIVITY INDEX OF CAYENNE PEPPER PRODUCTION (CASE STUDY IN NONGKHAI PROVINCE)

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Abstract

The production of cayenne pepper uses large quantities of raw materials such as fertilizer, manure and fuel for land preparation. The trend to increase not only productivity but also environmental awareness will continue in the future. The combined strategy to pursue both of these two issues is referred to as Green Productivity (GP). The measurement for success in GP is called the Green Productivity Index (GPI). The objective of this paper is to calculate the GPI for Cayenne pepper production in Nong Khai Province. Life Cycle Assessment (LCA) was the method used to assess environmental impact. Production costs were used to determine productivity. The primary data were obtained through questionnaires (n=84). The calculated GPI is 148.85. The results can be used as a guideline for further improvements in the Cayenne pepper production such as in reducing the use of certain materials in order to lower the environmental impact and to increase productivity.

Keywords: Green Productivity Index, cayenne pepper, life cycle assessment

Introduction

Cayenne Pepper is important to the Thailand economy as it is a major contributor to exports, along with domestic consumption revenues, in the form of the pepper itself and processed products such as curry and chili sauce. With the planting and growing of cayenne pepper plants in the country careful consideration must be given to the quantity and type of fertilizer and chemicals used, water resources and the use of modern technologies in production. Furthermore, effects on the environment and the health of farmers and consumers must be carefully monitored.

With the increase in environmental awareness and the need for continuing gains in productivity it is necessary to focus on all aspects of production (Moses L. Singgih et.al,2010)The strategies to accomplish GP were developed by the Asian Productivity Organization (APO) The concept of Green Productivity is drawn from the integration of two important activities -productivity improvement and environment protection.(APO, 2001)

This study being conducted to determine the indicators of GP in Cayenne pepper in NongKhai Province, takes into account cultivation of seedlings field preparation for planting, maintenance and harvesting. As well, the principles of Life Cycle Assessment (LCA) are applied to determine environmental impact, the cost to produce one ton of Cayenne pepper and the GPI.

Methodology

Green Productivity Indicator

GP is a strategy for enhancing productivity and environmental performance for overall socioeconomic development. Since the measurement is important for the evaluation of GP performance, it will require appropriate indicators which include both productivity and environmental aspects of a system in an integrated fashion. The indicator is very much concerned with what level of GP to evaluate since there are many different levels of GPs such as global, national, corporate, factory, product and process levels. In this study, an appraisal has been done at a product level. The GP level of a product system or process can be measured by calculating the GP index from equation 1 and the index value can be used to compare with other equivalent product systems or processes by calculating this GP index. GP index is defined as the economic value created from the input of cost divided by the environmental impact. This index is intended to estimate the GP level to one product orservice and compare it to another competing, equivalent product or service. (IK Kim et.al, 2003) GPI is the ratio of productivity and environmental impact in equations 1,2 (N. Mohan et. al, 2006)

$$GPI = \text{Productivity / Environmental Impact} \quad (1)$$

$$= (SP/PC)/EI \quad (2)$$

Where SP: Selling Price (Baht/ton),
PC: Production Cost (Baht/ton)
EI: Environmental Impact (person for target year; Pt)

In this study the environmental impact analysis (EI) was carried out according to ISO 14000 series that specific requirement for Life Cycle Assessment (LCA). The selling price and cost of cayenne pepper production was analyzed that used for the GPI calculation. The system of cayenne pepper production in Nongkhai Province is shown in Figure 1. In this study, the functional unit is 1 ton of cayenne pepper produced.

A case study of cayenne pepper production in Nongkhai Province was carried out to illustrate the measurement of GP.

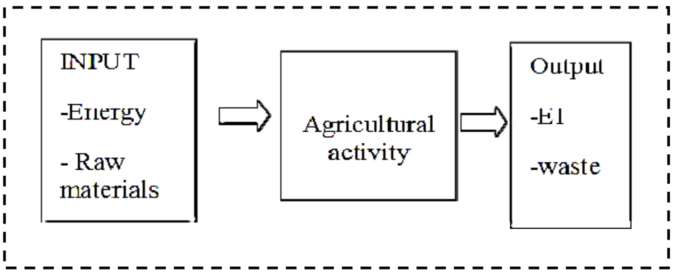

Figure 1 System of Cayenne Pepper Production in this study

Data collections

The data collections in this study are as follows:

1. Primary Data was collected through questionnaires in the use of materials and resources in the current season (2554-2555) such as the use of chemicals, fertilizers, seed, diesel oil used in the preparation. The production costs data, including fixed costs such as depreciation, property taxes, etc., variable costs such as labor, fertilizer, etc. Data collected for EI calculation was shown in table 1.

To determine the sample size consideration was given to Krejcie & Morgan theory at a 95% confidence level and an acceptable error level of 5%. In this study the sample size was 84.

2. Secondary data, such as statistical data for peppers planting statistics and export products from sources such as the Department of Agricultural, Department of Trade Promotion, literature review and website.

A Life Cycle Impact Assessment was conducted according to the framework of ISO 14042. The Life Cycle Impact Assessment result assigned to each of three impact categories selected in this study such as Global warming potential, acidification potential and eutrophication potential. They were converted into a single score by using weighting factor.

Results

Life Cycle Assessment

Life Cycle Inventory

A life cycle inventory (LCI) includes information on all of the environmental inputs and outputs associated with a product or service i.e. material and energy requirements, as well as emissions and wastes. In this study, fertilizer application, manure application and diesel oil used for land preparation were analyzed for the EI calculation. Activity data for the calculation of environmental impact (EI) is shown in table 1below.

Table 1 Activity Data for 1 ton yield

Source	Activity data	Quantity
Land preparation	Diesel oil used	1.21 Kg
Fertilizer application	N P K Fertilizer used	57.44 Kg
Manure application	Manure used	1.70 Kg

Table 1 shows activity data from a significant fertilizer application (57.44 Kg) Fuel use by tractor in land preparation was 1.216 Kg. Excessive quantities of fertilizers required by plants resulted in nitrous oxide (N_2O) being released into the atmosphere (Greenpeace, 2551). Tractor engine combustion generated greenhouse gas emissions such as CO_2, CH_4, N2O, etc.

In life cycle inventory analysis functional unit of life cycle inventory analysis is 1 ton of yield, all emission were calculated as a function of production activity and emission factor (Table 2.) using Equation 3 (J.F. ESHUN et al., 2011)

$$\text{Emission (kg substance)} = \text{Activity Data} \times \text{Emission Factor} \qquad (3)$$

Table 2 Emission factors used for the calculation of the emission

Source	Compound emitted	Emission factor	Unit	Reference
Land preparation	CO_2	3150.00	$g\ kg^{-1}$ fuel	Schwaiger and Zimmer, 1995
	N_2O	0.02	$g\ kg^{-1}$ fuel	Schwaiger and Zimmer, 1995
	CH_4	6.91	$g\ kg^{-1}$ fuel	Schwaiger and Zimmer, 1995
	NO_x	50.00	$g\ kg^{-1}$ fuel	IPCC, 1997
	NMVOC	6.50	$g\ kg^{-1}$ fuel	IPCC, 1997
	CO	15.00	$g\ kg^{-1}$ fuel	IPCC, 1997
N-fertiliser use	N_2O	0.03	$kg\ N_2O\text{-}N\ kg^{-1}\ N$	IPCC, 1997
	NO_x	0.03	$kg\ N_2O\text{-}N\ kg^{-1}\ N$	IPCC, 1997
	NO_3	0.35	$kg\ N_2O\text{-}N\ kg^{-1}\ N$	IPCC, 1997
P-fertiliser use	PO_4^{-3}	0.20	$kg\ PO_4^{-3}\text{-}\ P\ kg^{-1}\ P$	IPCC,1997

Table 2 shows emission factors used in the calculation of the emission from fuel used for land preparation and N-P fertilizer used. In the preparation of land compounds emitted include CO2, CH_4, CO, NO_x. N-P fertilizer emitted compound such as N_2O, NO_x, PO_4, etc.

The results of Life Cycle Inventory (LCI) of one ton of Cayenne pepper productions are shown in table 3 below.

For example of calculation can be expressed as follows

Emission (kg substance) = Activity Data x Emission Factor
Emission CO_2 (kg CO_2) = Activity Data x Emission Factor
Land preparation: Activity Data = 1.216 Kg diesel fuel.
Emission Factor = 3150 g/kg fuel
So Emission CO_2 (kg CO_2) = 1.21 kg fuel x 3150 g/kg fuel = 3.82 kg CO_2

Table 3 Results of Life Cycle Inventory (LCI) of 1 ton cayenne pepper production

	Substance	Amount	Unit
Air Emission	CO_2	3.82	Kg
	CO	0.0183	Kg
	NO_x	0.48	Kg
	SO_2	6.06×10^{-5}	Kg
	CH_4	0.01	Kg
	N_20	0.26	Kg
	NMVOC	7.46×10^{-3}	Kg
Soil Emission	PO_4	1.69	Kg
	NO_3	2.96	Kg
Waste	rotten	16.93	Kg

From table 3 shows that CO_2 emission has a maximum air emission value of 3.82 kg CO_2 the major portion coming from caused diesel oil used for land preparation. In soil emission NO_3 has a maximum value 2.96 kg ,the bulk of which is caused by N fertilizer and decaying product application (16.93 kg)

Life Cycle Impact Assessment

The inventory list is the result of all input and output environmental flows of a product system. However, a long list of substances is difficult to interpret and therefor, analysis is needed known as Life Cycle Impact Assessment (LCIA). LCIA consists of 4 steps.

- Classification of all substances are sorted into classes according to the effect they have on the environment (see table 4).

Table 4 Classification of all substances in each potential

Global Warming Potential	CO_2 ,CH_4 ,CO ,NO_x, N_2O , NMVOC
Acidification Potential	SO_2, NO_x , N_2O
Eutrophication Potential	PO_4 ,NO_3 ,NO_x, N_2O

Table 4 show that for each substance, a schematic cause response pathway needs to be developed that describes the environmental mechanism of the substance emitted. Global Warming Potential consists of CO_2, CH_4, CO, etc. Acidification Potential consists of SO_2, NO_x and N_2O. Eutrophication Potential consists of PO_4, NO3, etc.

- Characterization: all the substances are multiplied by characterization factors (table 5) which reflects their relative contribution to the environmental impact. For example, the calculation can be expressed as follows

Impact = Emission × Characterization factor (4)
Impact CO_2 = 3.82 x 1 kgCO_2-eq = 3.82 kgCO_2-eq
Impact CH_4 = 0.01x21 kgCO2-eq = 0.21 kgCO_2-eq
Impact N_2O = 0.26x310 = 80.6 kgCO_2-eq
Total Impact for Global warming potential = 84.62 kgCO_2-eq

Table 5 Characterization factors for each impact category calculation (Heijungs et al, CML 1992)

Substance	Characterization factors for Global warming potential	Substance	Characterization factors for acidification potential	Substance	Characterization factors for Eutrophication potential
CO_2	1	SO_2	1	PO_4	1
CH_4	21	NO_x	0.7	NO_3	0.1
N_2O	310	N_2O	0.7	N_2O	0.13
				NO_x	0.33

Summary of environmental impact assessment for each impact category shown in table 6

Table 6 Characterized value for each impact categories

Impact categories	Characterized Value
Global warming	84.62
Acidification	0.518
Eutrophication	2.178

The results of table 6 show that the major cause of global warming potential is CO_2, which is caused by the use of fuel in soil preparation. The eutrophication potential includes PO_4 and NO_3. That is caused by the use of N P fertilizer.

- Normalization: the quantified impact is compared to a certain reference value, for example the average environmental impact of one citizen in one year. Calculation is expressed in equation 5

$$NPj\ (product) = EPj \times (1/\ (TxERj)) \qquad (5)$$

Where

NPj (product) = Normalized environment impact potential (person)

T = Lifetime of product (1year)

ERj = Normalization reference (kg substance equivalent/person/year)

EPj = Environmental impact potential (kg substance equivalent)

- Weighting: different value choices are given to impact categories to generate a single score. Calculation is shown in equation 6

$$WPj = WFj \times NPj \qquad (6)$$

Where

WPj = Weighted environmental impact potential (person for target year; Pt)
WFj = Weighting factor
NPj (product) = Normalized environmental impact potential (person)

In this case study normalization value and weighting factor use the SimaPro software database 2007 in table 7.

Table 7 Normalization value and weighting factor

Impact categories	Unit (ERj)	1/(TxERj)	Weighting factor (WFj)
Global warming	kg CO_2-eq./kg/person/year	1.15E-04	1.3
Acidification	m^2/kg/person/year	4.55E-04	1.3
Eutrophication	m^2/kg/person/year	4.76E-04	1.2

From: SimaPro software database 2007

From normalization and weighting step (equation 5, 6) LCIA results of 1 ton of Cayenne pepper production shown in table 8.

Table 8 The LCIA Results of 1 Ton of cayenne pepper production

Impact categories	Characterized Value (EPj)	1/(TxERj)	Weighting factor (WFj)	Weighted Value
Global warming	84.62	1.15E-04	1.3	1.27E-02
Acidification	0.518	4.55E-04	1.3	3.06E-04
Eutrophication	2.178	4.76E-04	1.2	1.24E-03
			total	1.42E-02

In table 8 the weighted value were carried out to total 1.42E-02. This value was calculated for GPI in the next step. Which shows that the highest environmental impact categories were global warming potential with weighted value 1.27E-02, which major caused by diesel oil used and chemical fertilizer. Both chemical fertilizer and manure were causes of eutrophication potential.

Production Cost Calculation

Cost of cayenne pepper production consists of fixed costs and variable costs. (Jintana et al., 2546)

1. Variable costs (VC): Wages and fuel, agricultural materials, seeds, repair tools and equipment and the chemical fertilizer.

2. Fixed costs (FC): Equipment depreciation, property tax and land improvements

3. Total cost (TC) The total cost incurred by the use of various inputs. In the production of goods and services in the short-term the total cost can be expressed as follows;

$$TC\ (Baht) = TFC + TVC \qquad (7)$$

TFC: Total Fix Cost (Baht)
TVC: Total Variable Cost (Baht)

Therefore, the average cost (AC) is the average total cost per unit of output. The average cost (AC) can be expressed as follows. (Jintana et al., 2546)

$$AC\ (Baht/ton) = TC / Q \qquad (8)$$

Q: Quantity of average yield (Ton)

Primary data was collected through questionnaires in the costs of materials and resources in the current season (2554-2555). The average cost of 1 ton of Cayenne pepper production in Nongkhai Province shown in table 9.

Table 9 Average Cost of 1 ton Cayenne Pepper Production

	Average
Total Cost (TC),(Baht)	64,123
Quantity (ton)	13.96
Average Cost (Baht/ton)	4,731

The results of table 9 show that the average cost of 1 ton of Cayenne pepper production in Nongkhai Province was 4,731 Baht per ton, which total cost was 64,123 Baht per ton and average quantity of Cayenne pepper was 13.96 ton.

GP Index Calculation

Green Productivity Index (GPI) is ratio of productivity and environmental impact in equation 1 and 2. (N. Mohan et. al, 2006) Which include both the economic productivity and environmental factor together that already explained earlier in methodology, GPI Index can be used to estimate the GP performance of a product system or process and compare with other competing equivalent products or services. (IK Kim et.al, 2003). From production cost calculation and LCA result which solution of GPI calculation can be expressed as follows

GPI = Productivity / Environmental Impact
GPI = (SP/PC)/EI
SP = Selling Price = 10000 Baht/ton
PC = Production Cost = 4731 Baht/ton
EI = Environmental Impact = 0.0142 pt
GPI = (10000 (Baht/ton) /4731 (Baht/ton))/0.0142 (pt)
GPI = 148.85 (1/pt)

GP Index can be used to evaluate the economic and environmental. And find the way to reduce environmental impact and increase productivity of the activities and processes (Weny et al., 2011).

Discussion

Perspective on GPI of Cayenne Pepper production

GP strategies are focused on increasing productivity and reducing environmental impact. Equation 1 shows that GPI is the ratio of productivity and environmental impact. Therefore, cayenne pepper cultivation in term of GP needs to focus on both sides of increasing productivity and reducing environmental impact. Through a comparison between organic planting and non-organic planting of cayenne pepper it has been found non-organic planting used less resources than organic planting. That is to reduce production cost and reduce environmental impact. For this reason GPI assessment of non-organic planting is likely to be greater than organic planting which means non-organic planting tend to increase productivity and reduce environmental impact more than organic planting.

Thus, to improve the cayenne pepper crop for higher productivity and reduce environmental impact needs to use technology support. Such as the Clean Technology and process improvement with the concept of Lean such as the Value Stream Mapping, to analyze the cause of delay. Analyze what is causing the non-value added activity, as well as to analyze the causes of the low productivity in the manufacture by Fish bone diagram

In addition to reducing the environmental impact by a production green is consistent with the recycle of materials / resource reuse and recovery, etc. For example, the plastic sheet was reused in the next year to reduce the cost of production. The partially decayed cayenne pepper seeds can be planted in the following season. This will reduce the cost of raw materials. This help in sustainable production and the GP index calculation according to the strategy of the green productivity.

To check the accuracy of the various calculations in the foregoing work, Excel 2010 was used and figures were confirmed by using the Simapro program which is precise.

Conclusions

Improvement in productivity, coupled with environmental awareness and responsible practices, will make a substantial contribution to sustaining.GP is the strategy that provides a common link to providing a resolution to both issues the same time. GPI is the measurement that provides on-going feedback as to the success of the chosen operational methods and assists in identifying areas requiring improvement.

The LCA study shows that environmental impacts on Cayenne pepper production can be improved through a resource usage and GPI results can be used for the baseline indicator of process improvement and it used consistently, will result in higher yields without compromising the environment.

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