Eco-efficiency: Challenges in adjusting productivity of agriculture for food security purpose

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Abstract

This paper objective is developing eco-efficiency measurement for food security purpose. Increasing population growth will means that global demand for food will increase. Food supply will depend upon the ability and high productivity of food production. At the same time we are dealing with environmental degradation such soil degradations and pollutions caused by short-term high productivity of agriculture.

For those reasons, producing food without degrading environment is preferable. However, this sustainable agriculture still remains food security problems since it needs long time production and high production cost that lead to a low productivity. Sustainable food production often be assumed fail to cope high global demand of food. Many studies of food security innovation have been done. A high research cost related to agriculture researches has led to an analysis of the possibility of a sustainable agriculture system that meets demands of food security but simultaneously economically accepted. It is our challenge to develop a certain formula to analyze those of innovations economically and environmentally in one index.

Eco-efficiency is a concept that brings together two dimensions of economic and ecology. Assumed that food security as economic performance, agricultural eco-efficiency index can be assessed to indicate ratio food security level to its environmental impact. As a result, indicators of food security measurement and agricultural environment impact also would be proposed.

Keywords: Eco-efficiency, food security, indicator development

1. Introduction

The World Food Summit of 1996 defined food security as

> Access by all people at all times to enough food for an active, healthy life. Food Security includes at a minimum: the ready availability of nutritionally adequate and safe foods, and an assured ability to acquire acceptable foods in socially acceptable ways (e.g., without resorting to emergency food supplies, scavenging, stealing, or other coping strategies)

Food security have been a global concern, since doubling incremental of population, degradation of soil quality and high competition in land, water and energy used for other human activity. An agricultural revolution in 19-th century which has incredibly increase food security has simultaneously resulted in soil damage [1]. A local study in china has simulated that productivity losses will increase to 30% by 2050 if the soil be degraded at twice the present rate [2]. Recent encouragement of biofuel planting [3-4] have resulted more pressures in land competition [1]. At the same time, not only food production, food accessibility and utility have been a complex difficulty in food security problem [5-8].

Sustainable intensification program for limited land problem by management of water, organics substitutions, pesticides and fertilizers have been proposed in several researches [7, 9-12]. In spite of reasonable solutions for limited land, several studies has debated that those solutions os sustainable intensification resulted in low food security due to their contradictive long production time and high investing needed that can't be afford by developing countries [1, 13-14]. In another word, a sustainable food production is pressumed to be a low productivity activity.

Researches, studies and innovation of Sustainable Food Security improvement have been done recently. Biotechnology in crop production [7], Pesticide management [9], Farming management [15] are some of innovations in sustainable food production for food security purpose. Nevertheless, an obvious cost has led to a necessity for further analysis of productivity. Since sustainable food security is preferable, those of researches could be implemented in broader and larger scope only if they are feasible economically and environmentally.

Productivity measurement analyzes output of an activity to its input. In food security perspective, a finite natural resource as an input, term efficiency would be more appropriate. Eco-efficiency is one of advanced efficiency measurement that uses environmental impact as its input. The higher value of output to its lower impact to the environment is preferable. A quantified environmental impact justifies that the activity is sustainable. Eco-efficiency as a ratio of economic performance to its environmental impact is proposed to measure food security level to its environmental impact. To be expected this measurement can occupy food security and sustainable environment in one index. This ratio analyzes activities by quantify its benefits due to its environmental impacts.

This paper tries to propose indicator development for food security eco-efficiency by substituting food security to eco-efficiency ratio as in equation (1). The measurement tool deals with overall food security system that includes 4 dimension of food security: the availability of food; access to food; utilization of food; and food system stability, and would be substituted to eco-efficiency measurement tool to indicate ratio of food security level to its environmental impact.

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2. Eco-efficiency

Eco-efficiency, first introduced by World Business Council of Sustainable Development (WBCSD) in 1992 is a business link to Sustainable Development[16]. It is an instrument for sustainability analysis [17]. As a concern in environment resource depletion by the business practitioners, eco-efficiency assesses the sustainable development in business view with focusing in resources

saving and less environmental impact. Eco-efficiency is expressed as in (1) [18]:

$$\text{Eco-efficiency} = \frac{\text{Product or service value}}{\text{Environmental influence}} \quad (1)$$

In generalized definition, eco-efficiency of production is dealing with capability to produce goods and services while causing minimal environmental degradation [19]. Research areas of eco-efficiency are justifying indicators of numerator and denominator as in (1), method development, and implementation of eco-efficiency concept.

Being developed from simple productivity ratio output per input, term efficiency is more suitable for food security purpose due to its finite input of natural resources. The term Eco-efficiency is developed when input of that ratio is associated with environmental impact of the activity. Many researches have been done in doing eco-efficiency strategies and measurement tool for sustainable agriculture, [20] have done an eco-efficiency analysis respect to EMS (Environment management System) in ISO 14000. Focusing on farmer education and skill [15] assessed farming eco-efficiency.

3. Food Security Measurement

In line with eco-efficiency, food security measurement is still debatable. Some researchers have argued that food security is more precisely quantify by assesses food insecurity while food security may better conceptualized as a goal and measured by the low of hunger-food insecurity [5, 7, 21-26]. In this study, eco-efficiency of food security focuses on value added of a certain food security activity toward its environmental impact. Furthermore, eco-efficiency in food security analyzes every decision or innovation related to food security improvement economically and environmentally.

Food security measurement in this study refers to how eco-efficience food security improvement activities. Thus, this study uses term 'food security analysis' to describe food security measurement.

Being applied to equation (1) as numerator – economic performance output which should be maximized, food security would be assessed as it is food security not food insecurity. For this purpose, equation (1) could be modified into:

$$\text{FS eco-efficiency} = \frac{\text{FS economic value added}}{\text{Environmental Impact}} \quad .....(2)$$

FS eco-efficiency refers to Food Security eco-efficiency analysis. As economic performance of food security, numerator 'FS economic value added' in equation (2) refers to economic value added of food security improvement activities while the denominator 'Environmental impact' refers to its undesirable impact to the environment.

Another importance matter is that economic and environmental performance should be analyzed at social perspectives due to macro scope of food security topics.

Food security improvement itself can be achieved through enhancing 4 dimensions: Food Availability, Food Access, Food Utilization and Food Stability [27].

Food Availability deals with the 'supply side' of food security and is determined by the level of food production, stock levels and net trade. For detail, [22] explained that it ussually refers to physical availability through national food stocks and commercial food imports. [7] specified that not only availability of 'food' but 'good quality and nutritious food' . Thus it can be concluded that Food availability deals with 'physical availability of good quality and nutritious food through national food stocks and commercial food imports'.

Food Access is physical and economic access to food for an active , healthy life. This includes marketing and transport infrastructure, food distribution system and markets; purchasing power; social programmes to ensure access to nutritious food; and school meals which are nutritious and appealing to children. If food is available but people do not have the money to access it, they are food insecure [7].

Food Utilization is the safe and healthy utilisation of food. This includes good health status, since healthy individuals can make proper use of food; having nutritious food choices for all age groups; food safety and quality; and access to clean water and sanitation [7]. According to [22], there are two kinds of food utilization: physical utilization and biological utilization. Physical utilization describes the ability of a household to have all the physical means to use food available. This may include cooking utensils, culturally regulated feeding hierarchies, cuisine patterns, adequate housing, caretaker behavior, knowledge, family structure, and workload. Biological utilization is compromised by many factors including infection (increased nutrient demand), poor hygiene that could lead to diarrheal diseases or infestation, micronutrient synergy, or antagonism [22].

Food Stability is fact that to be food secure, a population, household or individual should have access to adequate food at all times and should not risk losing access to food as a consequence of sudden shocks (e.g. an economic or climatic crisis) [7].

Although a simultaneous goal should be fulfilled for every food security objectives [7, 22, 27], sometimes it is difficult to fulfill all those dimensions simultaneously. For food security eco-efficiency analysis, it depends on objectives of every activity. One can set their economic performance indicator and environmental indicator associated with the objective.

4. Indicators Development

Indicator shows what to measure. As showed in equation (2), FS eco-efficiency needs FS economic value added indicators and Envrironmental Impact indicators.

FS economic value added indicators could be addressed from 4 dimensions of food security while Environmental Impact performance indicators would be addressed from 7 elements of eco-efficiency [17], those are:

1. Reduced material intensity
2. Reduced energy intensity
3. Reduced dispersions of toxic substance
4. Enhanced recyclability
5. Maximized used of renewable
6. Extended product life
7. Increased service intensity

As mentioned, all indicators should be assessed within social perspective. For example, a farming activity has an economic value added indicator: 'value added per hectare' and environmental impact indicators LCA analysis of farming activity.

4.1 Food Security/Numerator Indicator

Food security indicators are determined based on 4 dimensions of food security: Food availability, food access, food utility, food system stability. [3, 7, 13, 22] has deployed elements of analysis in food security assessment based on those of 4 dimensions as in Table 1.:

Table.1
Indicator based on 4 dimensions of Food Security

Dimensions	Indicator
Food Availabiliy	Food volume
	Food storage
	Irrigation
Food Access	House hold resources
	Purchasing power
	Physical, social and policy environment
Food Utilisation	Bio utilisation
	Physical utilisation
	Culturally inappropriate food
Food stability	Stability and sustainable coping strategy
	Resources conservation
	Employment generation

Source: [22]

Indicator of Food Availability and Food Access[22]
Indicators of food availability may include crop production or food production index or possession index.
Fnancial and physical access to food refers to the equal distribution of the food available using existing structures and resources. Indicators of food access may include food price monitoring the diversity of household income sources, food handling and storage losses, household asset index, debt-to-asset ratio, dietary diversity, coping strategies index, and household expenditures indices

Indicator of Food Utilisation and Food Stability
Indicator of Food utilization covers the ability to absorb and use food nutrients and related to individual health status, water and food sanitation, and food and water safety among other factors[3].
Food utilization is realized when''food is properly used; proper food processing and storage techniques are employed, adequate knowledge of nutritionand child care techniques exist and are applied, and adequatehealth and sanitation services exist''. From this definition, it is evident that there are two forms of food utilization: physical utilization and biological utilization. The physical utilization reflects the ability of a household to have all the physical means to use food available. In contrast, biological utilization is concerned with the ability of the body to effectively use the nutrients once the food is consumed[22].
Indicator Food Stability refer to Stability and sustainable coping strategy, resource compensation, employment generation[22]

4.2 Environmental/Denominator indicator

Environmental indicators are determined based on environmental impact of agricultural and 7 elements of eco-efficiency [17] and may based on LCA (Life Cycle Analysis) of Crop Agriculture. According to [15, 28], environmental indicator can be refer to :
Resource Land Use
This indicator refers to land used for crop agriculture, the more wide land use the more poor environmental impact
Global Warming Potential
This indicator refers to Global Warming gas emission such as CO2, SOx, NOx. The more gas emissions, the more poor environmental impact. These gases may refer to human Toxicity, Aquatic Toxicity, Terrestrial Toxicity, Eutrophication, and Acidification.
Specialization
This indicator is measured as percentage of farm surface covered by the most important crop
Pesticide Risk
This indicator informs about the overall lethal toxicity released into the environment through the pesticide used for agricultural production
Energy Used
This indicator refers to energy consumed through crop production.

5. Developing Food Security Eco-efficiency

There is no prescribed formula to quantify and value both the numerator and denominator. Value added can be perceived as the function the activity fulfill for the end-user and possibly quantified with financial indicator. The denominator of eco-efficiency can possibly quantified with impact indicator based on environmental life cycle analysis (LCA)[22]. For example, a new biotechnology in crop production needs a Food Security Eco-efficiency. The value added could be food volume (crop production per hectare) and the environmental impact could be energy consumed, waste, and water consumed per hectare. A simple overall Food Security Eco-efficiency could be obtain by equation (3):

$$\text{FS Eco - efficiency} = \frac{\text{Crop production per hectare}}{\text{Energy consumed} + \text{Water Consumed} + \text{Waste}} \quad (3)$$

Equation (3) describes simple formula for FS eco-efficiency briefly but not exact quantitatively. Further calculation of eco-efficiency needs adjusted methods due to types of indicators and data available. Data Envelopment Analysis (DEA) is the most simple and often applied in eco-efficiency quantification.

5. Summary and Conclusions

High productivity agriculture has simultaneously resulted degradation of soil quality. Sustainable intensification on agriculture may become reasonable solution for soil quality degradation and limited land availability. However, this solution results low food security due to its long term production. This problem needs both justification for food security and sustainable solution.
Eco-efficiency for food security purpose measurement is proposed by this study which is a combination of food security level and its environmental impact as mention in equation (2).
Numerator and Denominator indicators are also developed. For Food Security, indicators are developed based on 4 dimensions of food security that is Food Availability, Food

Access, Food Utilizations, and Food Stability. The indicators are mentioned in Table 1.
For Environmental Impact, indicators are developed based on 7 elements of Eco-efficiency. The indicators are Resource Land Used, Global Warming Potential, Specializations, Pesticide Risk, and Energy Used. With Eco-efficiency for food security purpose, Food security and sustainable agriculture can be justified in one index.

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