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Sustainable Food Security Measurement: A Systemic Methodology

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Abstract. Sustainable food security measures how a region provides food for its people without endangered the environment. In Indonesia, it was legally measured in Food Security and Vulnerability (FSVA). However, regard to sustainable food security policy, the measurement has not encompassed the environmental aspect. This will lead to lack of environmental aspect information for adjusting the next strategy. This study aimed to assess Sustainable Food security by encompassing both food security and environment aspect using systemic eco-efficiency. Given existing indicator of cereal production level, total emission as environment indicator was generated by constructing Causal Loop Diagram (CLD). Then, a stock-flow diagram was used to develop systemic simulation model. This model was demonstrated for Indonesian five provinces. The result showed there was difference between food security order with and without environmental aspect assessment.

1. Introduction

Sustainable food security was discussed in 1993 by [1]. It was mentioned that sustainable development should encompassed aspects of food, agriculture and people. Research done by [2, 3] then discussed about the importance of nature stability in agricultural to maintain the food security. Discussions about measurement of food security and indicator development were done by [4] which used sustainable land resources as indicator of sustainable food security. In 2004, Atlas of Sustainable Food Security was published by [5] Indicators were reconstructed from basic food security indicators of previous publications. However, environmental indicators were built based on ecological footprint method. It assessed deforestation, remaining land and water resources that could be supplied by nature for future demand. Although it can give information resources supplied by nature for future demand, rising population and consumption of natural resources in recent years would generate problem in assuming time remaining for the natural supplies. For example: it is assumed that fresh water supplies will sufficient for next five years, 'doing business as usual' in rising population and consumption would bias those of information. Unsustainable process of food fulfillment would degrade environment rapidly that we could not restrain. The assumption of five years might turn to one year. This paper tried to reconstruct indicators of sustainable food security, by applying eco-efficiency as environment assessment for the whole indicators.Known as widespread use of sustainable performance assessment tool in industries, eco-efficiency has extended into broader scope of applications. Economic consideration of environmental assessment in integrated index has simplified the next step of decision making at higher management. Emerged as business link to sustainable development, it results win-win solutions for economic and environment performances. Industrialists can maintain the environment while enhance their revenues [6, 7]. This has made it applied in broader scope of studies. As regional sustainable assessment, eco-efficiency was applied excellently in European Union by [8] and Finnish region of Kymenlaakso by [9]. In government sector, it helped sustainable development policy makings in agricultures [10-12], transportations [13], and development of environmental regulation of industry areas [14, 15]. The difference between micro and macro level economics is a higher concern of social aspect in macro level. In micro level or industrial level, social aspect could be achieved separately with eco-efficiency assessment, such as programs of corporate social responsibility (CSR), otherwise in macro level or governmental level, social aspect is significant in every decision made. This paper proposed complete the triple bottom line of sustainable: economic, environment and social in eco-efficiency performance measurement especially for macro level applications supported with systemic approach to construct indicators and relationships between them. This systemic approach was an extended idea of system dynamic supported performance measurement developed by [16]. Similar research done by [8, 9, 17], used social indicators in separated part of eco-efficiency ratio and were not supported by systemic view of indicators relationships. That caused lack of information of what effects, feedbacks and trade-offs between them, even though social indicators related to economic and environment indicators have been identified. The systemic view of indicators relationships helps policy maker in trade-offs considerations for every indicator.

However, some researchers argued that being eco-efficient doesn't mean completely sustainable. Being eco-efficient is minimizing resource and energy used, so cost of raw material resource and risk of waste generated could be minimized as well. Eco-efficiency has not required yet for the social indicators of sustainable development, since it is only incorporate indicators of economic and environment. Besides those criticisms, eco-efficiency helps units deciding the beneficially way tobe sustainable. The more eco-efficient activities, the more activities with environmental considerations that would accelerate goal achievement of sustainable development [6, 9].

This study was done for indicators identification of eco-efficiency on sustainable food security. Using a systemic approach by constructing Causal Loop Diagram (CLD), complete economic, environment and social indicators of eco-efficiency were identified. A 'new' eco-efficiency indicators come up from constructing process of relationship between existing indicators of food security in CLD. Indicators were identified according to eco-efficiency ratio as mentioned in Eqn. (2). Existing indicators were indicators of food security in Food Security and Vulnerability Atlas of Indonesia 2009 developed by [18].

2. Eco-Efficiency in Micro And Macro Levels

Concept of eco-efficiency was initiated in 1992 by World Business Council of Sustainable Development (WBCSD) at Earth Summit Rio de Janeiro. It is defined as: 'Eco-efficiency is achieved by the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle to a level at least in line with the earths estimated carrying capacity'. In quantitative term, it is stated as ratio of product or service value (added) to its environmental impact and written as [19, 20]:

$$\text{Eco-efficiency} = \frac{\text{Product or service value (added)}}{\text{Environmental impact}} \qquad (1)$$

Eqn. (1) is a general form of eco-efficiency and could have differed interpretations. The basic ratio of eco-efficiency is a modified output per input of basic ratio of efficiency which maximizing output for minimizing input would be better efficiency result. Product or service value (added) as the numerator explains the economic performance of unit measured, what can unit gain from every activity done. Environmental impact, the denominator is related to resource, energy used or waste resulted for the environment. This form of ratio is commonly used in micro level or industrial level studies.

There is no consensus for exact form of eco-efficiency ratio used in any activities. It depends on research purpose, scope, and data available. Research done by [11] used ratio of 'served function to its environmental impact' for measuring number of land space could serve by crop protection product. For environmental-impact emphasized, [21] compared eco-efficiency by applying 'environmental impact points per 1000 euro'. In macro or government level of applications, European Environment Agency (EEA) quantified eco-efficiency as [19]:

$$\text{Eco-efficiency} = \frac{\text{more welfare}}{\text{less nature}} \qquad (2)$$

Eqn. (2) interpreted as economic development gained for less nature used and disruption. [8] and [15] referred 'more welfare' to Gross Domestic Product (GDP) which is an economic performance in macro level.

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Nevertheless, the term 'more welfare' should be referred to achievement of meeting the human needs or quality of life that not always measured with money. Reduced number of poverty and hunger, increased number of higher education or reduced number of unemployment could be one of interpretations of 'more welfare'. So it is more than prosperity of the people in a region.

3. Case of Sustainable Food Security

Food security is a performance measurement of how well a region be able to fulfill its people with sufficient food at all times. It was defined by FAO in World Food Summit 1996 as: 'Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life'. This definition is detailed into 4 dimensions of, food availability, food access, food utility and food stability [22]. Legal food security assessments were done by World Food Program (WFP) of FAO and published as food security map, for example: Food and Vulnerability Atlas (FSVA), The Food Security Atlas, Food and Nutrition Security Atlas, Vulnerability Analysis and Mapping, and The Food Insecurity. Since arising concern of environmental degradation, those of assessments were accomplished with environmental considerations such as: climate change, deforestation, and rainfall fluctuation.

Eco-efficiency is a sustainability performance measurement by using ratio of economic performance to its ecology performance. Proposed by World Business Council of Sustainable Development (WBCSD) at Earth Summit Rio de Janeiro 1992 as accountability of industrialist to environment degradation, eco-efficiency has appeared to be a win-win solution for realization of sustainable development. With that of principle, eco-efficiency become wide spread accepted by companies for sustainable development assessment and extended to broader level of economic activities, such as in regional or national level [23, 24].

As rising population growth, focus of environmental researches are widen to consumption side under the concept of Sustainable Consumption, whereas consumption side are blamed on the negation of resource efficiency achievement through their increasing demand namely rebound effect [25-27]. The challenge is more than just doing cleaner production, saving energy and water. At the same time, consuming products efficiently and do not speed up more productions has to be integrated fashion with the sustainable production. We need production and consumption as a whole system concerned [26]. However, dealing with environmental system of production-consumption means dealing with complex, time dependent and dynamic system. Strategy implemented on the production-consumption system based on conventional performance measurement sometime doesn't appropriate the objectives decided. Conventional performance measurement results are mostly used for controlling tools rather than improvement tools. An explicit description of system response to every changing condition is needed to support goal achievement effectively [28, 29].

This paper objective is developing dynamic eco-efficiency production-consumption conceptual framework to overcome the challenge of environmental complex system problem. Dynamic eco-efficiency of production-consumption is eco-efficiency measurement combined with system dynamic principles approach for production-consumption system. The differences with previous concepts built by [30, 31] are explicit description and inclusion of time dependence relationship within production and consumption in development of eco-efficiency measurement.

In this paper, the conceptual framework would be built on the implementation to measurement of sustainable food security. Eco-efficiency assessment of sustainable food security conducted based on food system that consists of food production, distribution and consumption and relates to food security measurement dimensions.

4. Eco-Efficiency of Sustainable Food Security

Officially, the term eco-efficiency is then defined by the World Business Council of Sustainable Development (WBCSD) in Rio de Janeiro Earth Summit in 1992 as [32]:

"Eco-efficiency is achieved by the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the earth's estimated carrying capacity".

The essence of this definition is "satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity". While protecting environment is considered as the extended cost, this term tries to clarify that protecting environment could be a profit for the business.

Derived from simple efficiency formula, output/input, (1) illustrates economic and environmental performance represented by numerator and denominator above. Product or service value as output representing economic performance refers to the value of the product and service produced by a company, the sector or the overall economic activity. While the denominator environmental influence as the input is the effect on the environment per unit of the product or service that is produced. Each numerator and denominator are measured based on indicators which is determined correspond to unit economic activity measured.

There is no standard of eco-efficiency ratio or indicator used for any economic activity. The ratio and indicator could be adapted to unit activity measured that assesses economic performance to its environmental impact. Nevertheless, for macro or meso level of economic activity, European Environment Agency (EEA) suggested using ratio of more welfare to less nature [33].

For sustainable food security, this paper uses ratio of food security achievement to its environmental influence as represented as:

$$\text{Eco-efficiency of food security} = \frac{\text{food security}}{\text{Environmental influence}} \tag{3}$$

Equation (2) above describes: numerator food security refers to food security achievement which is measured by four indicators of Food Availability, Food Access, Food Utility and Food Stability. Denominator environmental influence refers to environmental impact of food security achievement with production-consumption point-of-view.

5. Eco-efficiency Based on System Dynamic

System dynamic approach on environmental issues was first performed in 1972 in the book Limits to Growth to describe the simulated world began in 1900-2100 with 12 scenarios and analyse its response to environmental conditions [34]. In connection with the determination of the policy environment, [35] identified that the system dynamic used in the environmental impact assessment, solid waste management, analysis of greenhouse gas emissions and global warming, water resources planning, environmental planning and management, environmental sustainability, ecological modelling and so on. According to its function, in the field of environmental system dynamic approach is widely used in analysing the effects of policies in the field of environment in the span of the next few years [36], then began to be integrated with environmental performance measurement systems such as the study by [37, 38] with the consideration that the performance measurement system is the basis for policy-making in determining the next strategy. In this study, system dynamic will be used in systemic approach to eco-efficiency performance measure. Eco-efficiency is one of the performance measurement tool used to measure the level of sustainability or the sustainability of an activity. This measurement uses a process approach to activities taking into account the economic and ecological performance in the form of a ratio of value added to the economy gained as a result of environmental pressures. Increasing complexity of the systems involved in an activity, the measurement of eco-efficiency by the narrow limits of a system cannot represent the actual system sustainability. Here a holistic approach or whole on a system is needed to be able to measure the level of sustainability of actual system.

Eco-efficiency measurements with system dynamic approach is based on a review that the system dynamic approach is needed to be able to complete the performance measures with an explanation of the relationship between the factors that affect performance, trade-offs that occur between these factors and the behaviour of the system using causal loop diagrams and stock and flow diagram in response to policies that have been taken at the time when the next performance monitoring policy implementation strategies. System dynamic approach would also explain the non-linear interactions, delay, feedback loops and other elements that refer to the dynamic complexity of using quantitative simulation.

5. Causal Loop Diagram (CLD) development

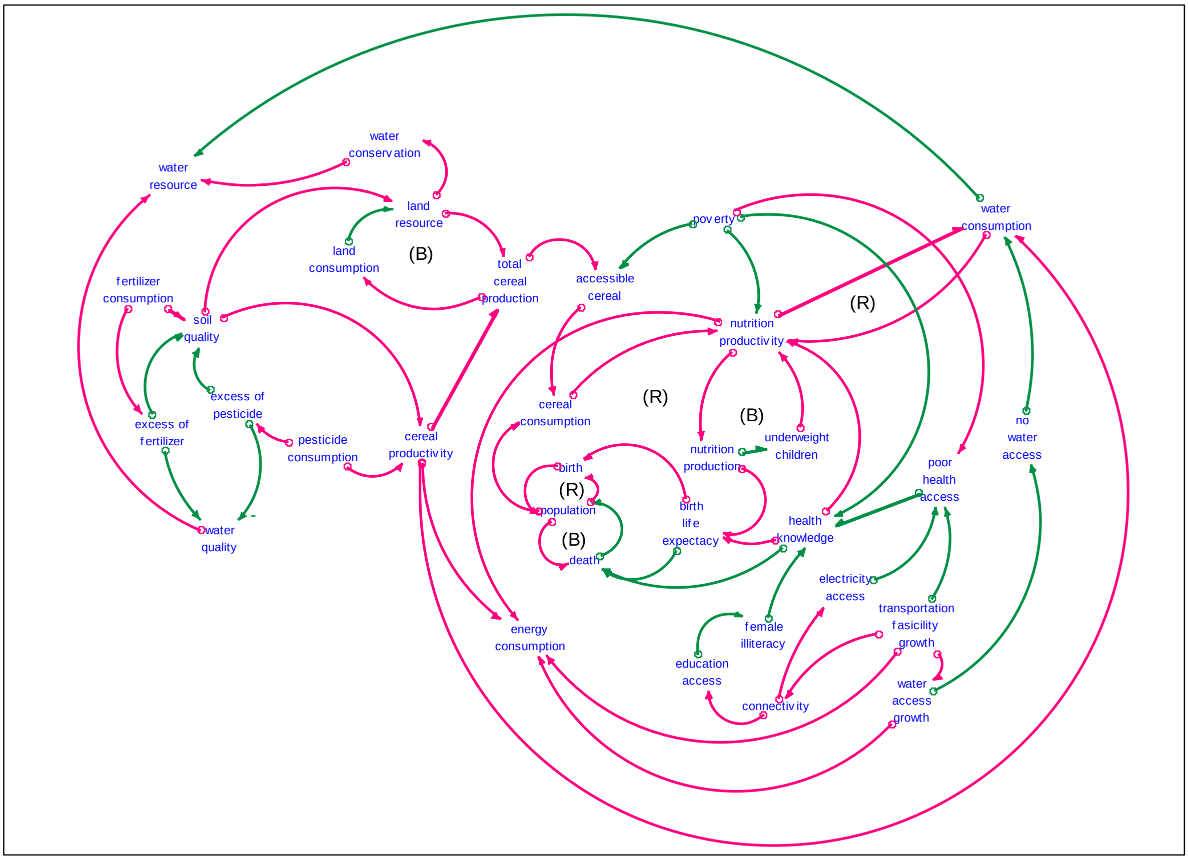

Figure 1. Causal Loop Diagram of Food Security

Figure 1 describes causal loop of eco-efficiency of sustainable food security. Conducting the overall measurement of sustainable food security eco-efficiency, indicators of food security achievement and environmental influence are defined by performing the influence relationship within subsystem of food system and subsystem of food security dimensions. This description of relationship supports the identification of intervention actors of the system that can be used as the indicator.

Following measurement framework designed by [29], relationships between sub systems then support the indicators of eco-efficiency identification by deploying as figure 3. As Equation (2), eco-efficiency of food security consists of numerator and denominator indicators. Figure 3 shows the numerator as food security and Denominator as Environmental Influence indicators deployment refers to food security and relationship with Food Production. Environmental influence is measured by food production influence to environment defined by its irrigation, fertilizer and seeds. Figure 4 describe eco-efficiency area after the simulation, and there is change in sown area order of five provinces of Indonesia.

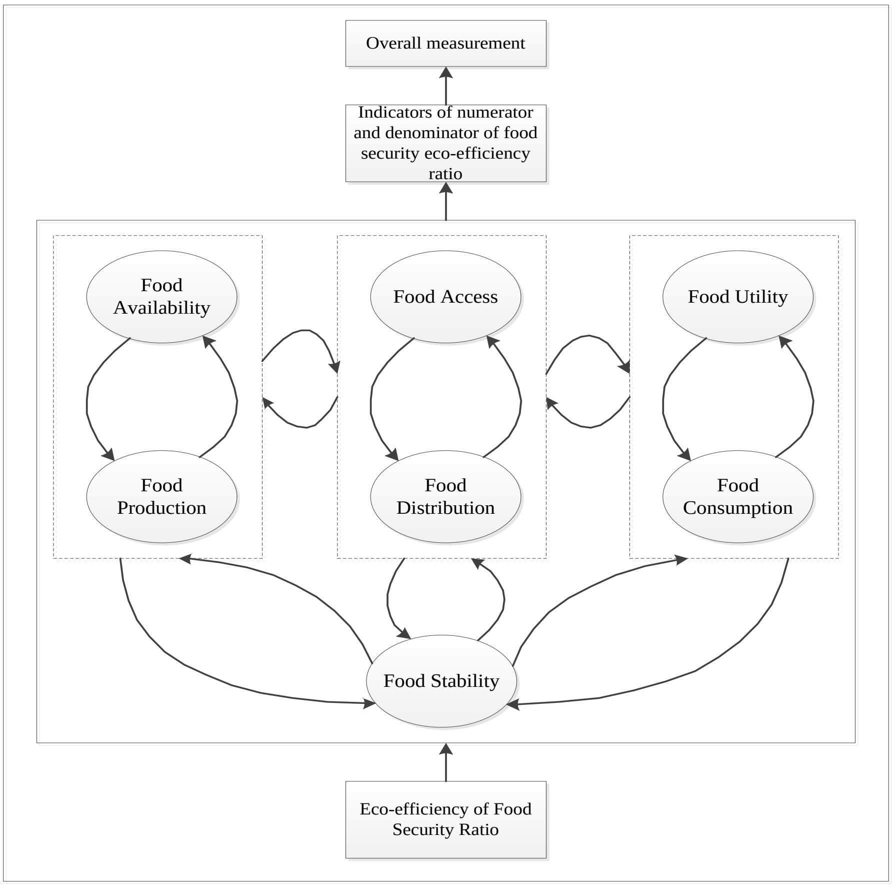

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Figure 2. Framework Of Dynamic Eco-Efficiency for Sustainable Food Security Measurement

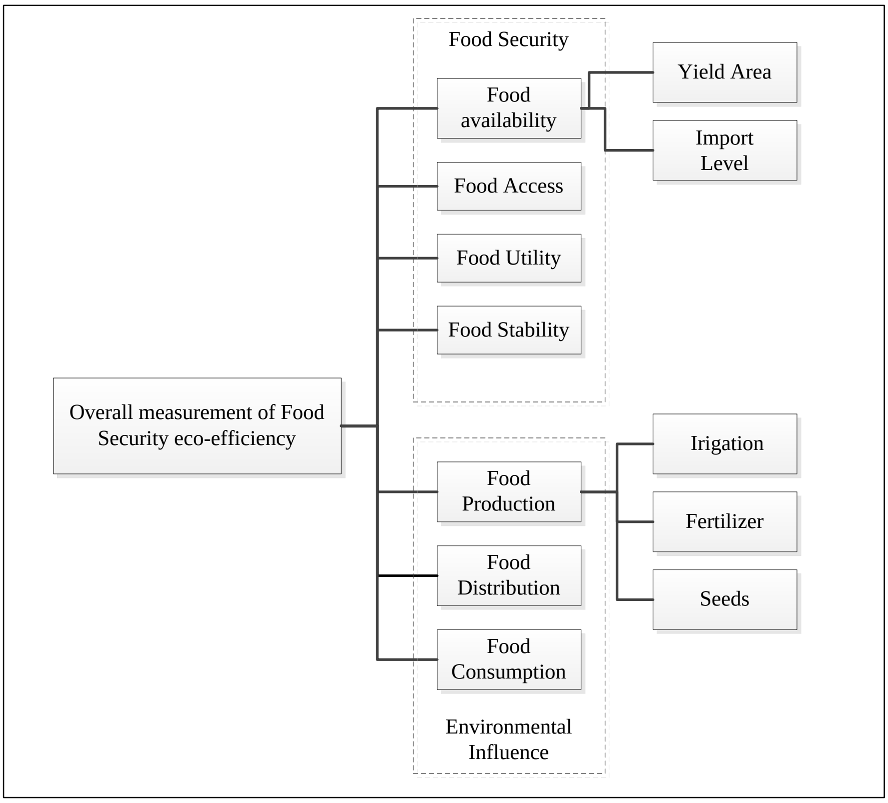

Figure 3. Food Security Eco-efficiency Deployment

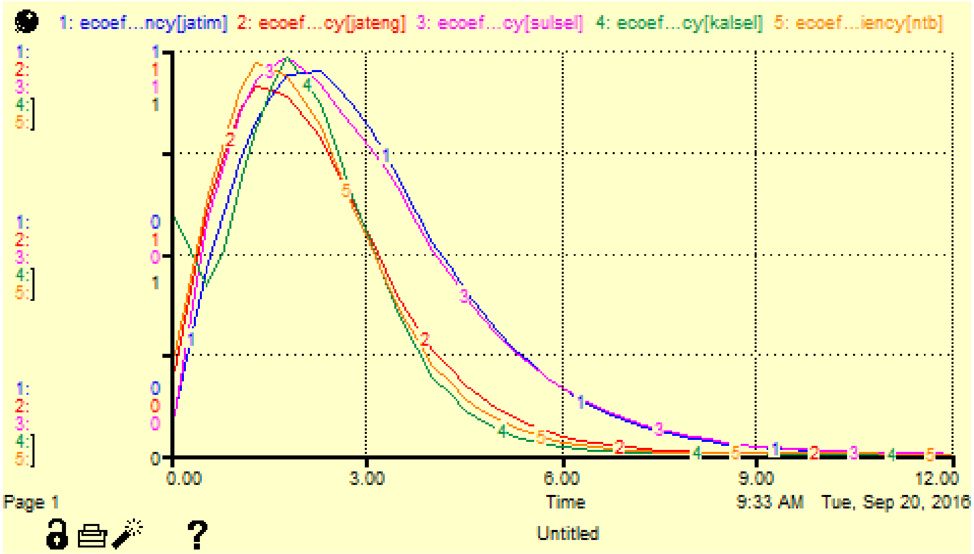

Figure 4. Eco-efficiency after simulation

6. Conclusion

This paper objective is to develop a eco-efficiency for sustainable food security measurement. Eco-efficiency of sustainable food security needs system dynamic combining to cope with complexity, time dependent and dynamic system that can't be cope by ordinary performance measurement. The use of system dynamic supports identification of intervention actors of system that can be used to be the indicator of measurements beside the standard indicators

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