Concept of Sustainable Agriculture and Its Link to Agroforestry System

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Abstract

The paper reviews previous studies emphasizing on sustainable agriculture, in terms of its history, dimensions, and indicators; and its link with agroforestry. Promoting economic viability, social welfare, providing food for satisfying human needs and enhancement of natural environment are the prime focuses of sustainable agriculture. Several indicators are used to assess these economic, social and environmental aspects of sustainable agriculture. This paper initiates the idea of application of indicators of sustainable agriculture in analyzing sustainability of agroforestry system. The concept of agroforestry system is consistent with the concept of sustainable agriculture in terms economic viability and being socially and ecologically sustainable. This idea being a novice approach is not sufficiently developed for application and thus encourages further studies in developing methodologies focusing on inter relation of indicators, for selection of indicators so as to analyze sustainability of agroforestry system. However this paper finds agroforestry system of being capable of leading to sustainable agriculture, should be promoted through decentralized planning and implementation of strategies. This can lead to development of sustainable agriculture in developing countries including Thailand.

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Introduction

Sustainable agriculture has found its place in various literatures for ages. Various definitions with various background assumptions have been proposed regarding sustainable agriculture. For example, "Agricultural sustainability must be defined with respect to the systems, rather than inputs or crops, as crop varieties and inputs produce nothing in isolation, but when combined as components of a system they produce output. Sustainability is the result of the relationship among inputs, technologies and management" (Lynam & Herdt, 1989). While Harwood (1990) defined sustainable agriculture as "a system that can evolve indefinitely towards greater human utility, greater efficiency of resource use and a balance with the environment which is favorable to human and most other species." Furthermore, Sustainable Agriculture Initiative (2003) defined sustainable agriculture as "an agricultural system that is efficient, competitive and productive but at the same time protects and improves the environment and the ecosystem, while maintaining the conditions of socio-economy of the local communities and also maintains human dignity". Various literatures have established indicators for measurement of sustainable agriculture and these indicators over time have defined this concept from various viewpoints such as that of productivity, utility, efficiency, continuity etc. Agricultural sustainability indicators play an important role of providing valuable information for policy makers and thus guide them in decision making, monitoring and evaluation.

Agroforestry is relatively a new nomenclature for a set of old practices involving two or more species of plants or combining plants

and animals. Simple practices of shifting cultivation ranging to complex hedgerow intercropping systems in the humid tropics are also denoted as agroforestry (Nair, 1993). Diversification in agriculture by shifting from specialized cropping and monoculture to various crop and animal production is a very common process in the humid tropics (Ruthenberg, 1971; Harwood, 1979). Diversification is recognized for its role to spur sustainable growth in the rural sector, and the extent of its sustainability effects and the gains in the more complete utilization of resources in a diversified form is more visible than in a monocrop production system (Barghouti, et al., 2004). Increased diversity of crop or animal species is a strategy frequently associated with sustainability (Hansen, 1996; Ellis, 2000). Diversification helps to minimize the technical and economic risks associated with monoculture (Kasem & Thapa, 2011). On-farm diversification also thrives upon strategic complementarities among activities, such as integration among different crops, crop-livestock integration, and the like (Barrett, et al., 2001). However there is a lack of literatures dealing with the use of sustainable agriculture indicators for analyzing the sustainability of agroforestry system. It is challenging to determine which of the indicators of sustainable agriculture can monitor and model agroforestry system in a sustainable way. The main objectives of the paper are to review the concept of sustainable agriculture in terms of history, dimensions and indicators, and to explore the usefulness and relevance of sustainable agriculture indicators to analyze sustainability of agroforestry. To achieve these objectives, it succinctly reviews international and Thai recommendations on sustainable agriculture in terms of history, dimensions and indicators, and scans the existing literatures for the state of knowledge on agroforestry system for linking it to sustainable agriculture.

This paper consists of three parts. The first part reviews and presents a brief history of sustainable agriculture in international and Thai contexts. It then moves to a discussion of the dimensions and indicators of sustainable agriculture. The second part analyzes the use of the sustainable agriculture indicators to analyze the sustainability of agroforestry system. The last section concludes the reviews in the preceding sections.

Sustainable Agriculture

History of sustainable agriculture in international and Thai contexts

The concept of sustainability has been associated with agricultural policy, agricultural science and farming practices for a long time through the years. Sustainable Agriculture has played a role not only in the theory but also in the practice for hundreds of years till the middle of 19th century in English agriculture (Peters, 1979). In the 19th Century, the vegetarian and the back-to-the-land movements in the USA developed concepts of appropriate production practices, different kinds of communities to support and also to be supported by, through the development of sustainable systems (Peters, 1979). Since as early of 20th century, members of UK's medical community had conducted clinical research experiments on the subject of connection among soil condition, food quality, and human health (MacRae, 1991). This research is considered yet another important historical influence of importance on the development of sustainable agriculture. Besides, several agreements at international levels, such as Chapter 14 of Agenda 21, have focused on the promotion of sustainable agriculture and rural development and highlight the linkages of objectives at the social, environmental and economic level. Another example is that of the Commission for Africa, which had considered "Agriculture as the Key

to Africa". The lessons learnt from the Green Revolution in the Asia and Pacific region indicated resource degradation in terms of the groundwater quality owing to overexploitation, increased soil salinity due to excessive use of chemicals, and quality of drinking water being exposed to arsenic poisoning in some communities (Food and Agriculture Organization, 2006b). This adversely impacted agriculture and led to reduced grains production in consideration of the area concerned being considered for long-term sustainability for wheat production in the country and the region as a whole (Food and Agriculture Organization, 2006a). In view of this, many developed nations and their agro-environmental policy reforms have been stressing on promotion of sustainable agriculture and rural development. In the similar line, the members of the European Union have formulated the "Agenda 2000" incorporating the objective of integration of environmental goals into the common agriculture policy. The "Farm Bill" formulated in 1996 by the United States of America aimed at strengthening of Conservation Reserve Programs by reducing soil erosion and water pollution. In 1997, Canada also formulated its "Agriculture in Harmony with Nature" strategy with the view of promoting environmentally sustainable agriculture and agro-food (Kasem, 2010).

In Thailand, the government has been promoting export-oriented cash crop monoculture practice since 1960. In order to increase the productivity, intensive use of agricultural machines, chemical fertilizer, herbicides and insecticides, have been spread all over the country. After two decades, the problems from these intensive uses of chemicals and machinery have started appearing in 1980s. The problems were, for example, worse soil condition, lower productivity, farmers' debt due to a purchase of chemical fertilizers and herbicides, as well as, health damages from intensive use of herbicides and insecticides (Shozo &

Toushirou, 2006). Export-oriented agriculture is practiced by both small and large-scale farmers in Thailand and on the other hand small-scale farmers serve the domestic market and their own consumption. For these the poor farmers are the ones, who have to rely on unstable rainfall (Isarangkun & Pootrakool, 2009). In addition, Farmers previously practiced monoculture but as the prices of inputs such as chemical fertilizer, herbicide and insecticide increased, they financed money to invest more by making a loan (Jitsanguan, 2001). Due to declining agricultural products' prices, they could not pay back their loans. Besides, there were also a certain number of farmers, who experienced health damages from using herbicides and insecticides, and who once came to work in the city but under many circumstances, they were forced to go back home in the rural areas (Jitsanguan, 2001). The concept of sustainable agriculture in Thailand was first created to help these people. Nevertheless, there is no unique method for all regions or all countries. Each country has to find its own way to attain sustainable agriculture itself under its ecological, economic, and social conditions (Kazutake, 2005). Even though, the Philosophy of Sufficiency Economy, bestowed by His Majesty the King Bhumibol Adulyadej, to the people of Thailand in 1974, it was in practice applied to real terms after the economic crisis in 1997. Post 1980s, the government and various NGOs started promoting to encourage farmers in switching from conventional mono-cropping to diversified cropping systems, and also to engage in production of high value products such as livestock, fisheries and fruits (Kasem, 2010). With an emphasis more on a balanced, holistic and sustainable development approach, this philosophy of Sufficiency Economy and crop diversification have encouraged the Thai government to change the agricultural development direction to the objective of achieving sustainability.

Dimensions and indicators of sustainable agriculture

Sustainable agriculture can be defined through three different, although interrelated dimensions (Barnett, et al., 1995): 1) Biological/ physical: This dimension can be reflected in the physical quantity of agricultural output that again depends on the physical quantity of input and biological growth processes. The declining trend in the quantity of agricultural output can be attributed to degradation of the resource base caused by erosion, water logging, soil structure destruction, pests and plant diseases and climate change etc. 2) Economic: The economic dimension can be reflected through the value or prices at which the agricultural products or outputs are sold in the market. Even though the agricultural physical output remains constant over time, the surrounding economic environment can lead to the failure of the system because of declining agricultural product prices, increased input costs and other related economic changes. 3) Social: The social dimension can be reflected in the capacity of governmental or non-governmental organizations and policy makers in adequately supporting farming communities. The sustainability of an agricultural system depends on the human capital engaged in farming; and poor agricultural policy, changing labour conditions, insecure land tenures can lead to inefficient and non-sustainable agricultural systems. This is consistent with Shiva and Bedi (2002) who viewed sustainable agriculture to be based on the use of natural resources in a sustainable way. According to them, the usage of natural resources in a sustainable way calls for the ownership and resources' control to lie with decentralized agricultural communities that in turn is capable of generating livelihoods, can arrange provision for food and also conservation of natural resources. They put forward ecological, livelihood and food security as three different dimensions to be the most essential requirements for a sustainable and equitable agriculture policy.

Establishing indicators for sustainable agriculture measurement are a combination of many ideas and interests of different stakeholders (policy makers at the national or local levels, local people, community-based organizations, the private sectors, government and non-government organizations, scholars and experts, interest group, etc.) having different views as to the priority of indicators. Many stakeholders have developed different indicators that can finally be considered as a part of a more comprehensive set of indicators for sustainable agriculture. Many researchers have defined indicators of agricultural sustainability and some of them are reviewed for this research work: Barbier (1987) put forward biological productivity, enhancement of equity, genetic diversity, participation and social justice as indicators for economic development of sustainability in the nature to be relevant for the Third World. For example, in a rural setting, increase in productivity of agro-ecosystem and its equal distribution among people are considered as sustainable. Simon (1989) defined certain performance indicators of agro-ecological systems based on his review of sustainability and considered sustainability as the central focus for linking of the physical environment to human activity of local in nature and further to a political economy in wider sense. According to him an effective and tenure system can reflect social equity.

Brklacich et al. (1991) introduced certain indicators in assessing sustainable food production system. They emphasized on the perspectives of environmental accounting and carrying capacity. Environmental accounting refers to agricultural productions' biophysical limits, and carrying capacity represents the supported maximum population level on a continued basis. Viability of production and sustained yield's perspectives were drawn upon resources' economic views, which basically refer to output levels that are maintained on a continuous basis and also

primary producers' ability to continue agriculture, respectively. Security and supply of product primarily focused on food supplies' adequacy. Equity concerns with the foresight and effectiveness of distribution of derived products from resource use. Certain important indicators for sustainability assessment of farming practices in Australia were put forward by Smith & MacDonald (1998). According to them, profitability in terms of net farm income and total production are very important economic indicators for agricultural sustainability. Trends in land and water use were studied as environmental factors affecting agricultural production in the long run. They viewed maintaining biodiversity, declining soil loss, replacement of nutrient, efficiency enhancement of water use etc. as potential challenges pertaining to sustainability.

The framework for evaluation of sustainability was studied by Chantalakhana (1994). The framework approach involved assessment of ecological, economic, and social indicators as tentative indicators of sustainability. He defined agricultural sustainability indicators from environmental point of view, based on the soil quality and quantity, water quality and quantity, weather, biodiversity, and conservation measures used such as for reducing soil erosion; from economic point of view; he defined agricultural sustainability based on net farm profitability, efficiency of input, diversity of income, proportion spent on food, livestock population, and subsidy/financial support from government; from the point of view of social terms, he defined indicators such as adoption of conservation practices, land tenure, and labor: availability of farm labor and time spent on farm operation. On similar grounds, Barnett et al. (1995) defined agricultural sustainability indicators from environmental point of view, based on the TFSP (Task Force on Seasonal Prediction) trends and climate change trends due to external factors; from economic point of

view; they defined agricultural sustainability based on profitability on selling of agricultural products, other economic factors influencing costs of input and fluctuation in output prices, besides they considered the education and experience of farmers as an indicator on economic terms; from the point of view of social terms, they defined indicators such as meaningful lifestyle, migration patterns of farmers and condition of community life.

According to Zhen & Routray (2003), in the developing countries, the agricultural sustainability indicators are divided into three dimensions. These indicators were defined from environmental point of view, based on amount of fertilizers/pesticides used per unit of cropped land, amount of irrigation utilized per unit of cropped land, soil nutrient content, depth to ground water table, quality of ground water for irrigation, water use efficiency, and nitrate content of ground water and crop; from economic point of view; they defined agricultural sustainability based on crop productivity, net farm income, benefit-cost ratio, and per capita food grain production; from the point of view of social terms, they defined indicators such as food self-sufficiency, equality in income and food distribution, and access to resource and support service. Similarly, Muangkaew (2006) studied sustainable livelihood of rice based farming system in Southern Thailand. She introduced agricultural sustainability indicators from environmental point of view, based on soil fertility management, water use management, and pest/disease management; from economic point of view; she defined agricultural sustainability based on productivity, profitability, farm efficiency, and distribution of household income; and from the point of view of social terms, she defined indicators such as food security, accessibility to agricultural information, agricultural marketing services, and farmer organizations.

In the same line, Chowdhury et al. (2006) identified sustainability assessment indicators for shrimp farming system. Sustainability indicators from environmental point of view were defined as water/effluents and soil quality, land use pattern, salinisation, and biodiversity; from economic point of view were productivity, profitability, stability, wealth creation, and international competitiveness; and from the point of view of social terms were employment opportunity, food security, knowledge, equity , and social acceptability.

The above review indicates that agricultural sustainability assessment has been applied in various studies and researches. Several indicators that have been reviewed can be summarized in Table 1.

Table 1 Sustainability indicators: theoretically proposed and practically applied

Sources	Environmental	Economic	Social
Barbier (1987)	- Genetic diversity	- Increased productivity	- Equity enhancing - Social justice - Participation
Simon (1989)	- The species of crops kept - Land carrying capacity	- Yield	- The productive technology used - The land tenure system
Brklacich et al. (1991)	- Environmental accounting - Carrying capacity	- Sustained yield - Production viability	- Product supply and security - Equity

Chantalakhana (1994)	- Soil quality and quantity - Water quality and quantity - Weather - Biodiversity - conservation measures used	- Net farm profitability - Efficiency of input - Diversity of income - Proportion spent on food - Livestock population - Subsidy/financial support from government	- Adoption of conservation practices - Land tenure - Labor
Barnett et al. (1995)	- TFSP trends - Climate and external trend	- Profitability - Education and experience of farmers - Flexibility of the system - Macroeconomic trends	- Meaningful lifestyle - Effects on community life - Migration patterns
Smith & McDonald (1998)	- Land capability - Nutrient balance - Soil erosion - Use of fertilizers/ pesticides - Water use efficiency	- Production cost - Production price - Net farm income	- Access to resources - The skill and knowledge base available of farmers - Public awareness of conservation - Planning capacity of farmers

Zhen & Routray (2003)	- Amount of fertilizers/pesticides used per unit of cropped land - Amount of irrigation water used per unit of cropped land - Soil nutrient content - Dept to ground water table - Quality of ground water for irrigation - Water use efficiency - Nitrate content of ground water and crop	- Crop productivity - Net farm income - Benefit-cost ratio - Per capita food grain production	- Food self sufficiently - Equality in income and food distribution - Access to resource and support services
Muangkaew (2006)	- Soil fertility management - Water use management - Pest/disease management	- Productivity - Profitability - Farm efficiency - Distribution of household income	- Food security - Accessibility to agricultural information - Agricultural marketing services - Farmer organizations
Chowdhury et al. (2006)	-Water/effluents and soil quality - Land use pattern - Salinisation - Biodiversity	- Productivity, Profitability - Stability - Wealth creation - International competitiveness	- Employment opportunity - Food security - Knowledge - Equity - Social acceptability

Sustainable Agriculture and Agroforestry System

Agroforestry is a system of low external-input and combines trees with crops at varied sequences or combination. The concept of low external-input sustainable agriculture (LEISA) is also related to sustainability of agriculture that is applicable to farmers at the subsistence level, as requirement for capital is almost nil for provision of external inputs that are expensive (Ong, et al., 2007). This is also consistent with the findings of Jitsanguan (2001). LEISA believes in integration of various components related to farm such as crops, trees and livestock so as for optimization of the usage of resources and in turn for achieving long term stable and adequate production of essential commodities in a sustainable way (Reijntjes, et al., 1993). Agroforestry system is the production of trees along with a variety of crops and animals in the same area. These crops can be grown together simultaneously, or in rotation to one another, or even can be grown in separate plots of lands as long as material from one are beneficial to the another. Agroforestry integrates trees, plants and animals in system of long term conservation and production and makes maximum use of land (Somboonsuke, et al., 2011). With the decrease of the sizes of land holding at an average, farmers with small land holdings are now unable for allocation to trees and crops for separate areas. Amidst these situations, practicing agroforestry with the integration of trees along with lands for crops bear potential for provision of possible opportunity for use of land in order to achieve sustainability for the smallholders, at the same time supplying fuel and other tree products. Systems such as silvopasture, windbreaks, alleycropping, forest farming for non-timber forest products, and riparian buffer strips are part of agroforestry. Farmers generally practice agroforestry in view of reasons such as; enhancing stability in terms of economic factors and efficient use of natural resources (Beetz, 2002).

One main objective of agroforestry is optimizing efficiency for the use of natural resources (Ong et al., 2007). Benefits of agroforestry systems include the provision for diverse products and services. For example, integration of trees in a farm along with the other crops generate sources of income in addition to the income from crops since trees can provide products such as timber, nuts, fruits and also carbon credits, thus bearing the potential for creating significant amount of income (Ong et al., 2007). Additionally, integrating trees can create spreading of farm labor all throughout the year, and hence increases the productivity of the other crops (Beetz, 2002); and thus can lead to soil and water resources conservation and also improve food security scenario (Ong et al., 2007).

Pandey (2007) stated that there is a need for land use options that enhance livelihood security and reduce vulnerability to climate and environmental changes. Resource management adaptations such as agroforestry systems essentially improve livelihoods by producing food, firewood and fodder at the same time, and also mitigate climate change impacts. Pandey (2007) also studied the benefits of multifunctional agroforestry systems on livelihoods improvement in India and mentioned that such systems contribute ecologically, socially and economically. Agroforestry systems in India aid in biodiversity conservation; augmentation of storage of carbon in agroforestry; enhancement of soil fertility; provision of goods and services for the society and thus overall well-being of the people of the society. Also Reyes (2008) studied agroforestry systems pertaining to sustainable livelihoods in Tanzania and cited that households who practice agroforestry systems earn an annual gross income which is twice the income from farming practices that are traditional and also can earn net income that is 13 times higher than the income from traditional farming practices. Apart from incomes being higher with the use of agroforestry,

it also provided food security. Moreover, agroforestry systems can aid in limiting losses of nutrient to very minimum levels and also bear the potential of enhancement of certain nutrients in the soil and increase the biological diversity of production systems. In the long term, agroforestry potentially can aid in alleviation of poverty and development of the rural people and areas and thus leading to sustainable livelihoods of farmers. Significance of multilayered agroforestry system on sustainable agriculture was mentioned by Rahim et al. (2007). They stated that multilayered agroforestry provides fruits, fuel wood, timber and various agricultural products as well as restores the equilibrium in the ecosystem and contribute to agricultural conservation and poverty reduction. The importance of multilayered agroforestry system in reducing poverty level through sustainable land use, efficient utilization of natural recourses, maintaining biodiversity, enhancing generation of income and opportunity for employment for the rural youth and women was addressed in this paper. Agroforestry systems integrate crops, livestock, trees and shrubs. Integrating livestock with trees put forward various benefits such as diversification of sources of income, enhanced production from biological sources etc. (Beetz, 2002). Farming systems that are mixed, produce various products and contribute to reducing risks and are more productive than farming systems based on either animals or crops. One noted benefit of crop-livestock production systems is that of the feeding of livestock on residues from crop and other products, which would otherwise have posed as a problem of waste disposal of major concern. As for example, damaged fruits, straw, grains and wastes from households can be food for livestock (Fakoya, 2007). As in the case of crop – livestock production systems in Nigeria, Fakoya (2007) stressed more in the practicing of crop – livestock production systems for achieving sustainable agriculture. The

results revealed that utilization of crop – livestock production systems resulted in extra income through sales, sustained food and enhanced soil fertility. Increased interest in utilization of crop-livestock production systems was emphasized and suggested to be promoted because of its beneficial outcomes.

In case of rubber production, rubber that is grown along with secondary forest was termed as jungle rubber (Penot, 2004) or rubber agroforestry. From the viewpoint of environmental conservation, jungle rubber play the role of prime reservoir for biodiversity for the areas of disappearing forest and rubber jungle has positive value with good hydro-orology characteristics, resistance to erosion and enrichment of plant biodiversity (Penot, 2004). As compared to other systems of land-use such as coconut, oil-palm, cocoa, coffee, or pulp trees; rubber agroforestry systems can better maintain biodiversity. Yet another prime benefit of combining rubber with trees lies in diversification of income and this in consistency with Sonboonsuke et al. (2011) also. Moreover, the jungle rubber system is a low-input agroforestry system in which unselected rubber competes with the re-growth of the natural forest, thus providing more flexibility for changing systems. The system is not expensive and demands less labor to establish and maintain. Moreover, agroforestry provides farmers with many options for market adaptability and to their own needs (Penot, 2004). As evident from the above discussion, agroforestry has led to development and promotion of sustainable agriculture. The above review indicates (Table1) the application of agricultural sustainability assessment in various researches and studies. Several indicators that have been introduced to produce common indicators for analyzing sustainability of agroforestry system from environmental point of view based on biodiversity, efficient use of natural resources, and conservation of natural resources; from

economic point of view based on productivity, net farm income, and diversity of income; and from the point of view of social terms, indicators such as food security and employment opportunity were defined. Hence, analyzing of the role of agroforestry system in sustainability of agriculture can be summarized in to three dimensions of sustainable agriculture as follows:

Biological/ environmental dimension

Agroforestry system is consistent with the concept of sustainable agriculture in terms of environmental issues. Biodiversity, efficient use of natural resources, and natural resources conservation are the environmental indicators. Biodiversity in agroforestry system lead to achievement of environmental sustainability by restoring the equilibrium in the ecosystem. One of the prominent objectives of the agroforestry system that addresses the issues of efficient use of natural resources depletion is sustainable agriculture. Integration of various components in agricultural production leads to optimization of the usage of resources. Agroforestry system practices natural resource conservation through enhancement of soil fertility by providing natural fertilizer for the soil while small plants help retain moisture.

Economic dimension

Productivity, net farm income, and diversity of income are economic indicators. Agroforestry system based on integration of various productions potentially lead to increased benefits from economies of scope by spreading farm inputs and moreover different farm activities complement each other to reduce unit cost, hence increase farm productivity. In general, the types of crops or animals in the monoculture system will depend on the expected market demand and price. Thus, there is always the risk of excess supply and decreasing prices. Agroforestry system based on multiple

types of production potentially not only increase net farm income but also increase source of income and thus lead to reduced risk and uncertainty from a supply surplus and falling prices.

Social dimension

Food security and employment opportunity are social indicators. Combination kinds of plants, especially food plants like rice, vegetables, and fruits, help in achieving long term stability and adequate production of essential commodities. At the community level, several contexts of agroforestry system can be applied to alleviate poverty. It encourages communities to employ rural youth and women.

Application of the agroforestry system emphasizes on long run sustainable development rather than short run high growth. This has been a development that has embraced agricultural development with the support of strong environmental, economic and social sustainability.

Conclusions and Implication

From ages across the globe people have thrived for appropriate production practices linking soil condition, food quality and human health so as to achieve sustainability. Several international agreements have also focused on the promotion of sustainable agriculture and rural development in achieving sustainability at social, environmental and economic level. In Thailand, the concept of sustainable agriculture was initiated to help farmers who suffered from export oriented monoculture practices. The philosophy of Sufficiency Economy bestowed by His Majesty the King of Thailand along with the promotion of crop diversification also encouraged agricultural development in achieving sustainability.

Sustainable agriculture is an agricultural system's ability in maintaining production for satisfying human needs even in the events of difficulties related to ecology, economic pressures and social anomalies. Several indicators have been used to assess the social, economic and environmental dimensions of sustainable agriculture. An appropriate set of indicators should be based on valid criteria such as that of reliability, relevance, feasibility and coverage. These valid criteria would ensure the quality of data and thus determining the quality of the indicators and analyzing on which they are based. The aggregation of these indicators into groups and sub groups largely depend upon the use to which it is put.

Agroforestry is a system of low external-input related to sustainability of agriculture in terms economic viability and ecological and social sustainability. This study initiates the idea of application of indicators of sustainable agriculture in analyzing the sustainability of agroforestry system. It can be analyzed from environmental point of view based on biodiversity, efficient use of natural resources, and conservation of natural resources; from economic point of view based on productivity, net farm income, and diversity of income; and from the point of view of social terms, based on food security and employment opportunity. Even though this idea is initiated from review of previous studies, it is not sufficiently developed for application and thus encourages further studies to develop methodologies for selecting indicators to analyze sustainability of agroforestry system. Previous studies along with this paper have focused on selection criteria that are typically applied to indicators individually and have not focused on inter relation of indicators. This paves the way for methodologies to be developed to put a set of indicators at the heart of the selection process and not individual indicators, thus focusing on inter-relation of indicators.

Causal chain networks can facilitate in identifying relevant indicators in regards to specific problem location or domain. This will in turn lead to a set of powerful, efficient and transparent indicators. Indicators initiated in this paper for analyzing sustainability of agroforestry system may not be sufficiently developed enough but still the paper guides a way of achieving sustainable agriculture through agroforstry. Agroforestry system being of multifunctional values and if are promoted through planning and implementation of strategies in a decentralized way, bear the potential for paving the way for sustainable agriculture development in Thailand and also in other developing countries.

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