Chapter II

Review of Literatures

This chapter discusses literature, which related on the study. At the beginning of the chapter concern on definitions, which related to the study. End part of this chapter is devoted to elaborate methods that are used in the study using previous research and empirical works.

2.1 Sustainable development

Sustainable development is a term that has come in to widespread use in the last decade. Many scholarly disciplines have some thing to say on the topic, each from their own field. Therefore, it should have some clear cut definition to avoid confusion for people. World Commission on Environment and Development (1987) defined sustainable development is "meet(ing) the needs of the present without compromising the ability of future generations to meet their own needs". Hear they concern about human welfare through multigenerational time and paid attention to particular resources. A particular resource may be thought essential for production of consumption good, for direct consumption by human, for fulfillment of aesthetic or spiritual need or reasons independent of human valuation.

Davis (2000) emphasized same idea; sustainability is "rests on the principle that we must meet the needs of the present without compromising the ability of future generations to meet their own needs. Therefore, stewardship of both natural and human resources is of prime importance. Stewardship of human resources includes consideration of social responsibilities such as working and living conditions of laborers, the needs of rural communities, and consumer health and safety both in the present and the future. Stewardship of land and natural resources involves maintaining or enhancing this vital resource base for the long term".

In the development process agriculture play vital role in a country. Agriculture and utilization of natural resources are closely related; consequently, word of sustainable agriculture has become a high priority in scientific research and on policy agendas.

2.2 Sustainable agriculture

Sustainable agriculture has been given a number of different definitions like sustainable development, but the term implies three basic values: sustainable agriculture is ecologically sound, economically viable, and socially just and humane. In term of agriculture technology, the major components of sustainable agriculture are cultural practices and plant breeding, soil and water management, non-chemical pest and weed control, integrated plant – animal production and nutrient recycling (Huang, 1995). Sustainability of agriculture in the context of development efforts has to meet production efficiency, resilience of ecological aspects, appropriate technology, maintenance of the environment, cultural diversity, and satisfaction of the basic needs (Praneetvatakul *et al.*, 2001). Agriculture activities on the interface of two complex, hierarchically organized systems: socioeconomic and natural ecosystem (Conway, 1987). This implies that in any analysis of define farming system one will always find legitimate and contrasting perspectives with regard to the effects of changes in the system. When intensify the production (return) can be coupled with more stress on ecological system. When dealing with issue of sustainability, a correct assessment of agricultural performance should be based on an integrated analysis of trade–offs rather than on the use of isolated analysis. Therefore, before analysis the agricultural system we have to know about component of sustainability of the agricultural system.

Agricultural sustainability encompasses biophysical, economic and social factors operating at the field, farm, and watershed, regional and national scales (Smith and McDonald, 1998).

The changes in agriculture, included by new policies or technical innovation, are unlikely to result in absolute improvement on all stake-holders and social actors involved, nor in absolute improvement on all scales (soil, farm field, watershed, regional, global) on which the (side-) effects of agriculture production can be described. Hence "correct" assessment of agriculture performance should best be based on analysis of trade- offs that reflect the various perspectives, both positive and negative, with regard to the effects that a proposed technological or policy change will induce on the various scales and actors involved (Pastore and Giampietro, 1998).

Multi-criteria approaches tackle sustainability issues at different levels of aggregation (Plot, farm, landscape, state, nation, global) subject to the decision problem, which is handled. At each level, different units of analysis, agro-technical possibilities and constraints have to be taken into account.

Different perspectives, related to different hierarchical levels of analysis, should be used when discussing technological changes in agriculture. In fact, technological choices are affected by: (I) the characteristics of the socioeconomic system to which the farming system belongs; (ii) the characteristics of the ecosystem managed for agricultural production; and (iii) the farmers' feelings and aspirations (Giampeietro, 1997).

2.3 Sustainability assessment

2.3.1 Sustainability indictors

For any study on sustainable agriculture, the question arises as to how agricultural sustainability can be assessed. Indicators of agricultural sustainability can be perceived at several levels, depending on the scale at which evaluations are made. Apart from different scales of indicators may also differ in the directness of measurement, and the time scale of operation (Smith and McDonald, 1998).

According to studies many indicator sets and frameworks for sustainable agriculture have already been presented in past.

Rasul and Thapa (2004) assessed sustainability of ecological and conventional agricultural system in Bangladesh using 12 field level indicators. Ecological sustainability was assessed by based on five indicators: land use pattern, cropping pattern, soil fertility management, pest and disease management, and soil fertility status. Economic sustainability was assessed by land productivity, yield stability and profitability from staple crops. Social sustainability was assessed by input self-sufficiency, equity, food security, and risk and uncertainty.

Ferraro *et al.* (2003) field scale indicators were developed to evaluate the effects of pesticides and tillage on agro mixed cropping systems in Argentina. The proposed indicators require four input variables: number and type of applied pesticides, rate of applied pesticides, number and type of tillage tools, and land capability class of each field. In regards to pesticide impact, the indicators consider the toxicity effects on mammals and insects, while the tillage impact is evaluated taking into account the effects of different tillage operations on the retention of crop stubble on the soil surface, and the stability of soil aggregates. Two overall outputs were obtained: pesticide index and tillage index. The developed indicators were used to compare the potential environmental effect of current practices carried out in Inland Pampa (Argentina).

Different perspectives, related to different hierarchical levels of analysis, should be used when discussing technological changes in agriculture. The agricultural in put per hour of labor and per hectare obtained at farm level is evaluated against two sets of indicators characterizing the constraints coming from societal and ecological sides. Economic growth pushes for increases in the intensity of the in put 'per hour of labor' and 'per hectare' at the farm level (two indicators, namely socioeconomic and demographic pressure, are proposed to assess this effect). The need of maintaining ecological compatibility generates a contrasting pressure pushing for keeping as low as possible the intensity of input in the agro ecosystem. A family of indicators (the ratios of 'current environmental loading and critical environmental loading) is proposed to assess such a pressure. Feelings and aspirations of farmers determine the acceptability of compromises, at the moment of technological choices, after considering the severity of these two pressures. Plan 'productivity per hour' and 'productivity per hectare' can be used to study technological changes on societal level and farming system level (Giampietro, 1997).

Pacini *et al.* (2003) utilized field level indicates to evaluation of sustainability of organic, integrated and conventional farming systems. They used a set of financial indicators and environmental indicators. Financial indicators: gross margins including revenues from production, compensation and agric-environment payments, costs of fertilizers and pesticides, maintenance costs of ecological infrastructures (surface drainage system and hedges) and other variable costs. Environmental indicators: nutrient, erosion, pesticide and biodiversity indicators.

Praneetvatakul *et al.* (2001) developed specific indicators to assess agriculture sustainability for their study under different criteria for household and village level (Table 2.1).

Table 2.1 Sustainability indicators of agriculture at household and village level

Environment indicators	**Economic indicators**	**Social indicators**
Soil erosion Water shortage Health impact from	Productivity of rice Land size Farm labor	Land tenure Education Food sufficiency

Sources: Praneetvatakul *at el.*, 2001

According to the literature common feature of the indicator selection for sustainability assessment, selected indicators were field specific. Although, many indicators have been developed they do not cover all aspects on sustainability. Moreover, due to variation of biophysical and socio economic conditions, indicators used in one country are not necessarily applicable to other country (Rasul and Thapa, 2003).

2.3.1 Normalization of indictors

When assess the overall sustainability of the system it should be addressed all disciplines which regard the sustainability. Difficult tasks are how we sum up and get final value for overall sustainability for given system. How we give the priorities for each indicator. Indicators in different criteria have different units and measurement. Therefore, before combined the indicators to quantify the overall sustainability, indicators should be normalized

Malczewski (1999) suggested "score range procedures" to normalize the multi scale attributes. Following formula was used to normalize the multi criteria indicators

$$x'_{ij} = \frac{x_j^{max} - x_{ij}}{x_j^{max} - x_j^{min}}$$

Where; x'_{ij} is normalized value for i object and j attribute, x_{ij} is raw vale for i object and j attribute, x_j^{max} - x_j^{min} is range of the given criterion. The major advantage of this method is that the scale of measurement varies precisely between zero and one for each criterion. The worst normalized score is always equal to zero, and the best score equal to one.

Some past studies used "score range procedures" to normalize multi criteria indicators.

Krajnc and Glavic (2005) developed composite sustainability index to compare companies performance considering dimension of economic, environment, and societal in their study. They normalized their indicators using below formula.

$$I_{nj} = \frac{I_{aj} - I_{\min j}}{I_{\max j} - I_{\min j}}$$

Where I_{nj} is normalized indicator value, I_{aj} is raw value of the indicator, and I_{MAX} and I_{min} are maximum and minimum values in the sample respectively. Here also normalized indicators scale is 0-1.

Allard *et al.* (2004) utilized to normalized indicator values for following formula on sustainability assessment of rehabilitation project in urban building.

$$I = \frac{I_i - I_w}{I_b - I_w}$$

Where, I is normalized indicator value, I_i is raw vale of the indicator, I_b and I_w are best value and worst value in the sample respectively in term of sustainability.

After normalization, sustainability indicators have no dimensions and are bounded zero to one.

After normalization, all indicators are in same scale. Now they can be aggregated to get one number to overall objective. Before aggregate the indicators, it should be weighted.

2.3.3 Aggregation of indicators

In order to aggregate all ecological, economic, and social impacts to a single target value of response measures for each option, the standardized and weighted performance scores should be added up along a hierarchical tree.

Malczewski (1999) proposed weighted sum method (weighted linear combination method) to spatial multi attribute decision making.

$$A = \sum w_i x_{ij}$$

Where A is overall score, w_i is weight assigned for i^{th} attribute, and x_{ij} is the score of the i^{th} alternative with respect to the j^{th} attribute.

The Weighted sum method is the most commonly used approach for aggregation multi criteria, especially in single dimensional problems (Pohekar and Ramachandran, 2003).

A common aggregation function that combines preference weights (wi) and criterion scores (x_i) is known as the suitability index S. Weighted linear combination is a common means of calculating the suitability index (Strager and Rosenberger, 2005).

$$S = \sum w_i x_i$$

Many studies in the past used weighted sum method to aggregate indicators for constructing sustainable index in different disciplines (Ugwu and Haupt, 2005; Mendoza and Prabhu 1999; Wirtz and Liu, 2005; Hermann *et al*. 2005; Strager and Rosenberger, 2005; Karydas and Gifunb, 2005; Krajnc and Glavic, 2004).

2.4 Analytical hierarchy process (AHP)

Sustainability is multidiscipline concept. Overall sustainability is consist different type of criteria and indicators. When calculate the overall sustainability of system theses different type of values must be added together. But problem is how each criterion or indicator contributes to overall sustainability of the system. This is a multi criteria decision problem. Therefore, relative important of each criteria and indicators are required. This usually achieved by assign weights to each indicator.

Many weighing methods were used in the past studies. Some used outside expert's idea some used local stakeholder perspectives to weigh the indicators.

Analytic Hierarchy Process (AHP) is a multiple criteria decision-making tool that has been used in almost all the applications related with decision-making (Omkarprasad *et al.*, 2004). AHP is a method where the objectives, attributes, or elements of a decision are formatted in a hierarchy and weighted according to the degree of preference the decision makers assign to each element.

2.4.1 Analytic hierarchy process (AHP) as decision making tool

Analytic Hierarchy Process (AHP), since its invention, has been a tool at the hands of decision makers and researchers; and it is one of the most widely used multiple criteria decision-making tools. Many outstanding works have been published based on AHP: they include applications of AHP in different fields such as planning, selecting best alternative and resource allocations. The specialty of AHP is its flexibility to be integrated with different techniques like Linear Programming, Quality Function Deployment, Fuzzy Logic, etc. This enables the user to extract benefits from all the combined methods, and hence, achieve the desired goal in a better way (Vaidya and Kumar, 2004).

To compare companies on relevant dimensions of sustainability, three dimensions of sustainability: economic, environmental, and social used and to determine weights of indicators, the pairwise comparison technique (AHP) was used according to their impact on overall sustainability assessment of the companies have been performed. A group of seven experts was put together to serve as the assessment team in order to determine relative weights of indicators (Krajnc and Glavic, 2005).

Assessment of agricultural ecosystems, determining the weight of each index in the index system is as important as establishing the index system itself for the assessment. The reason lies in that the performance of a system is a result of interactive of various factors but every factor plays its own role and makes different contribution to the system as a whole. In determining the weight of each of the indexes, AHP was employed to calculate the weights (Xiang *et al.*, 2005).

Integrated approach to the construction of socio-economic scenarios required for the analysis of climate change impacts on European agricultural land use. A stepwise down scaling procedure based on expert-judgment and pair wise comparison was presented to obtain quantitative socio-economic parameters (Abildtrup *et al.*, 2006).

To identify the high-priority areas for land conservation used stakeholder preferences with GIS data in a spatial multi criteria framework. Preference weights were measured using the Analytical Hierarchy Process (Strager and Rosenberger, 2005).

2.4.2 The AHP process

The AHP is a multi criteria decision-making technique, which decomposes a complex problem into a hierarchy, in which each level is composed of specific elements. The overall objective of the decision lies at the top of the hierarchy, and the criteria, sub-criteria and decision alternatives are on descending levels of this hierarchy (see Figure 2.1).

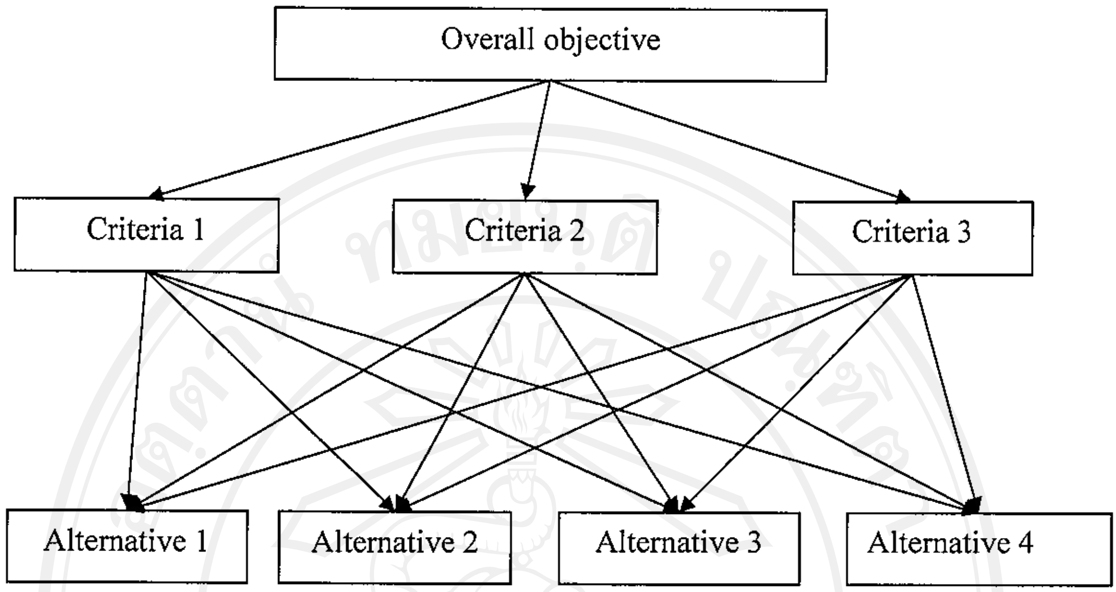

Figure 2.1 Hierarchical model for a problem

2.4.2.1 Assigning the pairwise comparison values

Once the hierarchical model has been structured for the problem, the participating decision makers provide pairwise comparisons for each level of the hierarchy, in order to obtain the weight factor of each element on that level with respect to one element in the next higher level. This weight factor provides a measure of the relative importance of this element for the decision maker. To compute the weight factors of n elements, the input consists of comparing each pair of the elements using the following scale set (Alphonce, 1996). Explanation of the scale is in Table 2.2.

$$S = \{1, 2, 3, 4, 5, 6, 7, 8, 9\}$$

Table 2.2 The nine point scale for pairwise comparison

Importance	Definition	Explanation
1	Equal importance	Two elements contribute identically to the objective
3	Weak dominance	Experience or judgment slightly favors one element over another
5	Strong dominance	Experience or judgment strongly favors one element over another
7	Demonstrated dominance	An element's dominance is demonstrated in practice
9	Absolute dominance	The evidence favoring an element over another is affirmed to the highest possible order
2,4,6,8	Intermediate values	Further subdivision or compromise is needed

Source: Alphonce, 1996

The pairwise comparison of element i with element j is placed in the in the position of a_{ij} of the pair wise comparison matrix A as shown below

$$A = \begin{bmatrix} a_{1,1} & a_{1,2} & \ldots\ldots & a_{1,n} \\ a_{2,1} & a_{2,2} & \ldots\ldots & a_{2,n} \\ . & . & \ldots\ldots & . \\ a_{n,1} & a_{n,2} & \ldots\ldots & a_{n,n} \end{bmatrix}$$

The reciprocal value of this comparison is placed in the position a_{ji} of A in order to preserve consistency of judgment. Given elements, the participating decision maker thus compares the relative importance of one element with respect to a second element, using the 9-point scale shown in Table 2.2. For example, if element one were strongly favored over element two, then a_{12} would be given a score of five. If the converse was true, element two was strongly favored over element one, then a_{21} would be given the reciprocal score of 1/5. The pairwise comparison matrix is called a reciprocal matrix for obvious reasons (Alphonce, 1996; Karami, 2005; Malladi and Min, 2004; Ananda and Herath, 2002).

2.4.2.2 Weight Computation

After construct reciprocal matrix, to calculate the weights for considered indicators column total of the reciprocal matrix are computed as follows.

$$\begin{bmatrix} a_{1,1} & a_{1,2} & \cdots\cdots & a_{1,n} \\ a_{2,1} & a_{2,2} & \cdots\cdots & a_{2,n} \\ \cdot & \cdot & \cdots\cdots & \cdot \\ a_{n,1} & a_{n,2} & \cdots\cdots & a_{n,n} \end{bmatrix}$$

$$a_{Tc1} \quad a_{Tc2} \ldots\ldots\ldots\ldots\ldots a_{Tcn}$$

Where:

A = reciprocal matrix

a_{Tc} = Column total

Once the column totals have been determined, the numbers in the matrix are divided by their respective column totals to produce the normalized matrix as follows:

$$A_{nor} = \begin{bmatrix} \frac{a_{1,1}}{a_{Tc1}} & \frac{a_{1,2}}{a_{Tc2}} & \cdots\cdots & \frac{a_{1,n}}{a_{Tcn}} \\ \frac{a_{2,1}}{a_{Tc1}} & \frac{a_{2,2}}{a_{Tc2}} & \cdots\cdots & \frac{a_{2,n}}{a_{Tcn}} \\ \frac{a_{1,n}}{a_{Tc1}} & \frac{a_{2,n}}{a_{Tc2}} & \cdots\cdots & \frac{a_{n,n}}{a_{Tcn}} \end{bmatrix}$$

A_{nor} = Normalized matrix

To determine the weights for consider indicators, the average of the various rows from the normalized matrix are calculated as follows.

$$\text{Row average} = \frac{\frac{a_{1,1}}{a_{Tc1}} + \frac{a_{1,2}}{a_{Tc2}} + \frac{a_{1,n}}{a_{Tcn}}}{N}$$

Where: N is number of element in the row

Finally, the normalized geometric mean of the rows will yield the relative weight vector (Alphonce, 1998).

After calculating the weights, consistency of the decision should be checked.

2.4.2.3 Checking consistency

The consistency ratio is the ratio of the decision maker's inconsistencies and the inconsistencies obtained from randomly generated preferences (Alponce, 1996).

The consistency ratio represents the degree by which a judgment follows the transitive property, i.e. if A is more important than B and B is more important than C, then A is more important than C. A consistency ratio equal to or less than 0.1 suggests that the comparison is consistent. The ratings resulting from the pairwise comparisons and deliberation and adjusted the ratings by way of additional iterations of deliberation and pairwise comparisons until the final consistency ratio was calculated to be less than or equal to 0.1 or deemed acceptable (Karydas and Gifun, 2005).

Once the judgmental matrix of comparisons of criteria with respect to the goal is available, the local priorities of criteria are obtained and the consistency of the judgments is determined. The priorities of criteria can be estimated by finding the principal eigenvector w of the matrix A. That is:

$$Aw = \lambda_{max} w$$

When the vector *w* is normalized, it becomes the vector of priorities of the criteria with respect to the goal. λ_{max} is the largest eigenvalue of the matrix A and the corresponding eigenvector *w* contains only positive entries. The consistency of the judgmental matrix can be determined by a measure called the consistency ratio (CR), defined as:

$$CR = \frac{CI}{RI}$$

Where: CI is called the consistency index and RI, the random index. CI is defined as:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

RI is the consistency index of a randomly generated reciprocal matrix from the 9-point scale, with reciprocals forced. The RI values for matrices of different sizes are shown in Table 2.3.

Table 2.3 Average consistencies of random matrices

Size of the matrix	1	2	3	4	5	6	7	8	9	10
Random index(RI)	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Sources: Malczewski, 1999

If CR of the matrix is higher, it means that the input judgments are not consistent, and hence are not reliable. In general, a consistency ratio of 0.1 or less is considered acceptable. If the value is higher, the judgments may not be reliable and have to be elicited again (Ramanathan, 2001).

2.5 Comparisons of drip irrigation and surface irrigation

Surface irrigation is traditional use irrigating method and it has been used in world wide Due to increased water scarcity water saving irrigation methods such as drip to replace surface irrigation. Drop by drop application of water to the plants through the drip irrigation system originated in Israel in the early 1960's at commercial scale. Now it is widespread through out the world. As the basic theory drip irrigation gives various Advantages such as saving of water, Better yield of crops, saving in labor and energy, Suitable for poor soil, Weed growth minimized, Convenient for cultural practices, less soil erosion, Use of saline water, and Improve efficiency of fertilizers (Chakravarthy and Singh, 1994). In practice there are so many studies with different crops and different places to prove benefits, which can provide by drip irrigation.

Antony and Singandhupe (2003) realized morphological, biophysical, yield and water use efficiency (WUE) of capsicum (*Capsicum annum* L.) has better performances with drip irrigation than surface irrigation.

Comparative study of Grapevines (Otis *vinifera* L.) under drip and surface irrigation (furrow irrigation) show that drip irrigation may increase the potential for control of vine growth by making vines more dependent on irrigation and N fertilization than surface irrigation (Araujo *et al*., 1994).

Srivastava and Upadhayaya (2004) conducted one research in India to study on feasibility of drip irrigation in shallow ground water zone with sugarcane, result realized drip irrigation save more energy than surface irrigation.

Moteos *et al*. (1991) compared the water productivity of drip and furrow (surface) irrigated cotton. Outcome demonstrated water productivity of drip irrigated cotton always higher than surface irrigated cotton.

Sharmasarkar *et al*. (2000) conducted a research on "Assessment of drip and flood irrigation on water and fertilizer use efficiencies for sugar beets" in USA. They found out agronomic water use efficiency and fertilizer use efficiency for drip irrigation was always higher than those for flood irrigation.

Drip irrigation is not a miracle technology, since excellent as well as poor results were obtained.

Although its benefits are numerous, drip irrigation is not without disadvantages. Drip systems require consistent maintenance and monitoring. Emitters can become clogged, and leak can develop as a result of mechanical or animal damage. Drip irrigation technology is expensive to install and requires high technical skills for proper design and maintenance. Flood irrigation can flush the salts that accumulated in the root zoon and it can develop microclimate around the plant (Skaggs, 2001).

Some past studies demonstrated results; drip irrigation has poor performance than surface irrigation.

Indeed required equipment is expensive and not necessarily affordable, therefore low and medium value crops are not fit with (in term of economic) drip irrigation (Luquet *et al*., 2005).

Capra and Scicolone (2004) conduct a research to test for emitters and filter for reuse wastewater in Italy. The test confirmed the great influence of the water quality on the performance of drip irrigation systems: for the same kind of emitter and filter, when the total suspended solids and organic matter content increased, the percentage of totally clogged emitters also increased.

2.6 Drip irrigation and banana cultivation

The banana plant is a tropical herbaceous evergreen; it has a high leaf area index and a very shallow root system. These factors make the crop extremely susceptible to water shortage. Consequently, banana plants require irrigation during dry periods to prevent reductions in yield and fruit quality (DOA, 1995).

Many banana-producing regions of the humid tropics experience bimodal rainfall patterns the dry periods may reduce yield and fruit quality. Therefore supplementary irrigation for banana is play vital role in this area. Several studies and statistic that can be used to performance of irrigation of banana have been found in literature. Chakravarty and Singh (1994) gave details, drip irrigated banana in India: yield 100 percent increase when compare the conventional surface irrigated banana.

Goenaga and Irizarry (1998) conducted one research on yield of banana grown with supplemental drip irrigation on an ultisol for the duration of three years in Puerto Rico. The result were realized when compare the rainfed condition drip irrigation treatment give high bunch weight, yield, bunch mean hand weight, weight and fruit diameter of the third and last hands, and length of fruits of the third hand and highest marketable yield (47.9 tons/ ha).

Thadchayini and Thiruchelvam (2005) conducted research to evaluate of drip irrigation project for banana cultivation in Jaffna district in Sri Lanka. The results show yield and net revenue with drip irrigation is 31 percent and 24 percent higher than surface irrigation respectively. But in term of initial investment 34 percent higher in drip irrigation than surface irrigation.

Kuruppuarachchi (1981) compared banana with drip irrigation and surface irrigation and rainfed systems in the northwestern dry zone of Sri Lanka. Outcome realized economic benefits, which derived from drip irrigated banana, were higher than surface irrigated banana.