Sustainability of Agriculture: Competing Theoretical and Empirical Spectrum

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Abstract

The increasing demand for food and use of modern package of cultivation (primarily intensive in nature) has been creating pressure on the agricultural sector. Consequently, the concern about the sustainability of the sector has been a prime component in the agricultural policy of the developing countries like India since 1970s, because of the problem of population explosion in those nations. So, wide range of researches have been undertaken to study different aspects of sustainable agriculture from farm level to national level. Therefore, in this paper it is aimed to review the conceptual issues, theoretical frameworks and empirical results of the literature available on sustainable agriculture and agricultural sustainability. It can be concluded that the research on the issue has been evolving from simple production economics to constructing complex composite agricultural sustainability index both at the theoretical and empirical level. But the concept of agricultural sustainability is still remaining vague and elusive as it includes three major dimensions- economic, social, environmental and wide range of positive and normative values. Basically, while constructing an index for sustainable agriculture it is quite challenging to incorporate the important but subjective social variables adequately. Using different econometric tools have been gradually removing the subjectivity of those variables. In spite of that, based on the findings of research, different policies have been implemented from farm to national level throughout the world in order to ensure sustainability and thereby food security of the people.

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Key Words: Population explosion, sustainable agriculture, agricultural sustainability, food security.

Introduction:

Agriculture being the supplier of food i.e. one of the basic necessities of life needs sustenance in every direction. Specially, in the face of ever increasing world population, mostly contributed by the developing economic giants like India and China, there will be pressure on both intensive and extensive type of agricultural operation. Food and Agricultural Organisation in the report entitled "***How to Feed the World in 2050?***" (FAO, 2012) had estimated that the world population will reach 9.1 billion, 34 percent higher than today, by 2050. It can be easily assumed that, this will be great challenge. Critical point is that almost all of this population is being projected to increase in the developing countries and in urban areas. It can easily be understood that a significant burden will fall in India as it is the second highest populous country of the world right now. There will a need to increase the food production by 70 percent in order to meet the dietary needs of 9 billion population in 2050 and rice will play the pivotal role in Asia in general or India in particular. But in the report it has been cited as a major challenge in front of the agricultural sector for constraints like scarcity of land, water and environmental issues relating to fertilizer use. Because Uncontrolled and indiscriminate application of different modern inputs such as HYV seeds, chemical fertilizer, pesticides & insecticides, irrigation as a composite package in agriculture results in severe permanent loss of soil quality and water pollution in general or environmental pollution in general. The problems of the developed states of India such as Andhra Pradesh, Punjab etc. need not any documentation where the production and productivity has been affected due to this self-generated problem in cultivation. Not only that, it also affects the quality of the food posing health threats to the consumers. It is a known fact that since the organization of first International Conference on Human Environment, 1972 in Stockholm under the leadership of United Nations Organisation, the policy makers in the developed and developing countries have been giving importance on sustainable development and ecological sustainability of different socio-economic activities. Moreover, people, across the globe, have been becoming increasingly conscious about their dietary needs and food quality due to rapid expansion of different diseases and information &

communication technology. But problem is that, in the developing countries of the world like India, the farmers are mostly illiterate and they don't have the required knowledge or training on using composite package of modern cultivation practices. In the absence of intimate and continuous extension services the farmers willingly or unknowingly ignore the environmental adverse consequences in the process of achieving maximum yield (Haque, 2006). That is why a new component has been incorporated in the study of resource use efficiency of agriculture very recently i.e. eco-efficiency or environmental efficiency. CIAT's Medium Term Plan defined-"Eco-efficient agriculture increases productivity while reducing negative environmental impacts. Eco-efficient agriculture meets economic, social, and environmental needs of the rural poor by being profitable, competitive, sustainable, and resilient. It harmonizes the economic, environmental, and social elements of development, and strives toward solutions that are competitive and profitable, sustainable, and resilient, and generate benefits for the poor" (CIAT, 2009). So, eco-efficiency is related to both economy and ecology or environment. It not only gives importance to sustainable use of farm inputs generating less negative impact on the environment but ensures the sustainability of the farming system as a whole (Wilkins,2008).

Under this backdrop it is quite an interesting area of research in agriculture economics to develop proper measures of sustainable agriculture and thereby estimate sustainability at the farm level. But it has been a developing area, because of the complexity of the term sustainability and measuring its different dimensions quantitatively. Therefore, in this paper attempts to review different issues relating to the stated problem using existing literatures and find out the research gaps.

Objectives:

The objectives of the paper are-

i) to review the conceptual debates and theoretical frameworks on sustainability, agricultural sustainability and its measurements.
ii) to analyse the contrasting empirical findings to figure out research gaps.

Analysis:

The analysis part of the paper has been divided in to three sections. Section-I of the paper deals with the conceptual issues, Section-II discusses the areas of indexing

agricultural sustainability and the Section-III gives some insights on studies of agricultural sustainability at farm, sector and regional level.

Section-I: Sustainable Development and Sustainable Agriculture

According to Redclift (1994) the etymological root of the word *sustainability* is the Latin verb '*sustenere',* which means to uphold. But, Wiersum (1995) opined that the concept of sustainability was first used by Von Carlowitz in the eighteenth century, because the most commonly accepted German equivalent term is *'Nachhaltigkeit'* and he used that term to "*describe the maintenance of long term productivity of timber plantations to continuously provide construction poles for the mining industry*" (Becker, 1997). It is very clear that the political interest behind conceptualization of the term has not changed even after almost two centuries in the publication of the World Commission on Environment and Development (WCED), 1984 report. Again the combined term *sustainable development* was first coined in the World Conservation Strategy of the IUCN in 1980 (Becker, 1997). As a concept it has been gaining global concentration since the United Nations Conference on Human Environment, Stockholm, 1972. Later on the WCED, 1984 popularly known as Bruntdland Commission defined sustainable development in their report "*Our Common Future*" as "the process of development that meets the needs of the present generation without compromising the ability of the future generations to meet their own needs". This definition clearly has stated the necessity of inter-generational and intra-generational equity the development processes. Sustainable development has been one of the core processes of development (Kadekodi, 2008), which is essentially concerned with enhancement of living conditions of people. But it differs from the classical models of development, because it takes into account not only the economic dimensions but ecological and social aspects of the resources and something even more. The classical and neo-classical models of development basically relies on the efficiency and equity principle (Kadekodi, 2008), but that is also in a very limited form. For example, in order to ensure efficiency in the production and consumption activities, the economic system must ensure proper valuation of the resources used.

The total economic valuation of the resources specifically the natural resources includes both use and non-use value of the same (Sankar, 2011). The non-use value component is neglected in the mainstream development theories, but the irreversibility of the ecological processes makes the inclusion of this dimension equally important.

This becomes significantly important if there is the presence of negative externality in the process of production and consumption. Ronald Coase had explained the fact that due to absence of property rights the competitive equilibrium may not be a socially efficient or optimal level to produce goods (Kolstad,'2009), because the firm will not include the marginal external cost in the total cost calculations that leads to the problem of under-pricing and over-production of the commodity subjected to generation of entropy. The Box-diagram:1 shows the gradual shift in the paradigms towards the process of sustainable development. As it is clear from it the concept and dynamics of sustainable development is much wider than other development paradigms. All other development models exclude some of the important components without which sustainability can't be realized. Therefore, it has been a multifaceted concept. The Fig-1 displays the three core dimensions of sustainable development viz. economic, social and environmental.

Box: 1 Paradigms of Development

Growth	Development	Social Development	Sustainable Development
Included Notions			
Efficiency	Efficiency	Efficiency	Efficiency
	Equity	Equity	Equity
		Proper Valuation	Proper Valuation
			Resource Stock Recognition
			Resilience

Source: Bhattacharya (2008)

In the report *Our Common Future* it is stated that "*in essence, sustainable development is a process of change, in which exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirants*". The Venn-Diagram in Fig-1 depicts clearly that sustainability in its true and strongest form is the intersection of the three dimensions. If any of the components is left out some way or other then sustainable development process will be compromised (Bohringer & Jochem, 2007) and it may be depicted as weak form of sustainability. This issue has been developing with different notions (such as weak & strong sustainability) and rules of sustainability such

as Hartwick-Solow Approach, London School Approach, Safe Minimum Approach, Daly's Operational Principles etc. (Bhattacharya, 2008). Most importantly there is as strong normative component in the sustainable development. Although this value based normative aspect makes the concept very much attractive for the policy makers but it has two severe disadvantages (Becker, 1997) viz.. *firstly* it can easily be misused for ideological objectives and economic interests and *secondly*, it restricts the neutral and scientific analysis of the concept.

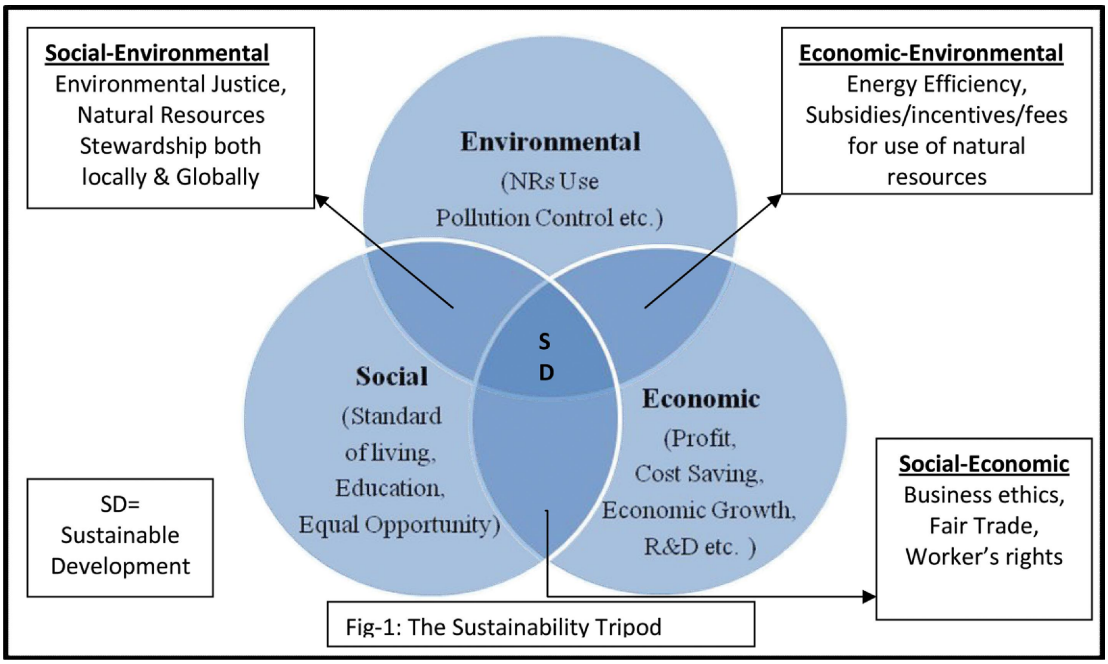

Fig-1: The Sustainability Tripod

It is a well known fact that there exist crucial inter-linkages between environment and economic activities which is modeled by Allen V.Kneese, R.U Ayers and R.C.D Arge in the form of Materials Balance Principle. Environment provides three basic services to the economy viz. life support services, supply of natural resources and acting as waste sink of the residuals. Importantly there is a trade off among all the services of the environment i.e. if we use any of the services at an increasing rate it will be affecting the other services (mostly in negative manner). For example if we expand the quantum of the production activities, there will be more use of natural resources. Accordingly more waste in absolute terms will increase (because according to entropy law of thermodynamics entropy increases as energy conversion process can't be hundred percent

efficient), which will be limiting waste sink capacity. Creation of degradable and non-degradable residuals above the assimilating capacity of the environment at a point of time will negatively affect the quality of life support services. Therefore, in this nexus agriculture sector is considered to be core sector because maximum percentage of population in the developing countries, like India, depends on this sector. The Fig-2 shortly depicts the issue of threatened sustainability in connection with agriculture.

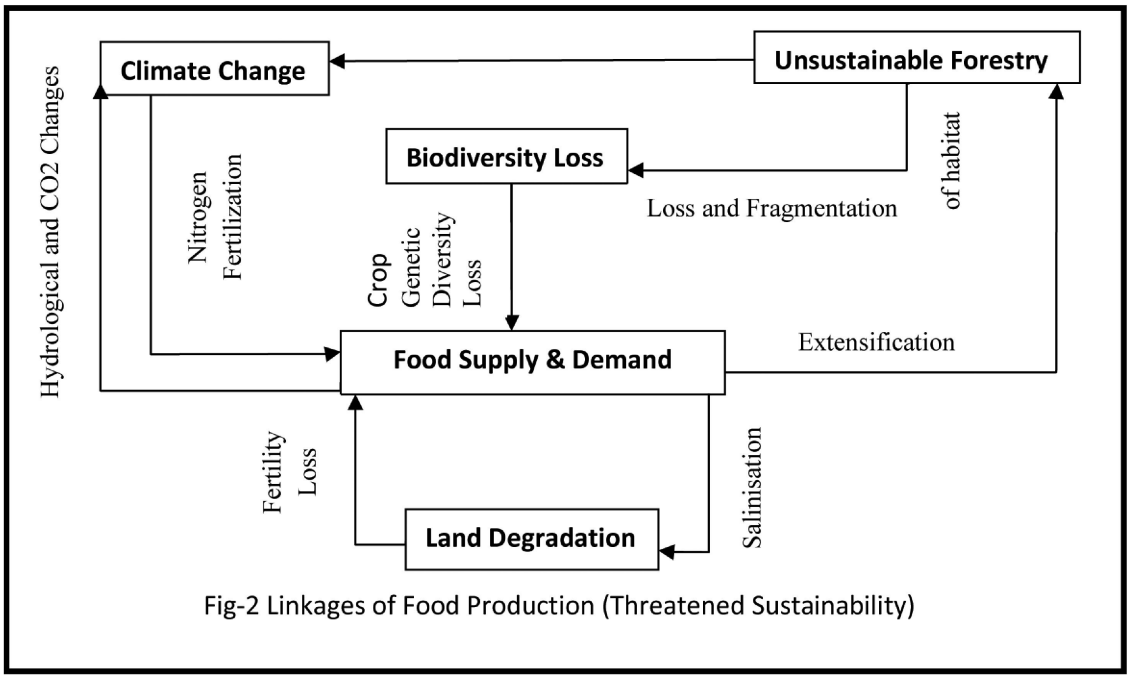

Fig-2 Linkages of Food Production (Threatened Sustainability)

Source: Chakraborti, 2008

The Fig-2 portrays the complex set of two way relationship between agriculture and the local, regional and global environmental problems. Therefore, sustainable agriculture is not only required to maintain the uninterrupted flow of food production to equate demand, but to improve environmental qualities. Although, there are growing literature on sustainable agriculture, measuring sustainability at the farm level the term has still be vague and elusive (Reig *et. al.*,2010). Many people use the words like eco-efficient agriculture, organic farming, climate smart agriculture to indicate sustainable agriculture which are not justified. The earlier use of the term *sustainability* in agricultural

literature was to mean the ability of a system to maintain productivity in spite of a major disturbance or sustainable yield of agricultural crops (Becker, 1997). The mission statement of the Consultative Group on International Agricultural Research (CGIAR), 1989 used the sustainability term in the context of agriculture as "successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources". But these earlier definitions have been expanded to very much comprehensive and holistic concept where it is considered that "*agriculture is sustainable when it is ecologically sound, economically viable, socially just, culturally appropriate and based on holistic scientific approach*" (Spendjian, 1991).This definition seems to be quite attractive, but it is very difficult to materialize and quantify it in practical applications. Senanayake (1991) points out that Douglas (1985) identifies three major schools of thought in defining agricultural sustainability as follows-

i) *The 'productivity' school, where sustainability is seen as supplying enough food to meet everyone's demand and economics become the primary factor of concern.*
ii) *The 'stewardship' school, where sustainability is seen as an ecological phenomenon and the environment becomes the primary factor of concern.*
iii) *The 'community' school, where sustainability is seen as the conservation of social phenomena such as social organization and culture. Here the quality of rural life becomes the primary factor of concern.*

In this connection we can cite one more practically valid definition given by American Society of Agronomy- "*A sustainable agriculture is one that, over the long term, 1) enhances the environmental quality and the resource base on which agriculture depends, 2) provides for basic human food and fiber needs, 3) economically viable, and 4) enhances the quality of life for farmers and society as a whole*" (Dunlap *et.al*, 1993). Therefore sustainable agriculture should equitably balance the concerns of environmental soundness, economic viability and social justice among all the sectors of the society (Allen *et.al*. 1991).

Section-II: Assessment of Sustainability of Agriculture

Assessment systems of agricultural sustainability are very much important because it illuminates scientific understanding of policy and development (Rao & Rogers, 2006). Although the word sustainable agriculture has become a catchword in the intellectual and research ambit of agriculture economics and hence there are a growing number of literatures on the assessment of sustainability of agriculture, but even then

the assessment part has been evolving only (Jain, 2005). This is because of the complexities in the multi-dimensionality and ordinal components there is the lack of a well defined and accepted tools of measurement (Harwood, 1998, Clark, 2003). The literature shows two distinct approaches of on agricultural sustainability consideration. These are as follows-

i) *General and Non-Econometric approach:* The earlier and initial studies on sustainable agriculture are based on general consideration of the sustainable development issue relating to the production, productivity, profitability, growth, total factor productivity etc. These studies essentially focused on the economic dimension of sustainability assessment, giving less importance on the other two dimensions. The stable growth, increasing profitability and constant cost or reduction in cost functions were considered to be the signs of sustainable agriculture. Jodha(1991), Chapman & Barker (1991), Ninan & Chandrasekhar (1993), Reddy (1995), Rajasekaran (1997), Chand and Haque (1998), Kumar *et.al* (1998), Othman and Jusoh (2001) , Murgai *et.al* (2001), Singh and Kalra (2002), Goyari (2005), Ray & Ghosh (2007), Shergill (2007), Picazo-Tadeo *et.al* (2009), Parent *et.al* (2010), Singh (2012) etc. are some of the instances of such kind of studies. It is notable that they have considered some environmental and social issues in normative way in different ecological zones and farming systems, such as excessive use of chemical fertilizer, water pollution and depletion of ground water, overuse of resources, irrigation and watershed management etc. But, this approach of has some limitations-

-*firstly*, it has been a partial study of the complex and wide ranging issue of agricultural sustainability as it gives less focus on the social and ecological dimensions.

-*Secondly*, most of the studies are macro level studies giving importance to either overall agricultural sector or a particular farming system. Hence, farm level sustainability can't be understood which may be very difficult to micro-level planning and policy implementation.

-*thirdly*, most of the studies are non-econometric in nature and hence have failed to develop a composite agricultural sustainability index. This is because of which they could not provide explicit treatment to the more or less qualitative social dimensions. But, in reality the econometric treatment is very much important to cover the multidimensionality of the problem.

ii) *Composite and Econometric Approach:* Given all the difficulties of the above mentioned

approach a composite approach based on composite sustainability indicators is necessary. Because, composite index can summarize complex and multidimensional realities by reducing the size of indicators without dropping the underlying information base, which enables the users to compare and interpret all the dimensions effectively (OECD-JRC, 2008). But, utmost care must be taken so that it could be based on sound theoretical, conceptual and statistical base. Otherwise, the poorly constructed index may be either simplistic or misleading.

The recent developments on agricultural sustainability assessments are centered around developing composite indices of sustainability giving proper valuation to all the three dimensions. Moreover, it has different components and priorities at farm, regional, national and global level. Therefore, an integrated framework of environmental assessment (OECD, 1993, Woodhouse *et. al.*, 2000), agroecosystem assessments (Esty *et.al.*, 1994, Lynam *et.al.*, 1989; Conway, 1997) and sustainable rural livelihood assessments (Chambers *et.al.*, 1991; Scoones, 1996) may create a sound base for proper measurement of agricultural sustainability. Rao & Rogers (2006) has constructed a integrated general framework for agricultural sustainability as shown in Fig-3. The indicators of sustainability are identified in two stages. In the first stage the DPSIR framework has been used to select the variables to be grouped into four components in the next stage such as agro-ecosystems, agro-ecosystems stress, agro-ecosystems vulnerability and agro-ecosystems management. It helps in tabulating a broad range of indicators relating to three main dimensions of sustainability and to measure quantitatively.

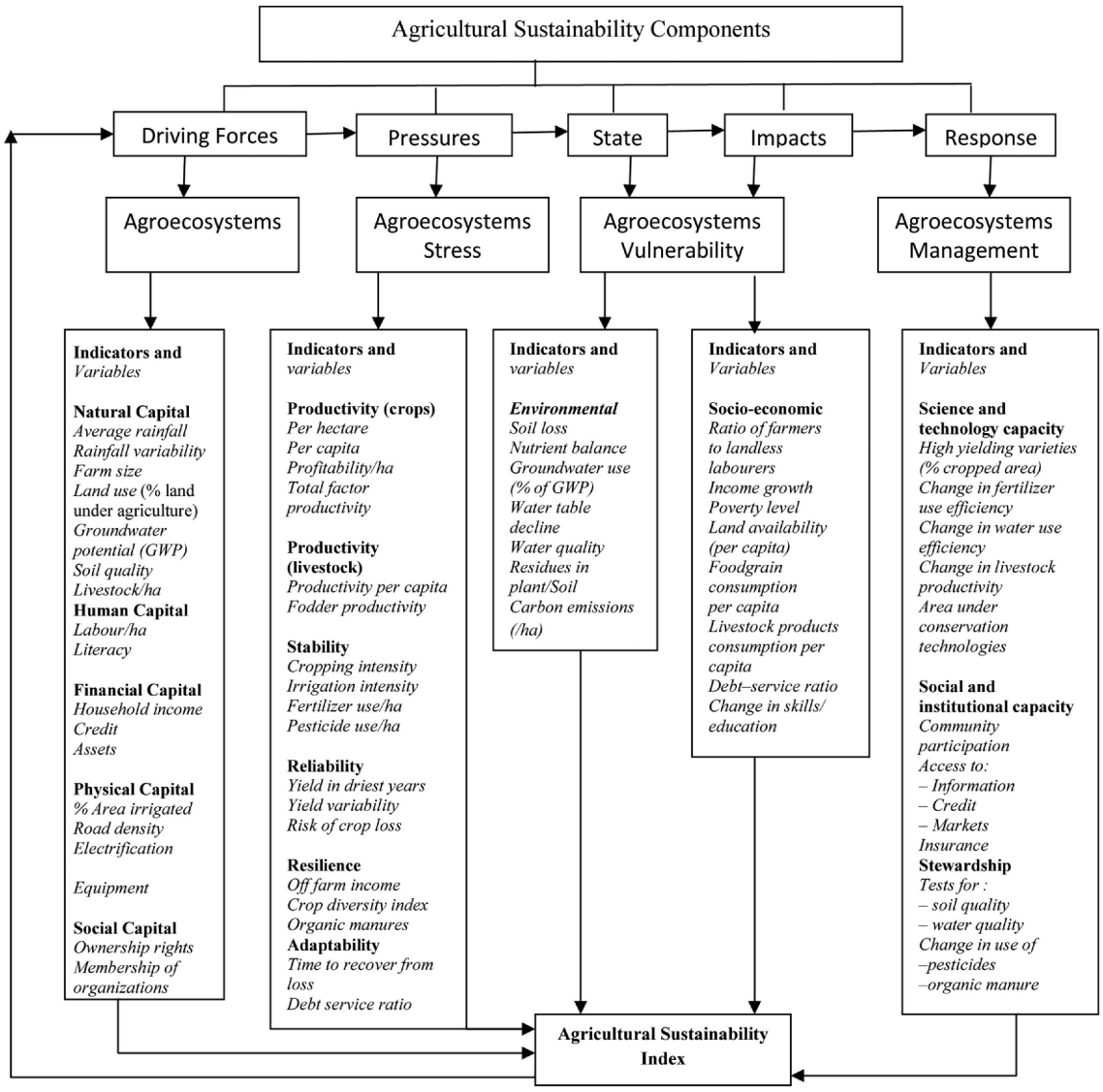

Fig-3 Agricultural Sustainability Assessment Framework (Source: Rao & Rogers, 2006)

There are basically four main stages in the construction process of a farm level composite sustainability index (Limon & Fernandez, 2010). These are as follows-

a) *Selection of Indicators:* This is the most important but difficult stage of the process, because the researcher needs to select the relevant indicators from all the dimensions. This stage is crucial because, if the selection procedure is not based

on strict quality criteria and solid theoretical framework, then there will the possibility of deficiency and mismanagement of essential data. Van Cauwenbergh *et al.* (2007) proposed a theoretical approach in this context which is known as "Sustainability Assessment of Farming and the Environment Framework" (SAFE). This approach is a hierarchical that encompasses three stages viz. principles, criteria and indicators. In the first strata of hierarchy different functions of agriculture such as economic functions, environmental functions and social functions are considered. In the second stage these functions transformed into some criteria and ultimately they are used as indicators. For example, the principle of economic function may be transformed into some criteria, say- farmers' income guarantee, minimization of risk of impacts etc; which can ultimately be used as indicators as income of the farmers, insured area etc. This method is sound theoretically, because it helps in generating quantifiable indicators for social dimensions also. Limon & Fernandez, (2010) have used this approach in their study. Rao (2006), proposed a DPSIR framework as explained above. Gomez et.al. (1996) applied the Framework for the Evaluation of Sustainable Land Management (FESLM) developed by FAO to select the potential indicators. Pannell and Glenn (2000) also proposed a model based on 'Bayesian Decision Theory'. Rasul and Thapa (2003) used the DSR (i.e. driving forces, state and response indicators) framework developed by OECD in 1997. Here in this framework Driving force indicators refer to the factors that brought changes in farm management systems and use of inputs. State indicators show the effect of cultivation on different components of the environment and Response indicators represent the remedial measures to all those changes..

b) *Normalisation of Indicators:* In order to make the selected indicators mathematically operational normalization is important. The dimension indicators are calculated using different units of measurements. Therefore, if they are not transformed into homogeneous units, then aggregation becomes problematic. In this case multiple attribute utility approach, reference values (like UNDP methodology of HDI calculation) may be used. The most popular method of normalization is "min-max" procedure. In this method the value of indicators varies in between '0' and '1', where '0' means the least sustainable and '1' means the most sustainable condition. Limon & Fernandez (2010), Passel et.al. (2007), Gowda & Jayaramaiah

(1998), Diaz-Balteiro & Romero (2004) used this method. Other methods used for normalization are ranking, standardization (or Z scores), distance to a reference measure, categorical scale etc. All these are subjected to own limitations and advantages. So, the researcher could use meeting the needs of the conceptual and theoretical framework.

c) *Weighting of Indicators:* Agricultural sustainability is essentially a social construction. Therefore in order to represent the social preferences to different indicators weighting is necessary. OECD-JRC (2008), classified the weighting techniques in to two category-*positive* or *endogenous* and *normative* or *exogenous*. In the earlier method the weights are assigned to the base indicators by using definite statistical procedure and it is free from value judgments. Principal Component Analysis (PCA) (Sands & Podmore, 2001), Data Envelopment Analysis (DEA), Regression Analysis etc. are commonly used positive techniques of weighting. On the other hand the normative techniques assign weights as a resultant function of either experts or external decision makers. The Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), direct assignment of points, Swing Weighting, tradeoff weighting, the SMART method etc. Every method has its own advantage and limitations. (Limon & Fernandez, 2010, Reig *et.al.,* 2010).Moreover, some people also use a combined method of both the techniques to reduce the influence biasness on the final result of sustainability index.

d) *Aggregating of Indicators:* The aggregating functional forms may be different depending on the notions of sustainability used by the researcher. Because, the notions of *weak sustainability* and *strong sustainability* require different methods of aggregation (Hediger, 1999). Additive Aggregation Methods (AAM), Geometric Aggregation Method (GAM), Multi-Criteria Decision Making (MCDM) approach, Non-Compensatory Multi-Criteria Approach (NCMC) approach etc. could be used for aggregation in case of composite index formulation. Reig *et.al.* (2011), used a combined approach of both DEA and MCDM methods.

Section-III: Empirical Evidence on Sustainable Agriculture

Empirical analysis of the sustainable agriculture is not only essential for attaining soundness and improving efficiency in theoretical developments, but practical planning

and implementation at different levels of the sector also. The literature on sustainable agriculture shows the two approaches as mentioned in Section-II. The issues and results have been found contesting and contrasting in a wide range of issues.

Chapman & Barker (1991), while discussing the sustainability of developing country agriculture, environmental protection and resource depletion mentioned that sustainability in economic context implies the satisfactory relationship between agricultural production and consumptions. The population growth in the developing countries had been experiencing population growth at an average of 2-3% annually after World War-II but only a few developing countries had not been able maintain the growth of the agricultural sector to meet the increasing food demand accordingly. Therefore, many developing countries, at their initial stages of development, have been trying to shift from the traditional to energy intensive production based on increasing use of chemical fertiliser, irrigation, HYVs. Although the demand for environmental protection has been increasing in the developed world, the developing countries may not contribute too much, because these countries can't compromise with the food security of the people in the short run. Research and application of bio-technology can be an alternative to this end in the long run. Reddy (1995), opined that there exists a tradeoff between environmental protection and agricultural sustainability in practice in most of the developing countries. It has also emphasized on the issue of productivity and stability, equitability and sustainability. It has concluded that the problem of environment and sustainable agriculture are more or less available in all types of resource regions, stages of development in varying degrees. So, in this context convincing people towards environmental protection or sustainable agriculture may not be practically possible in a country like India. Othman and Jusoh (2001) examine the structure of the Malaysian agricultural production function during the period 1960-96 and analyse the changing pattern of shares of factors and total factor productivity to agricultural growth using the Cooley-Prescott (C-P) time-varying parameter (TVP) model. A comparison of OLS estimates and C-P model is made to study the factors causing variation in the growth of agriculture. The parameters of TVP framework shows that the stability in the first twenty years declined, but strengthened subsequently. Importantly, the later phase was featured by massive development through deforestation that leading to serious environmental degradation.

Another issue of sustainability is the intensification of the agriculture sector and

its impact on the agro-ecological system. Because, the heavy pressure of population on land has been limiting the scope of extensive cultivation, particularly in the developing countries and hence intensification is an almost natural substitute for the farmers. But Pretty (1997), opines that the intensification must be sustainable that confirms the use of an integrated approach of adopting wide range of technologies in managing pests, nutrients, soil and water. Moreover, the concerned authorities must not rigidly define a specific technology for the farmers; rather they should be given incentives to adapt to changing demand of conditions. Pretty and Bharucha (2014) have defined sustainable intensification "*as a process or system where agricultural yields are increased without adverse environmental impact and without the conversion of additional non-agricultural land*". They suggested that the combined impacts may be reduced by improving crop variety, integrated pest management, management-intensive rotational grazing, agro-forestry systems, patch intensification and system of rice intensification. Reardon et.al (1999), Vanlauwe et.al (2014) suggest that appropriate institutional support and policy reform must be initiated to achieve this goal, but in Africa such policy reforms had generated ambiguous impacts regarding use of chemical fertilizer, organic matter and agrarian capital. The capacity building of farmers must be there along with the available technologies, to choose and innovate sustainable expansion paths.

The impact of agriculture on the ecology also depends on the nature of the resource zones. The implications on the sustainability and policy planning may also differ in this case. Jodha (1991) studied the sustainable agriculture in fragile resource zone relating to resource base and productivity. He opined that the prospect of sustainable agriculture in the fragile resource areas has been a severely constrained. Because, due to changed circumstances the pressure on fragile resources has been quite high and therefore the necessary high productivity can't be possible with conservation by means of conventional measures. This needs research and development in those areas. Ninan & Chandrasekhar (1993) analyse the sustainability dimension of dryland agriculture in India through the growth and instability component in the pre and post green revolution period. Besides they also incorporated the equity consideration relating to the issue of food security and watershed development programmes. They concluded that the irrigated crops dominated the growth of agriculture in India in the post green revolution period but there were increasing instability in yield and production cost also. Due to various socio-economic and environmental reasons there is the problem of sustained growth of the sector.

Therefore, it is needed efficient utilization of local resources without compromising the ecological quality concern.

Irrigation and watershed management is an important component of modern agricultural systems. In order to reduce the negative impact on the environment as a consequence of using the composite package while maintaining production and productivity, efficient use of irrigation and watershed management is necessary. Because it will not only reduce the surface water pollution, but significantly improve the ground water depletion related problems. Rajasekaran (1997) emphasized the sustainability of the agriculture under watershed development projects, because the main long term objective of the watershed development projects is to sustain the carrying capacity of land in the dry region as well as to ascertain a socially acceptable living to the people. But this requires the maintenance of ecological and social sustainability achieved through adequate peoples' participation. The empirical evidence validate that the increase in yield, reduction of income inequality in the dry regions where the projects were implemented. Goyari (2005), stated that the state of Assam has the potentiality of achieving high growth rate of agriculture, but frequent and devastating floods have been threatening the sustainability of rice and other crops. So, effective flood control management must be there to increase sustainability of the sector in the state. Ray and Ghosh (2007) had studied the sustainability of modern Bodo paddy or summer paddy production in West Bengal in terms of cropping pattern, output and yield growth, profitability and impact on ground water. It had documented that although the yield of Bodo paddy has been increasing over time, but it has resulted in uncontrolled use of groundwater and agrochemicals. This shift from eco-friendly traditional cropping pattern to exploitative modern input intensive cropping practice had made it ecologically unviable.

Sustainability is a social construction. Therefore, the social issues directly affects the type of agricultural operation and hence sustainability. Landais (1998) opined that "the sustainable development discourse is actually a new social contract that is offered to farmers. And we cannot exclude that sustainability will play the same role in the next decade that productivity has played in previous ones". Parent *et.al* (2010) connected the social aspect in the study of farm sustainability in Quebec, Canada. This is important that he has considered different indicators that will ensure the social sustainability dimension in the dairy farms. They have used four social dimensions viz. quality of life,

social integration, farm succession and entrepreneurship and also twenty indicators from all those dimensions to cover the issue of social sustainability. Singh (2012), Altieri (2000) discuss the policy issues and institutional mechanisms like contract farming, corporate farming in small holder farming of Punjab. It concludes that neither policy incentives nor the institutional mechanism are very much concerned about the small farmers, for which they have been loosing economic viability and negatively affecting the sustainability dimension. Proper horizontal diversification and input efficient rice intensification system may reduce the severity of the problem in the state. Chand and Haque (1998), Kumar *et.al* (1998) have also opined the same about the sustainability of rice-wheat based cropping system of Indo-Gangetic region by relating different socio-environmental issues to the yield trend. But Shergill (2007) re-examined and had given a contradictory result that the Wheat-Rice production was quite sustainable in the state. The returns were the highest among the competing crop rotation combinations and there were no imminent ecological threat such as decline in the water table below the danger level. Murgai et.al (2001) compared the growth of productivity and sustainability in the Indian and Pakistan Punjabs agriculture in the post green revolution phase. The paper uses the total factor productivity model to analyse the trends in production, input use and resource degradation particularly in three major crops rice, wheat and cotton. Intensification, especially in the wheat-rice system, resulted in resource degradation in both the states. Data from Pakistan show that resource degradation reduced overall productivity growth from technical change and from education and infrastructure investment by one-third. It implies the need for policies that will promote agricultural productivity and sustainability through public investments in education, roads, and research and extension; and that reduce resource degradation by decreasing or eliminating subsidies that encourage intensification of inputs.

But all these initial studies have neglected various other dimensions of overall sustainability. The concept of sustainability has not been treated directly, because their main concern were production and productivity growth, profitability, resource use and the stability relating to some of the environmental issues in most of the cases. Moreover, the composite index has not been estimated using any mathematical or econometric tool. But there are various studies that go beyond these conventional treatments of sustainability. Singh and Kalra (2002) look at different issues to the massive expansion of rice cultivation in Punjab, India since 1970's and consequent environmental

implications like declining yield, reduction in ground water tables. They have used different varietal indices such as Entropy Index, Modified Entropy Index, and Composite Index along with the general components of production and growth economics of agriculture such as productivity, cropping intensity, total factor productivity etc. Rice cultivation has been transformed from a relatively insignificant part as per as area under cultivation is concerned to a very significant provider of food security in the state. But not only the yield rate which has been either stagnant or declining since 1989-90, but serious impact on the sustainability has been recorded resulting from overuse and exploitation of inputs. Bouma & Droogers (1998) relates the land quality indicator to the sustainable agricultural production of wheat under Dutch conditions. A mathematical simulation model was applied for thirty years and prime soil in Netherlands under long term organic farming and conventional farming system. The soil quality indicator was consistently higher in case of land under organic farming. This implies that this kind of farming system will be a key for sustainable agriculture because it takes care of the environmental dimension specifically. But organic farming and sustainability cannot be used interchangeably (Rigby & Caceres , 2001). But, Reig-Martinez et.al (2011) have constructed a composite index of agricultural sustainability including al the three dimensions. They have constructed an index using a combined methodology of DEA and MCDM methods and applied it to a database of 163 farms of Campos Country region in Spanish Northern Plateau. Their findings show that the value of global sustainability index is 0.561 with maximum value of 0.973 and minimum 0.373. More importantly, the economic and environmental sustainability indicators of sustainability are positively correlated. Increasing farm size, agricultural specific technical education of farmers and membership in farmers' cooperatives generate significant positive influence on sustainability.

Limon & Fernandez (2010) measured the sustainability of two agricultural systems, the rain-fed agriculture of the Castilla y León countryside and the irrigated systems of the valley of the River Duero, Spain a composite sustainability index covering all three dimensions viz. environmental, economic and social. The Composite Indicator of Agricultural Sustainability shows that the sustainability in both the systems increases as the farm size, the percentage of land in operator ownership, the level of specialized training in agriculture increases etc. The larger farms can utilize the technique of production which will be cost effective as well as ecologically compatible. Gowda &

Jayaramaiah (1998) calculated a composite index to four rice farming systems (i.e. irrigated, rainfed lowland, rainfed upland and tankfed), where the rainfed lowland farming system is found to be the most sustainable followed by irrigated production. Most importantly, the best sustainable production system does not dominate in any of the three dimensions and hence it confirms that sustainable farming balance all the outcome variables, rather than maximizing any single variable. Likewise, Reig et.al.(2010) used the ANP method and ranked three rice production technologies namely unrestricted traditional, agro-environmental and ecological used in Albufera Natural Park of Valencia (Spain). They concluded that ecological technique is the most sustainable technology followed by agro-environmental and unrestricted traditional if all the dimensions are considered for sustainability measurement. But, if only the economic dimension is considered then the result gets reversed. It confirms the need of inclusion all the three dimensions in sustainability measurement at the farm level

Resource use efficiency is a very important area under the study of sustainable agriculture, because efficient or optimum use of the agricultural resources may also lead to overall sustainability in every dimension. Therefore, very recently the efficiency studies in agriculture has been incorporating and developing the *environmental efficiency* component besides the classical concepts of technical and allocative efficiency. Pannell *et.al* (1999), raised the issue of sustainable agriculture as a matter of ecology, equity and economic efficiency. According to them most of the indicators of sustainable agriculture ultimately boil down to environmental stability, intergenerational equity and economic efficiency. Picazo-Tadeo *et.al* (2009), related the component of efficiency with the survival of valuable agro-ecosystems in Rice farming in European Mediterranean Wetlands (specifically the Albufera National Park, Eastern Spain). They suggested that the existing scheme of environmental payments would bring about the long run competitiveness of efficient farmers and guarantee the conservation of biodiversity associated to the Albufera wetlands. De Koeijer et.al.(2002), has analysed the sustainability within the ambit of efficiency analysis. The measurement of technical and sustainable efficiency through DEA method was applied to the Dutch Beet growers. Here in this case efficient use of polluting inputs is considered to be prerequisite for agricultural sustainability. They have found that there exists a positive correlation between technical efficiency and sustainable efficiency. Passel et.al. (2007) analysed the same issue in case of Flemish dairy farms but applied a valuation method based on opportunity cost. The empirical

panel data regression model shows increase in the size of the farm, farmers' age and dependency on support payments affect positively in the value of sustainable efficiency.

Conclusion:

The review based study made above makes it clear that the issue of sustainable development and agricultural sustainability has been a topic of explicit treatment in the socio-economic and political debate since 1970s. But, the problem of agricultural sustainability is a major concern in the development policies of the developing countries of Asia and Africa, because in one hand maintaining environmental sustainability is seen to be luxury for them, because they will have to face severe consequences in the direction of food security for it in the absence of prolong external assistance from the developed countries. The theoretical and empirical studies in this context reveal that the conventional trade-off between economic sustainability and environmental sustainability may not be always true. Because, the overall concept of agricultural sustainability is not about stabilizing the production and productivity of the sector in conventional sense, rather it encompasses a wide range of variables from three dimensions-economic, social and environmental. All these dimensions are integrated and therefore maintaining environmental sustainability will also be contributing to ensure long term economic and social sustainability.

References:

Allen, Patricia, Debra Van Dusen, Jackelyn Lundy & Stephen Gliessman (1991): "Integrating Social, Environmental, and Economic issues in Sustainable Agriculture" *American Journal of Alternative Agriculture*, Vol-6, pp 34-39.

Altieri, Miguel A. (2000): "Developing Sustainable Agricultural Systems for Small Farmers in Latin America", *Natural Resources Forum*, Vol-24, pp 97-105.

Becker, Barbara (1997): "Sustainability Assessment: A Review of Values, Concepts, and Methodological Approaches", published by the Consultative Group on International Agricultural Research, World Bank, February, 1997.

Bhattacharya, R.K. edt. (2008): Environmental Economics: An Indian Perspective, Eighth Impression, OUP.

Bohringer, Christoph. & Patrick E.P. Jochem (2007): "Measuring the Immeasurable — A survey of Sustainability Indices", ECOLOGICAL ECONOMICS, Vol-63, pp 1-8.

Bouma, J. & P. Droogers (1998): "A Procedure to derive Land Quality indicators for Sustainable Agricultural Production", *Geoderma*, 85 (1998), pp 103–110.

Chakraborti, P.(2008): "Global Environmental Issues and Initiatives" in *Environmental Economics: An Indian Perspective* (ed.) by R.N Bhattacharya, OUP, pp 249-278.

Chambers, R. and Conway, G. (1991): *Sustainable rural livelihoods: practical concepts for 21st century*. IDS Discussion Paper No. 296, Brighton, 1991.

Chand, Ramesh & T. Haque (1998): "Rice-Wheat Crop System in Indo-Gangetic Region: Issues concerning Sustainability", *Economic and Political Weekly*, Vol. 33, No.26 (Jun. 27 - Jul. 3, 1998), pp. A108-A112.

Chandre Gowda, M.J. & K.M. Jayaramaiah (1998): "Comparative Evaluation of Rice Production Systems for their Sustainability", *Agriculture, Ecosystems and Environment*, Vol-69, pp 1-9.

Chapman, Duane & Randolph Barker (1991): "Environmental Protection, Resource Depletion, and the Sustainability of Developing Country Agriculture", *Economic Development and Cultural Change,* Vol. 39, No. 4 (Jul., 1991), pp. 723-737.

CIAT (Centro International de Agricultura Tropical) (2009): CIAT's medium-term plan 2010–2012. Cali, Colombia

Clark, W. C. and Dickson, N. M., Sustainability science, the emerging research program. *Proc. Natl. Acad. Sci. USA*, 2003, 100, 8059–8061.

Conway, G. (1997): *The Doubly Green Revolution*, Cornell University Press, New York, 1997.

De Koeijer, T. J., G. A. A. Wossink , P. C. Struik & J. A. Renkema (2002): "Measuring Agricultural Sustainability in terms of Efficiency: The case of Dutch Sugar Beet Growers", *Journal of Environmental Management* , 66, pp 9-17.

Diaz-Balteiro, Luis., & Carlos Romero(2004): "In Search of a Natural Systems Sustainability Index", *Ecological Economics*, Vol-49 (2004), pp 401– 405.

Douglas, G.K (1984): "The Meanings of Agricultural Sustainability", in G.K. Douglas(ed.): Agricultural Sustainability in a changing World Order, Westview Press, Boulder Colorado, pp 1-29.

Dunlap, Riley E., Curtis E. Beus , Robert E. Howell & Jack Waud (1993): " What is Sustainable Agriculture?", *Journal of Sustainable Agriculture*, Vol-3(1), pp 5-41.

Esty, D. C., Levy, M., Srebotnjak, T. and de Sherbinin, A. (2005): *Environmental Sustainability Index: Benchmarking National Environmental Stewardship*, Yale Center for Environmental Law & Policy, New Haven, 2005.

FAO (2012): "How to Feed the World in 2050?", January,2012.

Gomez, A. A., David E. Swete Kelly, J. K. Syers, K. J. Coughlan (1996): "Measuring Sustainability of Agricultural Systems at the Farm Level", Soil Science Society of America, 677 S. Segoe Rd., Madison, WI 53711, USA. *Methods for Assessing Soil Quality,* SSSA Special Publication 49.

Gómez-Limón, José A. & Gabriela Sanchez-Fernandez (2010): "Empirical Evaluation of Agricultural Sustainability using Composite Indicators", *Ecological Economics* Vol-69, pp 1062–1075.

Gowda, M.J Chandra and K.M Jayaramiah(1998): "Comparative Evaluation of Rice Production Systems for their Sustainability", *Agriculture Ecosystems & Environment*, 69, pp 1-9.

Goyari, Phanindra (2005): "Flood Damages and Sustainability of Agriculture in Assam", *Economic and Political Weekly*, June 25, 2005, pp 2723-2729.

Haque, T (2006): "Resource Use Efficiency in Indian Agriculture", *Indian Journal of Agricultural Economics*, Vol-61(1).

Harwood, R. R.(1998): Sustainability in Agricultural Systems in Transition – At What Cost? Keynote address, Workshop on Sustainability of Agricultural Systems in Transition, ASA, CSSA, SSSA and the World Bank, Baltimore, USA, October 1998.

Hediger, W.(1999): " Reconciling 'Weak' and 'Strong' Sustainability", *International Journal of Social Economics* Vol-26 (7/8/9), pp 1120–1143.

Jain, Ravi (2005): "Sustainability: Metrics, Specific Indicators and Preference Index", Clean Techn Environ Policy (2005) 7: pp 71–72

Jodha, N. S. (1991): "Sustainable Agriculture in Fragile Resource Zones: Technological Imperatives", *Economic and Political Weekly*, Vol. 26, No. 13 (Mar. 30, 1991), pp. A15-A26.

Kadekodi, G.K (2008): "Environment and Development", *in Environmental Economics: An Indian Perspective* (ed.) by R.N Bhattacharya, OUP pp 162-217.

Kolstad, C.D. (2009): Environmental Economics, Fourth Impression, 2009, OUP.

Kumar, Praduman, P. K. Joshi, C. Johansen & M. Asokan (1998): "Sustainability of Rice-Wheat Based Cropping Systems in India: Socio-Economic and Policy Issues", *Economic and Political Weekly*, Vol. 33, No. 39 (Sep. 26 - Oct. 2, 1998), pp. A152-A158

Limon, Gomez and G.S Fernandez (2010): "Empirical Evaluation of Agricultural Sustainability using Composite Indicators", *Ecological Economics* 69, pp 1062-1075.

Lynam, J. H. and Herdt, R. W. (1989): "Sense and Sustainability as an objective International Agricultural Research. *Agric. Econ.*, Vol-3, pp 381–398.

Mitchell , G., A. May & A. McDonald (1995): "PICABUE: A Methodological Framework for the Development of Indicators of Sustainable Development", International Journal of Sustainable Development & World Ecology, 2:2, pp 104-123

Murgai Rinku., Mubarik Ali & Derek Byerlee (2001): " Productivity Growth and Sustainability in Post-Green Revolution Agriculture: The Case of the Indian and Pakistan Punjabs", *The World Bank Research Observer*, Vol. 16, No. 2 (Autumn, 2001), pp. 199-218.

Murgai, Rinku, Mubarik Ali & Derek Byerlee (2001): " Productivity Growth and Sustainability in Post-Green Revolution Agriculture: The Case of the Indian and Pakistan Punjabs", *The World Bank Research Observer*, Vol. 16, No. 2 (Autumn, 2001), pp. 199-218.

Ninan, K. N. & H. Chandrashekar (1993): "Green Revolution, Dryland Agriculture and Sustainability: Insights from India", *Economic and Political Weekly*, Vol. 28, No. 12/13 (Mar. 20-27, 1993), pp. A2-A7.

OECD (1993): *Core Set of Indicators for Environmental Performance Reviews*, OECD, Paris, 1993.

OECD-JRC (2008): *Handbook on Constructing Composite Indicators: Methodology and User Guide*, Published by OECD and Joint Research Centre of European Union, Spain.

Othman, Jamal & Mansor Jusoh (2001): "Factor Shares, Productivity, and Sustainability of Growth in the Malaysian Agricultural Sector", *ASEAN Economic Bulletin*, Vol. 18, No. 3 (December 2001), pp. 320-333.

Pannell, David J. & Steven Schilizzi (1999): "Sustainable Agriculture: A Matter of Ecology, Equity, Economic Efficiency or Expedience?", *Journal of Sustainable Agriculture*, Vol-13(4), pp 57-66.

Pannell, David J. & Nicole A. Glenn (2000): "A Framework for the Economic Evaluation and selection of Sustainability Indicators in Agriculture", *Ecological Economics* Vol-33, pp 135–149.

Parent, Diane, Valérie Bélanger, Anne Vanasse, Guy Allard & Doris Pellerin(2012): "Method for the Evaluation of Farm Sustainability in Quebec, Canada: The Social Aspect", 9th European IFSA Symposium, 4-7 July 2010, Vienna (Austria), *WS2.1 – Methods and procedures for building sustainable farming systems, pp 922-930.*

Picazo-Tadeo, Andrés J. , Ernest Reig-Martínez and Vicent Estruch (2009): "Farming Efficiency and the Survival of Valuable Agro-Ecosystems: A Case Study of Rice Farming in European Mediterranean Wetlands", *Open Environmental Sciences,* Vol- *3,pp* 42-51.

Pretty, Jules N. (1997): "The sustainable Intensification of Agriculture", *Natural Resource Forum,* Vol 21 No 4. pp 247-256.

Pretty, Jules. & Zareen Pervez Bharucha (2014): "Sustainable Intensification in Agricultural Systems", *Annals of Botany* Vol-114; pp 1571–1596.

Rajasekaran, N. (1997): "Farmers, Sustainability and Watershed Programmes", *Economic and Political Weekly*, Vol. 32, No. 26 (Jun. 28 - Jul. 4, 1997), pp. A55-A61.

Rao, N. H. & P. P. Rogers (2006): "Assessment of Agricultural Sustainability", *Current Science*, Vol. 91, No. 4, pp 439-448.

Rasul, Golam & Gopal B. Thapa (2003); "Sustainability Analysis of Ecological and Conventional Agricultural Systems in Bangladesh", *World Development* Vol. 31, No. 10, pp. 1721–1741.

Ray, S & Dhrubajyoti Ghosh (2007): "Modern Agriculture and the Ecologically Handicapped: Fading Glory of Boro Paddy Cultivation in West Bengal", *Economic and Political Weekly*, Vol. 42, No. 26, pp. 2534-2542.

Reardon, Thomas., Christopher Barrett, Valerie Kelly & Kimseyinga Savadogo (1999): "Policy Reforms and Sustainable Agricultural Intensification in Africa", *Development Policy Review* Vol. 17, pp 375–395.

Redclift, Michael (1992): "Sustainable Development: Exploring the Contradictions", Routledge, London.

Reddy, V. Ratna (1995): "Environment and Sustainable Agricultural Development: Conflicts and Contradictions", *Economic and Political Weekly*, Vol. 30, No. 12 (Mar. 25, 1995), pp. A21-A27.

Reig, E., J. Aznar & V. Estruch (2010): "A Comparative Analysis of the Sustainability of Rice Cultivation Technologies using the Analytic Network Process", *Spanish Journal of Agricultural Research*,Vol- 8(2), pp 273-284.

Reig-Martinez, Ernest, Jose A. Gomez-Limon & Andres J. Picazo-Tadeo (2011): "Ranking Farms with a Composite Indicator of Sustainability", *Agricultural Economics*, Vol-42, pp 561–575.

Rigby, D. & D.Caceres (2001): "Organic Farming and the sustainability of Agricultural Systems", *Agricultural Systems*, Vol-68, pp 21-40

Rigby, Dan., Phil Woodhouse, Trevor Young & Michael Burton (2001): "Constructing a Farm Level Indicator of Sustainable Agricultural Practice", *Ecological Economics*, Vol-39, pp 463–478.

Sands, Gary R. & Terence H. Podmore (2000): "A Generalized Environmental Sustainability Index for Agricultural Systems", *Agriculture, Ecosystems and Environment* 79 (2000), pp 29–41.

Sankar, U edt. (2011): Environmental Economics, Eleventh Impression, OUP.

Scoones, I. (1996): *Sustainable Rural Livelihoods: A Framework for Analysis*, IDS Working Paper 72, Brighton, 1996.

Senanayake, Ranil (1991): "Sustainable Agriculture", *Journal of Sustainable Agriculture*, 1:4, pp 7-28.

Shergill, H.S. (2007): "Sustainability of Wheat-Rice Production in Punjab: A Re-examination", *Economic & Political Weekly* (December 29, 2007), pp 81-85.

Singh, Karam & Sajla Kalra (2002): "Rice Production in Punjab: Systems, Varietal Diversity, Growth and Sustainability", *Economic and Political Weekly*, Vol. 37, No. 30 (Jul. 27 - Aug. 2, 2002), pp. 3139-3148.

Singh, Sukhpal (2012): "Institutional and Policy aspects of Punjab Agriculture: A Smallholder Perspective", *Economic & Political Weekly*, January 28, 2012 VOL XLVII NO 4, pp 51-57.

Smith, A. J. and Dumanski, J.(1994): *FESLM: An International Framework for Evaluating Sustainable Land Management*, World Soil Resources Report No. 73, FAO, Rome, 1994.

Spendijan, G(1991): "Economic, Social and Policy aspects of Sustainable Land Use", in "Evaluation for Sustainable Land Management in the Developing World", Vol.2, Technical Papers, pp 415-436, International Board for Soil Research and Management.

Van Cauwenbergh, N., K. Biala & C. Bielders (2007): "SAFE —A Hierarchical Framework for assessing the Sustainability of Agricultural Systems" *Agriculture, Ecosystems and Environment* Vol-120 (2–4), pp 229–242

Van Passel, Steven, Frank Nevens, Erik Mathijs & Guido Van Huylenbroeck (2007): "Measuring Farm Sustainability and explaining differences in Sustainable Efficiency", *Ecological Economics*, 62 (2007) pp 149-161.

Vanlauwe, B., D Coyne, J Gockowski, S Hauser, J Huising, C Masso, G Nziguheba, M Schut &P Van Asten (2014) : "Sustainable intensification and the African smallholder farmer", *Current Opinion in Environmental Sustainability*, Vol-8:pp 15–22:

Weirsum, K.F. (1995): "200 Years of Sustainability in Forestry: Lessons from History", *Environmental Management*, Vol.19, No.3, pp 321-329.

Wilkins, R J (2008): "Eco-Efficient Approaches to Land Management: A Case Study for Increased Integration of Crop and Animal Production System", *Philosophical Transactions of the Royal Society*, B (2008), 363, pp. 517-525.

Woodhouse, P., Howlett, D. and Rigby, D.(2000): *A Framework for Research on Sustainability Indicators for Agriculture and Rural Livelihoods*, Working Paper 2, DFID project no. R7076CA, 2000.

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