INDICATORS FOR ASSESSMENT OF AGRICULTURAL SUSTAINABILITY IN INDIA: REVIEW AND SYNTHESIS

ABSTRACT

The concept of sustainability and its dimension in agriculture system is complex in nature and there is no common understanding among the researchers about the dimensions of agriculture sustainability. Various parameters have been proposed by the researchers for the measurement of agricultural sustainability. There should be a formal system for the assessment of agricultural sustainability that will further help in designing policies and programs and help in achieving sustainable agriculture development. This article reviews some aspects of agricultural sustainability and its dimensions and provides a set of indicators for assessing agricultural sustainability at regional and district levels involving environmental sustainability, social security, and economic security in India based on theoretically proposed and practically applied indicators by researchers. The indicators to be used for assessment of agriculture sustainability should be location specific for better understanding and should also be constructed according to the ecological and socioeconomic situation.

Keywords:*Agricultural sustainability, Measures of sustainability, Sustainability indicators, Environmental sustainability, Social Security, Economic security.*

INTRODUCTION

The concept of sustainable development has been summarized as a state of dynamic equilibrium between societal demand required achieving development and the supply of economic and environmental goods and services required to fulfill this demand. The concept of sustainable development is multidimensional and it gets popularized in the report of the World Commission on Environment and Development, “Our Common Future”. It defined sustainable development as “development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs”. The formalization of this concept was completed by three pillars- Social, Environmental and Economic- described in the World Summit on Sustainable Development in 2002. A concept of integrative perspective for the three dimensions with wide scientific and policy interest in sustainable development was considered. A range of studies related to international initiatives and various systematic and analytical frameworks for sustainability assessments were made which were based on theory in ecological sciences and environmental policy. The Sustainable Development Goals (SDGs) [43] are being commonly used as a “blueprint to achieve better and more sustainable future for all” by 2030, but there are several challenges that are faced by the social planners since the time of implementation. The SDGs were framed by integrating sustainability in all forms of production, distribution, and consumption. To achieve sustainable development by 2030, The SDG-2 (zero hunger), SDG-12 (responsible consumption and production), SDG-13 (climate action), and SDG-15 (life on land) all are considered as crucial goals to achieve agriculture sustainable development. However, the use of chemical input-intensive farming practices has threatened sustainability such as degradation of soil and water, loss of biodiversity which leads to long-term ecological loss and in addition to several social and economic repercussions. To overcome this issue, sustainable agriculture alone can meet the current and long-term needs of the society for food and fiber, while maximizing the net benefit of long-term ecosystem services and functions [40,41].Analyzing agricultural sustainability is essential for designing and assessing rural development initiatives[17]. The 2030 Agenda suggests that all sectors including agriculture be

considered from three dimensions of sustainability: economic, social and environmental. The mainstream approach posits three basic rules for sustainable agriculture: “ecological soundness”, “economic viability”, and “social acceptability” [31,40, 44].Earlier sustainability was primarily defined considering the environmental criteria but in recent years, there has been a realization that for being sustainable, there is a need to include economic and social dimensions along with environmental dimension and putting the farmer in the center.Even though agriculture has made great progress in feeding the ever-increasing population, but it faces lots of problems and challenges. Along with the environmental problems, intensive agriculture practices also cause social damage and the loss of economic growth itself in the medium/long term. Therefore, integration of environmental and social dimensions is a key for economic development and sustainable agriculture is seen as an approach towards successful future.The main aim of sustainable agriculture is to meet this exponential demand for food and reduce the negative impacts on the environment and giving equal emphasis over the social and economic dimension of sustainability. In order to capture the multidimensional nature of sustainable agriculture system the themes on productivity, profitability, resilience, land and water, decent work and well-being all have to be given equal importance.

VISION OF SUSTAINABLE AGRICULTURE

As early as 1988, the FAO Council, the organization’s governing body, defined sustainable agriculture as “The management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Sustainability 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[42]. Such development conserves land, water, plant and animal genetic resources and this is environmentally non-degrading, technically appropriate, economically viable and socially acceptable”. Sustainable agriculture is a time and space specific concept. In the long term, equal emphasis will be put on economic, environmental and socio-institutional development at national, regional and local levels[48].Food security and environmental protection are two key areas where sustainable agriculture may contribute to advance global sustainable development[37]. Sustaining and improving both economic capability and life quality are central to the Sustainable Development Goals (SDGs), which aim to meet people’s needs over long term without causing irreversible harm to environment and renewable resources, while also reducing the use of non-renewable resources [7]. The sustainable agriculture can be considered as food production that integrates the goals of environmental health, economic efficiency and social equity [33]. The concept of ‘agricultural sustainability’ is both ambitious and ambiguous, as diverse factors influence its attainment and assessment[32]. There is complex interaction among the environment, economics and society because of several components, attributes and indicators involved at different levels. Agricultural sustainability is one of the most fundamental activities that help in achieving long term profitability of farming communities. Sustainable agriculture is a complex, dynamic, and contextual concept consisting of overlapping and interactive social, economic, and environmental processes. Flexibility and scalability of sustainable agriculture practices elevates the quality of life for farmers and contributes to increased profitability[38].

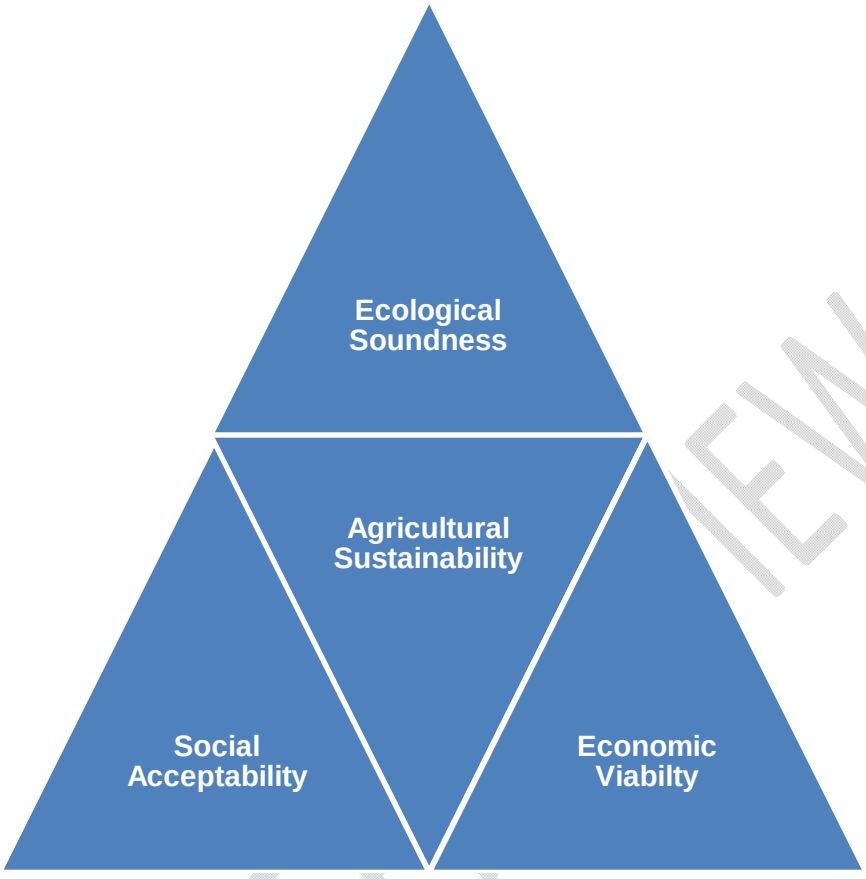

Figure1 : Triangle of Sustainability

ASSESSMENT OF AGRICULTURE SUSTAINABILITY

Analyzing agricultural sustainability is essential for designing and assessing rural development initiatives. However, accurately measuring agricultural sustainability is complicated since it involves so many different factors[17]. Sustainable agriculture criteria for facilitating human well-being and environmental resilience must address the three 'legs' of sustainability [38]. At national level, there is large scale heterogeneity in terms of agro climatic conditions and socioeconomic conditions thus it becomes a challenge to assess agricultural sustainability rather it could be better assessed at farm level. Indicators concerning quality of environment, economic efficiency, and social equity have been widely used to assess farm-level sustainability. Such quantifiable and measurable indicators of sustainability can be useful in decision- and policy-making processes[8]. However, little attempt has been made to assess sustainability at the farm-level through primary data from farmers to make required changes in the existing practice[24].The measurement of sustainability in terms of social, economic, and ecological indicators significantly influences the achievement of sustainable development goals [20]. The tools developed for assessing the agricultural sustainability can help on making on-farm decisions that will contribute in sustainable development of farms. Different terms are used in literature to describe sustainability assessments such as methods, methodological approaches, frameworks, and tools. Indicator-based sustainability assessment tools vary widely in their scope (geographical and sector), target group (e.g. farmers or policy makers), selection of indicators, aggregation and weighing method, and time requirement for execution[3,22,35].In

order to make proper policy and planning for sustainable agriculture development it is necessary to have a formal assessment system. In addition to strategies for preserving natural resources and changing production practices, sustainable agriculture requires a commitment to changing public policies, economic institutions, and social values[42]. An assessment of agricultural sustainability is complex as it encompasses complex interactions between technologies, environment and society[5]. It also has different components, attributes and priorities at different scales; global national, regional, local and farm[13,29]. With the help of diverse indicators under different dimensions like environmental, economic and social, the assessment of agricultural sustainability can be done by meaningfully integrating the indicators into an index. Indicators concerning quality of environment, economic efficiency, and social equity have been widely used to assess farm-level sustainability[1, 6, 27, 34]. A sustainability index allows integrated assessments about the sustainability of the system, after taking into account all information provided by indicators[29]. Such quantifiable and measurable indicators of sustainability can be useful in decision- and policy-making processes[8,34].

INDICATORS OF AGRICULTURAL SUSTAINABILITY

The World Commission on Environment and Development (WCED), 1987 defined sustainable agriculture as the management and utilization of the agricultural ecosystem in a way that maintains its biological diversity, productivity,regeneration capacity, vitality, and ability to function, so that it can fulfill today and in future-significant ecological, economic and social functions at the local, national and global levels and does not harm other ecosystems. Indicators can be used for identifying, simplifying and quantifying agri-environmental aspects of sustainability[47]. Indicators must be relevant, robust and scientifically defensible[45].The researchers argued that at the farm level, it is possible for actors to weigh up, trade off and agree on these criteria for measuring trends in sustainability. But as we move to high levels of the hierarchy, to regional, national and international levels, it becomes increasingly difficult to do this in any meaningful way[10,15, 28]. Sustainability indicators are quantifiable and measurable attributes of a system that are judged to be related to its sustainability[26,29]. Indicators are the tools that help in understanding the complex system in a simpler way. At the farm level, indicators act as the suitable method for assessing sustainability and about the status of farm resources. The sustainable agricultural system is a complex concept and evokes a multitude of responses and implies an agricultural production that guarantees ecological stability, economic viability, and socio-cultural permanence[40]. The mainstream approach posits three basic rules for sustainable agriculture: “ecological soundness”, “economic viability”, and “social acceptability” [31,44].The term “sustainability” reflects our understanding of systems that in continual transition, so sustainability should be approached as a concept to strive for, like social wellbeing, rather than an objective that can be measured with common analytical techniques. In this sense, it is more useful to be able to track the performance of core indicators towards sustainability than set specific targets to be achieved, although setting targets is often useful to identify levels of satisfaction[17]. In order to achieve sustainability and for ensuring long term productivity in agriculture, it is important to make a balance between the three dimensions, as these dimensions are interconnected and essential for agriculture sustainability.

Based on an analysis of sustainable agriculture parameters, including principles, criteria, and indicators derived from various credible sources, it has been concluded that sustainable agriculture in its variable forms is in need of a common accepted framework of parameters including principles, criteria, and indicators. These macro-level sustainability parameters are modeled on the ‘three legs’ of the sustainability stool[38]. The ecological dimension of sustainable agriculture focuses on the general aim that sustainable agriculture should establish agricultural practices that are environmentally sound, preserve resources and integrate natural biological cycles [23]. The economic dimension refers to income and profit generation from the

agriculture farms while minimizing environmental impact and benefitting social well being. This includes crop productivity, net farm income, per capita food grain production and benefit cost ratio of production[14].The social dimension focuses on promoting equity, justice and a good quality of life to a farmer. Key aspects include the labor conditions such as fair wages, safe working environments and work life balance for farm workers, impacts on local communities such as effects on education, healthcare and education[16].

AGRICULTURAL SUSTAINABILITY ASSESSMENT INDICATORS PROPOSED BY RESEARCHERS

There have been systematic reviews conducted on agricultural sustainability indicators by several researchers. These reviews are based on identifying and evaluating various indicators under different dimensions which are used to measure the sustainability of agricultural. Sustainability in agriculture is multidimensional, encompassing environmental, social and economic factors. Indicators allow for a comprehensive assessment of these different dimensions to evaluate the overall sustainability of agricultural systems[2]. A comprehensive review of agricultural sustainability indicators is crucial to develop robust, multidimensional frameworks that can effectively guide the transition towards more sustainable food systems[21]. Proper reviewing and evaluation of the indicators will help in understanding the strength and limitation and helps in identifying the gaps that can be addressed.

Table 1. Proper reviewing and evaluation of the indicators

Dimension	**Indicators**		**Researchers**
Ecological	Water	Water is one of the important factor as it is responsible for the plant growth, moisture level of soil and overall agriculture productivity.	Zhen and Routray (2003), Hani *et al.*(2006), Rao *et al.*(2019)
	Soil	Soil is an important component as the soil microbes and its microbial activity plays an important role in the crop production system.	Zhen and Routray (2003) Hani *et al.*(2006), Rao *et al.*(2019)
	Temperature	Temperature plays a significant role and to ensure long term sustainability its important to adapt agriculture practices according to climate change.	Singh and Nayak (2020)
	Rainfall	Variation in rainfall and its assessment helps in developing strategies to perform agriculture practices according to the rainfall.	Krishna *et al.* (2020) Singh and Nayak (2020) Sridhara *et al.* (2022) Suresh *et al.* (2022) Jatav and Naik (2023)
	Biodiversity	Biodiversity includes variety of crop species, soil microbes, pollinators, animal species and these all components helps in maintaining the soil fertility, pest control, pollination and other functions of ecosystem.	Hani *et al.*(2006) Rao *et al.*(2019)
	Air quality	It is important to understand trends in agri-	Singh and Nayak

	index	environmental performance and mitigate the pollution levels and environmental risks through sustainable practices.	(2020)
	Plant protection	It is important to know the usage of plant protection products as it has harmful impact on air, water, and soil quality as well as on the terrestrial and aquatic biodiversity	Hani *et al.*(2006)
	Waste	The agriculture waste and its management helps in reducing the pollution, conserve resources and enhance ecosystem health.	Hani *et al.*(2006), Rao *et al.*(2019)
	Energy	It is important to measure energy use per unit of value added or output which helps in providing insights about energy efficiency, resource consumption and the overall sustainability of agricultural systems.	Hani *et al.*(2006)
	Groundwater	Groundwater quality and quantity assessment is important for maintaining long term agricultural productivity.	Zhen and Routray (2003), Van Cauwenbergh*et al.* (2007) Ghabru*et al.* (2017), Kareemulla*et al.* (2017) Rao *et al.*(2019) Singh and Nayak (2020) Sridhara *et al.* (2022) Suresh *et al.* (2022) Jatav and Naik (2023)
	Population density	It is important to consider the rising population density that lead to sustainable intensification. Increase in population density correlates with smaller farm sizes and low crop production.	Ghabru*et al.* (2017) Krishna *et al.* (2020)
	Livestock density,	Imbalance in the ecosystem affects the livestock farming and it is essential to know the livestock density for making balance in between agricultural productivity and environmental sustainability.	Ghabru*et al.* (2017), Kareemulla*et al.* (2017) Rao *et al.*(2019) Sridhara *et al.* (2022)
	Area under forest	It is important to consider the status of forests as these are responsible to provide essential ecosystem services which are fundamental for agriculture sustainability.	Ghabru*et al.* (2017), Kareemulla*et al.* (2017) Rao *et al.*(2019) Krishna *et al.* (2020) Singh and Nayak

			(2020) Suresh *et al.* (2022) Jatav and Naik (2023)
	Cropping intensity	High cropping intensity promotes integrated farming which enhances the nutrient recycling, better resource usage, contributes to climate mitigation and lead to a more sustainable agricultural system.	Sajjad and Nasreen (2016) Kareemulla*et al.* (2017) Rao *et al.*(2019) Krishna *et al.* (2020)
	Net sown area	It reflects the total area cultivated at least once during a season of agriculture year resulting in efficient land utilization and higher productivity.	Rao *et al.*(2019)
	Renewable Power supply	The usage of renewable energy sources like solar, wind, biomass etc offers a promising alternative to fossil fuels and act as an aid for mitigating the climate change and helps in achieving long term sustainability in farming practices.	Rao *et al.*(2019)
	Eco-friendly agricultural practices	These practices help in reducing the negative impacts of agriculture on the environment, improve soil health and ensure long term sustainability.	Sajjad and Nasreen (2016)
Economical	Net sown area	Larger net sown area indicates higher agricultural productivity and more economic output but the use of larger area in sustainable manner is an important concern.	Ghabru*et al.* (2017) Sridhara *et al.* (2022)
	Per capita food grain production and Productivity	It reflects general food availability and self sufficiency in developing countries.	Zhen and Routray (2003) Ghabru*et al.* (2017), Kareemulla*et al.* (2017) Sridhara *et al.* (2022) Suresh *et al.* (2022)
	Available farm machineries	To enhance efficiency farm machineries are used and economically and resilient practices results in more harvest and generate more income for farmers.	Sajjad and Nasreen (2016)
	Benefit-cost ratio of production	This ratio helps in determining the total cost incurred in the agricultural production and the benefits drawn from it. This ratio also helps in knowing the efficiency and profitability of the farming practices.	Zhen and Routray (2003)
	Net farm income	It represents the difference between gross output and all expenses including depreciation at the farm level.	Zhen and Routray (2003),Kareemulla*et al.* (2017)

			Singh and Nayak (2020) Suresh *et al.* (2022)
	Female work participation rate	Migration of male members has led Feminization of Agriculture and women play a significant role in agriculture making up a substantial share of the total agricultural labor force and contribute in food production.	Kareemulla*et al.* (2017)
	Agricultural employment	It reflects the number of people employed in agriculture as it will reflect the viability of the agriculture sector.	Rao *et al.*(2019)
	Agricultural markets.	Agricultural market reflects the economic viability and resilience of the farming sector.	Van Cauwenbergh*et al.*(2007) Rao *et al.*(2019)
	Man land ratio	A higher man to land ratio has a negative influence on agriculture sector as it results in more exploitation of natural resources and also demands for intensive agricultural practices which is a threat to sustainability.	Jatav and Naik (2023)
Social	Working conditions	It is an important indicator as better working conditions lead to have a positive affect over the farm productivity and farmers consider the work environment when transitioning to the sustainable farming systems.	Hani *et al.*(2006) Van Cauwenbergh*et al.* (2007)
	Social Security	It is related with the conditions like farmer well-being, quality of life, food security, improved nutrition etc and these all are important aspects of sustainable farming system.	Hani *et al.*(2006)
	Food self sufficiency	It is crucial concept in ensuring food security and environmental well being.	Zhen and Routray (2003)
	Equality in income and food distribution	To achieve the sustainable agriculture development it is important to ensure zero hunger and also a proper income distribution will enable farmers to invest in sustainable agriculture practices and improve the productivity of the farm.	Zhen and Routray (2003)
	Access to resources and support services	It focuses on the easy access of the resources, financial support and services like market knowledge, proper training and workshops.	Zhen and Routray (2003) Suresh *et al.* (2022)
	Farmers knowledge and awareness of resource	Farmer's awareness on conservational agricultural practices can help in conservation of resources and also increase resilience to climate change and boost the long term productivity.	Zhen and Routray (2003)

	conservation		
	Literacy rate	It has a positive relation with the sustainability as higher the literacy rates more will be uniform distribution of information, easy adoption of sustainable practices, awareness on technical opportunities will help in achieving the sustainable agriculture development	Sajjad and Nasreen (2016) Ghabru*et al.* (2017) Suresh *et al.* (2022) Jatav and Naik (2023)
	Rural road connectivity	It provide better access to markets, reduce transportation costs and facilitate the flow of agricultural inputs, credit, extension services and new technologies.	Ghabru*et al.* (2017)
	Number of commercial bank branches.	Commercial bank acts as a core point which connects the sustainable practices into its operations with easy flow of credit to the farmers.	Ghabru*et al.* (2017)
	Adoption of improved practices	Adoption of sustainable agricultural practices is crucial for ensuring long term viability of the farming systems and helps in maintaining the ecosystem. Favourable socioeconomic conditions and positive attitude tends to have a higher adoption rate.	Rao *et al.*(2019)
	Marginal and small holdings.	Small family and small farm size play a significant role in regional food systems but they face challenges that are need to be addressed for achieving agricultural sustainability.	Rao *et al.*(2019)
	Community managed institutions	The institutions like women's self help group helps in organizing and regulating the interactions between different stakeholders such as farmers, consumers and policymakers which will also help in transition of farmers from conventional, input intensive agriculture towards more sustainable practices.	Kareemulla*et al.* (2017)
	Human Development Index	Agriculture plays a significant role in human development as it is source of food, income and employment for many people particularly in rural areas.	Kareemulla*et al.* (2017)
	Sex ratio	Sex ratio in agriculture is influenced by various social factors like migration and labor participation impacting sustainability. Gender equality is crucial for achieving sustainable agriculture goals, with women increasingly contributing to the agricultural workforce globally.	Singh and Nayak (2020) Jatav and Naik (2023)
	Membership of	Cooperative membership can have a positive impact on the probability of	Jatav and Naik (2023)

	agricultural credit society.	farmers adopting green and eco-friendly production practices as access to institutional credit is positively associated with agricultural sustainability.	

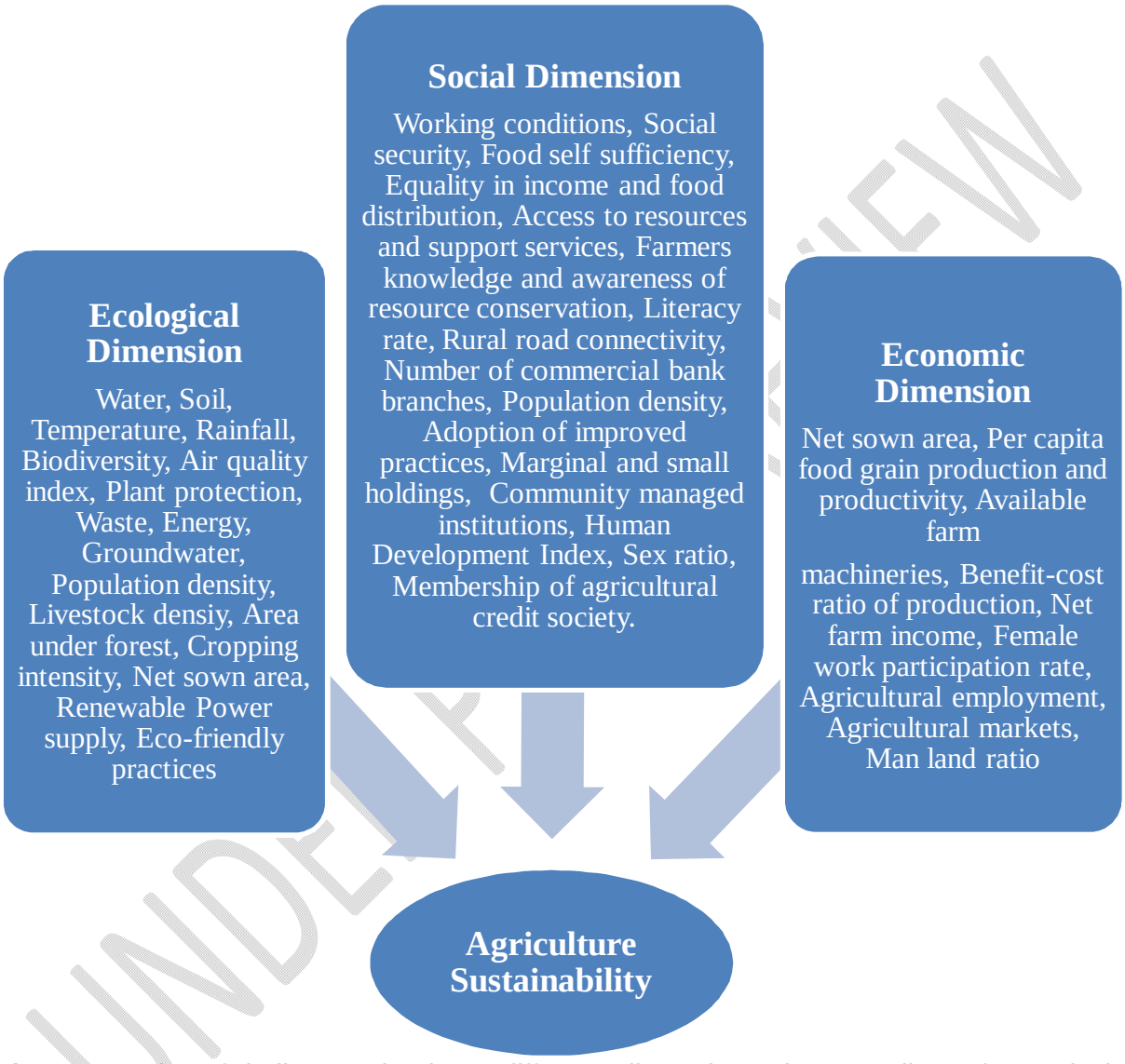

Figure 2: List of indicators in three different dimensions that contribute for agriculture sustainability

SUMMARY AND CONCLUSION

To achieve sustainable agriculture development there is a need to integrate ecological, economic and social dimensions and have a comprehensive assessment of indicators under each dimension. Sustainable agriculture is practiced in such a manner that meet society's present and food needs without compromising ability of future generation to meet their needs.

Ecological dimension describes the relationship between people and the environment. It includes activities which are environmentally friendly, less use of non-renewable inputs, preservation of resources and nature balance. Economic dimension deals with ensuring profitability efficiently perform the agricultural practices and maintain the economic viability of farm operations and improve the standard of living of farmers and society as a whole. It mainly focuses on farm income, cost efficiency, access to market and economic resilience. Social dimension encompasses equity, justice, and quality of life focusing on well being of farmers within farming communities. Indicators may vary across different regions due to geographical characteristics so while selecting indicators for the index an important criterion is to be location specific and index should be constructed according to the socio-economic and ecological situation. Proper assessment in terms of ecological, economic, social dimension of agricultural sustainability will help in formulating the policies, schemes and various programs that will help in achieving sustainable agriculture development.

On the basis of all the reviews a comprehensive list of indicators under three dimensions of agriculture sustainability can be enlisted in which Economic dimension includes indicators like net sown area, per capita food grain production and productivity, available farm machineries, benefit cost ratio of production, net farm income, female work participation rate, agricultural employment, agricultural markets and man land ratio. Social dimension includes indicators like working conditions, social security, food self sufficiency, equality in income and food distribution, access to resources and support services, farmers knowledge and awareness of resource conservation, literacy rate, rural road connectivity, number of commercial bank branches, adoption of improved practices, marginal and small holdings, community managed institutions, human development index, sex ratio and membership of agricultural credit society. Ecological indicators include water, soil, temperature, rainfall, biodiversity, energy, groundwater, population density, livestock density, cropping intensity, eco-friendly practices, plant protection, air quality index, area under forest, net sown area, and renewable power supply.

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