Natural Farming: A Game Changer in the Era of Social, Economical and Ecological Crisis

Discussion Paper 11

MANAGE- Centre for Agricultural Extension Innovations,
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About the Publication

The research report is based on the research conducted by Ms. Aakanksha Tiwari as MANAGE intern under the MANAGE internship programme for Post Graduate students.

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PREFACE

The three major challenges confronted by the agriculture sector in India are, increase in productivity per unit of land, reducing rural poverty through a socially inclusive strategy and meeting food security needs. As a result of population increase, more and more marginal areas are being used for agriculture which led to rapid natural resources degradation, particularly soil degradation, which manifests itself mainly in the form of land on which the soil layer has been eroded away and nutrients have been continuously extracted with little or no any replenishment. Thus, there is need for appropriate interventions to address the prevailing constraints using suitable technologies for improved and sustainable agricultural production. Some innovative farming systems using low inputs have improved yields while safeguarding the resource base.

The intern Ms. Aakanksha reviewed various national and international research reports as well as ongoing schemes and policies to support sustainability in agriculture. This study indicates need of socio-ecological development of agriculture system to enhance food security.

I appreciate the work done by Ms. Aakanksha and giving recommendations to various stakeholders. Ultimately, it is crucial that agriculture development agencies utilize interdisciplinary teams to develop a complete understanding of the agronomic, ecological, and social context of a community-based project.

Dr. Saravanan Raj
Director (Agricultural Extension)

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Abbreviations

AI	Artificial Intelligence
BNP Paribas	Banque de Paris et des Pays-Bas S.A.
EPI	Environmental Performance Index
FAO	Food and Agriculture Organization
GPRS	General Packet Radio Service
GSDP	Gross State Domestic Product
GoI	Government of India
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
ICAR	Indian Council of Agricultural Research
ICT	Information and Communication Technology
IFAD	International Fund for Agricultural Development
IoT	Internet of Things
IPM	Integrated Pest Management
LEISA	Low External Input Sustainable Agriculture
LGP	Length of Growth Period
MoEF& CC	Ministry of Environment, Forest and Climate Change
MSSRF	M.S. Swaminathan Research Foundation
NAPCC	National Action Plan on Climate Change
NARP	National Agriculture Research Project
NBSS&LUP	National Bureau of Soil Survey and Land Use Planning
PPVFR	Protection of Plant Varieties and Farmers' Right Act
RWCS	Rice Wheat Cropping System
SIFF	Sustainable India Finance Facility
TCS	Tata Consultancy Service
WAC	World Agroforestry Centre
WWF	World Wildlife Fund
WTO	World Trade Organisation
UNEP	United Nations Environment Program
UNCED	United Nations Conference on Environment and Development
ZBNF	Zero Budget Natural farming

Abstract

Understanding the perception and awareness of farmers and other local stakeholders remains a challenge for the adoption of agricultural sustainability. It plays a key role in protecting the environment and preserving landscapes and biodiversity loss due conventional agriculture system. The present study was conducted in three states (Rajasthan, Telangana, and Andhra Pradesh) situated in similar agro-ecological zone of India. The sample study comprised of a total of 150 respondents selected through simple random sampling.

This study is focused on the need and significance of developing knowledge of all the local stakeholders related to agriculture encompassing the social, economic, and ecological issues caused by current agricultural practices. It also endeavors to ascertain their satisfaction and opinion on the schemes and programmes initiated by Government of India (GoI) to promote ecological agricultural practices. It suggests effective ways to increase people's interest and participation in environmental protection. Although earlier studies have been conducted in various parts of India regarding the environment and management of natural resources, a study on the knowledge of farmers concerning these aspects of sustainable development is yet to be comprehensively carried out. Therefore, this study was designed to assess the environmental behavior, level of satisfaction, and suggestions of the respondents selected for this study. The present study is based on both primary and secondary data and is exploratory in nature. The data was collected from the respondents through an interview schedule. A structured questionnaire was administered to 150 randomly selected respondents from different districts in the three states under this study viz., Rajasthan, Telangana and Andhra Pradesh, through multistage and simple random sampling. The collected data has been analyzed by using the percentage analysis. The study revealed that nearly 50% of the respondents have medium level knowledge on environmental awareness. The statistical analysis shows that educational status, age, and information accessibility had significant influence on environmental awareness and perception of farmers and other local stakeholders. However, respondents' sex had no influence on their environmental behavior. Variations in agricultural perceptions can be attributed to differences in education, farming experience, environment, and culture. Insufficient information, lack of organized training centers, and poor environmental education provisions were some of the constraints in improving environmental knowledge and behavior of farmers. Cognitive mapping identifies key factors within agricultural belief systems which can aid research agencies in developing a greater understanding of community perception of farming system. Improving farmers' environmental awareness is vital for conservation of India's remaining natural resources and biodiversity. Therefore, all international, national, and local stakeholders must work jointly to improve the environmental behavior of farmers.

Executive Summary

FAO reported in 2012 that modern agriculture practices which are heavily dependent on the use of chemical pesticides, inorganic fertilizers and growth regulators have raised the agricultural production manifold but at the cost of resource depletion, environmental deterioration and loss of crop diversity. Therefore, it was realized that modern agriculture is not sustainable in the long run; hence, the concept of sustainable agriculture emerged which not only emphasizes on the conservation of the natural resources but also maintains the quality of the environment. Sustainable agriculture is in fact the successful management of resources for agriculture to satisfy the changing human needs, while maintaining or enhancing the quality of environment and conserving the natural resources. It is a balanced management system of renewable resources including soil, wildlife, forest, crops, fish, livestock, plant genetic resources and ecosystems without degradation. It also endevours to provide food, livelihood, for current and future generation maintaining and improving productivity and ecosystem services of these resources. According to FAO (2017), sustainable agriculture is at the heart of the 2030 agenda, and the first fundamental step to secure zero hunger. As agriculture contributes to the development of economic activities, is a source of livelihood and, the 2030 Agenda suggests that all sectors including agriculture, be considered from three dimensions of sustainability: economic, social and environmental. While Indian farmers have traditionally followed principles of sustainability, new technology now makes them more effective. For instance, for soil enhancement, certified biodegradable mulch films are now available which are protective materials applied to the soil to conserve moisture and fertility. A biodegradable mulch film is directly degraded by microorganisms in the soil and thus conserves the soil properties, eliminates soil contamination, and saves the labor cost with polyethylene (PE) mulch films. The other perpetual challenge for India's farms is availability of water. Excessive tillage and wet tillage (puddling), use of rotavators, and freewheeling of the tractors and harvesters (combines) have in general resulted in gradual compaction of soils, leading to a reduction in long term soil productivity, especially in the rice-wheat cropping system. There is an increasing acceptance that excessive tillage and puddling is causing compaction in soils where rice-wheat cropping system is continuously practiced. The inorganic chemicals used in agriculture have contributed towards increasing productivity of cash crops and also led to various environmental issues. After a prolonged dependence on unsustainable methods for agriculture growth, there has been an increasing demand to rethink agricultural growth strategy. Search for alternate methods, with a focus on long term sustainability of agriculture, has been enhanced in the last decade. The agriculture sector can globally build a lasting competitive advantage through innovation that raises agricultural productivity, minimises dependence on fuel and fertilizer use, and preserve the environment and resources it draws on. The more complex the environmental issue, the more difficult it becomes for farmers to make an informed decision. Good farm resource management decisions depend on accurate information which requires reliable data. Timely and accurate information can help a farmer make rational risk management decisions. Innovative development in agriculture policy can promote farm families in making significant progress towards managing their land and water sustainably. The current efforts of national and state government to increase farmers income and food production should happen within the framework of sustainable management of natural resources to avoid further depletion of water tables, biodiversity and habitat for wild species, and land and soil degradation which have contributed to the environmental crisis facing India today.

Introduction

To feed the growing population, it is estimated that food production will need to increase by 60 percent by 2050 (FAO, 2009). This increasing food demand is promoting farmers worldwide to increase crop production, which builds pressure on the environment and exceeds its carrying capacity to repair or replace itself, leading to its serious degradation. 'Natural Farming' or 'Eco-Agriculture' or 'Ecofriendly Agriculture' is suggested as a neoteric approach to improve both traditional and modern agricultural practices, which aims to safeguard the environment, public health, and communities (Mishra 2013). Sustainable agriculture practices enable food production without compromising the needs of future generation (World Bank, 2017).

> According to a survey by Yale University, India has been ranked 177 out of 180 countries in 2018's Environmental Performance Index (EPI) (http://epi.envirocenter.yale.edu).

The origin of this low rank such as, the on-going population explosion, unsustainable agriculture practice and fast scientific and technological advancement cannot be reversed unless there is collective thinking, will and effort. These call for public awareness and participation to bring about an attitude change and finally restricting further damage to the environment. However, in recent years, environmental awareness has gained increased attention and it has become a bit of a trend: from environmental friendly green building to organic food, environmental awareness is a hot topic. The term "go green," is often used to sensitize people regarding protection of the natural environment and to help them to make better economic choices, such as use of glass or ceramic water bottle instead of disposable plastic water bottles as plastic takes years to break down, and a significant percentage of it pollutes oceans and kills plant and animal life. When people 'go green', they are practicing environmental awareness. In both developed and developing countries, there is a need to adopt new approaches to increase food supplies while protecting the resource on which they depend.

Objectives of the study

- To identify and measure the awareness and behavior of farmers and other local stakeholders towards agriculture driven environmental issues.
- To find opportunities and actions to increase the demand of natural farming over chemical based conventional farming system.
- To recommend management policies on the basis of opinion of farmers and other local stakeholders for integration of environmental concern along with socio-economic concern in governmental policies.

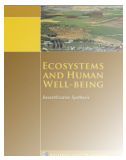
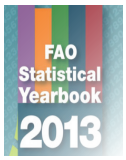
Transforming Agriculture: Snapshots from around the world

In developed counties the initiatives towards greening agriculture have been prompted both by market attractiveness as well as state support activities. Usage of bio-fertilizers and bio-pesticides (Kawalekar

2013) organic farming, Biodynamic farming (Turinek *et al.,* 2009) low input agriculture (Poux 2008), permaculture, sustainable agriculture, integrated farming practices (integrated pest management and nutrient management), are some of the practices that are being espoused by proponents both in developed and developing countries. All these practices have evolved as alternatives to chemical use in agriculture keeping in view the increasing demand for green agriculture products across the world (Sharma 2012). Indonesian rice farmers adopted Integrated Pest Management (IPM), which reduces the need for pesticides and achieved higher yields than those who relied solely on pesticides.

In most cases, the increasing population aggravates land use changes as reflections of socio-economic developments. These changes are mostly due to lack of resource management strategies (Freeman *et al.,* 2005) in terms of agriculture and livestock grazing that drives changes.

Table 1: Global priority analysis of agriculture driven impacts on environment

Environmental issues associated with agriculture	**International Reports**						
	 Millennium Ecosystem Report, 2005	 UNEP, Environmental food crisis, 2009	 UNEP, Global environmental outlook, 2012	 WWF 2050 criteria, 2012	 FAO statistical yearbook, 2013	 MIT Joint Program on The Science and Policy of Global Change, 2018	 IPCC Summary for policymakers, 2018
Water depletion	✔	✔	✔		✔	✔	✔
Climate change	✔		✔	✔	✔		✔
Air pollution	✔		✔		✔		✔
Biodiversity and habitat loss	✔	✔	✔	✔	✔		✔
Water pollution	✔	✔	✔		✔	✔	✔
Soil degradation			✔	✔	✔	✔	✔
Pesticides and chemical fertilizers				✔			✔
GMOs		✔					
Agricultural Waste						✔	✔

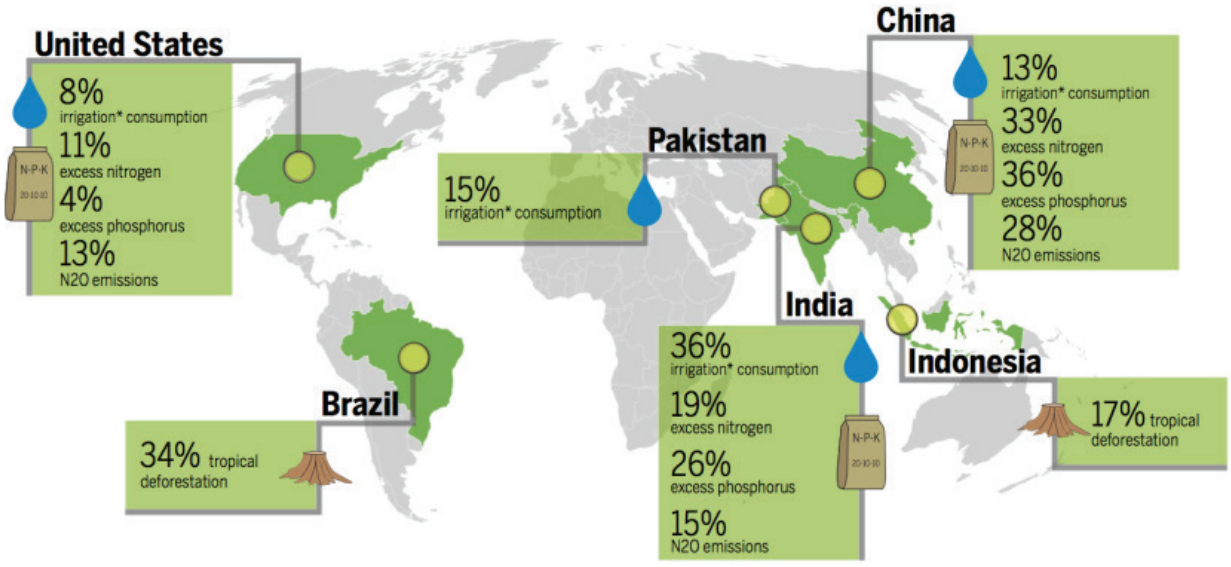


Fig 1: Global environmental issues due to agriculture.

The agriculture driven environmental issues are shown on the global map (figure 1). There is a need to increase agriculture research and development (R & D) intensely in both developed and developing countries, to accelerate their transformational potential. Through the precepts of Green Revolution, farmers have raised their production by planting improved varieties, benefited by more water and increased inputs of agrochemicals, fossil-fuel energy, and capital investment. By investing more inputs to obtain greater output, they have improved upon the previously more 'extensive' strategies of production that were characterized by both low inputs per unit area and correspondingly low outputs. Thus, there is a high need to shift the agriculture system from 'Green Revolution' to 'Evergreen Revolution' (Tirado 2009).

Sustainability as a goal in Indian agriculture development

Sustainable agriculture is the practice of farming using principles of ecology and it integrates three main goals – Environmental (environmental health), Social (social and economic equity) and Economic (economic profitability).

> The word sustainability is derived from the Latin 'sustinere' and it denotes the capacity to endure, which basically means conserving an ecological balance by avoiding depletion of natural resources.

According to FAO (2012), agriculture development that conserves land, water, plant and animal genetic resources is environmentally non-degrading, technically appropriate, economically viable, and socially acceptable; it leads to agricultural sustainability. Although it is common today to talk about sustainable agriculture, as well as sustainability of any human activity, the meaning of sustainable is seldom defined. It is possible to mistake sustainable agriculture for organic farming, or for some biodynamic version of agriculture, or for the reduction of agrochemical inputs. Actually,

any activity or economic system able to maintain itself for an indefinite period of time can be defined as sustainable. However, there has been a realization that being sustainable reaches much further to include economic and social dimensions, and putting farmers in the center. If a farm is not economically sound or not resilient to external shocks, or if the well-being of those working on a farm is not considered, then a farm cannot be sustainable.

Agriculture is at the heart of all the great debates related to the environment, water, biodiversity, war on hunger, all issues that will determine the future of our planet. However, the perception of agriculture by the media, politicians and the public at large conceals numerous misconception that are the result of continuing misinformation and a lack of communication on the part of farmers on how their profession and practices have evolved. Intensive agriculture is wrongly perceived as synonymous with productivism and pollution, and extensive agriculture is meant to protect the soil when in fact it leads to soil depletion through overgrazing, deforestation, and expanding desserts. This is why extensive agriculture is often considered as sustainable as opposed to intensive agriculture that is thought responsible for pollution and diminishing of our future resources. Sustainability creates and maintains the ideal conditions between man and the environment; it is a profession that places man closest with nature and it needs to be well tuned with the surrounding environment. India is a global agricultural powerhouse (World Bank, 2012) as agriculture with its allied sectors, is the largest source of livelihood. The management practices in sustainable agriculture are generally aimed at achieving sustainable production with limited or no chemical inputs giving priority to farm-grown inputs without pollution and minimum damage to natural resource base. Farmers are considered as food Gods and their involvement is the key to prevent hunger and to increase food security in the country. Evidence for India's food challenge can be found in the fact that the yield per hectare of rice, one of the India's principal crops, is 2177 kg per hectare (Kg/ha), behind countries such as China and Brazil that have yield rates of 4263 Kg/ha and 3265 Kg/ha respectively. The cereal yield per hectare in the country (as shown in figure 3) is also 2981 Kg/ha, far behind countries such as China, Japan and the United States.

Fig 2: Global difference in cereal yield in 2014 (Source: World Bank report, 2014)

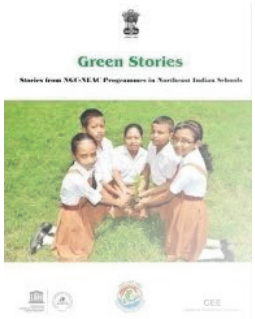
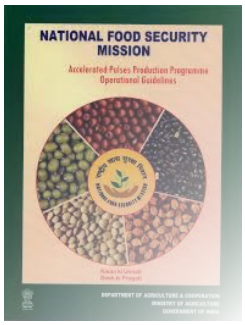
WWF (2016) had reported that, "out of 50 percent of the world's accessible freshwater, 70 percent consumption is accounted for agricultural purpose. 80percent of the water used in agriculture is consumed by thirsty crops". Many food crops such as rice and sugarcane have a high water requirement. In a country like India, where majority of the agricultural land is rain-fed, low rainfall years can wreak havoc for crops and cause a slew of other problems- a surge in crop prices and a reduction in access to essential food items. Again Indian farmers have a long experience in water conservation that can now be enhanced through technology. Seeds can now be treated with enhancement that helps them improve their root systems that leads to more efficient water absorption. In addition to soil and water treatment, the third big factor, better seed treatment can also significantly improve crop health and boost productivity. These solutions include application of fungicide and insecticides that protects the seed from unwanted fungi and parasites that can damage crops or hinder growth and increase productivity. While sustainable agriculture through soil, water and seed management can increase crop yields, an efficient warehousing and distribution system is also necessary to ensure that the output reaches the consumers (Tomich 2011). Innovations such as special tarpaulins that keep perishables cool during transit and more efficient insulation solutions can reduce rotting and reduce energy usage in cold storage. Thus three aspects – production, storage and distribution need to be optimized if India is to feed its ever-growing population.

Multilateral efforts to promote sustainability in agriculture system

The Indian government's schemes and programmes have always emphasized food grain self-sufficiency, which has not necessarily coincided with agricultural sustainability. The growth of agricultural production and productivity, which had risen significantly during 1970s and 1980s, declined during 1990s. These slowdowns have worsened since 2000; both overall agricultural production and food grains production showed negative growth rates in 2000-01 to 2002-03 periods (GoI, 2002). Decline in the growth rates of agricultural production and productivity is a serious issue considering the questions of food security, livelihood, and environment. As such, a critical examination of the approaches for sustainable agricultural development is necessary. This examination must be framed not only by India's ongoing need to ensure food self-sufficiency, but by the consequences of access to international markets. Environmental planning and management is a widely expanding and rapidly evolving dynamic area. Various projects and programmes for environmental awareness and agricultural sustainability are represented in table 2, which are conducted nationally and internationally.

Table 2: Multilateral efforts for agricultural sustainability

Projects	Status	Objectives	Source
Global Environmental Facility (GEF)	International	Assist with: 1. Sustainable agriculture 2. Food security 3. Climate change adaptation. 4. Efficient land use	www.thegef.org
International Fund for Agricultural Development (IFAD)	International	To ensure that poor rural people have better access to resources and the skills and organizations they need to sustainably take advantage of natural resources. It is a specialized agency of the UN that funds agricultural development projects in areas that depend largely on agriculture	www.ifad.org
Environmental Education Awareness and Training (EEAT)	National	To enhance the understanding of people at all levels about the relationship between human beings and the environment and to develop their capabilities. 1. National Green Corps (NGC)- Eco-club programme 2. National Nature Camping Programme (NNCP) 3. Capacity Building Activities	www.moef.nic.in
National Environment Awareness Campaign (NEAC)	National	To create awareness on environmental issues followed by field actions at the local, regional and national level. Spectrum of short duration programmes supported by MoEF & CC for creating environmental awareness through new themes each year like Swatch Bharat mission, Ganga rejuvenation and river cleaning.	www.moef.nic.in

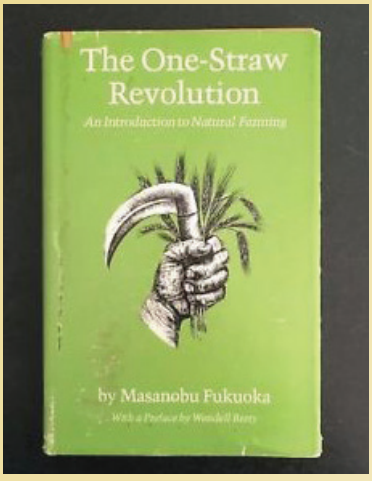
Environment Education in School System (EESS)	National	The Environment Education and Training Scheme of the Ministry is precisely meant for environmental awareness. Under this scheme, various programmes are conducted every year for creating environmental awareness both through non-formal activities as well as through formal education system. To provide hands-on activities through Global Learning and Observations to Benefit the Environment (GLOBE) programme.	 www.archive.india.gov.in
National Action Plan to Combat Desertification (NAPCD)	National	Activities to increase the quality of life and raise awareness of the local communities, promote R&D initiatives and interventions which are locally suited, supports drought management, preparedness and mitigation. It is a 20-year comprehensive National Action Program (NAP) for combating desertification, which is part of UNCCD and implemented by MoEF & CC in India	United Nations Convention to Combat Desertification www.envfor.nic.in
National Food Security Mission (NFSM)	National	National Food Security Mission (NFSM) is a Central Scheme of GoI launched in 2007 for 5 years to increase production and productivity of wheat, rice and pulses on a sustainable basis so as to ensure food security of the country. The aim is to bridge the yield gap in respect of these crops through dissemination of improved technologies and farm management practices. Sustainable increase in the production of targeted crops through area expansion and productivity enhancement.	 www.agricoop.nic.in

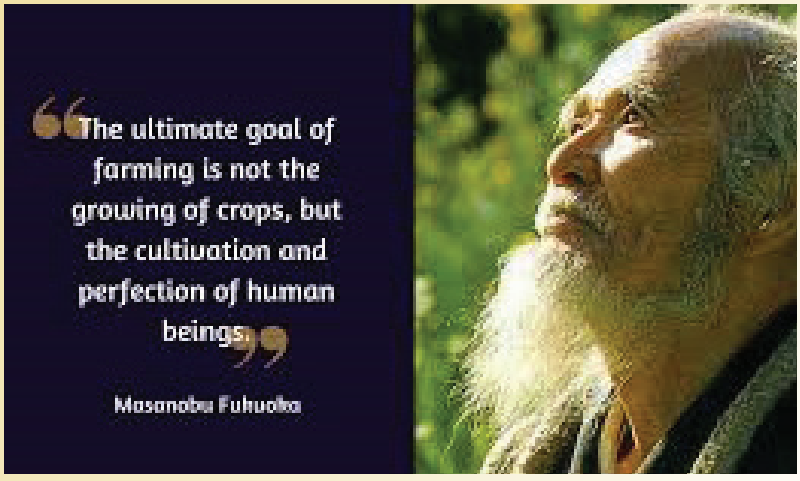
Rashtriya Krishi Vikas Yojana (RKVY)	National	Organic farming is promoted through adoption of organic village by cluster approach and PGS certification. Neem Coated Urea (NCU) Scheme for production of agriculture products free from chemicals and pesticide residues by adopting eco-friendly low cost technologies.	rkvy.nic.in
National Mission for Sustainable Agriculture (NMSA)	National	Popularizing integrated farming system for climate resilience 1. Rain-fed Area Development (RAD) programme 2. Climate change and sustainable agriculture: Monitoring, modeling & Net Working (CCSAMN) 3. Soil Health Management a. Soil Health Card Scheme (SHC) b. Paramparagat Krishi Vikas Yojna (PKVY)	www.nmsa.dac.gov.in
National Mission on Agricultural Extension and Technology (NMAET)	National	To restructure and strengthen agriculture extension and enable delivery of appropriate technology and improved agronomic practice to farmers. a. Sub Mission of Agricultural Extension (SAME) b. Sub Mission on Seed and Planting Material (SMSP) c. Sub Mission on Plant Protection and Quarantine (SMPP) d. Sub Mission on Agricultural Mechanization (SMAM)	www.agricoop.nic.in

Pradhan Mantri Krishi SinchaiYojana (PMKSY)	National	Sustainable water management through Diggi, Jal Hauz, Farm pond (Khettalai) and irrigation Pipeline programmes are being implemented by Agriculture Department 1. Accelerated Irrigation Benefits Programme (AIBP) 2. Har Khet Ko Pani 3. Per Drop More Crop 4. Watershed Development	 www.agriculture.rajasthan.gov.in
Green Agriculture project	International + National	To transform agricultural production and to generate global environmental benefits. a. Policy Transformation b. Management Transformation	 www.fao.org

Origin and importance of natural farming

Natural farming is not a technique but a view, or a way of seeing ourselves as a part of nature, rather than separate from or above it. It is also referred as "the Fukuoka Method", "the natural way of farming" or "do-nothing farming". The title refers not to lack of effort, but to the avoidance of manufactured inputs and equipment. Natural farming is related to fertility farming, organic farming, sustainable agriculture, agroecology, agroforestry, ecoagriculture and permaculture, but should be distinguished from biodynamic agriculture.





(Source- www.finalstraw.org)

So called "do-nothing" technique was developed by a Japanese scientist Fukuoka, who rejected both modern agribusiness and centuries of agricultural lore. 'The One Straw Revolution: An Introduction to Natural Farming' is the title of book written by Fukuoka in which he propagates how to use common

sense and sustainable practices by all; discontinue the use of pesticides, fertilizer, tillage, and perhaps most significantly, wasteful effort. The main features of natural farming system are:

- Physical work and labor can be highly reduced as compared to other agricultural systems.
- Yields similar to chemical agriculture is possible.
- There is an increase in soil fertility year after year.
- Water requirement is minimized.

Natural farming aims to increase farmer's yield by maximizing production factors (labor, soil, equipment) and by avoiding the use of non-natural inputs (fertilizer, herbicides and pesticides) to optimize production potential and thus provide abundant, high quality, healthy food at the best price. The golden rule is to enrich the level of organic matter into the soil, which supports microbial life, and therefore the soil's fertility. Conventional farming, on the other hand, does not aim to optimize yields through the use of inputs, which requires extensive cultivation over larger areas to produce the desired quantities. Thus, such farming has the blessing of all those who dream of a world where "Mother Nature" would over throw technical progress, is nonetheless responsible for one of the greatest tragedies for biodiversity: the disappearance of millions of acres of forest. An excessive use of chemical inputs can produce harmful effects. Natural farming aims at improving and preserving the quality of soil, whereas in every case conventional farming destroys. The important step in natural farming are conservation of crop diversity, no tillage, watershed management, efficient water

Social Welfare

The substitution of chemical inputs in natural farming generally results in higher demand for labour in comparison with conventional agriculture and therefore, should contribute to rural employment and help keep in business small farms which would otherwise not be able to cope with intensification and global competition.

Economic Wellbeing

Nature based farming represents real opportunities on several levels, contributing to rural economies through sustainable development such as ecological tourism to Natural farms is a tool to help small farmers to earn additional income and in this way support the transition from conventional farming to natural farming.

Ecological Aspects

Natural inputs provides a better root system and ability to interact with beneficial soil micro-organisms, ability to suppress weeds, contributing to soil, crop and seed health, good product quality, high yield level and high yield stability.

Fig 3: Social, ecological and economic attributes of natural farming

management, integrated nutrient management, integrated weed management, integrated pest management and crop diversification.

Innovative models and strategies for agricultural sustainability

Agriculture provided the foundation for civilization, and modern innovations in agriculture have helped in its evolution. Industrial monoculture, the farming method by which most of the global food supply is grown, degrades the land, reduces ecological resilience and diversity, and requires an enormous amount of fossil fuels. Conservation Agriculture is a theory defined by Food and Agriculture Organisation as a concept for resource saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. Well aware of the flaws, growers, scientists, and innovators have developed alternative models and methods that enrich the earth and produce healthy food. The new models focus on "non-monetized agriculture" and acknowledge other factors besides the sales of surplus crops as a way to alleviate hunger and poverty.

A. Sustainable Agriculture through System for Crop Intensification (SCI) method

The contemporary strategy for intensification that depends primarily on making genetic improvements and increasing external inputs is, however, not the only kind of intensification that warrants consideration, especially given growing concerns about the sustainability of current agricultural practices (IAASTD, 2009) and about their impacts on climate change. To meet our global food-security requirements throughout this 21st century, agriculture sectors around the world will need to pursue appropriate strategies for sustainable intensification of agricultural production (Royal Society 2009 and Montpellier Panel, 2013). System for Crop Intensification (SCI) practices enable farmers to mobilize biological processes and potentials that are present and available within crop plants and within the soil systems that support them. Such agro-

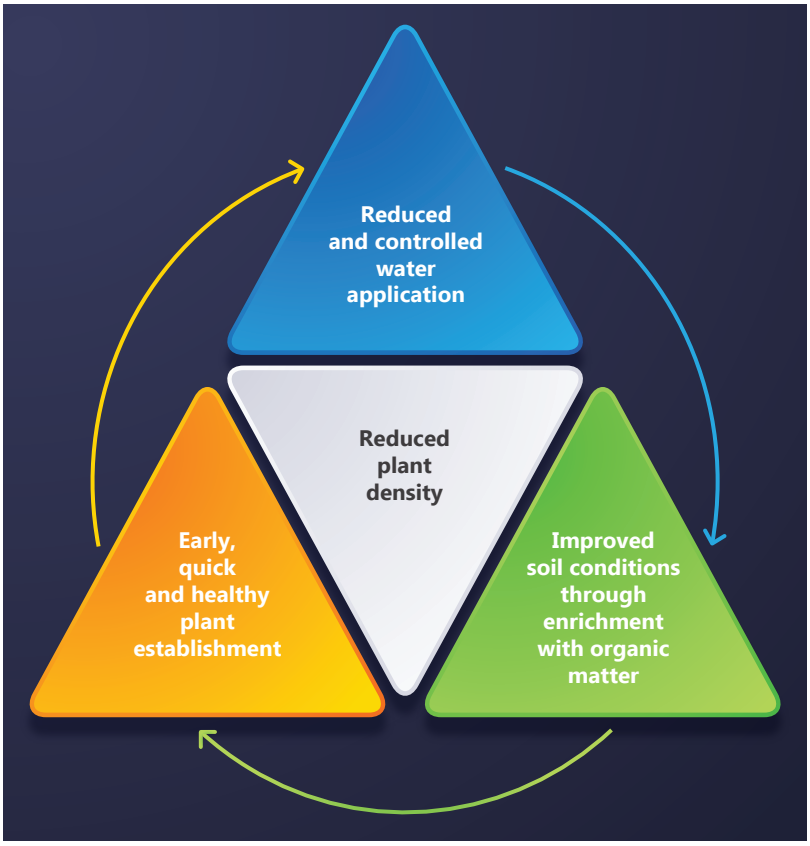


Fig 4: Four main principles of System for Crop Intensification
(source: www.sri.ciifad.cornell.edu)

ecological innovations represent a departure from the current paradigm for 'modern agriculture.' The terminology used can vary: Sustainable Agricultural Intensification (World Bank, 2006), low-input intensification, and sustainable crop production intensification (FAO, 2011). It is based on the cropping principles of significantly reducing plant population, improving soil conditions and irrigation methods for root and plant development, and improving plant establishment methods. Basically, it is a climate-smart, agro-ecological methodology which aims to increase the productivity of irrigated rice by changing the management of plants, soil, water, and nutrients.

On the basis of these principles, farmers adapt recommended SCI practices to respond to their agro-ecological and socio-economic conditions. Adaptations are often undertaken to accommodate changing weather patterns, soil conditions, labor availability, water control, access to organic inputs, and the decision whether to practice fully organic agriculture or not. These principles can also be applied to irrigated or rain-fed rice (System of Rice Intensification) and to other crops, such as wheat, sugarcane, teff, finger millet, pulses, showing increased productivity over current conventional planting practices.

B. Zero Budget Natural Farming: A Green Approach for Andhra Pradesh

The Government of Andhra Pradesh has launched a scale-out plan (on 2nd June 2018) to transition six million farms/farmers cultivating 8 million hectares of land from conventional synthetic chemical agriculture to Zero-Budget Natural Farming (ZBNF) by 2024, making Andhra Pradesh India's first 100 percent chemical-free agriculture farming state. The word Zero Budget refers to the zero net cost of production of all crops (inter crops, border crops, multi crops). The inputs used for seed treatments and other inoculations are locally available in the form of cow dung and cow urine. ZBNF farmers thus have lower cost of inputs and thus have better capacity to increase the incomes. At the same time ZBNF crops helps in retaining soil fertility and is climate change resilient. The aim of this program is to contribute towards the UN Sustainable Development Goals, focusing on Goal1-'No Poverty', Goal 6- 'Clean water and Sanitation', Goal 12-'Responsible Consumption and Production' and Goal15-'Life on Land'. This programme is supported by the Sustainable India Finance Facility (SIFF) -an innovative partnership between UNEP, BNP Paribas, and the WAC. It is both a social and environmental programme which ensures that farming (particularly for small landholders) is economically viable by enhancing farm biodiversity and ecosystem services. It aims to reduce farmers' costs by eliminating external inputs and using in-situ resources to rejuvenate soils, whilst simultaneously increasing incomes, and restoring ecosystem health by means of diverse multilayered cropping systems.

Table 3: Main stakeholders of Zero Budget Natural Farming program

Stakeholders	Description	Source
UN Environment	It provides leadership and encourages partnership in caring for the environment by inspiring, informing and enabling nations and people to improve their quality of life without compromising that of future generations.	www.unenvironment.org
BNP Paribas	It is a leading bank in Europe with international reach.	www.bnpparibas.co.in
The World Agroforestry Centre	It is a globally leading center of scientific excellence which is a member of CGIAR consortium, a global research partnership for a food secure future that supports achievement of SDG.	www.worldagroforestry.org
RythuSadhikaraSamastha	Not-for-profit organization established by the government of Andhra Pradesh has pioneered ZBN.	www.apzbnf.in

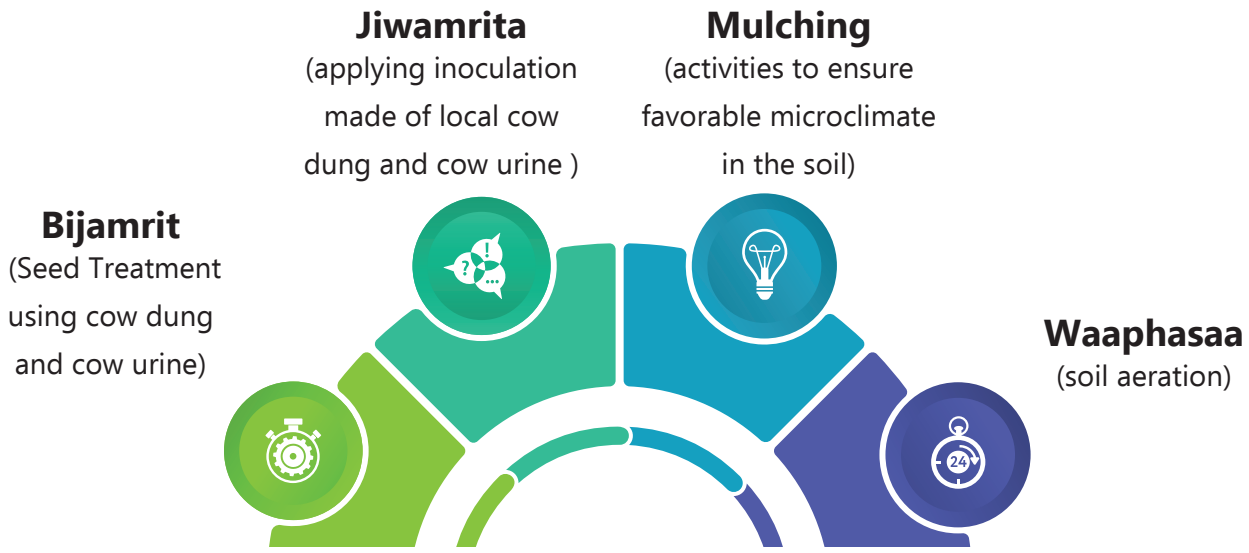


Fig 5: Four important guidelines for Zero Budget Natural Farming (Source: www.apzbnf.in).

C. Strategies for eco-agriculture

The natural farming (eco-agriculture) is considered even superior to organic farming in the sense that the former does not lay emphasis on ecosystem function and wild biodiversity conservation. The eco-agriculture increases agricultural production and simultaneously restores biodiversity and other

ecosystem functions, in a landscape or ecosystem management context. McNeely and Scherr (2003) have suggested six strategies for eco-agriculture. These are stated briefly as follows:

(i) Creation of biodiversity reserves that also benefit local farming communities. An example of what has already been done in this regard by the MSSRF is in Wayanad, Kerala, India. There, the MSSRF has developed a 'model' farm that cultivates several spices (black pepper, ginger, turmeric and cardamon), vanilla, coffee, several medicinal plants, tuber crops (Dioscorea species), jack fruit trees and several wild but economically useful tree species (Syzygiumtravancorium and Cinnamomummalabatrum) and also maintains a few farm animals. The farming principle includes the Low External Input Sustainable Agriculture (LEISA). Rainwater harvesting and management and soil health care are integral parts of the system. The crop pests are largely controlled (but not completely eliminated) by a traditional practice. The farm manure and 'vermicompost' (that is the compost of digested farm waste by earthworms which also pulverize the soil) are extensively used to enhance the soil organic matter, particularly the humus. The economic viability is ensured through regular income from composite culture of medicinal, agricultural and plantation crops, and farm animals. From the biodiversity point of view, the shift from the usual monoculture to polyculture ensures that a wider spectrum of species of insects, birds, small mammals and reptiles make use of the habitat. The inclusion of honeybees (apiculture) provides additional income from honey and also helps in pollination of vanilla; where adequate water is available, edible and ornamental fish culture is also included.

(ii) The second strategy is the development of habitat networks with agriculture in non-farmed areas. This involves the integration of agricultural landscapes in many non-farmed areas with high-quality habitat for wild species that are compatible with farming. For example, the traditional farmers provide facilities for barn owls to contain destructive rodents.

(iii) The third strategy is the reduction or even reversal of the conversion of wild lands into agriculture by increasing farm productivity.

(iv) The fourth strategy is to minimize agricultural pollution through more resource-efficient methods of managing nutrients, pests and waste. This is a basic principle governing all the approaches towards sustainable agriculture, conservation of biodiversity and health and welfare of all the rural women, children and men constituting especially the farming families.

(v) The fifth strategy is the modification of the management of soil, water and vegetation resources, in order to enhance the habitat quality in and around farms. An excellent example is the community-managed gene, seed, grain, water and fodder bank set up in the 'biodiversity-rich hotspots' in Orissa, India by the MSSRF. Swaminathan (2000 a,b, 2001 a) has described the concept of promoting a community-led integrated gene management system to achieve sustainable development and food. The Equator Initiative is a global movement committed to identifying and supporting innovative partnerships that reduce poverty through conservation and sustainable use of biodiversity. In addition, the Protection of Plant Varieties and Farmers'

Right Act, 2001 of India recognizes farmer as cultivator, conserver and breeder. Accordingly, it allows farmers the right to register farmers' variety, right to receive reward and recognition for conservation of agro-biodiversity, right to receive benefit sharing from a new commercial variety developed by using farmers' variety and right to re-sow, exchange, share or sell farm saved seeds.

(vi) The sixth strategy is the modification of the farming systems to mimic natural ecosystems. Economically useful trees, shrubs and perennial grasses are integrated into farm in ways that mimic the natural vegetative structure and ecological functions to create suitable habitat niches for wildlife. In a nutshell, eco-agriculture involves developing mutually reinforcing relationships between agricultural productivity and conservation of nature (Kesavan and Swaminathan 2006). Thus, the eco-agriculture involves concurrent action plans towards agricultural growth, poverty alleviation and biodiversity conservation. In the conventional approach, these three goals seldom complemented one another. In fact, agricultural growth and biodiversity conservation were erroneously regarded as mutually exclusive.

D. Precision in farming

The digitalization of agriculture, including various technologies for precision farming, artificial intelligence (AI), robots and drones, holds the promise to make modern agriculture more efficient and sustainable. This may be achieved by drastically increasing the amount of information available to make educated farming decisions on fertilizer and plant protection or by substituting human labor altogether. These technologies will not only boost biomass production, also livestock farming will improve its environmental footprint, Or, to put it in a nutshell: less input, more output and lower environmental footprint. The digitalization of food and biomass production is in full swing all over the globe, though at different paces and levels, equivalent to the extent of the farmers' realities and needs. Technology providers with the ambition to globally supply their products are therefore faced with the challenge to meet the farmers' needs. In addition, as in other applications of digitalization, the question of data security and data ownership arises. This affects not only the interests of the farmer but also the economic interests of technology companies and countries. The impact of the new technologies, such as robotics, drones and Artificial Intelligence (AI) is revolutionizing our food production system. Precision farming is generally defined as Information and Technology based farm management system, to identify, analyze and manage variability within fields for optimum profitability, sustainability and protection of the land resources. In this mode of farming, new information technologies can be used to make better decisions about many aspects of crop production. Precision farming has shaken up a number of large companies to invest in the development of new solutions for future farming technologies. Tata Consultancy Services (TCS) has a branch called Digital Farming Initiatives that developed a suite of flexible multi-pronged technologies, termed InteGraTM. These combine the so-called five digital forces – social networks, mobility, analytics, Cloud and Internet of Things (IoT) to create 'market smart' and 'climate smart' farming enterprises, coined Progressive Rural Integrated Digital Enterprises (PRIDETMs). With most parts of the country dependent on the monsoon for irrigation, farming continues to be a risky venture in India. Lack of timely and reliable

access to farm inputs, markets, technology, information, credit, and marketing support hinders small farmers' efforts to improve their output, yield, and prices. This is why TCS in 2009 launched mKRISHI, a for-profit rural mobile services platform that uses ICT to help solve farming challenges. The goal before the TCS Innovation Labs team was to create a 'Google' for rural India by collecting, managing, and leveraging a wide range of data related to farming. Today, mKRISHI delivers a range of personalized services such as agro advisory, best practices, alerts, weather forecasts, and supply chain management to farmers on their mobile phones. mKRISHI's mobile component instantly digitizes available field data and transmits it over GPRS or similar networks to a web dashboard for analysis by experts and operational planners.

Global, national and local stakeholders favoring sustainable agriculture

A stakeholder is someone with a vested interest; someone who stands to gain or lose (Anonymous, 2012). Here it refers to those who are responsible for creating environmental awareness regarding environmental impacts of agriculture, either because they caused it or because it is their duty to manage it. These stakeholders can be Global, National or local regarding their level of action as presented in table 4. Stakeholder value advocates that the success of an organization should be measured by the satisfaction among all stake holders. Prime Minister's Council identified Department of Agriculture & Cooperation and DARE to play the role of Lead Agency for preparation of Mission Document on NMSA. NAPCC has identified the following focus areas (Thirst areas) for NMSA – dry land agriculture, risk management, access to information and use of bio-technology. In order to prevent environmental issues due to agriculture and for the sustainable use of natural resource, understanding and taking into consideration the local stakeholders' environmental awareness, perception and problems, play their own substantial roles. The 'local stakeholders' are those individual, group or community living within the influence of the site or likely to be affected by a management decision or action, and any individual, group or community likely to influence the management of site.

Table 4: Global and national stakeholders of agriculture system

Stakeholders	Description	Source
Food and Agriculture Organization of the United Nations (FAO)	The Food and Agriculture Organization (FAO) is a specialized agency of the United Nations that leads international efforts to defeat hunger. It is an intergovernmental organization working to make agricultural production more productive and sustainable.	www.fao.org
United Nations Environment Programme (UNEP)	It is an agency within the UN coordinating and implementing environmental actions. As one of their many duties, UNEP is tasked with helping to implement the SDGs. The UNEP is a global authority that: a. Sets the global environmental agenda b. Promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations system c. Serves as an authoritative advocate for the global environment.	www.unenvironment.org
World Bank Group	It is a leading investor in agriculture globally, working with countries and providing infrastructure and resources to the food and agriculture sector.	www.worldbank.org
World Trade Organization (WTO)	One of its treaties, the Agreement on Agriculture, aims to limit barriers to trade in agriculture and to open agriculture market access. The WTO has many roles a. It operates a global system of trade rules b. It acts as a forum for negotiating trade agreements c. It settles trade disputes between its members d. It supports the needs of developing countries.	www.wto.org

Ministry of Environment, Forest and Climate Change (MoEF & CC)	It is a nodal agency in the administrative structure of the central government for the planning, promotion, co-ordination and overseeing the implementation of India's environmental and forestry policies and programmes. The broad objectives of the Ministry are: a. Conservation and survey of flora, fauna, forests and wildlife b. Prevention and control of pollution c. Afforestation and regeneration of degraded areas d. Protection of the environment e. Ensuring the welfare of animals	Ministry of Environment, Forests & Climate Change Government of India www.envfor.nic.in
Ministry of Agriculture and Farmers welfare (MoA & FW)	It is an apex body for formulation and administration of the rules and regulations and laws related to agriculture in India. Ministry of Agriculture & Farmers Welfare has been organized in three major departments: a. Department of Agriculture Research and Education (DARE) b. Department of Agriculture, Cooperation and Farmers Welfare (DAC & FW)	 www.agriculture.gov.in

Table 5: Local stakeholders of agriculture system

Stakeholders	Description	Source
Agriculture Research Station (ARS)	It is a scientific research center that investigates biological, economic and social difficulties and potential improvements to food production and agribusiness. These were established under state agriculture department. Its major objectives are: 1. For large scale multiplication of quality breeder and foundation seeds for distribution to State Department of Agriculture, private seed farms and seed production farmers. 2. To expand the research activities relating to evaluation of new varieties and to identify innovative technologies to improve crop production. 3. To produce University/ Government Labelled Seeds of different agricultural crop varieties from 2013 onwards. 4. Training to the farmers who involved in the seed production Foundation/ Certified.	 www.sknau.ac.in
Krishi Vigyan Kendras (KVKs)	The mandate of KVK is Technology Assessment and Demonstration for its Application and Capacity Development. To implement the mandate effectively, the following activities are envisaged for each KVK: a. On-farm testing to assess the location specificity of agricultural technologies under various farming systems. b. Frontline demonstrations to establish production potential of technologies on the farmers' fields. c. Capacity development of farmers and extension personnel to update their knowledge and skills on modern agricultural technologies. d. To work as Knowledge and Resource Centre of agricultural technologies for supporting initiatives of public, private and voluntary sectors in improving the agricultural economy of the district. e. Provide farm advisories using ICT and other media means on varied subjects of interest to farmers.	 http://icar.org.in

Non-Governmental Organizations (NGOs)	The task of development is so vast and complicated that simply implementing government plans is not sufficient to fix the problem. To achieve this, a holistic vision and collaborative efforts involving various departments, agencies and even NGOs is required. Such NGOs are task-oriented and driven by people with a common interest. NGOs perform a variety of service and humanitarian functions, bring citizen concerns to Governments, advocate and monitor policies and encourage political participation through provision of information.	 http://ngodarpan.gov.in
Farmer Producer Organization (FPOs)	Mobilizes farmers into groups called Farmer Interest Groups (FIGs) to strengthen farmers' capacity through training on best agricultural practices for enhancing crop productivity in a sustainable manner. The society is a pioneer in organizing small and marginal farmers as Farmers Interest Groups, Farmers Producers Organization and Farmers Producers Company for endowing them with bargaining power and the benefit of economies of scale. It provides a platform for increased accessibility and cheaper availability of agricultural inputs to small and marginal farmers and in establishing forward and backward linkages in supply chain management. This initiative has triggered mobilization of farmers for aggregation across the country with ultimate aim of sustainable business model and augmented incomes.	 www.isapindia.org
Panchayat/Block Samiti	It is an informal body that addresses the common needs and aspirations of the local community. Its members are the decision makers that represent all the hamlets in the area. Gram as defined under the Act (meaning a village or a cluster of villages) is divided into a minimum of five constituencies (again depending on the number of voters the Gram has). From each of these constituencies, one member is elected; each GP under a Block Panchayat elects one/two/ three members directly to the Block Panchayat; GP pradhans are ex-officio members of the Block Panchayats.	 www.narmada.org

Rural Agrarians (Farmers)	The rural household, indigenous people and their communities, a substantial number of whom are women, have been the stewards of much of the Earth's resources. Understanding the particular dynamics of rural society in any given place and time requires analysis of the experiences and political culture of agrarian classes and communities.	 http://sedac.ciesin.columbia.edu/

Research methodology

Area of study

With a population of 1.27 billion, India is the world's second most populous country. It is the seventh largest country in the world with an area of 3,288 million square kilometres. India's climate varies from humid and dry tropical in the south to temperate alpine in the northern reaches and has a great diversity of ecosystems. Agriculture and allied sectors contribute 28 percent of the total GDP and provide employment to around 70 percent of the Indian population with 82 percent of farmers being small and marginal. A larger part of Indian population is dependent on agriculture for their livelihood. Rural population is in majority in India and accounts for about 12 percent of the world population. The proportion of total area operated by marginal farmers increased from nine percent in 1970-71 to nearly 15 percent in 1990-91, while the proportion of large farmers declined from about 31 percent to 17 percent in the same period. The size of average holding is very unevenly distributed among the states. The diversity of India's agro-ecological setting, high biodiversity and relatively low cost of labour provide potential for agricultural competitiveness in a globalized economy. In 2017-18, total food grain production was estimated at 275 million tonnes (MT). India is the largest producer (25% of global production), consumer (27% of world consumption) and importer (14%) of pulses in the world. It is the largest producer of Milk, Jute and Pulses, and has the world's second largest cattle population. Fruits and vegetables account for nearly 90% of total horticultural production in the country. India is now the second largest producer of rice, wheat, sugarcane, cotton and groundnut, as well as the second-largest fruits and vegetables producer in the world. It is the leading producer of several horticultural crops namely, mango, banana, papaya, cashew-nuts, areca nut, potato, and okra. While agriculture in India has achieved grain self-sufficiency, the production is resource intensive, cereal centric and regionally biased. Increasing population and economic growth are changing the patterns of land use making potentially unsustainable demands on the country's natural resources.

1. Rajasthan state

Rajasthan is the highest producer of Mustard, Gram and Bajra in the country. It is the second largest producer of moth beans and third largest producer of Pulses and Wheat. Also, it is the second largest producer of milk in the country. In most of rain-fed areas of the state, only one crop can be grown during the year. ICAR reported that among all the districts of Rajasthan state that lie in semi-arid, agro-ecological region (AER) 4, Alwar, Bharatpur and Dhaulpurare – classified under hydrologically unsustainable zone for rice-wheat cropping system (RWCS) – and also these districts fall under similar the agro-climatic zone (flood prone eastern plains) of Rajasthan state. Rice–wheat is the most important cropping system in terms of area, fertilizer use and crop productivity (FAO, 2005). Increasing salinity, declining water table (over exploitation of groundwater) and depleting soil fertility are the major concerns Erenstein, *et. al.,* (2007). Therefore, farmers need to make agriculture practices more resilient in the light of ever harsher and changing agro-ecological conditions.

Alwar

Alwar comprises of rivers, mountains, plains and semi-arid areas. It is bordered by Gurgaon of Haryana on the North, on its North-East lies the Bharatpur district of Rajasthan and Mahendragarh of Haryana. The capital city, Jaipur, is situated to its South-West and Dausa to its South. Out of the five rivers, two (Arvari and Ruparel) flow after revitalization and rest have been dried up due to encroachment. The rainfall distribution in the district is uneven and scattered which sometimes results in flood or drought problems in the area, thereby, affecting the agriculture production as well as cropping pattern in Kharif and Rabi season. Thus, agriculture in the district by and large depends upon the rainfall distribution. The water conservation technologies in this area are not yet adequately introduced. Modern technologies have a vast scope and can have a direct impact upon the socio-economic status of the farmer community in this region.

Bharatpur

Bharatpur is located 180 km away from Delhi. It is bordered by Gurgaon of Haryana in North, Mathura in the East, Agra of Uttar Pradesh and Dholpur of Rajasthan in the South and Dausa and Alwar in the West. The main rivers of the district are Ruparel, Gambhir, and Ban Ganga which passes through the district. It has an important place in agriculture production in Rajasthan. The climate of this district is dry, which becomes extremely hot during summer and extremely cold during winter. The period of monsoon is very short. In the last ten years rainfall is very less, dry spells have occurred frequently and uneven distribution of rainfall is reported.

Dhaulpur

It is the eastern most district of Rajasthan state falling under flood prone region with scanty and erratic rainfall. The district plays a vital role in the domestic economy of the state. It is surrounded by Agra district of Uttar Pradesh in the North-East, Morena district of Madhya Pradesh in the south-east and Koroli district of Rajasthan in west. Chambal, Parvati and Gambhiri are the major rivers in the district. The soil has excellent surface drainage and is exposed to common erosion problem. It is low in nitrogen, phosphorus and potash are available on a medium scale. Rainfall occurs between June and September through the south west monsoon making up for about 80% of the annual rainfall.

2. Telangana state

Telangana, the 29th state of India, was formed in June 2014, with Hyderabad as its capital. The economy of this state is mainly supported by agriculture. Farmers in Telangana mainly depend on rain-fed water sources for irrigation. Rice is the major food crop. Other important local crops include cotton, sugarcane, mango and tobacco. Recently, crops used for vegetable oil production such as sunflower and peanuts have gained favour Agricoop (2017-18). There are many multi-stage irrigation projects involving Godavari River Basin Irrigation Projects. Telangana is developing into a seed hub

in India and was selected as a certifying agency as per OECD standards for ten states. It exports seeds to countries like Sudan, Egypt, Phillipines *etc.* Based on climatic parameters *i.e.* Rainfall, Soils and cropping pattern *etc.* the state is divided into four Agro-climatic zones. The two districts, Ranga Reddy and Mahbubnagar lie in Southern Telangana Zone. The agricultural planning for this zone is supported with the research and recommendations of Regional Agriculture Research Stations of ANGRAU setup within each zone.

Rangareddy

The boundaries of Rangareddy district are Nalgoda, Mehbubnagar, Karnataka state, and Medak district in the east, south, west, and north, respectively. It is located at the heart of Dashinapatha or the Deccan plateau of the Indian subcontinent. The climate of the district is characterized by a hot summer and is generally dry except during the southwest monsoon. The rainfall distribution in the district is erratic and unevenly distributed. The District frequently experiences late onset of monsoons and also continuous dry spells during the months of July, August or sometimes even in the month of September. Continuous rain during the flowering period during the time of maturity is also setback to the production. A major part (about 65 %) of the district is covered by the Musi river Basin. The next largest basin in the district is the Kagna Basin, which has good potential as it can irrigate large areas. The third basin in the district is the Manjira basin, which is a part of the Godavari basin where the area under irrigation is very limited.

Mahbubnagar

It is the largest district in Telangana state in terms of area. It is bounded on the north by Rangareddy district of Telangana, on the east by Nagarkurnool district of Telangana, on the south by Wanaparthy and Jogulamba-Gadwal district of Telangana, and on the west by Raichur and Gulbarga districts of Karnataka state. Two important rivers, Krishna and Tungabhadra flow through the district. Unfortunately, drought is an ever persistent problem in the district which perhaps is one of the reasons for its backwardness.

3. Andhra Pradesh state

Andhra Pradesh was among the very few states in the country which adopted the Green Revolution in Rice cultivation in 1970s Chakroborty and Murray (2011). Agriculture has been the chief source of income and main occupation for the state with 60% of population engaged in it and in other related activities. Rice is the major food crop and staple food of the state. Other important crops are sugarcane, cotton, mango, tobacco, maize, pulses *etc.* The major irrigation projects are Nagarjuna Sagar Dam and Godavari River Basin Irrigation Projects. Andhra Pradesh is a role model in using the technology at optimum level for effective delivery of services in implementation of agriculture insurance scheme. It is also a pioneer in the implementation of village insurance scheme to mitigate the plight of the farming community in the country. The state is divided into five agro-climatic zones; the classification mainly concentrates on the range of rainfall received, type, and topography of the

soil. The two districts, Kurnool and Kadapa, lie in a scarce rainfall zone. Crops produced in semi-arid tropics (SAT) is determined by two major natural resources *i.e.* climate and soil which are to be best utilized.

Kurnool

The district is bounded at the north by Mahbubnagar district of Telangana state, on the south by Kadapa and Anantapur district, on the west by Bellary district of Karnataka state and on the east by Prakasam district. The climate of the district is normally good and healthy. South-West monsoon brings fair quantum of showers. The principal rivers flowing in the district are Tungabhadra, Krishna, and Kunderu.

Kadapa

Kadapa district is said to be the heart of Rayalseema as it is centrally located and well connected with the four districts of Rayalseema. Kadapa is one of the districts in Rayalaseema area, with an uneven and isolated rainfall pattern in different parts of the district, and has large dry tracts. The rainfall of Kadapa district is mainly influenced by the South-West monsoon and some parts of the district receives rainfall from the North-East monsoon also. Principal Rivers like Penna, Papaghni, Chitravati and Mandavya cut across the district giving the land sanctity of its own.

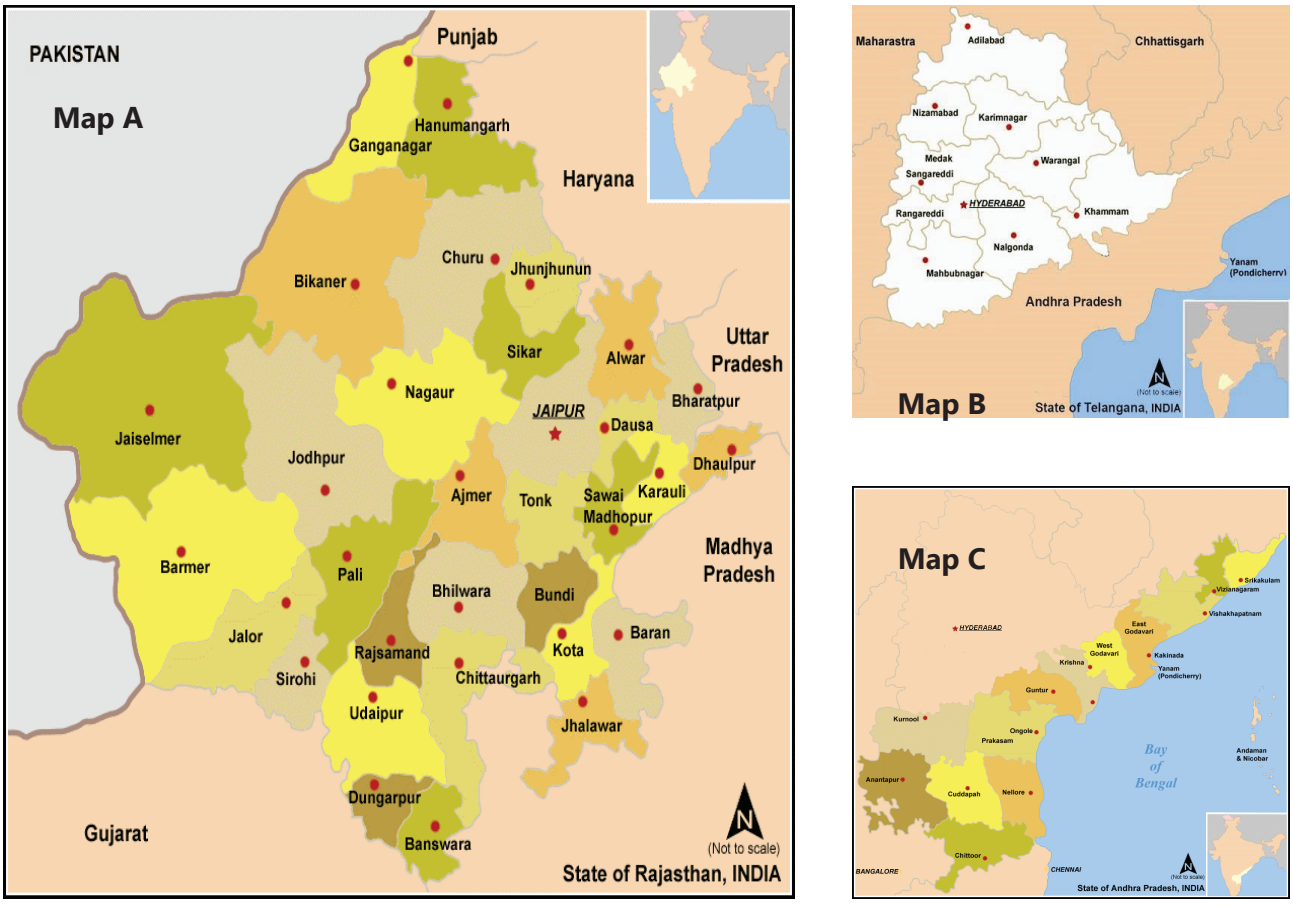


Fig 6: District maps of areas of study (A. Rajasthan state, B. Telangana state and C. Andhra Pradesh state) [Maps are not on the scale]

Table 6: Agro-climatic conditions in the areas of study

State	District	Total cropped area (ha)	Average Annual Rainfall (mm)	Temp. (ºC)		Major crops		Soils	Major sources of irrgation	Agro-Climatic zone and Agricul-ture Research Station
				max.	min.	**Kharif** (Jul-Oct/Nov)	**Rabi** (Nov-Apr)			
Rajasthan	Alwar	7,81,615	724	41.1	7.3	Bajra, Maize, Jowar, Kharif pulses; Arhar, Sesamum, Cotton, Guar *etc.*	Wheat, Barley, Gram, Mustard, Taramira, Rabi pulses *etc.*	Red sandyloam and sandy	Wells and Tubewells	Food prone eastern plains zoneand Navgaun, Alwar
	Bharatpur	6,06,309	664	41.7	7.4	Rice, Jowar, Bajra, Maize, Arhar, Urad, Moong, other kharif pulses, Cotton, Castor seed, Moth, small millets, Sunflower *etc.*	Wheat, Gram, Masoor, Rapeseed and Mustard, Barley, Peas and Beans, Linseed *etc.*	Sandy loam and loam	Tubewell	
	Dhaulpur	1,64,000	815	42.1	7.4	Bajra, Sesame Clusterbean *etc.*	Mustard, Wheat, Chickpea, Potato *etc.*	Sandy loam and loam rocky	Tubewell, tank irrigation and canal	
Telangana	Ranga Reddy	2,28,700	616	34	23	Rice, Red gram, Jowar, Maize, Cotton *etc.*	Rice, Chickpea, Ground-nut *etc.*	Red soil and black soil	Canals, tanks, open wells, bore wells, lift irrigation and micro-irrigation	Southern-Telangana Zone and Palem, Mehbubnagar
	Mahbub-nagar	7,37,000	882	39.5	15	Rice, Castor, Jowar, Redgram *etc.*	Ground-nut, Paddy *etc.*	Red soil and black soil	Canals, tanks, open wells and Tubewells	
	Kurnool	9,59,500	659	39.9	16.7	Cotton, Rice Castor, Maize, Green gram, Bajra *etc.*	Bengal gram, Rice, Sorghum, Sunflower *etc.*	Black and red soil	Canals, tanks, tubewells, Lift irrigation and micro irrigation	
Andhra Pradesh	Kadapa	3,65,000	753	19	40.1	Cotton, Rice, Redgram, Ground nut *etc.*	Sesa-mum, Corian-der, Bengal-gram, Rice *etc.*	Black and red soil	Canals, tanks, open wells, bore wells and micro-irrigation	Scarce rainfall zone and Nandyal, Kurnool

Research Methodology

Random sampling was done in the selected three states (Rajasthan, Telangana and Andhra Pradesh) selected for primary data collection. Rural agrarians (farmers) and experts (Agriculture Research Stations, Krishi Vigyan Kendra, Non-Governmental Organizations and Farmer Producer Organizations Members) were selected to collect the data. To collect the views about conventional and sustainable agriculture practices, Focused Group Discussions (FGDs) with farmers and in-depth interview of experts was used for sampling through a descriptive-survey method. The total number of respondents selected was 150, which were chosen through random-stratified method. Different farms were visited in the selected districts to gauge the perception and check the awareness of farmers regarding the various environmental issues caused by agriculture practices during its different phases like tillage, sowing, harvesting, *etc.* Also, many experts, who are working with farmers in the selected districts, were interviewed. Case study work in four different farms (based on farming inputs) in three different states involved information a the farm, farming practice and different philosophies for management of soil, pests, and water on their farm. A mixed method that involves initial rapport building, qualitative and quantitative study in the selected area of study for target population was used. Primary data for this study was collected by interviewing the experts and focus groups. The secondary data regarding agricultural status of the districts was collected through document review and through the websites such as Science direct, Springer, Scopus, MoAFW, MoEF & CC, FAO, World Bank, WWF, UNEP, ONCED, *etc.* A semi-structured interview schedule was prepared to study the different environmental issues occurring due to agriculture practices and what the most sustainable ways to transform it to make agriculture highly efficient for farmers both in quantity as well as quality of crops grown by them are. In-depth interview and focused group discussion (FGD) methods were used during field survey work·

Table 7: Details of target respondents for this study

States	Districts	Sample size	
		Farmers	Experts
Rajasthan	Alwar	20	2
	Bharatpur	15	3
	Dhaulpur	20	2
Andhra Pradesh	Kurnool	20	2
	Kadapa	20	2
Telangana	Rangareddy	20	2
	Mahbubnagar	20	2
Total		150	

Instrumentation

The questionnaire prepared as a tool for this study mainly comprised of closed-ended questions, supplemented by partially open-ended ones. The purpose of the questionnaire prepared for this study was to get first-hand information about current agriculture practice in each state. The basic demographic information was collected in the beginning of the survey to foster mutual trust during the interview process, and to prevent refusal to disclose real information. This measure was taken to improve the accuracy and completeness of the data. The questionnaire used in this study was designed based on Likert scale and Guttman scale to quantify the degree of awareness, knowledge, attitude, evaluation ability of farmers regarding type of agriculture practice which is common in their area, and their participation with current schemes and programs. Dichotomous scale ("Yes" and "No") is used mainly to identify the skill of farmers and knowledge of experts. The guttman scale is used to identify satisfaction on the statements regarding the governmental schemes asked about. In order to simplify the calculations and statistics, each possible answer to the closed-ended questions was assigned a Likert scale value. The difference between the Likert scale values for adjacent answers was constant (one point). Higher Likert scale point values were assigned for higher levels on the Likert scale. The internal consistency of the items/questions in the questionnaire was checked through formula-

$$\alpha = \frac{N \cdot \bar{c}}{\bar{v} + (N-1) \cdot \bar{c}}$$

Here N is equal to the number of items/questions, c-bar is the average inter-item covariance among the items and v-bar equals the average variance. It is found that the value of cronbach's alpha value is 0.99, which suggests that the items have relatively high internal consistency.

Table 8: Questions asked from farmers

S. No.	Questions	Reference No. from Bibliography
1	Which agriculture practice is done by you?	59 ; 60 & 61
2	Which are the environmental issues caused by the unsustainable agriculture practice?	35; 40; 42; 43 & 57
3	How do you get to know about these environmental issues?	7; & 63
4	How satisfied you are with governmental schemes and programs?	38 & 56
5.	Suggest some good traits of sustainable agriculture?	52 & 53
6.	What are the challenges faced in adopting these good traits?	2;21& 24
7.	Give your opinion on suggestions mentioned in National Agriculture Policy (NAP) of India for agricultural sustainability?	14 & 17

Table 9: Questions asked from experts

S. No.	Questions	Reference No. from Bibliography
1	Which of the environmental issues given below are caused due to unsustainable agriculture practices?	35; 40; 42; 43 & 57
2	How agriculture activities can cause depletion in water?	43; 44 & 45
3	How agriculture induces change in climate?	39; 41; 43 & 45
4	How agriculture activities are polluting air?	39; 42 & 45
5	How agriculture causes biodiversity and habitat loss?	40 & 43
6	How agriculture activities are polluting water?	42
7	How agriculture activities cause soil degradation?	43 & 44
8	How pesticides and fertilizers are harmful for environment?	36; 38 & 43
9.	How Genetically Modified Organisms cause harm to the environment?	40
10.	How agriculture activities generate waste?	44

Collection Methods

Data collection methods used are -

- Literature review
- Focused Group Discussion (FGD) with farmers
- In-depth interviews of experts
- Observation
- Case studies

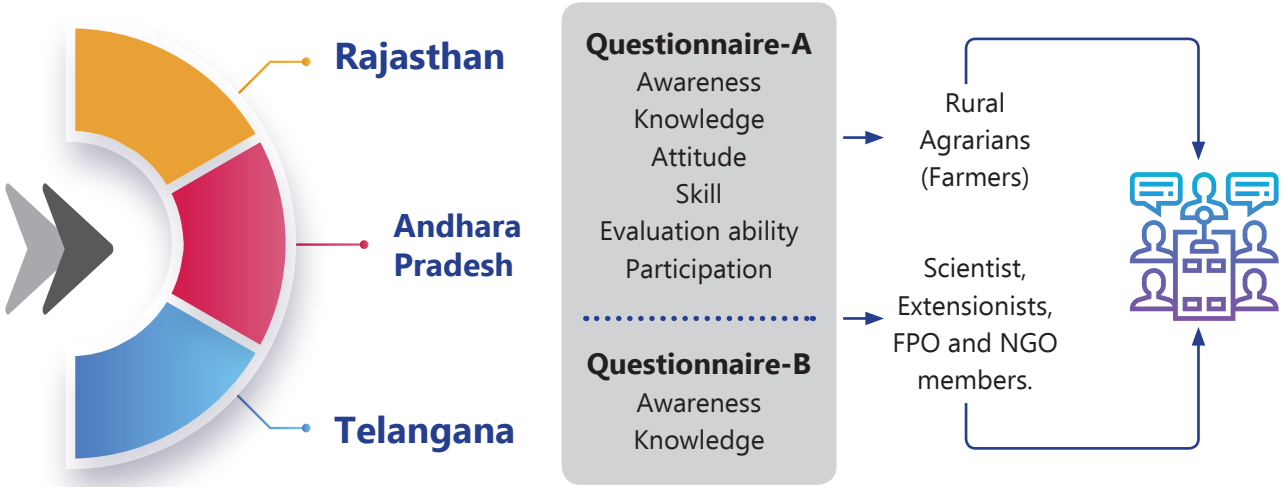


Fig 7: Framework representation of primary data collection for this study.

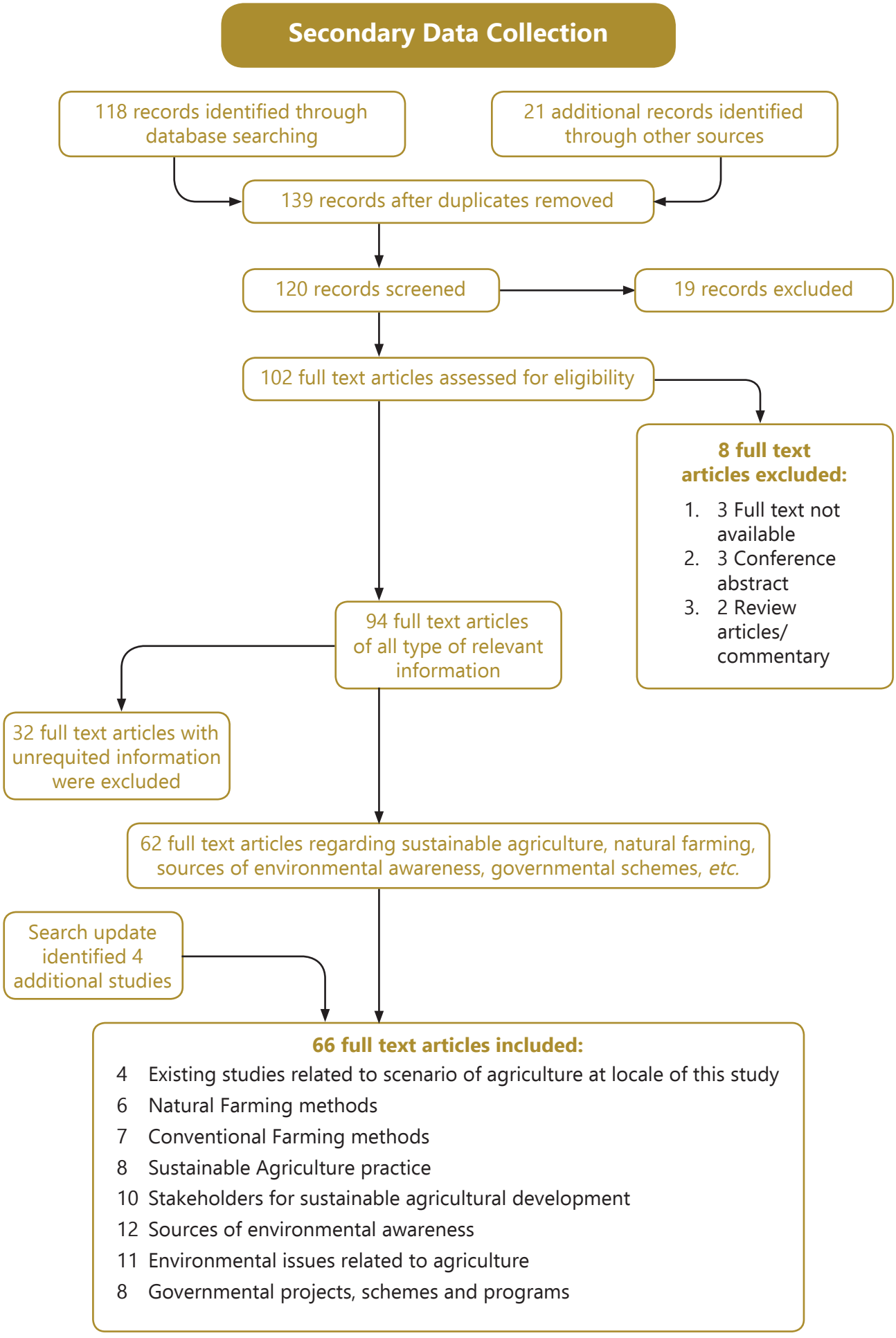


Fig 8: Flow chart of study inclusion and exclusion for secondary data collection.

Data analysis

This study first determined the factors important to farmers (Skill, Awareness, Attitude, Participation, Knowledge and Evaluation ability) based on literature study on current farming practices. From the identified set of factors and their relationships to agricultural farming systems, the study further determined that different groups (farm communities compared with researchers/extension personnel) weighed these relationships differently due to experience, knowledge, and the social, cultural, and ecological conditions of the groups and/or area of study. The entire data collected after survey was summarized and categorized in different ways for ease of representation and comprehension of result. Inductive analysis was used to frame the result. Further, four case studies were prepared on the basis field survey for the evaluation of causal links between various components of farming practices in relationship to environmental issues, food security and socio-economic security for farmers. In this study, the farmers define the components of what determines their willingness to try a sustainable farming technique. Later the case studies of different farms in all the three states were done to allow research professionals to adapt the findings for application in agriculture development projects. According to Groode and Hattin 1953, case study is a method of exploring the life of a social unit (Goode and Hattin,1953). These case studies in the areas of study had particular focus on the awareness and knowledge of conservation agricultural practices such as minimum tillage, micro-irrigation and use of natural inputs. The case study work involved: a. Site Visit and b. Data collection; where study participants were asked to develop determining factors influencing their decisions. These case studies are external representations that correspond to the way in which study participants have constructed and organized internal versions of external reality in their minds. Furthermore, the mapping of various farms (chemical, organic, natural and mixed) show how a system operates based on defined components and the causal links between these components. In terms of this study, these components act as quantifiable constructs measuring such concepts as various farming practices in relationship to profits and soil qualities in relationship to yield and/or profits. Participants can either define the components in the system, or be given pre-selected components with instructions that components can be added or removed. During the case study, the farmers define the components of what determines their willingness to try a new farming technique. Next, participants were asked to indicate connections between system components and stages of farming system. Participants typically drew directional arrows from one component to another and then indicated the stages of influence. In an effort to expand the use of these case studies in environmental management and display how agribusiness professionals can adapt this for application in agriculture development projects, these case studies concentrated on modelling the various agricultural systems of farmer communities practicing in states of Rajasthan, Telangana and Andhra Pradesh. Insight gained from the subsequent models are intended to demonstrate how understanding of the agricultural system can differ between communities, and can shape decision-making regarding cultivation methods, crop selection, and management practices. With this information, researchers and extension personnel can develop adoption strategies with the farm community while fully incorporating their beliefs. The chances of adopting introduced innovative practices have a higher probability of success with a community participatory approach and emphasis on shared value systems

Result and Discussion

Socio-Economic background of target respondents

Farmers have been characterized as having ties to the land that give them a deep awareness of natural cycles, appreciation for natural beauty, and sense of responsibility as stewards. In contrast, their relationship to the land has been characterized as more utilitarian than others who are less directly dependent on its bounty. The demographics of the survey respondents are listed below in table 11 and 12. The gender distribution for the expert respondents was approximately 27:73 percent, female to male ratio, while among the farmers, the ratio was 21:79 percent. From the demographics, it is easily visible that most of the respondents were male. All expert respondents had a minimum of a secondary school education, with the average education being a Bachelor's degree. Master's and PhD were the highest qualification of experts. Farmers had an average minimum primary school education in Alwar, Ranga Reddy, Mahbubnagar, Kurnool and Kadapa, with the exception of Bharatpur and Dhaulpur districts where respondents had on average a pre-school education. Of the farmer respondents, average ages ranged between 33 and 40 years. Age demographics were not collected from expert respondents.

Table 10: Questions asked from experts

Variable	Total response	Range	Average
Age (Years)	135	33-52	46
Gender			
Male	107	-	-
Female	28	-	-
Education			
Primary	66	-	-
Secondary	39	-	-
College	22	-	-
Other	8	-	-
Total landholdings (Acres)	135	2-25	8
Years of Farming Experience	135	1-50	18

Table 11: Socio-economic background of surveyed experts

Variable	Total response
Age (Years)	135
Gender	
Male	11
Female	4

Education	
Primary	0
Secondary	2
College	4
Other	9

Agriculture directly impacts food security and has significant share in India's Gross Domestic Product (GDP). It provides employment to almost two-thirds of the workforce and hence it is an integral part of the Indian economy. Agro-based industries like sugar, textiles, jute, food and milk processing *etc.,* depend on agricultural production for their requirement of raw materials.

Analysis of media exposure of farmers

There are many types of sources of information available to help farmers to gain high yield and profit with optimum water consumption. Minimum soil tillage, minimum or no utilization of chemical pesticides and fertilizer, promoting use of renewable energy based machineries on farm, providing solution to maintain natural potential of microbes and agricultural biodiversity, less agricultural water pollution, information about GMOs and hybrid seeds, better use of agriculture waste, and means for mitigation of climate change.

Table 12: Sources of information used by farmers

Sl.No.	Types of information sources	% of respondents	Mean
1	Radio	47	0.093
2	Television	98	0.195
3	Newspaper	71	0.142
4	Mobile	80	0.160
5	Personal computer	31	0.062
6	Internet	77	0.153
7	Social media	67	0.133
8	Books/Magazine	18	0.035
9	Educational events	12	0.024

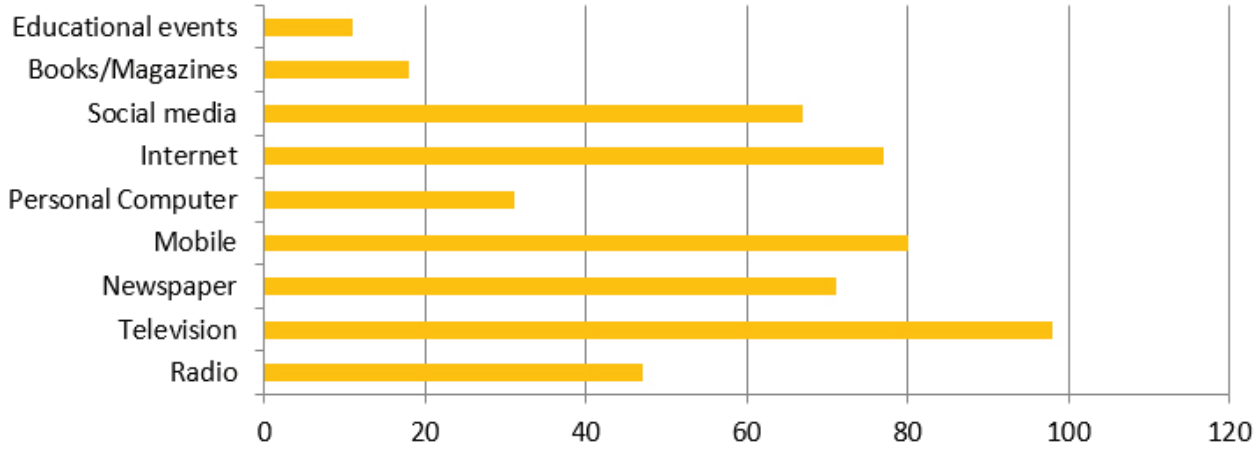


Fig 9: A bar-graph representation of sources of information used by farmers

It was analysed that the primary sources utilized by farmers to collect any information related to farming were television programmes, newspapers, internet and social media in the surveyed three states of India which is in accordance to as concluded in Kapoor (2012). These sources were also promoting farmers to practice environmental friendly farming in their regions.

Table 13: Different types of social media sites used by farmers

Sl.No.	Types of social media sites	% of respondents	Mean
1	YouTube	93	0.4
2	WhatsApp	68	0.293
3	Facebook	53	0.228
4	Twitter	15	0.064
5	Instagram	3	0.014

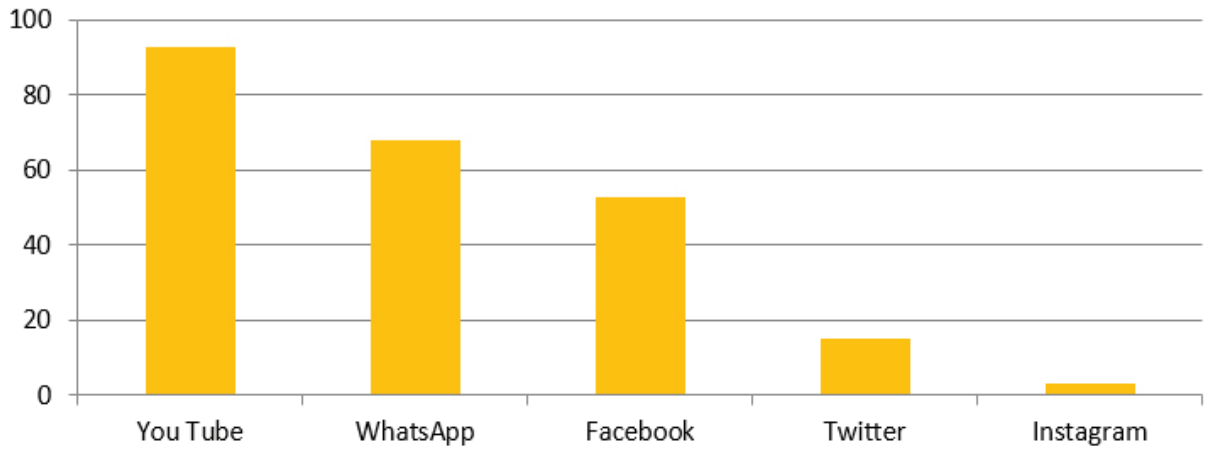


Fig 10: A bar-graph representation of different types of social media sites used by farmers.

Majority of farmers were using YouTube, WhatsApp and Facebook. It was found that these sites were source of entertainment for high number of farmers similar to as reported in Oreszczyn *et. al,* S., A.

Lane, and S. Carr. (2010). YouTube was ranked as number one social media site and was found to give more useful information to the farmers than other sites in all the three states.

Analysis of Farmers' skill based on agriculture practice

Agriculture development, while vital to our quality of life, can be harmful to the environment due to poor management. Globally, the agricultural activities cause serious environmental damage either by water infiltration in soil with the consequent possibility of nutrient and pesticide leaching, or if water undergoes surface runoff by erosion process that can lead sometimes to transportation of relevant amount of soil particles to water streams. However, it represents only a small part of the impact of the agriculture on the environment and does not point out the actual role that agriculture practices play in their interaction with the environment. The farmers' value perspective emphasized responsibility over profitability. The understanding of relationships among selected respondents about agriculture practice and their resource use pattern is critical in designing community-based management programmes as well as conservation and development strategies.

Table 14: Analysis of agriculture practice in the areas of study

States	Type of farming systems and % of respondent			
	Chemical farming	Organic farming	Natural farming	Mixed farming
Rajasthan	55	13	7	25
Andhra Pradesh	10	13	65	12
Telangana	13	55	25	7

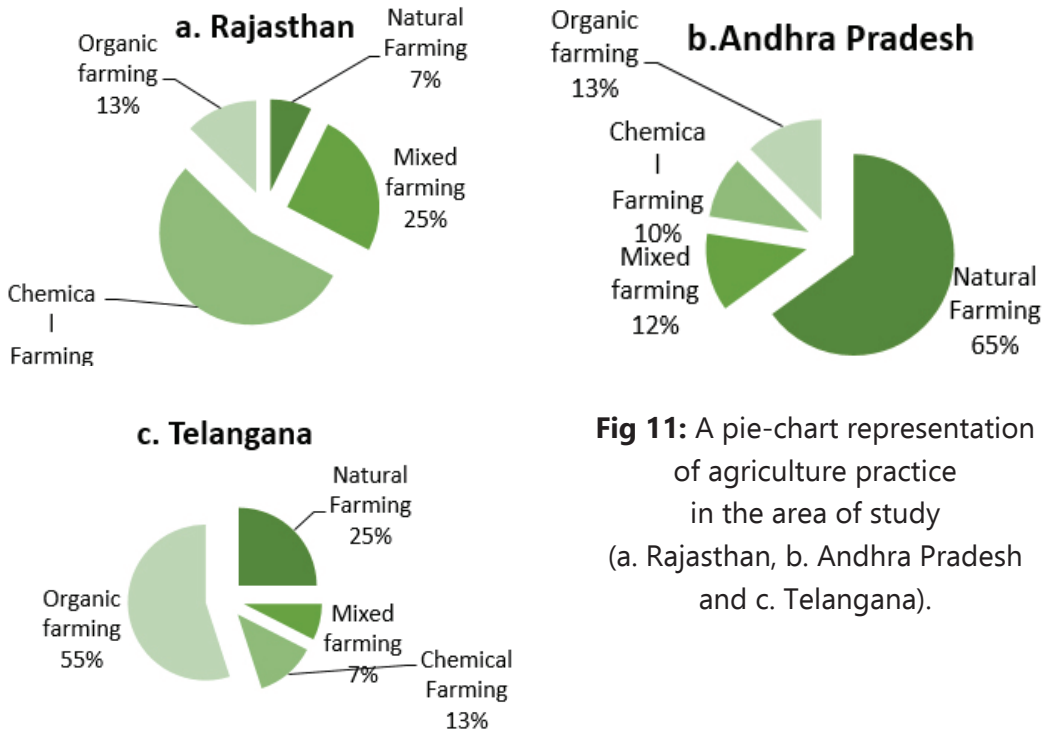


Fig 11: A pie-chart representation of agriculture practice in the area of study (a. Rajasthan, b. Andhra Pradesh and c. Telangana).

Chemical based farming followed by mixed farming was the most dominant agriculture practices in Rajasthan. In mixed farming, the farmers use both chemicals (DAP and urea) as well as cow dung manure in their farms. Organic and Natural farming were less practiced in Rajasthan. Natural farmers were very high in numbers in Andhra Pradesh followed by organic farming practice. There were natural farmers in Telangana state also, but they were comparatively less than organic farmers. Overall, it was found that farmers were highly skilled in chemical and mixed farming in Rajasthan state. Organic farming was highly practiced in Telangana state and natural farming practice was highly active in Andhra Pradesh state for the districts similar to as stated in Erenstein, *et. al.,* (2007).

Analysis of awareness on environmental issues driven by agriculture

Optimum use of natural resources (such as soil and water) and conservation of biodiversity, are important for developing sustainable yields for food security and income generation. Through analysis of various international research reports, it was found that water depletion, change in climate, air pollution, biodiversity and habitat loss, water pollution, and soil degradation are the most significant issues, while pesticide and chemical fertilizers, genetically modified organisms and agricultural waste are least significant environmental issues which are globally considered to be caused due to agricultural practices.

Table 15: Awareness on environmental issues among target respondents

S.No.	Environmental issues due to agriculture practice	Types of response	Percentage of response	Mean
1	Depletion in water	Agree	97	1.97
		Disagree	3	
2	Soil Degradation	Agree	96	1.96
		Disagree	4	
3	Biodiversity and habitat loss	Agree	79	1.79
		Disagree	21	
4	Water Pollution	Agree	14	1.14
		Disagree	86	
5	Air pollution	Agree	48	1.48
		Disagree	52	
6	Chemical fertilizers and pesticides	Agree	99	1.99
		Disagree	1	
7	Climate change	Agree	17	1.17
		Disagree	83	

8	Genetically Modified Organisms	Agree Disagree	7 93	1.07
9	Agricultural waste	Agree Disagree	5 95	1.07

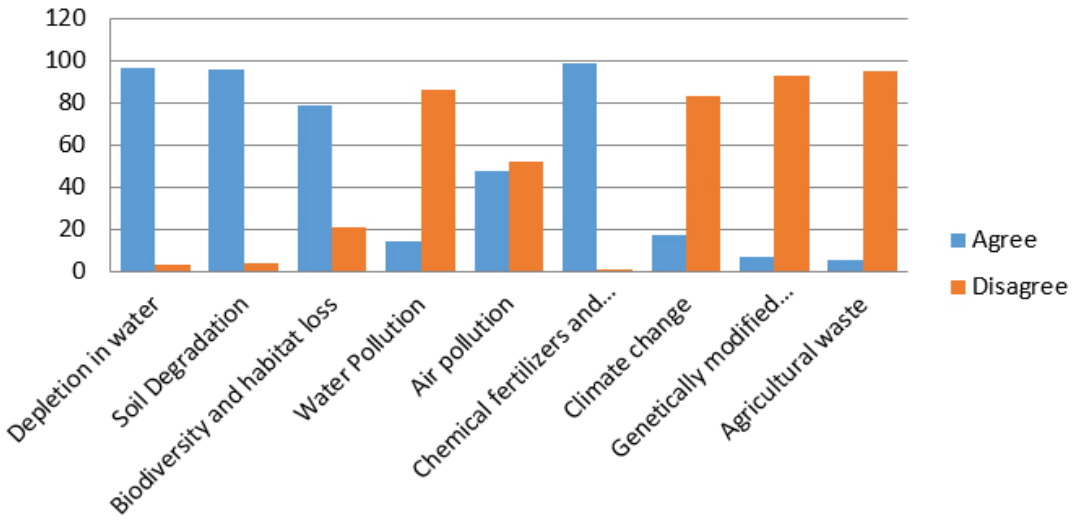


Fig 12: A bar-graph representation of awareness on environmental issues.

There was a general lack of awareness about biodiversity and habitat loss, water pollution, use of genetically modified organism, climate change, and generation of agriculture waste among the farmers which was in accordance with the reports of Kavita and Muthoni, (2018). Majority of them were aware about the depletion in water, soil degradation, ill-effects of chemical fertilizer and pesticides and air pollution which is complementary to as concluded in United Nations Environment Programme (2009). Use of Genetically Modified Organism (GMO) was found negligible in the areas of study which is in accordance to the report of Food and Agriculture Organisation (2013). Farmers were not burning the stubbles on their field but were using them as firewood for cooking in Rajasthan and for mulching or vermi-composting in Telangana and Andhra Pradesh.

Analysis of farmers' participation towards schemes and programs

The government of India is giving more priority to farmers in the country through its several farmer's welfare schemes and programmes to revitalize agriculture sector and to improve their economic conditions. There are various schemes, programs and plans rolled-out by national and state governments such as Zero Budget Natural Farming (ZBNF), Neem Coated Urea (NCU), Soil Health Card (SHC), Paramparagat Krishi Vikas Yojana (PKVY) and Pradhan Mantri Krishi Sinchai Yojana (PMKSY) to benefit all the farmers of India. Knowledge and attitude of farmers help their community to actively participate in conservation of environment, to develop a sense of ownership, and to evaluate sound policies and strategies for responding to the economic and social impacts of water depletion and land degradation.

Table 16: Participation of farmers in governmental schemes and programs (NS- Not satisfied and S- Satisfied)

State	Governmental schemes and programs and percentage of response									
	Zero Budget Natural Farming		Soil Health Card		Neem Coated Urea		Pradhan Mantri Krishi SinchaiYojana		Paramparagat Krishi VikasYojana (Organic Farming)	
	NS	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**	**NS**	**S**
Rajasthan	62	8	49	51	15	85	7	93	51	49
Telangana	45	55	20	80	10	90	15	85	8	92
Andhra Pradesh	5	95	15	85	10	90	5	95	5	95

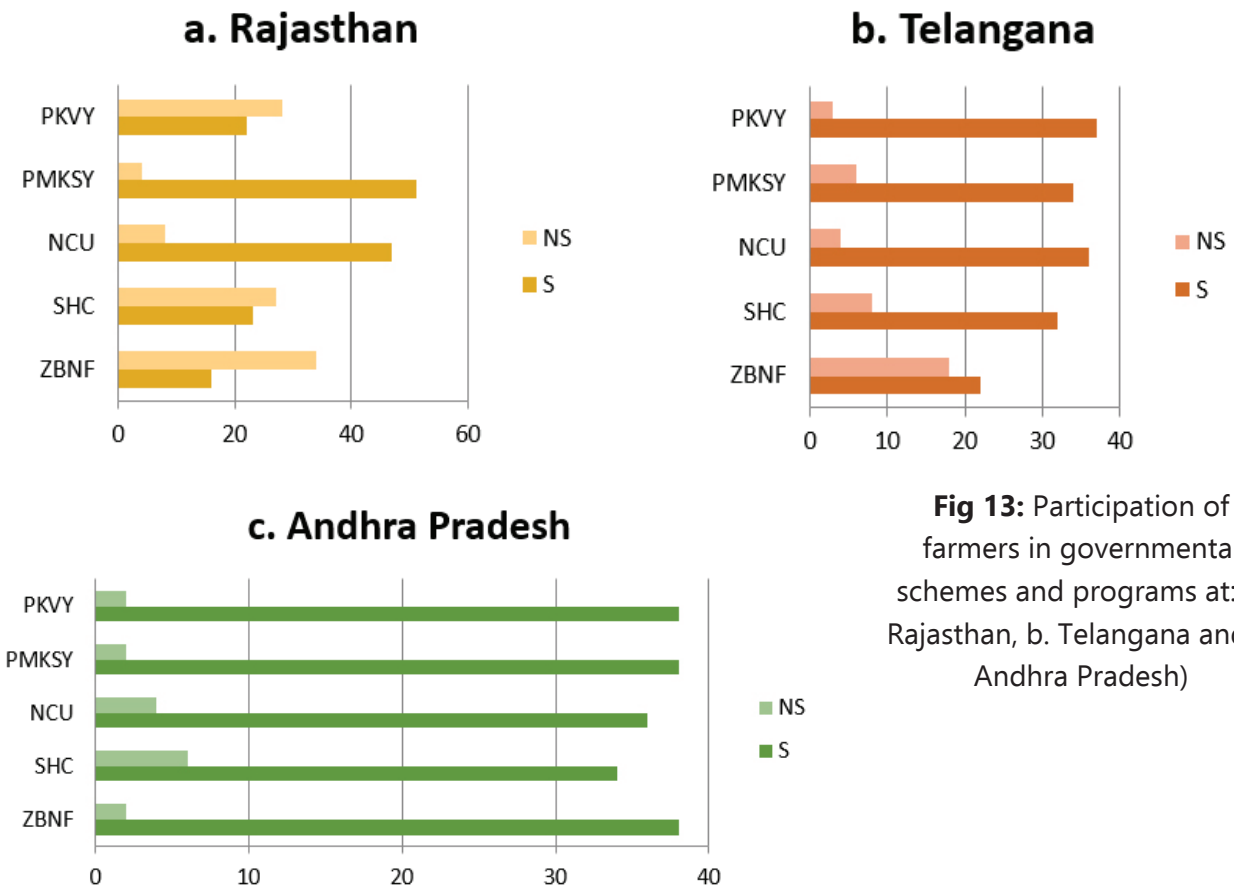


Fig 13: Participation of farmers in governmental schemes and programs at: a. Rajasthan, b. Telangana and c. Andhra Pradesh)

The level of satisfaction of farmers with the current government schemes in the area of study was highest for Parmparagat Krishi Vikas Yojana in Telangana and Andhra Pradesh; whereas, in Rajasthan, farmers were more satisfied with Pradhan Mantri Krishi Sinchai Yojana. Other schemes like Neem Coated Urea and Soil Health Card were beneficial in all the three states. The Zero Budget Natural Farming was common among farmers in Andhra Pradesh and Telangana but it was least satisfactory for farmers in Rajasthan as reported by the Government of India (2002). There was a positive relationship between the increased flow of information and participation of farmers in governmental schemes and programmes in comparison to study of Ritchie *et. al.* (2018).

The large amount of knowledge and the relevant information exists in research institutions, universities, and public offices of the country, but only a small amount of this agricultural information is accessible to rural farmers. This status largely depicts the weak linkages between research, extension, and farmers.

Analysis of knowledge about agricultural sustainability

Farm resource management decisions depend on accurate information which requires reliable data. Timely and accurate information was highly available to help farmers make rational risk management decisions which were contradictory to as stated in Kesavan and Swaminathan (2018). The sources of information available include farm records, off-farm statistics, and information from input dealers, traders, extension workers and other farmers and market price data. The good linkage between expert and farmer is the main reason farmers could use new technologies and innovative farming models to improve their farming activities in many regions of Rajasthan and Telangana. In Andhra Pradesh, this linkage between experts and farmers was found to be very strong and stable which is similar to as reported McNeely and Scherr - (2003).

Table 17: Farmers' knowledge on good traits of sustainable agriculture practices

S. No.	Traits	Total Score	Mean Score	Rank
1	Bring down water usage	716	4.77	I
2	Maintain soil fertility	668	4.45	II
3	Provide high quantity yield	661	4.41	III
4	Increase income of small landholding farmers	629	4.19	IV
5	Increases eco-tourism in rural areas	626	4.17	V
6	Promote self-sustenance skills of farmers	620	4.13	VI
7	Provide high quality yield	616	4.11	VII
8	Chemical inputs are minimized	612	4.08	VIII
9	Promote multiple use of agriculture	612	4.08	IX
10	Protects or conserves biodiversity	608	4.05	X

Analysis of attitude towards adoption of agricultural sustainability

The major challenge for agriculture in the areas under study was to keep the attitude to increase production, while minimizing environmental impact which was similar to as stated in Mishra M. (2013). This includes conserving and protecting the quality of the resources that determine the performance of agriculture like land, water, and air. Reduction in yield, although determined by many factors, may be partially a consequence of land and water exploitation in all the regions which

is in accordance with Sharma, (2012). Non-governmental Organizations like Sehgal and Lupin Foundation in Rajasthan, SERP in Telangana and CSA in Andhra Pradesh, safeguard the interest of marginal farmers and empower them with traditional and time-tested agricultural methods. They distribute tools, technology, organic seeds and other necessary aids. Besides, special workshops are organized to promote farmers to grow healthy food on their farms with the help of natural inputs, which is also mentioned in Kawalekar, (2013).

Table 18: Attitude of farmers toward adoption of sustainable agricultural practices

Sl.No.	Challenges	Total Score	Mean Score	Rank
1	Poor soil health	606	4.04	III
2	Lack of water in the area	647	4.31	I
3	Capital inadequacy	522	3.48	VIII
4	Lack of infrastructure support	598	3.99	V
5	Rising food demand	580	3.87	VI
6	Extreme climate events like hail storm and heat storm	628	4.19	II
7	Preference of buyers to quantity over quality of crop	602	4.01	IV
8	Poor governmental policies	561	3.74	VII
9	High reliability of farmers on self-knowledge	439	2.93	X
10	Improper use of agriculture waste	501	3.34	IX

Analysis of farmers' evaluation ability

For effective decisions to be taken, farmers need good evaluation ability on many aspects of the farming practices. Developing knowledge of farmers' evaluation ability with regards to suggestions mentioned in India's National Agriculture Policy for adoption of sustainable agriculture to enrich the soil and increase yields was aiding extension practitioners in devising alternate agricultural intervention strategies which is contradictory to as stated in Agrawal, (1995). Agricultural experience, local soil conditions, and traditional or learned knowledge were found to be the key factors for the community decision making process of whether to adopt new agricultural practices over the long term which supports the statement in Gadgil *et al.* (2000).

Table 19: Evaluation ability of farmers for agricultural sustainability

S. No.	Suggestions	Total Score	Mean Score	Rank
1	Emphasis on rational use of ground and surface water so that over-exploitation of ground water resources can be checked.	569	3.79	IV

2	Utilization of barren wastelands for agriculture and afforestation.	521	3.47	VII
3	Containment of biotic pressures on land and to control indiscriminate division of agricultural lands for non-agricultural uses.	531	3.54	V
4	Enhancement of cropping intensity through multi-cropping and inter-cropping.	528	3.52	VI
5	Adoption of watershed approach and water harvesting method for development of cropped area of the country which is dependent on rainfall.	606	4.04	I
6	Involvement of farmers and landless laborers for the development of pastures/ forestry programmes on huge public wasteland by providing adequate financial incentives and entitlement of trees and pastures	578	3.85	III
7	To adopt better technologies such as drip and sprinkler irrigation system so as to arrange more economic and efficient use of water.	578	3.85	II

4.10 Selective Case Studies

The case study work carried out within the three different states can be seen as an empirical enquiry; investigating phenomena that are contemporary, within real life context, in order to get real life

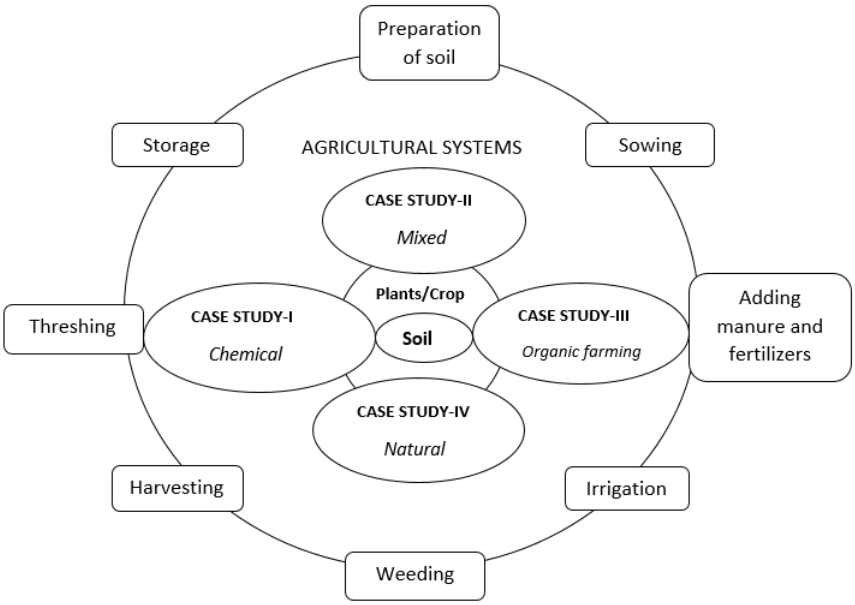


Fig 14: A diagrammatic representation of agriculture production systems studied.

insight Yin, (2009). The "case" or phenomenon in this study has demonstrated that the agriculture practice highly differs in each state based on the characteristics of inputs, cost of production, barriers to participation and accessibility of support. Farm location and main crops grown by different farmers in their farms were represented in each of these case studies. The information about each farm was collected through observation at farm and interview/discussion with farmers.

These case studies addressed the experience of farmers involved in different agriculture production systems in the three different regions. The first area of interest, Rajakhera, is part of Dhaulpur district in Rajasthan. Most of the farmers in this region are doing chemical based farming. Mixed farming is also practiced highly in Rajasthan state. Thus, the second area of interest was a farm located in Kumher block of Bharatpur district in Rajasthan. The third area of interest was thus an organic farm located within close proximity to Hyderabad, Ranga Reddy district. Lastly, the study focused on farming community surrounding Utukur, Kadapa district in Andhra Pradesh. Most of the farmers in Andhra Pradesh turned out to be natural farmers. Plate 1, plate 2, plate 3 and plate 4 show the key farm design at each site. Characteristics of climate, soil and water were widely different at each farm. Farmers were predominantly growing crops such as Wheat, Rice, Jowar, Bajra, Millet, Mustard, Sunflower and Paddy due to medium to low rainfall in these regions (570 mm/year in Rajakhera, 530 mm/year in Kumher, 580 mm/year in Hyderabad and 615 mm/year in Utukur). The soil fertility was highest at the farm near Hyderabad, followed by farm at Kumher, Utukur and Dhaulpur. The availability of water was better again in the farm near Hyderabad, followed by the farm at Utukur,

Plate 1: Satellite view of site-I, **Plate 2:** Satellite view of site-II, **Plate 3:** Satellite view of site-III, **Plate 4:** Satellite view of site-IV.

Kumher and Dhaulpur. In this study, the economic benefit of farming with mixed inputs was highest and the benefit of organic farming was small due to a number of interlinked reasons. Farmers in all regions agreed that there was a serious need for better marketing of a sustainable produce. The framework to assist environmentally sustainable farming varied spatially, with disparities in accessibility of marketing facilities, cooperatives and services. Having said this, all farmers reported saving in terms of how much they were spending on inputs.

Each piece of information provided by farmers was according to their own experience and knowledge about their farm. All the parameters studied for each case were later compiled and summarized. The data provided by farmers regarding the cost of production was actually an approximate amount that they were spending according to the size of their land, labor availability and need, tools and equipment's utilized for farming, types of crops, *etc.*

Table 20: Information about the farms in case studies (where information is missing it was either not applicable, or the figures were not available)

Parameters		**Case study numbers and their details**			
		I	II	III	IV
a. Farming inputs		Chemical	Mixed	Organic	Natural
b. Farmer		Jaganlal Singh	Mahaveer Prasad	GangadharNaik	Praveen Reddy
c. Years in farming		12	8	5	3
d. Farm location		Rajakhera, Dhaulpur	Kumhevr, Bharatpur	Hyderabad, Ranga Reddy	Utukur, Kadapa
e. Total farm acreage (Acre)		5.6	8.4	6.9	7.5
f. Major crops		Wheat, Bajra, Mustard, Sesame, Chickpea and vegetables (apple gourd, tomato, *etc.*)	Wheat, Rice, Jowar, Bajra, Rapeseed, Mustard, Barley, Moong, peas and beans	Seed and grain producer, mainly paddy, groundnut and greengram	Paddy, foxtail millet Mangoes, chilly, tomato, brinjal, banana, carrot, and onion.
Cost of production	Land preparation cost	15000 per acre	10000-12000 per acre	4000-5000 per acre	800-1000 per acre uses bullock ploughing
	Manure cost	25000-30000 per acre	20000 per acre	7000per acre	1500 per acre

	Seed cost	38000	25000	All own seeds	8000-10000
	Intercultural operations cost	-	-	2500-3000 per acre	1000-2000 uses a one wheel manual tiller to save money
	Harvesting cost	12000 per acre	14000 per acre	2500 per acre	6000 per acre
	Net profit	3 lakh per acre	4.5 lakh per acre	30000 per acre	1 lakh per 2 acres
a. Climate type		Hot	Warm and temperate	Hot-dry	Local steppe and tropical
Soil texture		Sandy loam	Loamy	Black soil	Red soil
Water availability		Water scarce	Highly available	Partly available	Water scarce

To understand the philosophy of each farm, information was collected regarding the parameters like key soil management system, insect pest management system and irrigation system at each farm. Within the three areas of study there were both location specific and common themes that emerged. Firstly, and arguably most important, all farmers said that since they began natural and organic farming, the quality of life for them and their family improved. This was generally said to be due to improved nutrition and general well-being, as much as any financial improvements. Costly chemical inputs can be seen as one of the many reasons why so many conventional farmers are becoming indebted. Organic and natural farmers protect themselves from this by producing their own inputs at their farm (like cow urine mixed with neem leaves), which when applied to crops this mixture works in much the same way as chemical pesticide. It was reported that the natural farmer (Praveen Reddy) saved 50% on inputs since he stopped using chemical pesticides. This indicates the significant financial benefits of such techniques.

Table 21: Philosophy of farms in case studies

Parameters	**Case study numbers and their details**			
	I	II	III	IV
Soil management system	Addition of chemical fertilizers like Urea and DAP	Use neem coated urea and cow dung as fertilizers	Regular addition of mowed clover/ weed soil amendments	Reduced Tillage, Perennial and annual living mulch to keep soil covered year round

Insect pest management system	Timely application of pesticides.	Mahaveer Prasad	Gangadhar-Naik	Praveen Reddy
Irrigational system	Canal irrigation	Tube-well and Bore-well irrigation	Drip irrigation	Sprinkler irrigation

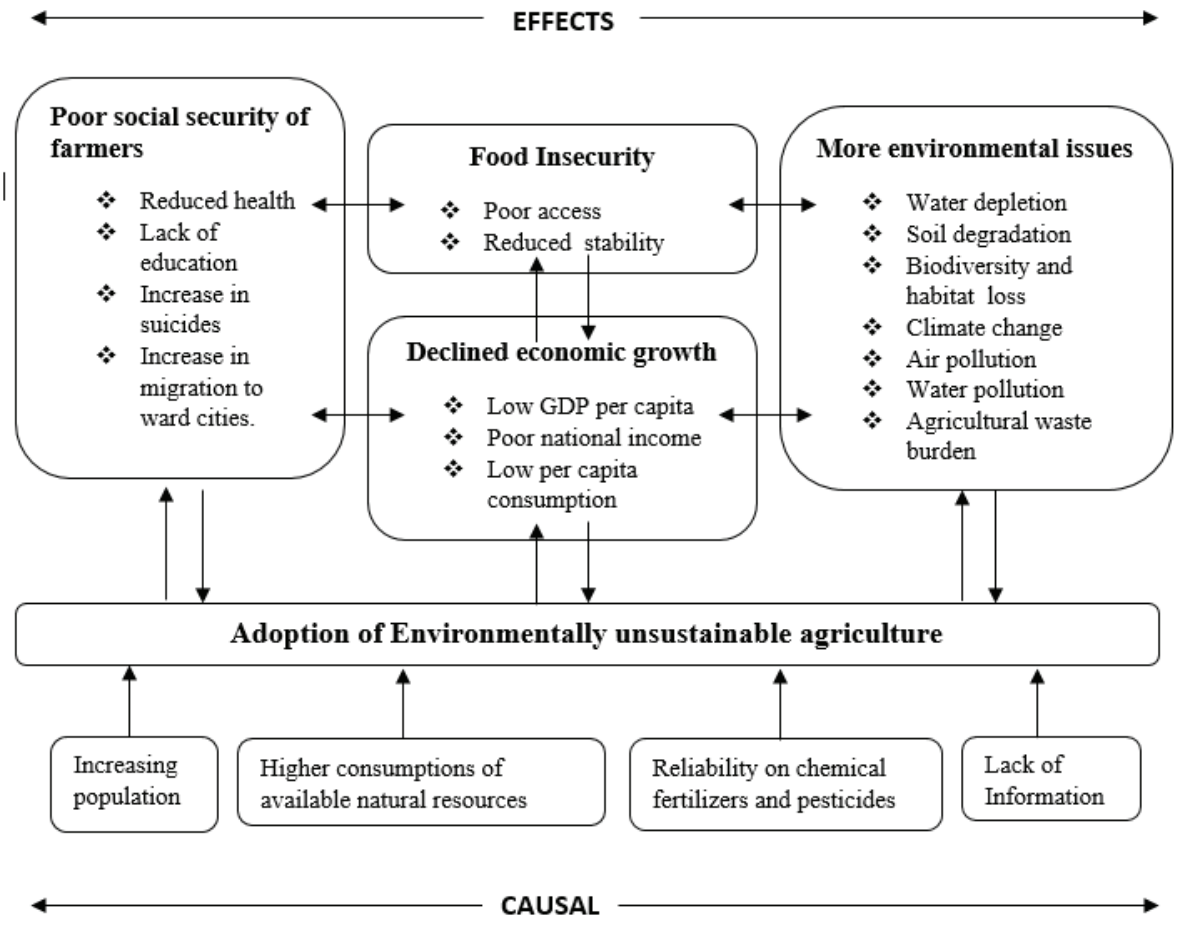
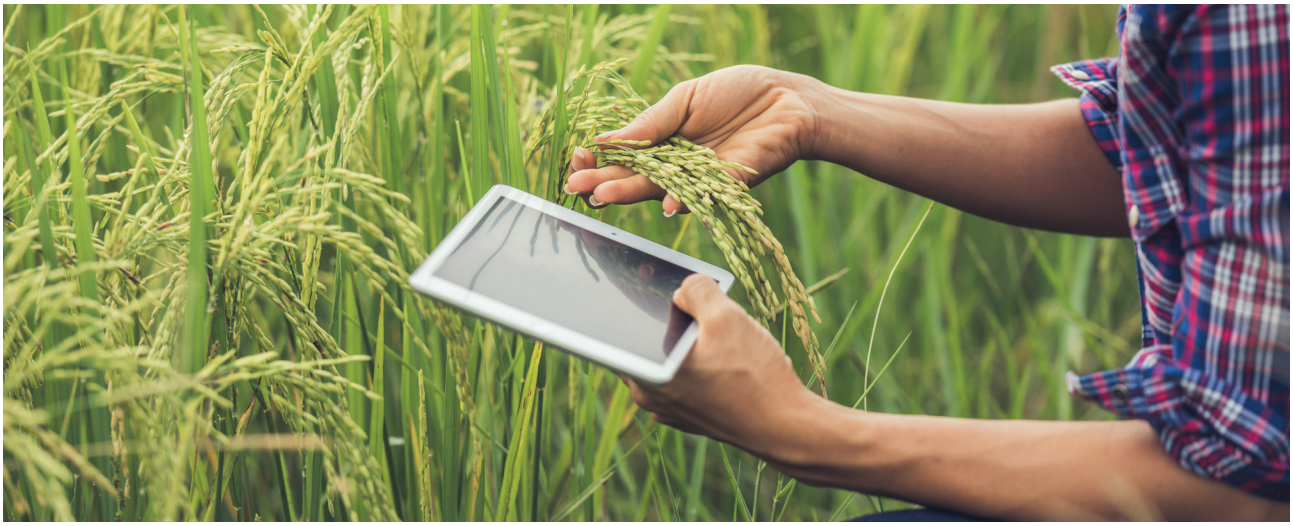


Fig 15: Conceptual framework to summarize the research result.



Conclusion and Future Prospects

Analysis and findings of this study were based on a number of factors that add to the awareness and fundamental agricultural knowledge of rural subsistence farmers, as well as of extension personnel and experts. Communities practicing chemical farming had a weak perceived relationship between chemical inputs and environmental issues, were reluctant to adopt conservation agriculture methods despite evidence that such practices are generally beneficial to adopt. In contrast, communities with organic and natural agriculture practice had a stronger perception of the linkage between soil fertility and sustainable agriculture practices, may more readily adopt introduced conservation technologies. Some of the important factors in relation to environmentally sustainable agricultural practices are: irrigation method, tillage practices, soil characteristics and agrobiodiversity, as they relate to yield and profitability. In a way, innovation seem to fulfil the urgent need to usher in an 'Evergreen Revolution' as sequel to the 'Green Revolution' and the 'Industrial Revolution' to save humanity and planet earth which are at a crossroads. With emerging farming models, researchers and extension personnel/other experts can develop adoption strategies with the farm community while fully incorporating their beliefs. The chances of adopting introduced farming practices have a higher probability of success with a community participatory approach and emphasis on shared value systems. In all the three states (Rajasthan, Telangana and Andhra Pradesh), new approaches and strategies should be utilised to increase food supplies while protecting the resource upon which they depend.

The present study was undertaken to ascertain whether there is significant awareness and benefit from sustainable agricultural practice, especially for farmers in Rajasthan, Telangana and Andhra Pradesh. The study revealed that farmers greatly rely on chemical fertilizers and pesticides since industrial revolution which is a causal reason for various social, economic and environmental issues. The experts perceived a strong relationship between chemical farming and various environmental issues, which are consistent with scientific research. However, the implications of such strong perceptions means that government needs to promote sustainable agricultural practices in areas with differing ecological constraints may require alternate intervention strategies to accommodate the needs and perceptions of each community. Farmers became susceptible to extreme climate like drought and famine nowadays because they gave up nature based traditional methods of farming. And burdened by the losses resulting from conventional farming, most of them abandoned their fields and migrated to the cities. This encourages need for drafting of environment friendly agriculture policies. Basically, this study has demonstrated two important needs for practitioners and policy makers. First, the success of adoption of any introduced agricultural practice requires information about knowledge and awareness of farmers and experts, such as researchers and extension personnel, such that gaps in perceptions of the agricultural system are recognized and incorporated into the development of implementation strategies. Second, it is crucial that agriculture development for agencies such as NGOs and FPOs utilize interdisciplinary teams to develop a complete understanding of the economic, ecological, and social context of a community-based project. As shown by this study, simply understanding how rural farmers think and approach agricultural decision-making does not

create solutions. It is through the supplemental discovery of all the factors driving these perceptions that a more complete picture of community needs and perceptions is developed and sustained productivity can be better promoted.

A. **Need of environmental education and awareness in farmers' societies-** To guarantee the conservation of environmental equilibrium so as to allow that productivity lasts on a permanently durable basis, *i.e.*, should not lead in dissipation of non-renewable materials or energy (sustainability of resources), full safety to the farmers and any other operators, in addition to hygienic and sanitary safe conditions to the consumer (sustainability of human health) and economically convenient production, *i.e.*, a profit to farmers (economic sustainability). This last requisite is that more frequently forgiven. Sometimes it is also be concealed either with financial subsidies to the farmers or, worse, by frauds against consumers.

B. **Need to develop knowledge of farmers' perceptions with regards to ideal traits of farming practices-** To prevent environmental issues and increase yields can aid extension practitioners in devising alternate agricultural intervention strategies. Agricultural experience, local soil conditions, and traditional or learned knowledge all contribute to the community decision making process of whether to adopt new agricultural practices over the long term. Planning for agriculture development projects must therefore consider the local context and perception from both the farmer and researcher/NGO perspectives to develop mutual understanding and improve the project design for the benefit of multi-stakeholder groups.

C. **Need for agriculture reforms-** As the agricultural sector ensures the food security and nutrition to this huge size of population of India and also supplies huge quantity of raw materials for expanding industrial base along with creating surplus for exports thus a fast and equitable reward system for the farming community who are trying to bring sustainable resource management along with attaining faster growth rate of the sector should be the important components of agricultural reforms. Private sector participation should be promoted through contract farming and land leasing arrangement, to allow accelerated technology transfer, capital inflow, assured market for crop production, especially of oilseed, cotton and horticultural crops.

D. **Development of eco-technologies-** For attaining growth that is pro-nature, pro-poor, pro-women and pro-livelihood oriented to combat the famine of livelihoods and the resulting food insecurity, there is a need of technologically, environmentally and economically sustainable development. Government should encourage application of biotechnology, remote sensing technologies, energy saving technologies, pre and post-harvest technologies, and technology for environmental protection.

E. **Less input more output based agriculture-** Farmers should adopt natural farming technique in order to minimize their input cost and enhance productivity. Cost of farming is growing constantly. The government needs to take appropriate steps for changing the existing methodology to attain the goal to double farm income by 2022.

Today, because of increasing input costs and decreasing commodity prices, the farmers are looking for new ways to increase efficiency and cut costs. Also, natural farming models like ZBNF, Rishi kheti, Avartansheelkheti, Eco-agriculture *etc.,* would be viable alternatives to conventional agriculture practice. Analysis and comparison of environmental sustainability of various emerging farming models with current practices in different states can help many farmers countrywide to improve the crop inputs and benefits. In India, the average land holdings are very small even with large and progressive farmers. It is necessary to build capacity in the context of Indian farming in all the other districts of Rajasthan, Telangana and Andhra Pradesh for effective comparison of agricultural inputs based on soil, weather and crop requirement to maximize sustainable productivity, quality and profitability. This study shows that there is a strong need to increase research towards:

- Full exploitation of natural processes such as recycling nutrients, using plants that fix their own nitrogen and can naturally achieve a balance between pests and predators.
- Reduction in their reliance on inputs such as chemical fertilizers and chemical pesticides.
- Diversification of agriculture system, making greater use of the biological and genetic potential of plant and animal species.
- Rotation of crops or development of agro-forestry systems that helps to maintain soil fertility.
- Optimum combination of agricultural practices, both old and new, in order to maximize sustainable output within the limits of available resources.

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