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Extension Approaches for Climate Resilient Livestock Farming

Edited by

Prabhat Kumar Pankaj, Sushirekha Das , Shahaji S. Phand, Vinod Kumar Singh, K. Ravi Shankar, G. Nirmala, K. Nagasree, Pushpanjali, R. Nagarjuna Kumar

ICAR-Central Research Institute for Dryland Agriculture, Hyderabad & National Institute of Agricultural Extension Management, Hyderabad

EXTENSION APPROACHES FOR CLIMATE RESILIENT LIVESTOCK FARMING

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This e-book is a compilation of resource text obtained from various subject experts for Collaborative Online Training Programme of ICAR-CRIDA, Santoshnagar, Hyderabad & MANAGE, Hyderabad on **Extension approaches for climate resilient livestock farming** from 01-03 March 2023. This e-book is designed to educate extension workers, students, research scholars, academicians related to veterinary science and Animal Husbandry about climate resilient for improving livestock productivity. Neither the publisher nor the contributors, authors and editors assume any liability for any damage or injury to persons or property from any use of methods, instructions, or ideas contained in the e-book. No part of this publication may be reproduced or transmitted without prior permission of the publisher/editor/authors. Publisher and editor do not give warranty for any error or omissions regarding the materials in this e-book.

Published for Dr. P. Chandra Shekara, Director General, National Institute of Agricultural Extension Management (MANAGE), Hyderabad, India by Dr. Srinivasacharyulu Attaluri, Program Officer, MANAGE and printed at MANAGE, Hyderabad as e-publication.

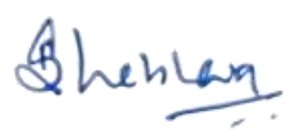
MESSAGE

National Institute of Agricultural Extension Management (MANAGE), Hyderabad is an autonomous organization under the Ministry of Agriculture & Farmers Welfare, Government of India. The policies of liberalization and globalization of the economy and the level of agricultural technology becoming more sophisticated and complex, calls for major initiatives towards reorientation and modernization of the agricultural extension system. Effective ways of managing the extension system needed to be evolved and extension organizations enabled to transform the existing set up through professional guidance and training of critical manpower. MANAGE is the response to this imperative need. Agricultural extension to be effective, demands sound technological knowledge to the extension functionaries and therefore MANAGE has focused on training program on technological aspect in collaboration with ICAR institutions and state agriculture/veterinary universities, having expertise and facilities to organize technical training program for extension functionaries of state department.

Presently, the climate change is the burning issue and a big challenge before agricultural sector worldwide. The climate change impacts are visible all over the world, but India is categorized among the most vulnerable areas. Almost 70 percent of livestock in India is owned by small and marginal farmers and landless labourers, and the animals of these resource poor livestock owners are more vulnerable to climate change and are at greater risk. Limiting the effects of climate change is necessary to achieve sustainable development and equity, including poverty eradication. The direct and indirect impacts that climate change will bring about are expected to exacerbate the vulnerability of livestock systems and to reinforce existing factors that are simultaneously affecting livestock production systems, such as rapid population and economic growth, increased demand for livestock food products.

It is a pleasure to note that, ICAR- Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad and MANAGE, Hyderabad jointly publishing an e-book on “Climate Resilient Animal Husbandry”. I wish the e-book will be useful for stakeholders across the country.

I would like to compliment the efforts of Dr. Shahaji Phand, Deputy Director, EAAS, MANAGE, Dr. Prabhat Kumar Pankaj, Principal Scientist (LPM), TOT Section, ICAR-CRIDA and Dr. Sushrirekha Das, MANAGE Fellow, MANAGE for this valuable publication.



Dr. P. Chandra Shekara
Director General, MANAGE

Foreword

ICAR-Central Research Institute for Dryland Agriculture is a premier research institute in the field of natural resource management for dryland agriculture in India under the Ministry of Agriculture and Farmers Welfare, New Delhi. ICAR-CRIDA is working closely with different stakeholders (farmers, line department officials, SAUs, other ICAR institutes, different ministries, etc) towards the development of climate resilient agriculture in India apart from production enhancement and revenue generation through introduction of easily adaptable cost-effective advance technologies in a sustainable ecosystem based approach.

ICAR-CRIDA is currently implementing the ICAR flagship programme, National Innovations on Climate Resilient Agriculture (NICRA), which is playing an important role at national level in evolving adaptation and mitigation strategies in agriculture and allied sectors and also taking up their demonstration in more than 150 villages representing key climate vulnerabilities. Efforts are being made for scaling up these technologies through the National Mission for Sustainable Agriculture (NMSA). Apart from this, ICAR-CRIDA has developed almost 650 district agriculture contingency plans involving all agricultural universities, several ICAR universities, Krishi Vigyan Kendra's (KVK's) and other stakeholders related to all the sectors of Agriculture. Extreme climatic events such as drought and floods occurring in the same crop growing season can seriously undermine our efforts to enhance production using current technology.

There is a vast scope for accelerating agricultural growth in rainfed areas through diversification into high-value crops, horticulture, and livestock-based enterprises with available water. Livestock based systems are important in semi-arid regions to ensure livelihood security.

Keeping this in view the the e-book has been prepared to sensitize different officials involved in extension activities about the importance of livestock for enhancing the nutritional security of the farmers as well as estabilishing climate resilient animal husbandry in India.

This e-book contains important topics on basics and new researchable areas linking meterorological concepts with vulnerabilities and resilience to be achieved in the livestock sub-sector. The book has also covered topics to create awareness amongst the professionals about easily adaptable technologies as well as gender issues with precision farming through better managemental interventions. indicators of climate change, vulnerability and risk assessment, institutional interventions for climate risk management in livestock sector. Hope wide circulation of this book will help a large number of readers to enrich their knowledge on this important topic of achieving climate resilient animal husbandry in India.

June, 2023

Dr. Vinod Kumar Singh
Director, ICAR-CRIDA

PREFACE

This e-book is an outcome of collaborative online training program on "Extension approaches for climate resilient livestock farming". This book is intended for SVUs/Veterinary officers, and livestock owners who are key players in the livestock sector as they are there to adopt resilient practices so as to make resilient villages and address the problems regarding impact of climate change, adaptable and mitigating technologies for optimal livestock production. There is urgent need to compile recent extension advances in technologies and innovations for better management of livestock especially reared under climate change scenario.

Climate change impacts all sectors of ecosystem in an unbiased manner, however, such impacts need to be quantified systematically. Food and nutritional security under climate change scenario depend upon our ability to adapt animal-agricultural systems to climate change. Agricultural systems are multi-faceted and complex because of the range of plant and animal commodities affected by the interactions between climate and management. The content of proposed e-book has been designed in such a way, so that it can provide updated information towards capacity building in proposed area. Attempt has been made to cover topics about advances in climate resilient animal husbandry with special reference to NICRA programme, indicators of climate change, vulnerability and risk assessment, agro-meteorological and physiological basis of climate change with abiotic stress management (adaptation and mitigation). Chapters like statistical tools for quantifying the climate resilience/impact of interventions in livestock sector, climate change and livestock: gender perspective, institutional interventions for climate risk management in livestock sector has also been included. Approaches for common managemental (genetic, nutritional, shelter, health) practices for livestock have been followed for the benefit of veterinary officials.

The valuable suggestions for future improvements are always welcome.

June, 20223

Editors

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Chapter-1

DRYLAND AGRICULTURE AND ANIMAL HUSBANDRY UNDER CLIMATE CHANGE SCENARIO

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Introduction

Dryland Agriculture refers to cultivation of crops entirely under natural rainfall without irrigation. The major characteristics of drylands are deficit in the absolute amount of rainfall (500 and 1200 mm), length of wet season is small, rainfall is less than 40% of potential evapotranspiration. Soils of the drylands are not only dry but also deficient in macronutrients like nitrogen and phosphorous (called as thirsty and hungry soil). Once we consider the soil-plant-animal continuum, these deficiencies percolate to animal level (called as hollow gut syndrome) to imposing them to be deficient in certain micro-nutrients making them more vulnerable to climate change impacts.

Livestock rearing is one of the major occupations in dryland as well as other parts of India and is making significant contribution to the country's GDP. The animal husbandry sector has a good growth potential. Livestock rearing in India provides manure, draught power for agriculture and local transportation and forms important source of food and cash income to millions of households spread across various parts of the country.

The temperature in dryland varies greatly imposing impacts on livestock in terms of heat stress directly. However, during the period of moisture stress and drought, the temperatures accelerate the crop development resulting into forced maturity affecting both fodder as well as grain yields on which livestock production system is dependent.

Small size of land holdings (less than 2 hectares) usually fragmented and scattered, lack of market facilities, poor economic condition and other socio-economic issues related to drylands make the problem of farmers bigger under climate change scenario. Thus, present chapter has been made to sensitize the stakeholders about problems, prospects, role and livestock management under climate change scenario in the drylands.

Prospects of dryland areas and livestock under climate change

Majority (more than 75%) of farmers involved in dryland farming are small and marginal. Therefore, improvement in dryland farming would raise the economic status of farmers thus helping in poverty elimination. Dryland farming holds immense significance especially in the context of fluctuating food grain production and expanding population in our country. By enhancing the productivity of crops like *jowar, bajra* and *ragi* which are mainly grown in dryland farming would increase the nutrient consumption levels of our nation.

Marginal lands in the semi-arid regions offer potential for fodder production to feed the livestock population which is an integral component of farming practice of this region. Moreover, it would also be helpful in eliminating the problem of hunger and malnutrition prevailed in below poverty line society of the country by virtue of quality protein content of meat, eggs and milk.

Climate change is thought to be the most important cause of unstable productivity in ruminant production systems in India through crop failures, feed and fodder scarcity and increased incidence of endemic and emerging animal diseases. Alterations in rainfall affect the water availability for feed and fodder production and also curtails drinking water resources for livestock. Further, scenario of feed and fodder availability and demand in India indicates the necessity of efficient utilization of available resources from crop and cropping systems and development of integrated farming systems for sustainability of livestock production as well as farmer's income. Thus, adaptive livestock management practices are important in view of diversified and heterogeneous groups of farmers of drylands.

Role of Livestock in economy of dryland

The livestock plays an important role in the economy of farmers. The farmers in India maintain mixed farming system i.e. a combination of crop and livestock where the output of one enterprise becomes the input of another enterprise thereby realize the resource efficiency. The livestock serve the farmers in different ways.

1. Draft: Although an increasing mechanization is replacing the animal power in the villages, reducing the total DAP, yet India has to depend on animal energy for many years to come from agricultural operations and transport of farm produce. The farmers especially the marginal and small depend upon bullocks for ploughing, carting and transport of both inputs and outputs.

2. Dung: In rural areas dung is used for several purposes which include fuel (dung cakes), fertilizer (farm yard manure), and plastering material (poor man's cement).

3. Employment: A large number of people in India being less literate and unskilled depend upon agriculture for their livelihoods. The land less people depend upon livestock for utilizing their labour during lean agricultural season.

4. Food: The livestock products such as milk, meat and eggs are an important source of animal protein to the members of the livestock owners. The livestock provides food items such as Milk, Meat and Eggs for human consumption. India is number one milk producer in the world.

5. Income: Livestock is a source of subsidiary income for many families in India especially the resource poor who maintain few heads of animals. Cows and buffaloes if in milk will provide regular income to the livestock farmers through sale of milk. Animals like sheep and goat serve as sources of income during emergencies to meet exigencies like marriages, treatment of sick persons, children education, repair of houses etc. The animals also serve as moving banks and assets which provide economic security to the owners.

6. Social security: The animals offer social security to the owners in terms of their status in the society.

Major areas of concern with respect to livestock

- Improving productivity in a huge population of low-producing animals
- Conservation of soil/water/fodder resources
- Need to evolve high yielding and drought resistant crop/fodder varieties
- Proper breeding policy for different categories of animals
- Evolving and implementation of adaptive measures for climate change
- Proper marketing and price policy to animal products and insurance
- Extension of climate resilient technologies

Climate change and livestock management in drylands

Heat waves, which are projected to increase under climate change, is directly impacting the livestock. Exposure to high temperature events can cause heat-related losses to livestock farmers. Heat stress affects animals both directly and indirectly. Over time, heat stress can increase vulnerability to disease, reduce fertility, and reduce productivity. Drought may impact pasture and feed supplies. Drought reduces the amount of quality forage available to grazing livestock. Some areas could experience longer, more intense droughts, resulting from higher summer temperatures and reduced precipitation.

For animals that rely on grain, changes in crop production due to drought could also become a problem.

Climate change may increase the prevalence of parasites and diseases that affect livestock. The earlier onset of spring and warmer winters could allow some parasites and pathogens to survive more easily. In areas with increased rainfall, moisture-reliant pathogens could thrive. Increases in CO_2 may increase the productivity of pastures but may also decrease their quality.

Most of the farmers in dryland keep few cattle, goats, sheep and chickens. Herds are small, as available grazing areas are limited. Only some of the progressive farmers who has the resources keep a bigger herd of animals. The livestock are usually fed on crop residues or are allowed to graze nearby. Even if the crop fails, the animals can graze on it or animals graze on the harvested fields also. Livestock provide manure for the fields, either by grazing on the stubble after the harvest, or through composting. Special fodder crops are meagrely used in drylands as farmers are not ready to put the fodder whenever water availability is there. The opportunity cost to divert cultivable land for fodder production in a big way might be very high. The only plausible option, therefore, is to revitalize the degrading common fodder and pasture resources in the country and improve their productivity. Small livestock are a source of ready cash and a safeguard in times of distress.

Population growth, urbanization and increasing per capita incomes are stimulating a rapid growth in demand for animal-based products in developing countries, especially in the dryland parts of world as well as India. Hence, in addition to improving crop production, it is important to pursue ways to improve dryland livestock production and crop-livestock systems. Vast tracts of arid and semi-arid lands are unsuitable for crop production but support livestock, especially small ruminants (sheep and goats). Livestock is not only a vital source of protein but also constitutes an important sector of the economy which makes use of land that would otherwise be unproductive, providing livelihoods to millions of people around the world. In order to fulfil crop needs like manure and animal traction, farmers move towards crop-livestock integration.

In arid and semi-arid regions where crop failures and draught are frequent dependency on livestock increases. Most people depend on the sale of livestock products like milk, meat and hide and livestock itself for their livelihood. Livestock is the main source of food and people different species that cope well with harsh dry environment. The most common and well adapted and acclimatized livestock in these regions are breeds of sheep, goats, camels and cows as per the necessity and purpose to rear these animals.

Provisioning of fodder banks: Livestock derive major part of their energy requirement from agricultural by-products and residues. Hardly 5% of the cropped area is utilized to grow fodder. India is deficit in dry fodder by 11%, green fodder by 35% and concentrates feed by 28% which aggravate due to draught. The common grazing lands too have been deteriorating quantitatively and qualitatively. Though meeting human needs is of immediate priority during drought, but saving the livestock is also great concern because of the economic benefits that livestock can provide in times when agriculture fails. Inadequate availability of good quality fodder is the major limitation in further development of the animal husbandry sector in the country. India has vast tracts of grazing and, most of which has fragmented or become degraded due to lack of appropriate policy interventions and management inputs. Pastoralism and nomadism are important land use systems with a high degree of dependence on browse trees for livestock production especially in dry season.

Migration of pastoralists: It is a common phenomenon in drylands which involves male family members who take along their livestock herd and look after the dry period in the irrigated areas. But sometimes, this migration involves all the family members moving along with their children and livestock for the same period and travels long distances (i.e., more than 200km). Although their return depends upon the rainfall. While migrating, the farmers have to travel long distance to reach the places where they can find food and feed for themselves as well as for their livestock.

Few of the initiatives taken up as a support to livestock component of drylands under climate change scenario

- Basic and strategic research of NICRA
- Technology demonstration of climate resilient technologies under TDC-NICRA
- Fodder cafeteria
- Contingency plans
- Promotion of improved fodder, backyard poultry, indigenous sheep breeds and group formation under FFP
- Training and promotion of fodder and backyard poultry under SCSP/TSP
- Promotion of climate resilient technologies through CRIDA-KVK
- Organic fodder production and sheep production

Conclusion: Livestock production is one of the important activities in arid and semi-arid regions of India. Livestock plays an important role by ensuring subsistence and security against crop failures under drought conditions. There is need of building synergy between adaptable appropriate technologies and climate change impacts. Our first task is to remove the void created by climate change and promote the convergence of technology and services leading to self-sufficient, supporting and strong agriculture-livestock and farmers in India. Apart from this, there are number of socio-economic and environmental challenges that need to be overcome through appropriate technologies and strategies in order to harness the potential of livestock reared by landless, small and marginal farmers in India.

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Chapter-2

AN OVERVIEW OF NATIONAL INNOVATIONS IN CLIMATE RESILIENT AGRICULTURE (NICRA) LIVESTOCK SPECIFIC ACHIEVEMENTS

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Background

Increasing impact of climate variability on agriculture is evident. Therefore, need for coping with current climate variability, preparing for future climate change is very crucial. It is also important to assess crop losses due to extreme events. The need for continuous data generation for identifying trends and building scenarios is also important. To meet the challenges of sustaining domestic food production in the face of changing climate and to generate information on adaptation and mitigation in agriculture to contribute to global fora like United Nations Framework Convention on Climate Change (UNFCCC), the Indian Council of Agricultural Research (ICAR), Ministry of Agriculture and Farmers Welfare, Government of India launched a flagship network project 'National Innovations in Climate Resilient Agriculture' (NICRA) during 2011. NICRA is the unique project which brings all sectors of agriculture viz., crops, horticulture, livestock, fisheries, natural resource management (NRM) and extension scientists on one platform.

Objectives

- To enhance the resilience of Indian agriculture to climatic variability and climate change through strategic research on adaptation and mitigation
- To validate and demonstrate climate resilient technologies on farmers' fields.
- To strengthen the capacity of scientists and other stakeholders in climate resilient agriculture
- To draw policy guidelines for wider scale adoption of resilience-enhancing technologies and options

Mission

Enhancing the resilience of Indian Agriculture to climate variability and climate change through both application of improved technologies and new policies

Vision

To develop and promote climate resilient technologies in agriculture which will address vulnerable areas of the country and the outputs of the project will help the districts and regions prone to extreme weather conditions like droughts, floods, frost, heat waves, etc. to cope with such extremes

Components

The scheme involved components viz. strategic research through network as well as sponsored/competitive grants mode, technology demonstration & dissemination and capacity building.

Strategic Research

In the strategic research, both short term and long-term research programs with a national perspective have been taken up involving adaptation and mitigation covering crops, horticulture, livestock, fisheries and poultry. The main thrust areas covered are (i) identifying most vulnerable districts/regions, (ii) evolving crop varieties and management practices for adaptation and mitigation, (iii) assessing climate change impacts on livestock, fisheries and poultry and identifying adaptation strategies. In the strategic research component, both short term and long-term research programs with a national perspective have been taken up to evolve adaptation and mitigation strategies in crops, horticulture, natural resources, livestock, fisheries and poultry About 41 ICAR institutes representing different sectors of agriculture are undertaking climate change research in a network mode focusing the respective them areas.

Some of the significant achievements of the NICRA under Livestock sector:

- State of the art climate change research facilities to understand the impact of climate change on different livestock species has been established at various research institutes across the country (Ex: Animal calorimetric system, Thermal imaging System, Methane analyzer, Psychrometric chamber, Environmental growth chamber, Laparoscope, Blood chemistry auto analyser, Hematology analyser, Chicken isolator & Growth chambers etc.)
- GHG emissions for different livestock production systems have been quantified
- Unique traits for thermal tolerance in livestock mapped, heat care mixture for poultry ready for commercialization
- Characterized physiological and metabolic markers and effect of various feed supplements for amelioration of thermal stress in cows and buffaloes
- Identified molecular markers in indigenous livestock which make them resilient to climatic stress

- Evaluated the impact of heat stress on milk production and quality parameters
- Risk maps were developed for Bluetongue disease for Karnataka and Tamil Nadu states
- Livestock Diseases Forewarning (LDF), a web enabled and mobile based application was developed for forewarning of the thirteen livestock diseases
- Studied impact of climate change on important vector borne and zoonotic diseases
- Studied impact of climate change on emergence of vector-borne infectious diseases and their effects on livestock production system in mid hills of Western Himalayas region
- Lifecycle assessment of greenhouse gas emission was done from different animal production system of Karnataka State
- Assessed the thermal stress in growing and lactating goats and supplementary strategies developed to ameliorate
- Supplementation of Herbal powder & herbal extract & administering of Vit. E-Selenium was found effective to reduce the climatic stress in goats
- Developed Stressol –G an herbal crude powder-based tablet to reduce the climatic stress in goats
- Studied the effect of climatic stress variables on productive parameters of sheep
- Assessed the effect of climate-driven multiple stress on metabolic profile, oxidative stress and immunity in sheep
- Determined comfort-zone and quantified threshold level of THI under simulated as well as in fixed model of microclimate for sheep
- Studies different feed formulations and phyto-chemicals for promoting resilience against thermal stress in sheep
- Supplementation of Beataine (0.1%), OTM (Zn 40 mg, Cr 2mg or Se 0.3mg/kg) reduced the ill effects of heat stress in broiler & rural chicken
- Supplementation (0.1%) of prebiotics (MOS/FOS) enhanced the immune responses in rural chicken
- Dietary inclusion (0.2 to 1%) of herbal extracts (Aswagandha, Tulasi, Amla and Turmeric) improved growth in broilers under heat stress

Many of these technologies developed have been evaluated in the farmers' fields for further refinement and upscaling. Research proposals addressing critical gaps not covered in the Strategic Research Component but have a major bearing of the productivity of principle commodities in the region are being funded through competitive and sponsored grants. So far, 18 sponsored and 33 competitive projects have been funded to undertake critical areas of climate change research in agricultural sector including Livestock.

Technology Demonstrations

Under NICRA demonstrations of proven technologies were given to enhance the adaptive capacity and to enable farmers cope with current climatic variability. Location specific technologies which are developed by the national agricultural research system which can impart resilience against climatic vulnerability are being demonstrated. TDC is being implemented in 121 climatically vulnerable districts of the country through Krishi Vigyan Kendras (KVKs) spread across the country. A representative village in each climatically vulnerable district was selected for implementation. The interventions are broadly divided into four modules viz., natural resource management, crop production, livestock and fisheries and creation of institutional structures for sustaining the activities envisaged and scaling up of interventions. Under the livestock module demonstrations on fodder production, especially under drought/flood situations, improved shelter for reducing heat stress in livestock, silage making methods for storage of green fodder and feeding during the dry season, breed selection and integrated farming system models in diverse agro-ecosystems are being taken up. Village level institutional mechanisms such as Village Level Climate Risk Management Committees (VCRMC), custom hiring centers are created for managing infrastructure created and to improve the timeliness of operations during the limited window periods of moisture availability in rainfed areas and to promote small farm mechanization for adoption of climate resilient practices. These interventions helped farmers to reduce the yield losses and enhanced their adaptive capacity against climatic variability.

Capacity building

A large-scale capacity building program on climate resilient agriculture is being undertaken with more than 1200 scientists, 450 research scholars and 100s of post graduate students are involved on climate change research and dissemination of climate resilient technology across the country. These resilient practices are being adopted by communities and spreading beyond NICRA villages. In the past 10 years 16,407 training programs were conducted throughout the country under NICRA project to educate farmers on various aspects of climate change and resilient technologies, covering 5.5 lakh beneficiaries. This will enable for wider adoption of climate resilient technologies and minimizing climatic shocks.

Conclusions

As per the recent IPCC report, Climate Change 2021, the scale of the climate crisis is very fast. Globe is on the path to 2^{o}C warming by mid 2100s. The report also highlighted increase in extreme weather events, ice melting, sea level rise, ocean warming etc., some of which cant reverse any more, at least for next thousand years. The commitments of the country to emission reductions require generate appropriate information and data on emissions as well as options that help reduce emissions. Techniques standardized so far under NICRA for estimation of GHG emissions from different management practices will be used for further reducing the carbon footprint of production systems in the country. Government of India has committed for the reduction of emission intensity of GDP by 32-35% by 2030 from 2005 levels, and the outputs of NICRA project contributing to several national project reports i.e., Intended Nationally Determined Contribution (INDC), Biennial Update Report (BUR), Nationally Appropriate Mitigation Action (NAMAs), National Mission on Sustainable Agriculture (NMSA) and several other Missions under National Action Plan on Climate Change. The system-wide impacts and responses to climate change need to be understood better and more comprehensively. NICRA findings have been published in high impact factor journals (280 International research papers, 8 policy briefs, 168 Technical bulletins). NICRA model village expansion in Maharashtra in the 4500 villages under world bank funded project (PoCRA) with a budget out lay of Rs 5000 crores. In many other states upscaling of climate resilient agriculture is being taken up (Ex: Bihar, Odiha, Telangana etc). The efforts in this direction, which have begun, should expand to all the risk prone areas in the country. It is therefore, necessary to identify and prioritize various location specific adaptation and mitigation options. To sum up, the activities initiated few years back under NICRA should continue and expand in scope and content, and enable to develop multi location multi sector mitigation and adaptation strategies, so that we combat major challenge posed due to climate change in Agriculture.

Chapter-3

VULNERABILITY AND RISK ASSESSMENT OF CLIMATE CHANGE FOR ANIMAL HUSBANDRY

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Introduction

Livestock is an important component of the broader agricultural sector in the country. While the contribution of agriculture to country's GDP is decreasing over time because of the faster growth in secondary and tertiary sectors, the contribution of livestock to agricultural GDP is increasing over time. At present, livestock accounts for nearly a third of value of agricultural production. There have been tremendous gains in productivity and production in case of milk, meat, eggs and other livestock products. The growth in livestock sector is largely influenced by demand growth occurring due to increasing population, rising incomes, expanding urbanization and changing food and dietary preferences. The performance of livestock is key to achievement of sustainable development goals related to poverty reduction, zero hunger and climate action. That the distribution of livestock is more egalitarian than that of land, dominance of female workers in livestock rearing further underscores the importance of livestock sector. Livestock sector is also largest emitter of greenhouse gases within agriculture.

However, as with other sectors, livestock sector is also challenged by increasing climate variability and climate change among other things. What is unique with respect to livestock is its role in adaptation as well as in mitigation. There are, broadly, three types of livestock systems in practice in the developing countries of Asia and Africa: (i) Agro-pastoral and pastoral systems, (ii) Small holder crop-livestock systems and (iii) Industrial livestock systems (Thornton et al., 2007). Livestock rearing in India is largely done in the form of mixed crop-livestock systems, though there are pastoral communities that predominantly rely on grazing. Nomadic communities rearing the small ruminants in the arid parts of north-west India, dairy sector and poultry sector are dominant examples of these three livestock typologies respectively.

The impacts of climate change on livestock is both direct, by affecting growth and physiology of animals or birds, the pest and disease incidence, and indirect, by affecting the availability of fodder and water. In order to minimize the adverse impacts of climate change on livestock sector and on those whose livelihoods are linked to sustained well-being of livestock systems, planning and implementation of adaptation strategies is essential. A purpose-oriented vulnerability and risk assessment is a necessary and useful precursor to such adaptation planning.

Climate change risk and vulnerability assessment

Climate change literature is rich with studies on such aspects as vulnerability, resilience, adaptation, risk, hazard, etc. many of which have been used with different connotations and in varying contexts. It is therefore important to understand what these terms and concept mean in the context of climate change. Given the multiple definitions and conceptualizations by researchers from various fields, the views on such terminology given by the IPCC may be more pertinent and acceptable while we are concerned with climate change.

The IPCC's Fifth Assessment Report (AR5) proposes a framework where in vulnerability is placed as one of the determinants of risk, the other two being 'exposure' and 'hazard'. The definitions given by AR 5 for risk and its components (Oppenheimer, et al., 2014) are given below:

Exposure: The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

A broad set of factors such as wealth, social status, and gender determine vulnerability and exposure to climate-related risk.

Impacts: (Consequences, Outcomes) Effects on natural and human systems. In this report, the term 'impacts' is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts.

Hazard: The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources. In this report, the term hazard usually refers to climate-related physical events or trends or their physical impacts.

Risk: The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur.

Risk = (Probability of Events or Trends) × Consequences

Risk results from the interaction of vulnerability, exposure, and hazard.

The AR5 risk conceptualization furthers the risk analysis by identifying two kinds of risk: key risks and emergent risks. Key risks are potentially severe consequences arising when systems with high vulnerability interact with severe hazards. Different criteria are suggested to categorize a risk as key which are based on the magnitude of the risk, high vulnerability of a particular group of population, criticality of the sector in the economy. Emergent risks are those that are not direct consequences of climate change hazard but are results of responses to climate change. For example, migration of population from a region due to climate change related hazards may increase the vulnerability and thus risk of receiving regions; similarly, increased groundwater extraction during a drought may increase the vulnerability and risk in future. Thus, emergent risks are a result of spatial linkages and temporal dynamics related to responses to changing climate.

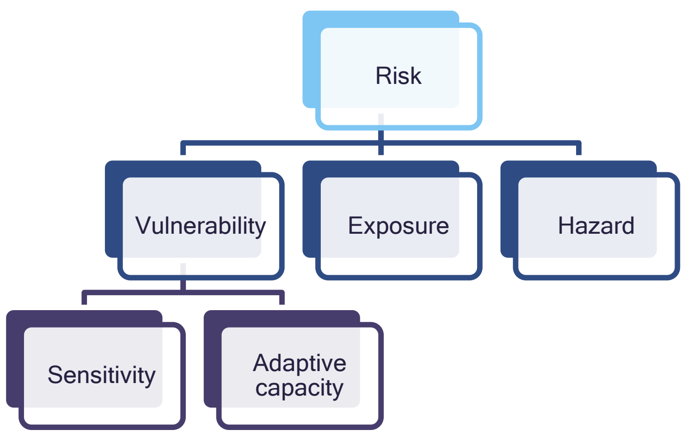

Fig. Schematic diagram of climate change risk

Vulnerability and risk assessment

There are a variety of approaches and methods to assessing vulnerability and risk. Simulation modelling, physical experimentation, agro-ecological modelling, statistical or econometric modelling, and indicator method are some of such methods. The choice of approach and method is determined by the purpose of assessment, scale of assessment, availability of data, financial and human resources. While most of these methods vary in terms of data requirements produce a quantified measure of vulnerability or risk. For example, various modelling-based studies showed possible reduction in milk production due to the climate-change induced rise in temperature and rainfall. Indicator method is somewhat different from other methods in that it leads to an assessment that gives relative vulnerability or risk of different entities subjected to assessment. Thus, this method helps identify 'hot spots' for targeting and prioritizing investments and interventions. It is one of the most frequently used method in vulnerability assessments.

The following diagram summarizes the process of indicator method of climate change risk assessment (Rama Rao *et al*., 2019):

Selection of indicators

As mentioned above, climate change risk contains three components: exposure, vulnerability and hazard. Indicators are those variables that reflect the underlying phenomenon of interest. It is this 'significance' to the phenomenon/ issue being addressed that makes an indicator out of a variable. Further, the indicators ideally should have a monotonic relationship with the underlying phenomenon over a reasonable range of values that they may take. In the present context, the three components of risk are represented through a number of indicators that would reflect these components. These indicators were chosen from a broader list of indicators based on review of literature, discussions with the experts and nature of relationship with the three components. The determinants of hazard are derived from climate projections and/or historical climate data depending on the context and purpose (Rama Rao et al., 2013).

Normalization of indicators

Often the indicators to be aggregated are measured in different units. It is necessary to bring all the indicators to be aggregated to a common scale. Statistics offer a gamut of normalization techniques. Choice of normalization technique depends on the data properties, context of the study and objectives of the composite index. Min-max, standardization, ranking, distance to a reference point are some of the frequently used normalization methods.

Assigning weights to different indicators

Assigning weights to normalized indicators while aggregating is at the core of the composite index building. Though no universally agreed methodology exists in this regard, different data driven and participatory methods can be used. The weights should reflect the relative importance of indicators in determining vulnerability. The methods of weighting may be classified in to three groups: (a) Equal weights, (b) Differential weights based on statistical models and (c) Differential weights based on public/expert opinion.

Method of aggregation to build a composite index

Method of aggregation also has a bearing on results. It is usual practice to use linear aggregation method. It proves to be a better choice if strength indicated in one dimension can compensate weakness indicated in another dimension which is known as compensability. If some degree of non-compensability is desired in the composite, multiplicative or geometric aggregation is a better choice. Geometric aggregation rewards those units with higher scores. Rama Rao et al. (2013, 2016) used linear aggregation while assessing vulnerability of agriculture to climate change in India at district level. UNDP (2016) used geometric aggregation to construct human development index (HDI), a composite of health, education and income.

Categorization of study units

Planners and policy makers usually like to have the output in the form of groups of study units like poor, better, best; which indicate action. Categorization of study units into groups should be done with consideration of normalization technique used and the objectives of the composite index. If Min-Max normalization technique is used, the composite index serves as a measure of relative vulnerability. Composite score of zero implies lowest and a score of one implies highest degree of (vulnerability/risk etc) among study units. In such cases, the units should be ranked based on composite score and be divided into equal groups and the number of groups may be determined from planning perspective. If the method of normalization used is z score, the units with composite score around zero may be regarded to have moderate vulnerability or risk. Absolute value of composite score will have a meaning if distance to a reference is used as a normalization method.

Some example indicators for various components of climate change risk

Vulnerability:

Indicator	Rationale and relationship
Crop-livestock integration	The higher ratio indicates higher amount of organic matter available thereby improving moisture retention capacity of soil for a longer duration and hence lesser vulnerability to drought
Employment diversification	More diversified income sources offset the income loss due to crop failure in uncertain rainfall. Hence, the more the employment diversification, the lesser the vulnerability
Herd size	The more the livestock holding, the lesser the vulnerability
Access to	Access to technology reduces vulnerability

Technology	
Access to land resources	The more the land holding, the lesser the vulnerability because it can serve as a cushion to absorb shock by utilizing this asset as a collateral to get loan in dire need or sell in hard times
Access to irrigation	The more the ratio, the lesser the vulnerability
Dependency ratio	The higher the ratio, the higher the vulnerability
Literacy	The more the education of the farm manager, the less the vulnerability
Farming experience	The more the farming experience, the lesser the vulnerability
Gender	Women can have a more difficult time during recovery than men, often due to sector-specific employment, lower wages, and family care responsibilities
Access to social Networks	Access to social networks decreases vulnerability
Access to agricultural training	Access to agricultural training, decreases vulnerability
Access to market	Lesser the distance, the more the access to market, hence the lesser the vulnerability.

Source: Gurung et al., (2011)

Exposure

- No. of livestock
- No of improved/cross-bred animals
- No. of farmers having livestock
- Area under forage/fodder crops

Hazard:

Changes in temperature, rainfall, relative humidity and the resultant changes in Thermal Heat Index.

Summing up

Livestock is an important sector contributing to livelihood security, food and nutrition security. Within agriculture, it is an important adaptation and risk management component against climate variability and risk. It is however a significant emitter of GHG gases. Given that the sustainability of livestock sector is challenged by a number of factors including global environmental change, there is a need to evolve and promote appropriate adaptation and mitigation strategies. A properly planned vulnerability and risk assessment will help identify 'hot spots' and interventions for vulnerability reduction and risk management. Out of the three components of risk, addressing vulnerability through appropriate measures is likely to be more useful as the other two components take longer to be managed through policy measures.

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Chapter-4

LIVESTOCK/ HORTICULTURE BASED IFS MODEL FOR DRYLAND/ RAINFED ECOSYSTEM IN INDIA

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Introduction

In the last 2 decades, the changing climatic conditions it is very much evident and climatic condition is fluctuating which resulting into problems related to livelihood security in general and particularly food and water security couple with depletion of natural resources has emerged as a worldwide major issue. This issue is more pertinent to developing countries and these countries are struggling a lot. The problem become more aggravated due to globalization and changing climatic scenario. Now the policy maker and decision maker across the globe have to sit together and decide the way of sustainable development more particular in light of livestock and considering the dryland/ rainfed system. Many countries of the world promoting the sustainable development through sustainable use of natural resources in the perspective of socio-economic conditions of the farmers particularly dealing with livestock. Agriculture has to be look always in broad perspectives and among these Integrated Farming system model emerged and holds special position as in this system nothing is going to be wasted as the byproduct of one system becomes the inputs for the other system. Here, it is pertinent to understand the few thing like IFS, dry land, rainfed, livestock, horticulture, crops, etc. in concise form.

Integrated farming is an integrated approach to farming as compared to existing monoculture approaches. It refers to agricultural systems that integrate livestock and crop production. Moreover, IFS system helps those farmers who has poor socioeconomic condition and marginal to small farm holdings. In this system most of the farm activities is to be performed by the family members for crop production and a few heads of livestock in order to diversify farm production, increase cash income, improve quality and quantity of food produced and exploitation of unutilized resources.

Rainfed agriculture is a type of farming system that relies on rainfall for water. Of India's 329 million hectares of geographical area, nearly 140 million hectares are net sown area and out of it 70 million ha is rain-fed. India is a subtropical country with 15 Agro-climatic zones and primarily dependent on the south-west monsoon and few state observed north-west monsoon. Rainfed Farming: Cultivation of crops in regions receiving more than 1,150 mm. Within the rainfed areas, priority will be given to arid, semi-arid and sub-humid eco- systems

- Rainfed agriculture includes both permanent crops (such as rubber, tea, coffee, etc.) as well as annual crops (wheat, maize, rice, millets, etc).
- Live-stocks (Dairy animals, small ruminants, Poultries, Bee Keeping, etc.
- Cultivation of mushroom, hydroponics, etc. are another area for landless or marginal farmers
- All the rainfed areas (i.e. areas which are not covered under assured means of irrigation) having large extent of cultivable land and potential for increasing agriculture productivity are to be covered under RADP.

Dry Farming: Cultivation of crops in the areas where rainfall is less than 750 mm per annum.

What is IFS?

- ➢ To integrate different production systems like dairy, poultry, livestock, fishery, horticulture, sericulture, apiculture, etc. with agricultural crops production as the base
- ➢ To increase farm resource use efficiency (land, labour and production/by- products) so as to increase farm income and gainful employment opportunity.
- ➢ To maintain environmental quality and ecological stability.
- ➢ Integrated farming system is a sustainable agricultural system that integrates livestock, fish, poultry, crop production, Horticultural crops, tree crops, plantation crops, vegetable crops, and other systems that benefit each other.
- ➢ It is based on the concept that ‘there is no waste’ and ‘waste is only a misplaced resource’ which means waste from one component becomes an input for another part of the system.
- ➢ IFS approach is considered to be the most powerful tool for enhancing profitability of farming systems especially for small and marginal farmers to make them bountiful.

Goals of IFS

- Enhancing productivity per unit area of cultivation
- Proper waste management

- Generation of continuous income round the year
- Reducing use of chemicals
- Maximization of yield of all component enterprises
- Soil health management
- Reduction in environmental pollution and hazards

Components of IFS

- Piggery/ Goatery
- Poultry /Duckery/ Quail
- Fishery
- Plantation crops/ Fruit cultivation
- Apiary
- Mushroom cultivation and hydroponics
- Vermi-composting

Table: Glimpse of IFS Module developed under ICAR-ATARI Zone IV

State	No. of KVKs having IFS Unit in its farm	No. of IFS units established at farmers' field in 2021
Bihar	27	73
Jharkhand	14	57
Total	41	130

Table: Comparative performance and components covered under IFS

Component Name	Number of Activities		No. of farmers benefited	
	Demo	Training	Demo	Training
Cereal Based IFS Dairy Based IFS Fish Based IFS Fruit Based IFS Apiary Based IFS Poultry Based IFS Mushroom Based IFS Pond based IFS Organic crop & Fruit based IFS	434	167	13294	2907

The available models or options are:

Model 1: Horticulture + Piggery + Fisheries + Plantation Crops

- Pig dung acts as excellent pond fertilizer and some fish feeds directly on the pig excreta
- Pond water is used for cleaning pigsties and bathing the pigs
- Plantation trees as shade for the fishery pond or planted as fodder production between orchard trees to prevent soil erosion

Model 2: Horticulture + Duckery + Fishery + Plantation crops + Vermicomposting + Apiary

Employment generation under integrated farming system

Sl. No.	Component of IFS	Area (M^2)	Gross Income (In Lakh)	Expenditure (In Lakh)	Net Profit (In Lakh)
1.	Fish + fish seed production	3600	6.25	1.67	4.58
2.	Dairy farming	250	On going		
3.	Poultry Farming	250	13.50	12.00	1.50
4.	Goat farming	150	1.40	0.86	0.54
5.	Duck farming	50	0.25	0.09	0.16
6.	Vermi-compost production	300	0.30	0.10	0.20
7.	Vegetable cultivation	50	0.43	0.22	0.21
8.	Fodder production	1150	-	-	-
9.	Horticulture	200	0.10	0.04	0.06
Total		6000	22.23	14.98	7.25

Economics of integrated farming system

Sl. No.	Component of IFS	Area (M^2)	Man days
1.	Fish production – fish seed production	3600	255
2.	Dairy farming (5 Cow + 2 Calves)	250	365
3.	Poultry Farming (Broiler 1000)	50	180
4.	Goat farming (25)	300	180
5.	Duck farming (50)	50	45

6.	Vermi-compost production	200	35
7.	Vegetable cultivation	150	45
8.	Fodder production	1150	45
9.	Horticulture	250	40
Total		**6000**	**1190 (3.2 Man Days/day)**

Vermicompost can be used either for commercial or manure for crop

Ducks excreta for pond fertilizer while they get their feeds requirements from aquatic weeds etc.

Apiary: Honey production and for pollination

Duck houses are constructed on pond dikes; hence no additional land is required

Expected outcome from ridge and furrow system of cultivation in one hectare low lying area (Area covered under-Ridges: 4000m^2 & Furrows: 6000 m^2)

Models	**Fruit crops on ridges**		**Crops/fish on furrows**				**Total income (Rs.)**
	Fruit crops (Perennial)	**Short duration fruit crops**	**Vegetable and other crops**			**Fish**	
			Rainy	**Winter**	**Summer**		
Option-I (Papaya /Banana+Veg)	Mango or Litchi (208 plants)	Papaya/ Banana (364 plants) Net income 125 Rs./Plant in papaya & 130 Rs./Plant from banana 45500-47320nos.	Paddy 15000	Mustard 27000	Moong 24000	-	112000-113000 (Up to 5 years)
Option-II (Papaya /Banana+Veg.)	-	45500-47320	Fallow	Faba bean	Cucurbits 30000	-	100000 - 101000

				24000			
Option-III (Papaya /Banana+Cowpea+ Fish)	-	45500 - 47320	Short duration fish		Cowpea 60000	25000	130000-132000
Option-IV (Papaya /Banana+Fish)	-	45500-47320	Year-round fish culture			54000	100000 - 101000
Mango/Litchi+Fish (After 5 years)	Rs.1000/ plant 1000x208= 208000	-	-	-	-	54000	262000 (After 5 year)
Existing cropping system							
Practice-I: Paddy-wheat T (Normal low land)	-	-	Paddy 25000	Wheat 35000	-	-	60000
Practice-II Maize-moong (Flush flood)	-	-	Fallow	Maize 30000	Moong 25000	-	55000

Livestock based production system

The livestock farming system in rainfed agriculture are complex and generally based on traditional socio-economic considerations. An understanding of production factors (livestock, capital, feed, land and labour) and processors (description, diagnosis, technology design, testing and extension) that effect animal production is pre-requisite for livestock integration. The productivity of livestock in farming systems in rainfed agriculture can be improved by increased fodder production as an intercrop with cereals, relay and alley cropping, forage production on bunds, improving the feeding value of stover by chopping, soaking with water, urea treatment, strategic supplementation of concentrate, urea molasses mineral block for enhanced utilization, improvement in productivity of grasses quantum and distribution decides the effective growing season and it becomes critical in selecting cropping systems for a given reason.

Livestock environment interaction

Different farming systems have been evolved independently and being practiced by the farmers without any rationale for utilizing the wastes and residues arising out of cropping/animals and other associated enterprises at farm resulting wastage of resources. The income from average farmers from cropping alone is hardly sufficient to sustain his family. Dairy, irrespective of kind of animals and their breeds, has been an integral part of prevailing farming systems across the country.

Farmers, in general, do not practice single livestock rearing system but incorporates different livestock (cows, buffaloes, sheep and goats, pigs and small numbers of poultry in the backyard) to meet their domestic needs. Therefore, livestock became an integral part of farming system as such. Other agricultural components like horticulture, plantation, vegetables, sericulture, agro-forestry are also prevalent in the homesteads. These units are operated either alone or in combination depending upon the size of the farm holdings and other available resources. In this system, animals are raised mainly on agricultural waste and the complementarities between different components are tried to exploit to its maximum level. The animal power is used for agricultural operation and the dung is used as manure and fuel. It may be possible to reach the some level of yield with proportionately less input in the integrated farming and the yield would be inherently more sustainable because of waste of one enterprise becomes the input of another leaving almost no waste to pollute the environment or to degrade the resource base.

Implication of livestock on soil fertility

Any farming would be sustainable only if the diminishing natural resources are checked in time. Severe soil loss due to erosion, and nutrient extraction from the soil by cereal cropping, indicate the need for soil conservation as a first step in conjunction with maintaining its fertility status, before planning nay programmes to increase productivity. Soil fertility maintenance is the combined result of the interactions between plants, animals, and their by-products, a complex but essential component of the whole farming system. Though animals have only a limited direct effect on restoring soil fertility, they are the major means by which plant produce is converted to manure. Addition of their dung helps to improve soil texture, and to decompose litter more easily. With a traditional feeding system, and farmyard manure (FYM) preparation method, an adult large ruminant animal provides about four tones of FYM and six large ruminants are sufficient to provide required FYM for one hectare of farmland under a rice – maize – wheat system for one year.

Livestock as a source of farm power

For human need, the livestock provide food, fiber, skin, fertilizer and fuel. Livestock and constitute a “living bank” providing flexible financial reserves in times of emergency and serve as “insurance” against crop failure for survival. Besides this it also gives drought power. In general, male animals are used for draught purposes usually in pairs. Almost all land preparation is performed by animals especially in hill areas where mechanization of agriculture is till in its infancy.

Livestock as a source of manure

For centuries, the excreta of animals have been used as manure for crop production. The excreta of various animals provide major nutrients like N,P, K, to the crops and hence widely used to improve the soil fertility. Experiments have shown that these animal manures are not only rich in major nutrients but also contains several micronutrients. The demand of livestock manure is very high for agricultural as well as horticultural crops.

The dung production varies with different categories of livestock. The amount of dung produced per animal per day depends upon the amount of forage fed to the animals. In general, the total output of dung (fresh weight) from cattle and buffalo per day to be about 10 kg and 12 kg, respectively giving a total of 3.6 tones and 4.3 tones of dung per animal per annum, respectively. Assuming the animals are stall fed, the annual output of N,P and K for cattle would be 12.6 kg N, 5.4 kg P and 7.2 K, and from buffalo 15 kg N, 6.5 kg P and 8.6 kg K.

The average dung production per head per year on dry matter basis are 1.10, 1.35, 0.25, 0.15, 0.15 and 0.5 tones for cattle, buffalo, pigs, sheep, goats and horses, respectively (Table)

Approximate dung production by different categories of livestock

Livestock	**Dung production per animal per year (Dry weight basis) in tones/year**	
	Range	**Average**
Cattle	0.4-1.8	1.10
Buffalo	0.8-1.9	1.35
Pigs	0.2-0.3	0.25
Sheep	0.1-0.2	0.15
Goat	0.1-0.2	0.15
Poultry (100 birds)	0.14	0.14

The availability of manure for use in agriculture and fish production can be calculated from the average dung production and nutrient value of the manure. The nutrient content of the excreta varies with different species of livestock. Generally, the nutrient value of the manure, in increasing order is cattle, sheep and goat, followed by pig, chicken and ducks.

Average N, P and K level in dung of different livestock

Source	N%	K%	P%	Ca%	Mg%
Poultry manure	2.12	1.16	1.40	2.32	2.45
FYM	0.65	0.50	0.18	3.82	3.96
Goat manure	1.16	1.09	0.40	3.20	3.65
Vermi-compost	2.15	0.95	0.55	4.15	3.60
Pig manure	0.50	0.28	0.35	2.15	2.85
LQM	0.56	0.18	0.45	0.10	0.07
Duck dropping	1.85	0.98	1.46	1.99	2.22
Azolla	5.20	3.60	0.48	0.75	0.62

Animal urine is very rich in nitrogen and potassium. The value in cattle urine has been reported to be 0.9 – 1.2 % N, a trace level of P and 0.5 – 10 % K. Urine output per kg body weight is in the range 17-45 ml/kg body weight. The average body weight of cattle, if taken as 200 – 300 kg the average urine production per day per animal would be about six to nine litres. To use the animal manure effectively, the animals are to be stall-fed and housing should be designed in such a way that entire urine is collected.

Integrated livestock – fish culture

Increasing population exert economic pressure for maximizing food production at minimum production cost along with a general concern for energy conservation. The integration of fish culture with livestock holds a considerable potential for augmenting production of animal protein, generation of employment opportunities in the rural areas and improvement of socio-economic condition of the farmers.

Integrated livestock-fish culture would be more successful if proper stocking density of fish and animals are followed. The stocking density of fishes and number of animals/birds required to fertilize unit area of pond has to be standardized to suit the particular environmental and resource availability in that particular region to ensure healthy rearing of fish. The use of animal waste to fertilize fish ponds leads to greater fish yield, as the manure provides active nutrients (NPK) for the metabolic cycle in the ponds and promotes the growth of plankton which is the natural food for fish. Cattle, pigs, poultry and ducks can be raised on the embankments or near by the ponds so that the manure can directly be utilized for pond fertilization. There are several types of integrated fish farming systems and the most common ones are discussed below.

(i) Cattle – Fish farming

Fish farming can become more production-oriented if integrated with cattle farming. Cattle are fed with the grass grown in and around the pond banks and manure is either collected or washed directly from the cattle sheds into the ponds for fish culture. However, there is a strong need to standardize the number of animals required to provide manure per unit area of fish ponds. The manure of cattle contains less nutrients than that of poultry and pig, especially when it is collected from the fields after being dried and/or after the nutrients are leached out. Approximately, five cattle/buffaloes are enough to fertilize one ha of fish pond.

(ii) Pig –Fish farming

This method is another classical Chinese integrated fish farming system widely practiced in its original geographic area. Small pigsties are constructed over the fish ponds, while the bigger ones are constructed on the dikes and pig manure is allowed to enter the pond directly or collected and fermented in suitable pits before applying in the ponds. Fresh pig manure is regarded as highly efficient for pond fertilization and fish can utilize directly the feed spilled by the pigs, which would otherwise go as waste. In this system, supplementary fertilization and feeding are not required for fish culture. Pig manure is rich in phosphorus and nitrogen, which are highly essential to sustain a good stocking density of fish fingerlings per ha. On an average, 30 to 40 pigs are sufficient to fertilize one ha pond water area. Depending upon the need and prevailing local market, non-descript as well as exotic or improved varieties of pig are recommended for rearing. The pig-fish culture system is economically viable when good managemental practices are followed.

(iii) Goat /Sheep-cum-Fish farming

Intensive goat and sheep raising is increasing due to high demand for chevon and mutton. Manure from goat and sheep is also potential for integrated animal-fish farming system but this is not yet used in widespread integration with fish culture. The fish feed produced in the ponds with goat manure is efficiently utilized by the fish biomass.

(iv) Poultry – Fish farming

Poultry farming can effectively be combined with fish farming keeping in view the fact that poultry droppings serve as an excellent fertilizer for fish ponds. The poultry - fish system requires little space, low capital investment and provide quick returns. Poultry dropping are rich in highly soluble inorganic salts and have high N and P values as compared to other livestock manures. Layer or broilder chicken can be raised in houses built above the fish ponds or on the dikes. This type of integration can be practiced both in large commercial ventures and in small farms.

Besides the feed for fish is available round the year, the egg and meat produced by poultry provides an additional income to the farmers. Commercial strains for meat and egg production (dual purpose birds like Vanaraja birds) are now available and have been proved successful. Approximately 60 kg/ha/day deep litter manure has to be applied in fish culture pond and 500 – 600 poultry birds are enough to fertilize one ha of fish pond.

(v) Duck – Fish farming

It is one of the classical systems of integrated fish culture. The system is based on the same concept of an efficient use of water area to increase its biological productivity through the use of duck droppings which either fall directly into the pond or are collected from duck sheds and used for fertilizing the ponds. The duck house is usually made up of locally available materials like bamboo, wood etc. The fish gather protein-rich natural food from the pond ecosystem and may consume directly the feed spilled by the ducks. Ducks usually consume tadpoles, mosquitoes and dragon fly larvae which are not consumed by fishes. Another advantage is that ducks feed on snails, which are vectors of certain fish parasites. Ducks are not only fertilize ponds nut also release nutrients from the pond soil by its dabbling activity and also enhance the availability of oxygen for fishes resulting in enhanced pond productivity.

The local ducks are not suitable for commercial raising and for that Khaki Campbell and Indian runners are recommended. Approximately, 200 – 300 ducks are enough to fertilize one ha of fish pond.

Number of animals required to fertilize 1 ha pond water area

SI. No.	Animals/fish	Recommended numbers/ha water area
1	Cattle/buffalo	4-5
2	Goat	50-55
3	Pig	30
4	Duck/Layers	450-500
5	Composite fish culture	7000-8000

Management of pond for pig based IFS:

Maintenance of pond for pig based integrated farming system is the largest challenge for the farmers due to variety of reasons.

Soil pH	Soil Type	Dose of lime (Kg/ha)
4.0 – 5.0	Highly acidic	2000
5.1 – 6.0	Moderately acidic	1200
6.1 – 6.5	Mildly acidic	1000
6.6 – 7.0	Near neutral	400

Manual cleaning of submergent/ floating weeds etc. is essential to maintain the optimum water quality for growth of fingerlings. Similarly, embankment should be firm with guarded inlet and outlet. Predatory fishes need to be removed through netting to maintain proper ratio of surface, middle and bottom feeders. The soil pH of pond should be maintained around 6.5 to 7.5. The correction of pH can be done by the means suggested in the table.

For pig based integrated farming system, cow dung and calcium carbonate should be applied in the pond at the rate of 5000 kg and 1200 kg per hectare.

Table : Fertilization of fish ponds (Kg/yr) by faecal material

Livestock/bird	Total DW of dung/ Droppings	DM %	Ash %	P	N	K	Ca
Duck	127.60	22.10	30.9	2.40	4.50	2.81	2.54
Poultry	965.08	35.42	32.2	13.32	9.65	24.13	11.10
Goat	140.40	28.57	22.9	1.83	4.96	2.75	8.87
Pig	576.0	30.71	33.7	5.12	8.93	7.49	13.25
Cow	1830.0	50.16	25.9	17.57	22.87	21.96	34.22

An ideal fish combination of 6 Species have been suggested for pig cum fish farming where a ratio of Surface feeder: Column feeder: Bottom feeder = 40:20:40 should be maintained. Commonly used surface feeder in the region are Catla and Silver carp, column feeder are Rahu and Grass carp, bottom feeder are Mirgal and Common carp.

Resource generation in IFS

Farming system is a resource management strategy to achieve economic and sustained production to meet diverse requirements of farm households while preserving resource base and maintaining a high level environmental quality (Lal and Millu, 1990). Integrated farming system models developed in different parts of the country involving dairy, duckery, poultry, horticulture, apiary, pisciculture and plantation crops viz; coconut, cocoa, nutmeg, banana, pineapple, etc. along with crops, have been found to increase net profit significantly as compared to cropping alone. These IFS systems were also found more sustainable and employment generative. Balasamy et al (2003) obtain net profit increase from Rs.22971/ha/annum in rice alone to Rs.31788/ha/annum in rice + fish + azolla. In Telangana zone of Andhra Pradesh, the major crops grown are rice, maize, jowar, groundnut, sugarcane and cotton and other components include buffalo, goat, sheep and poultry. The results of a study (Radha et al; 2000), conducted on survey based with three agricultural and livestock based farming systems viz., dairy, poultry and sheep rearing clearly revealed that all the farming system generated more than 3 times additional employment over arable farming. The net returns were higher in agriculture + dairy (Rs.35293) followed by agriculture + poultry (Rs.26830) and agriculture + sheep rearing (Rs.14665). Among different farming systems, the agriculture + dairy was proved to be more promising than others. The main reason for high return that stover of maize/jowar for fodder and their grains for feed as well as sugarcane crops to feed cattle buffalo were available at the farm. IFS studies conducted on farmers' fields in Punjab conditions, gross profit was found to increase from Rs.81200/ha/annum in cropping (Rice-wheat) alone to Rs.154000/ha/annum in crop+dairy and Rs.113200/- in fish+piggery system of farming (Gill,M.S.,2004). Encouraging results of IFS approach in Uttar Pradesh has also been reported by Gurbachan Singh (2004) and Singh et.al.(2007).

Table: Economic analysis of different farming systems (Adopted from PDFSR, Modipuram report)

Farming system	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	Benefit-cost ratio
Crops + Dairy	54960	95742	40782	1.74
Orchard (Mango)	122500	160000	37500	1.31
Floriculture (Marigold)	43919	112629	68710	2.56
Vegetables	44752	99599	54847	2.23
Fishery	95180	157500	62320	1.65
Bee keeping	125000	171250	46250	1.37
Poultry	65045	132927	67842	2.04

The studies conducted at PDFSR, Modipuram located in western plain zone of Uttar Pradesh for a period of six years (2004-2010) revealed that Integrated Farming System Approach applied on a piece of 1.5 hectare irrigated land, besides fulfilling all the requirement of 7 members household food and fodder demand (animals) inclusive cost of production, could create an additional average annual savings of Rs. 47000/- in first four years of its establishment and more than Rs.50, 000 in subsequent years. This saving could assist the family to meet other liabilities including health, education and social customs and improved the livelihood of small farm holders. Diversified nature of IFS and varied type of farm produces viz; milk, fruits, vegetables , fish and green fodders etc. in the system made the human and animal diet more nutritious compared to existing crop based farming system involving crops + dairy. Recycling of all the crop residues, animal and farm wastes and use of leguminous crops as green manure or dual purpose crops and bio-fertilizers could save more than 36% of plant nutrients. In addition, IFS approach generated more than the double man days as compared to crops alone which in turn can solve unemployment problem in rural youths. The analysis made on on-farm production and inter-relationship of different enterprises within the system envisage that more than 57 percent of the total cost on farm production Rs.1,97,883 per annum is met from the inputs (out- put of another enterprise/enterprises) generated within the system itself. This shows the significance of IFS approach in sustaining the farming with more economic gain by adopting it under small farm conditions. Hence, Integrated Farming System Approach to agriculture is a viable approach to solve many problems coming on the way of livelihood of small and marginal land holders in India.

Table: Year round green fodder production under IFS model:

Name of crops	Availability (duration)	Avg. annual green fodder production (q)	Avg. annual dry fodder production (q)
Irrigated:			
Sugarcane (cane tops)	Oct to April	-	89
Wheat straw	Round the yr	-	22
Maize curvi	August to Sept	-	5
Maize + Cowpea	May to June	44	
Pearlmillet	June to July	50	
Sorghum	July to Nov	241	
Berseem	Dec to April	72	
Oats	Dec to March	53	

Component enterprises of IFS Model:

I. Dominate farming system in Rainfed: Crops + small ruminants
in Irrigated: Crops + Dairy

II. Most promising enterprise for integration / diversification: Horticulture + Fishery

III. Supplementary enterprises: Apiary
Vermi-compost
Boundary plantation
Fodder cultivation

EMPLOYMENT GENERATION

Comparatively diversified and rather intensive nature of multifarious activities related to different enterprises included in the IFS model provide a lot of opportunities of employment (Photo 32-33) and keeps farmers and their family members engaged whole the year and as such can help in solving unemployment problem of the country mainly in rural youths. The man days required for the production of crops alone was 182/ha /annum wherein under IFS this number was 2.91 times more (795 man days) than crops alone (Table 15). Similar were the findings of Jayanthi et al (2001), Radha et al (2000), and Singh et al (2007).

Table: Effect of IFS approach on employment generation

S.No.	Component enterprises of IFS	Man days
1	Crop alone (1.04 ha)	189
2	Dairy (5 milch animals and their young ones)	365
3	Fishery (fish pond of 0.10 ha)	52
4	Apiary (10 bee boxes)	38
5	Goat (15 animals)	91
6	Vermi-composting (0.01 ha)	60
	Total IFS (1.5 ha)	795 man days
		~ 530 man days/ha

Conclusion:

Integrated Farming System is a promising approach for increasing productivity and profitability through recycling the farm by-products and efficient utilization of available resources. Further it generates employment opportunities to the farming communities round the year and provide a better economic and nutritional security. It also maintains environmental quality and ecological stability

Way forward

Further research and field demonstrations are required to develop suitable models for efficient integrated farming systems relevant to the specific region. For technology transfer and making farmers aware about the technology capacity building trainings and appropriate communication strategy is required.

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Chapter-5

STATISTICAL TOOLS FOR QUANTIFYING THE CLIMATE RESILIENCE / IMPACT OF INTERVENTIONS IN LIVESTOCK SECTOR

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Introduction

Assessment of change that can be attributed to a particular intervention, such as a project, program or policy is called Impact Assessment (IA). Impact assessment involves counterfactual analysis, whereas outcome monitoring is limited to examining whether targets have been achieved or not. The 'counterfactual' measures what would have happened to beneficiaries in the absence of the intervention, and impact is estimated by comparing counterfactual outcomes to those observed under the intervention. Counterfactual analysis enables evaluators to attribute cause and effect between interventions and outcomes. Impact Assessment is formal, evidence-based procedure that assesses the economic, social, and environmental effects of a project, program or policy (Adelle and Weiland, 2012). Impact assessment helps people answer key questions for evidence-based policy making: what works, what doesn't, where, why and for how much? Impact assessment helps by apprising policy makers about potential economic, social, and environmental ramifications. The International Initiative for Impact Evaluation (3ie) defines Impact Evaluations as: 'analyses that measure the net change in outcomes for a particular group of people that can be attributed to a specific program using the best methodology available, feasible and appropriate to the evaluation question that is being investigated and to the specific context'. Impact evaluation is now being increasingly applied in areas such as the agriculture, energy and transport. Resilience is defined as "propensity of a system to retain its organizational structure and productivity following a perturbation" (Holling, 1973). Unlike impact resilience primarily focusses on bringing back to normal productivity.

Assessment of Impact / Climate Resilience

Estimation methods broadly follow evaluation designs. Different designs require different estimation methods to measure changes in outcome from the counterfactual. In experimental and quasi-experimental evaluation, the estimated impact of the intervention is calculated as the difference in mean outcomes between the treatment group (those receiving the intervention) and the control or comparison group (those who don't). This method is also called randomised control trials (RCT). The single difference estimator compares mean outcomes at end-line and is valid where treatment and control groups have the same outcome values at baseline. The difference-in-difference (or double difference) estimator calculates the difference in the change in the outcome over time for treatment and comparison groups, thus utilizing data collected at baseline for both groups and a second round of data collected at end-line, after implementation of the intervention, which may be years later.

Impact Evaluations which have to compare average outcomes in the treatment group, irrespective of beneficiary participation (also referred to as 'compliance' or 'adherence'), to outcomes in the comparison group are referred to as intention-to-treat (ITT) analyses. Impact Evaluations which compare outcomes among beneficiaries who comply or adhere to the intervention in the treatment group to outcomes in the control group are referred to as treatment-on-the-treated (TOT) analyses. ITT therefore provides a lower-bound estimate of impact, but is arguably of greater policy relevance than TOT in the analysis of voluntary programs.

Every existing system will exert some resilience to an external (climatic) shock unless the shock is completely devastating. The outcome indicators like milk yield in lit/day per animal observed with an existing practice (generally conventional practice) in the event of a stress of a specified degree compared to normal outcome of the system in the absence of the stress may be referred as inherent resilience of the system to the stress of specified degree. An intervention proved for its potential to withstand the stress may induce some resilience over and above the inherent resilience. The difference between induced resilience and inherent resilience may be attributed to the intervention. Another way of looking at the resilience is from the perspective of impact potential. The loss in outcome indicator due to a stress of a specified degree as compared to normal outcome (in the absence of stress) may be referred as impact potential of the stress of specified degree. Then the resilience of an intervention may be assessed by computing the proportion of the impact potential bridged by the intervention. Same approach can be used to assess resilience potential of a set interventions too. As mentioned earlier it is very important to ensure that all other background conditions are same for outcome with and without intervention. Similarly, background conditions should be same for normal outcome and outcome under stress without intervention except for stress (Rama Rao et al., 2018).

Inferential statistics

Inferential statistics or **statistical induction** comprises the use of statistic (some function of sample values) to make inferences concerning some unknown aspect of a population called parameter. The aim of this section is to draw inferences about a population from a sample.

Sampling distribution

For example, consider a very large normal population (one that follows the so-called bell curve). Assume we repeatedly take samples of a given size from the population and calculate the sample mean ($\bar{x}$, the arithmetic mean of the data values) for each sample. Different samples will lead to different sample means. The distribution of these means is the "sampling distribution of the sample mean" (for the given sample size). This distribution will be normal since the population was normal. According to the central limit theorem, if the population is not normal but "sufficiently well behaved", the sampling distribution of the sample mean will still be approximately normal provided the sample size is sufficiently large. Thus, the mean of the sampling distribution of a statistic is equivalent to the expected value of the statistic. For the case where the statistic is the sample mean:

$$\mu_{\bar{x}} = \mu$$

where μ is the mean of the population distribution of that quantity.

The standard deviation of the sampling distribution of the statistic is referred to as the standard error of that quantity. For the case where the statistic is the sample mean, the standard error is:

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

where σ is the standard deviation of the population distribution of that quantity and n is the size of the sample (number of items).

Null Hypothesis: It is a statement about population parameters, which is tested for possible rejection under the assumption that it is true.

In practice it has to be identified with the "nil hypothesis", which states that "there is no phenomenon", and that the results in question could have arisen through chance. For example, if we want to compare milk yields cattle of two villages, a null hypothesis would be that the mean yield of village-A is same as the mean yield of village-B, and therefore there is no significant statistical difference between them:

H_0: $\mu_1 = \mu_2$

Where H_0 = the null hypothesis

μ_1 (mu 1) = the mean yield in village-A, and

μ_2 (mu 2) = the mean yield in village-B

Alternative Hypothesis: This is complementary to null hypothesis. When a null hypothesis is formed, it is always in contrast to an implicit *alternative hypothesis*, which is accepted if the observed data values are sufficiently improbable under the null hypothesis. The precise formulation of the null hypothesis has implications for the alternative. If one wants to test null hypothesis that mean yield of village -A is same as the mean yield of village -B then alternative hypothesis could be:

i) mean yield of village -A is not same as the mean yield of village -B – leads to two tailed test i.e. $\mu_1 \neq \mu_2$.

ii) mean yield of village -A is < mean yield of village -B – leads to left tailed test i.e. $\mu_1 < \mu_2$.

iii) mean yield of village -A is > mean yield of village -B – leads to right tailed test i.e. $\mu_1 > \mu_2$.

Level of Significance: It is the percentage chance that null hypothesis is rejected though it is true. If the null hypothesis is true, the significance level is the probability that it will be rejected in error. This chance of committing error arises due to fluctuations in sampling. Popular levels of significance are 5%, and 1%.

Example

	Truth	
Verdict	***True***	***False***
True	No Error	Type II Error
False	Type I Error	No Error

5% Level of Significance: It means there is 5% chance that we reject null-hypothesis though it is true. Consider the above example. Say we rejected null hypothesis and concluded that the mean yield of village -A is not same as the mean yield of village -B at 5% level of significance on the basis of sample scores. It implies that there is 5% chance that mean yield of village -A is same as the mean yield of village -B in the population and we concluded wrongly that they are not same.

1% Level of Significance: There is 1% chance that we reject the null hypothesis, though it is true. Consider the above example. Say we rejected null hypothesis and concluded that the mean yield of village-A is not same as the mean yield of village-B at 1% level of significance on the basis of sample scores. It implies that there is 1% chance that mean yield of village-A is same as the mean yield of village-B in the population and we concluded wrongly that they are not same.

Testing of hypothesis - small sample tests

The aim of this section is to draw inferences about a population from a small sample.

Two Sample t-Test

Let μ_1, μ_2 are the mean outcomes in treatment group and control group populations and $\overline{x_1}$ and $\overline{x_2}$ are mean outcomes of random samples of sizes n_1 and n_2 drawn independently from the populations of treatment group and control group.

Assumptions:

i) Population from which samples are drawn is normal.

ii) The samples are drawn independently and at random.

iii) Population standard deviations (S.D.s) are equal

Constraints:

i) Common population S.D. is not known

Null Hypothesis: $H_0 : \mu_1 = \mu_2$

Outcome in treatment group is equal to outcome in control group.

Test statistic:

$$t = \frac{(\overline{x}_1 - \overline{x}_2) - (\mu_1 - \mu_2)}{s_p\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}},$$

follows t distribution with $(n_1 + n_2 - 2)$ degree of freedom.

Where, S_p is Pooled S.D.

$$s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2},$$

$$s_1^2 = \frac{1}{(n_1 - 1)}\sum_{i=1}^{n_1}\left(x_{1i} - \overline{x}_1\right)^2$$

s_2^2 may be computed using a similar formula.

Conclusion: If calculated t is greater than t table value for $(n_1 + n_2 - 2)$df at required level of significance, the null hypothesis is rejected. It is concluded that there is significant difference between two means with respect to character under consideration. Otherwise null hypothesis is accepted.

Example: Principal Investigator (PI) of National Innovations in Climate Resilient Agriculture (NICRA) project wanted to see whether there is any difference in milk yield of cattle between NICRA adopted village and a neighbouring village in a drought year. A sample of 10 cows were drawn at random from each village. The milk yields (in l/day) recorded for the sampled cows are as under.

NICRA village	3.6	3.7	3.3	4.5	4.4	3.9	2.9	3.2	3.5	4.1
Neighbouring village	2.2	2.6	1.8	3.4	2.8	2.3	3.6	1.7	2.7	2.9

The difference in yield between the villages may be attributed to impact of NICRA interventions. Make a statement about the significance of the difference.

Solution:

i) sample sizes are n_1 = 10, n_2 = 10

ii) $H_0 : \mu_1 = \mu_2$

$H_1 : \mu_1 \neq \mu2$

iii) Test Statistic

$\bar{x}_1 = 3.71, \quad \bar{x}_2 = 2.6$

$s_1^2 = 0.387 \quad s_2^2 = 0.27 \quad S_p = 0.57$

$$t = \frac{(3.71-2.6)-0}{0.57\sqrt{\frac{1}{10}+\frac{1}{10}}} = 4.33$$

Conclusion: t (Cal) = 4.33 is greater than t (table) value i.e. 2.88 at 1% level of significance. Hence null hypothesis is rejected and concluded that the difference is statistically significant.

It can be inferred that NICRA interventions had positive impact and built resilience against drought.

Paired t-Test

When to use paired t-test:

The sample sizes should be equal and the two samples are not independent (sample observations are paired together). For example, difference in performance of a group of buffaloes before and after shelter management may be tested using this test. Let μ_1, μ_2 are the performances before and after training. A random sample of size n is drawn from the group of buffaloes and subjected to shelter management. Let x_{i1} and x_{i2} are the pair of observations pertaining to performance before and after shelter management respectively on i^{th} (i=1, 2, ...n) sampled buffalo.

Assumptions:

i) Population from which samples are drawn is normal.

ii) The paired sample is drawn at random.

iii) Population S.D.s are equal

Constraints:

i) Sizes of the samples are equal

ii) Common population S.D. is not known

Null Hypothesis : $H_0 : \mu_1 = \mu_2$

There is no difference in performance before and after shelter management

Test statistic: $t = \frac{\bar{d}}{\sqrt{\frac{S_d^2}{n}}}$ follows t distribution with $(n-1)$ degree of freedom.

where, $\bar{d} = \frac{1}{n}\sum_{i=1}^{n} d_i$ and $d_i = x_{i1} - x_{i2}$

$$S_d^2 = \frac{1}{n-1}\sum_{i=1}^{n}\left(d_i - \bar{d}\right)^2$$

Conclusion: If calculated t is greater than t table value for (n-1) df at required level of significance, the null hypothesis is rejected. Otherwise null hypothesis is accepted.

Example: Milk yield of a random sample of 15 buffaloes recorded before and after shelter management that controls temperature and humidity in the shed are as given below.

Buffalo	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
After Management	5.2	4.6	4.9	5.8	4.1	3.8	4.4	3.5	3.6	4.3	3.1	5.5	4.6	4.7	5.0
Before Management	3.2	3.8	3.4	2.9	2.8	3.5	3.1	3.4	3.0	2.8	2.9	2.5	3.3	2.4	2.8

Test whether the shelter management was effective in controlling the micro climate of the shed and improve milk yield in buffaloes

Solution:

H_0: Shelter management is not effective in enhancing milk yield and the increase in milk yield is due to fluctuations of sampling.

H_1: Shelter management is effective in in enhancing milk yield in buffalo

Computation of Test Statistic: $\bar{d} = 1.42$ and $S_d^2 = 0.86$

$$t = \frac{1.42}{\sqrt{\frac{0.86}{15}}} = 5.94$$

Conclusion: t (tab) value for 14 degree of freedom at 1% level of significance is 2.97. Here we find that t (cal) is > t (tab). Hence, null hypothesis is rejected at 1% level of significance and it is concluded that the shelter management was effective in controlling the micro climate of the shed and improve milk yield in buffaloes.

Testing for impact of a programme on Adoption of Technology

Proportion: The proportion of individuals having a particular characteristic is the number of individuals possessing the characteristic divided by total number of individuals. Suppose we create a variable that equals 1 if the individual has the characteristic and 0 if not. The proportion of individuals with the characteristic is the mean of this variable because the sum of these 0s and 1s is the number of individuals with the characteristic.

Test of Significance for Difference of Proportions

Testing of the Null Hypothesis H0: $P_1 = P_2$ (the population proportions are equal)

against Alternative Hypothesis H1: $P_1 \neq P_2$ (the population proportions are not equal).

The test is performed by calculating z statistic and comparing its value to the percentiles of the standard normal distribution to obtain the observed significance level. If this probability value is sufficiently small, the null hypothesis is rejected.

$$Z = \frac{(\hat{P}_1 - \hat{P}_2) - 0}{\sqrt{\hat{P}(1-\hat{P})\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \text{ follows N(0,1)}$$

Where $\hat{P}_1$ and $\hat{P}_2$ are the estimated proportions computed from samples of size n_1 and n_2, respectively.

$\hat{P}$ is the proportion of individuals having the characteristic when the two samples are pooled together.

$$\hat{P} = \frac{n_1\hat{P}_1 + n_2\hat{P}_2}{n_1 + n_2}$$

Example: Proportion of goats that suffered with Foot & Mouth Disease (FMD) in Non-NICRA and NICRA villages are 0.20 and 0.08 based on a random sample of 100 goats in each village. Test whether the impact of NICRA interventions is significant w.r.t. controlling incidence of FMD?

Solution:

H0: $P_1 = P_2$

H1: $P_1 \neq P_2$

$$\hat{P} = \frac{(100 * 0.2 + 100 * 0.08)}{100 + 100} = 0.14$$

$$Z = \frac{0.2 - 0.08}{\sqrt{0.14 * (1 - 0.14)\left(\frac{1}{100} + \frac{1}{100}\right)}} = 2.44$$

Conclusion: Calculated Z (2.44) falls in the rejection region, as Z table value is 1.96 at 5% level of significance. Therefore, null hypothesis is rejected and the claim of KVK is admitted. It is further concluded that impact of NICRA interventions is significant w.r.t. controlling incidence of FMD.

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Chapter-6

LIVESTOCK AND CLIMATE CHANGE - A GENDER PERSPECTIVE

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Introduction

India is an agriculturally oriented country, and the livestock sector is an important part of it. Livestock is often regarded as a critical asset for rural livelihoods. Livestock production contributes to 6 percent of GDP in the country. Of the 600 million poor livestock keepers in the world, around two-thirds are women and most live in rural areas. In most communities, all members of the household have access to livestock and are active in both production and livestock management. There is special relationship between women and livestock. The livestock has immense potential that it can provide income, employment and overall food and nutrition security and insurance to poor women and landless households against climate extremities (Jemimah Nijuki and Sanginga 2013). Poor women can own livestock when they are denied land, looking after livestock fits well with their work of running households and raising families. Hundreds of millions of women livestock farmers daily tend sheep goats and chickens, milch cows, buy and prepare food, plant and harvest crops, weed their plots besides household chores.

Strategic needs of women in livestock production

Women take part in livestock activities like cleaning of animals, cleaning of shed, watering of animals, making of dung cakes, and providing fodder to livestock in addition to house hold activities. Raising of poultry, goat and sheep is totally under the control of rural women and they need not to consult their male counterparts for decision making. Women spend 6 hours per day on livestock activities and men spend 3 hours on management of animals. With the exception of marketing, women are involved in all aspects of livestock production, and their roles appear to vary according to zone. Women in marginal rainfed areas have a greater responsibility for livestock production than their counterparts in favorable rainfed areas or irrigated areas. In marginal rainfed areas, women and girls are responsible for feeding, watering and cleaning sheep pens, while in irrigated zones, women and men share the responsibility in feeding animals (FAO 1995)

In India, livestock production is largely in the hands of women. Women do the majority of animal agricultural tasks such as fodder collecting (88%), cleaning of animals and sheds (67%), feeding (79%), watering, and health care (67%), as well as management, milking (46%), and household-level processing, value addition, and selling of milk and by- products. Involvement of women in livestock management practices varied depending upon the type of management practices (Seema Mishra et al 2018). Livestock provide income, create employment opportunities and provide food and nutrition security across different production systems and along different value chains. Moreover, vulnerable groups, particularly women and the landless, frequently engage in livestock production, thus highlighting the multifaceted virtues of livestock promotion as a pathway out of poverty.

Participation in Livestock activities: In a study in Pakistan had revealed that women participation in livestock production was medium in nature and reasons mentioned were that they had less opportunities in high paid jobs as they possessed low self-confidence levels, received less training and skills which makes women to resort to livestock activities as only livelihood option physical labour, as most of the livestock practices are labour intensive and involve drudgery and fatigue (Munawar et al 2013)

C**ontrol and Access to Livestock:** Majority of women involved in decision making related to taking loans (75 %), selection of type of livestock and breed (62.50%) and type of livestock to be sold and medical care, However, women in consultation with husband jointly made decision in respect of extent of investment in livestock production (25.00 %), deciding the number of animals to be reared (52.50) and fixing the price of produce (69.16). Areas where decisions were left to husband in relation to livestock management were 'type of breeding method (AI/NB) (47.50 %), 'growing of fodder (71.66 %) Purchase of feed/fodder (52.50 %) , Medical care (59.16 %) and place of marketing (14.16 %) (Reshma et al 2014).

Gender is a key factor in impacts, adaptation, or mitigation in the voluminous literature on climate change. Men and women experience, understand, and adapt to climate change in different ways, and it is important to understand changes currently taking place, and likely to happen in the near future, from a gendered perspective. Climate change is likely to exacerbate gendered vulnerabilities and differential abilities to cope with changes on livelihoods in rural areas.

The Climate change induced socioeconomic and environmental problems that received attention for its impact on global food security has impacted women much more tending small animals and livelihoods than men. Women and men vary in holding ownership over livestock, expressing control and decision making authority over different animal resources and women found to be more vulnerable to climate change . Climate-change related risks to agriculture and livestock based livelihoods include decreases in crop yields and crop failure, livestock loss, increased water scarcity, and destruction of other productive assets (FAO, 2008). Climate change and gender perspective in relation to livestock production and management being discussed in this paper.

Consequences of climate change on women managing livestock

Evidences on impacts of climate change on livestock sector revealed that six major areas being effected in livestock management which are; increased disease pest infestation, depleting grass and feed level, decreasing milk production, death of animal, heat stress and appetite loss. Among those six issues increased disease and pest infestation found to be most important followed by appetite loss and decreased milk production.

Vulnerability and adaptation of livestock holders

The livestock mix tends toward more small ruminants and fewer cattle. Laws and rules governing diverse and access to land, as well as migration of men, has led to a feminization of livestock keeping. The author demonstrates that this feminization is reflected in changes in herd composition. Herds have shifted away from cattle towards small ruminants (goats and sheep) dominated flocks. The changes have a direct impact on land use patterns as cattle and small ruminants have different grazing behavior and affect vegetation differently. Cattle are also well known to be more sensitive to drought and other climate impacts than small ruminants. Changing land use patterns and the differential sensitivity of cattle and small ruminants are decisive factors in planning ecosystem-based adaptation in the Sahelian country context (Turner 1999).

Female livestock holders are found to be more vulnerable to climate change. Livestock holders adapt to climate change as most livestock live in semi-arid areas where climate change impacts are high. Women significantly stresses in livestock sale under stress. Some of the adaptation strategies are mobility, herd management strategies like de- stocking, splitting herds, recuperating herds after crisis through family loans, livelihood diversification, and settlement.

Table. A gendered approach to understanding how climate change is affecting dimensions of food security across a spectrum of livestock holding livelihood groups

Livelihood	**Gendered Pathways of climate change impact on Food Security**		
	Economic	**Health**	**Nutrition**
Pastoral ↑	Time demand on women for collection of water and fuel ↑	Risk of disease due to proximity of women's work to reservoirs of disease agents and biologic risk ↑	Under nutrition due to availability of certain plant
↑	Time Demand on men to seek out water sources with herd ↑	Vulnerability to maternal mortality due to fertility associated ↑	Undernutrition due to separation of family members from milk producing animals

		with sedentarisation	
	↑ Productive and reproductive demands on women due to new coping mechanisms and livelihood modifications	↓ Mental and emotional health	↑ Undernutrition due to unfavorable terms of trade between animal products and gains
	↓ Financial autonomy of women due to probable liquidation of small animal assets		
Agro-Pastorals	↑ Time demand on women due to migration of men for herding or wage labor	↑ Vulnerability of newly sedentary households, particularly women	↑ Risk of food insecurity due to production of livestock and process of grains and other foods, particularly in women and children
	↓ Financial autonomy of women due to probable liquidation of small animal assets	Earlier weaning, shortened birth intervals, and risk of maternal depletion due to migration of men for herding or wage labor	↓ Diets may become less varied and less nutritious
	↑ Constraints on herd management due to shifts in households' herd management	↑ Incidence of anemia and stunting in children	
Urban livestock holders	↑ Vulnerability and poverty due to increased population growth and lack of employment opportunities	↓ Access to clean water, adequate sanitation and sufficient living areas	↑ Food insecurity due to higher food process and loss of income
	↓ Susceptibility to market fluctuations based on animal food supply from pastoral/agropastoral communities	↑ Child mortality of infectious diseases	↑ Malnutrition, including overnutrition
	↑ Access to inputs	↑ Incidences of chronic diseases	Shift towards unhealthier dietary

		↑ Incidence of infectious diseases	patterns
	↑ Urban nutrient cycling of food waste as to animal feed	↑ Levels of stress and depression	↑ Affordability, accessibility and availability of processed foods that are poor in nutrient value
			Transportation time may improve perishability and enhance food safety

(Adapted from Sarah L McKune et al 2015)

Conclusion

Climate change increased workload for women as men migrate and burden of management of large animals fell on women and in turn women converted large animas to small animals. The higher workload and decreased access to assets and decision making on the newly acquired agricultural land increased women's vulnerability. Both men and women should be equally involved in disaster risk management of livestock. For women, purchase or receipt of a cow does not necessarily imply ownership. Analysis of the specific conditions of the project area and target households and monitoring of change are important to formulate and achieve realistic project goals.

Due to differences in the ways in which men and women use income, increases in men's earnings from livestock-related activities may not be necessarily translated into improved household nutrition, whereas women tend to prioritize household well-being. The division of work between men and women in processing and marketing needs to be analysed and project activities adapted accordingly. An agreement among men and women beneficiaries that protects women's position must be found.

The role of women and their empowerment in the local and regional livestock production system should receive special attention. The local practices at the basis of livestock production must inform all development initiatives, and proposed technologies should be economically feasible, socially accepted and low risk.

Although income is not the only factor that determines women's socio-economic position, it greatly influences their status and living conditions. Increasing women's income by boosting livestock production therefore strengthens their position. As men may feel exposed by this process, projects must involve men and women in all negotiations to bring about equitable and sustainable changes. Efforts are needed to increase the capacity of women to negotiate with confidence and meet their strategic needs.

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Chapter-7

EXTENSION APPROACHES FOR CLIMATE RESILIENT LIVESTOCK FARMING

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Expected output of this chapter:

- Impact of climate change on livestock
- Situation Analysis
- Adaptation and mitigation
- Extension approaches
- Application of tools

Public understanding about climate change and its impacts on livestock is generally low and therefore needs to be improved through awareness campaign and using different extension tools. In order to overcome the negative impacts of climate change, extension service providers need knowledge of the appropriate climate change mitigation technologies and strategies.

Impact of climate change on livestock

Climate change is a long-term challenge. It is a threat to human wellbeing and planetary health. Climate change has caused substantial damages, and increasingly irreversible losses, in terrestrial, freshwater and coastal and open ocean marine ecosystems. Widespread deterioration of ecosystem structure and function, resilience and natural adaptive capacity, as well as shifts in seasonal timing have occurred due to climate change, with adverse socioeconomic consequences. We should understand climate adaptation processes and actions to reduce risks from human-induced climate change (IPCC, 2022). Resilience is the capacity of social, economic and ecosystems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure as well as biodiversity in case of ecosystems while also maintaining the capacity for adaptation, learning and transformation. Resilience is a positive attribute when it maintains such a capacity for adaptation, learning, and/or transformation - IPCC, 2022.

Climatic-smart agriculture/ Climate resilient agriculture is a technique for restructuring and reorienting agricultural growth in response to changing climatic circumstances. It's objective of food security and development is based on three interconnected pillars: productivity, flexibility, and mitigation (Charles and Onkundi, 2021).

The negative effects of climate change on livestock production was predominantly through the indirect impacts such as sudden disease outbreaks, less feed and water available as well as shrinking pasture lands (Sejian et al, 2022). Maintenance of homeothermy and homeostasis is mandatory for animals to survive, produce and reproduce. The risk potential for livestock production due to climate change depends on the levels of vulnerability, as influenced by animal performance and environmental parameters. As performance levels (body weight gain, milk production, egg production) increase, the vulnerability of the animal increases and, when coupled with adverse environment, the animal is at a greater risk. Combination of an adverse environment with high performance pushes the level of vulnerability and consequent risk to even higher levels. Inherent genetic makeup and type of management also play important role in deciding the risk level (NAAS, 2016). Major areas of concern with respect to livestock in dry land listed by Singh, 2021 are as follow:

• Improving productivity in a huge population of low-producing animals
• Conservation of soil/water/fodder resources
• Need to evolve high yielding and drought resistant crop/fodder varieties
• Proper breeding policy for different categories of animals
• Evolving and implementation of adaptive measures for climate change
• Proper marketing and price policy to animal products and insurance
• Extension of climate resilient technologies

Situation Analysis

Situation analysis: is one of the most important steps to understand real and ground level situation. It involves collection, compilation and analysis of facts in a given situation in order to identify local needs, interest, problems and priorities.

Necessity of situation analysis:

- Studying facts and trends about climate change
- Identifying problems and opportunities based on these facts and trends
- Making decisions about problems and opportunities related to livestock
- Helping in objective setting to solve the climate induced problem

Methods of situation analysis

1. Focus group discussions

It is a form of qualitative research consisting of interviews in which a group of people are asked about their perceptions, opinions, beliefs, and attitudes towards a product, service, concept, advertisement, idea, or packaging.

2. SWOT Analysis:

A SWOT analysis (alternatively SWOT matrix) is a structured planning method used to evaluate the strengths, weaknesses, opportunities and threats. It involves specifying the objective of the project and identifying the internal and external factors that are favorable and unfavorable to achieve that objective.

3. Rapid Rural Appraisal (RRA)

It is an interdisciplinary approach for assessing local people's need- is becoming very common.

It uses a set of tools - these consist of exercises and techniques for collecting information, means of organising that information so that it is easily understood by a wide range of people, techniques for stimulating interaction with community members and methods for quickly analyzing and reporting findings and suggesting appropriate action.

4. Participatory Rural Appraisal (PRA)

PRA places emphasis on empowering local people to assume an active role in analysing their own living conditions, problems and potentials in order to seek for a change of their situation. These changes are supposed to be achieved by collective action and the local communities are invited to assume responsibilities for implementing respective activities. The members of the PRA team act as facilitators.

5. Household Survey

Survey research is one of the most important areas of measurement in applied social research. The broad area of survey research encompasses any measurement procedures that involve asking questions of respondents.

Adaptation and mitigation

Adaptation can reduce the current risks of climate change impacts and can be used for addressing emerging risks.

Approaches for adaptation (NAAS, 2016)

1. Vulnerability and Exposure Reduction through Development, Planning and Practices

- Feeding management
- Improved animal housing
- Heat ameliorative measures
- Community animal shelters
- Weather forecasting and early warning system

- Coastal protection

2. Technological options

- Bioclimatic zone based livestock production-

  Transfer of technology and awareness

3. Institutional -Linkage development

Approaches for mitigation (NAAS, 2016)

It requires substantial reductions in GHG emissions over the next few decades and near zero emissions of CO 2, and other greenhouse gases by the end of the century.

1. Enteric Methane Emissions

- Improvement in animal feeding
- Use of feed additives
- Heat ameliorative measures
- Rationalization of livestock population:
- Supplementation of protected fat in feed to lactating cows and buffalo
- Intensification of livestock and crops

2. Emission of Methane and Nitrous Oxide in Manure Management

3. Other GHG Emissions Related to Livestock

4. Carbon Trading

Extension Approaches

The extension and advisory services related to climate smart livestock farming play important role to create awareness, motivation and adoption of suitable practices and technology. It may be Individual, Group and Mass approaches. The details of different approaches are given below:

- Climate wallpapers: Poster, display board to create awareness among general people and other stakeholders.
- Using a Public Address System (PAS): crucial climatic circumstances or agro-advisory services. Basically used in dissemination of urgent information like cyclone, natural climatizes etc.
- Meetings of the Climate Group: Men and Women of small group. They were discussing on different aspect and form a group to mitigate the problem.
- Visits for exposure: very useful for progressive farmers. Eexposure trips stimulate farmers to adapt these mitigation measures, resulting in proper climate smart agricultural implementation.

- Workshops on Climate Change: to educate farmers on suitable climate wise agriculture methods
- Demonstration Effect Approach: Very useful for progressive farmers. Framers were learning by seeing to others.
- Educational and Methods approaches: These approaches focused on education of farmers and use of various methods- exposure visits, field days, radio and television programs, film shows (cinema), leaflets and posters. These approaches resulted in improved farming practices, productivity and production.
- Training and Visit Approaches: Capacity building of trainers who works in field is important motive of this method. Trained person can be better training to farmers and other stakeholders.
- Climate Awareness Mass Media Campaigns: Extension functionary can reach to large number of audience in very short period of time. The main purpose of this method is to create awareness among stakeholders.
- ICT supported farmers in adaptation and mitigation: Use of smart phones, videos, radios etc. was done to address the climate change issue by creating awareness among the farmers about the availability of different adaptation and mitigation strategies. It also helps in coordination and monitoring.
- Climate Farmers Field Schools (FFS): It is a non-formal, participatory extension technique that prioritizes farmers and their needs via experience learning. Farmers can discuss and learn from their observations, allowing them to gain new practical knowledge and skills, as well as improve their individual and collective decision-making.
- Climate-Smart Villages (CSVs): The concept of climate resilient village (CRV) – i. to provide stability to farm productivity and household incomes and resilience through livelihood diversification in the face of extreme climatic events like droughts, cyclones, floods, hailstorms, heat wave, frost, and seawater inundation. ii. Development of CRVs warrants establishment of a host of enabling mechanisms to mobilize and empower communities in the decision-making process to manage and recover from climate risks.

  The overall program of establishing CRVs have structured village level institutions such as Village Climate Risk Management Committee (VCRMC), custom hiring center (CHC) for farm implements, community seed and fodder banks, commodity groups etc. The establishment of CRVs was based on bottom-up approach with village community taking a central role in decision making on institutional requirements, technological interventions and supporting systems with able support from experts (Srinivasa Rao, 2016).

- Climate literacy- village level climate workshops /campaigns to create awareness
- Climate Clubs- at village level as information sharing platforms.
- Dedicated post of Monsoon Managers at State and District level
- Within the Community one person may be selected as a Climate Manager at the village level to disseminate information
- Village Knowledge Centers may be established in every village
- Strategic partnership- government agencies, scientific institutions and farmers at the district and village levels
- Incentives may be provided to the farmers for switching over to Resource Conservation Technologies, which may encourage more farmers.

(Turyasingura and Chavula, 2022; Balasubramani and Dixit, 2016)

Application Tool

Human behavior depends on many factors. It passes through Innovation-decision process to change in the behavior. Innovation-decision process is "an information-seeking and information-processing activity, where an individual is motivated to reduce uncertainty about the advantages and disadvantages of an innovation" Rogers (2003). It involves five steps: (1) knowledge, (2) persuasion, (3) decision, (4) implementation, and (5) confirmation. These stages typically follow each other in a time-ordered manner. Different steps need different types of extension tool to act upon. In initial phase mass approach is important tool, in middle phase Group approaches are major tool and in final phase individual approaches are important tools to adopt and satisfy the stakeholders.

The focus should be to build community resilience and capacity to respond to climate change hazards; how to proactively work with multiple stakeholders; and how to use soft skills to communicate, build teams, and improve knowledge-sharing networks (Gowland-Mwangi, 2012). Extension service providers should therefore focus on increasing farmers' capacity to solve problems and to initiate and sustain effective links with producers, markets and other stakeholders in the agricultural product value chain (Davis, 2009).

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Chapter-8

IMPACT ASSESSMENT OF USE OF DIGITAL TOOLS IN EXTENSION: CASE STUDIES -REVIEW

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Introduction

In developing countries like India, productivity growth in small-farm agriculture can serve as an important driver of economic development and poverty reduction ((Mellor *et al*., 2017) and (Ogutu SO *et al*., 2019)). However, small holder farmers typically face many challenges, such as unpredictable weather conditions, market risks, and limited access to information, technologies, and financial services. These and other constraints result in low productivity and low rates of market participation (Key N *et al*., 2000). Hence, a key policy question for promoting rural development and poverty reduction is how the main information and market access constraints that small holder farmers face can be overcome.

In most developing countries, agricultural extension services are the dominant method of public-sector support towards knowledge diffusion and innovation in the small-farm sector (Takahashi *et al*., 2020).Traditionally, extension agents have either tried to educate farmers directly about best practices or have worked with selected “model farmers” who are then expected to act as information multipliers (Taylor *et al*., 2018). However, the effectiveness of traditional extension approaches has been limited, either because of too little funding and thus low outreach or information that is not sufficiently tailored to farmers’ needs (Pallavi Rajkhowa *et al*., 2021).

The application of Information and Communication Technology (ICT) across different sectors of the global economy has become a game changer in boosting work efficiency and productivity. The agriculture sector in the global economy is one of the industries experiencing tremendous ICT application in all spheres of its operations. Daum (2020) observed that in recent years, ICTs had become one of the main driving tools used by farmers to manage the essential factors of production (land, labour, capital, and soil) in agriculture. ICT applications have the potential to identify and find solutions to some of the numerous problems faced in the field of agriculture, which includes prolonged droughts, pest and disease outbreaks, seasonality and spatial dispersion of farming; high transaction costs and information asymmetry (Anh *et al*., 2019).

Wolfert *et al.* (2017) observed that technological advancement in the area of digital platforms, such as e-commerce, agro-advisory apps, big data, computational power, and satellite systems like remote sensing, among others, quicken communication and information sharing among farmers in recent years. Mobile phones that have internet connectivity (smartphones) are the most widely used ICT devices across the globe (O'Dea, 2020). Research published by Statista (2020), showed that the number of smartphone users around the world were 3.2 billion in 2019, and forecasted that this figure could reach 3.8 billion by 2021. The research further indicated that developing countries have the highest share of smartphone users worldwide (O'Dea, 2020).

Digital Tools usage in Livestock

The livestock sector is one of the primary sources of revenue for farmers that both assures food and nutritional security and offers income and employment opportunities (Ravikumar *et al.*, 2006; Borah and Halim, 2014).

Major problems facing in Livestock sector

Animal Identification and Traceability System critically contributes to increased food and safety and security and income of farmers and other stakeholders through improved disease monitoring and control, reduced restrictions export of livestock products and improved animal health and productivity and pasture utilization.

The number of livestock being transported to and from farms is constantly increasing year after year in tandem with consumer demand. During transit, animals are subject to a range of stressors including noise, vibrations, heat, cold, air quality, etc., which may lead to injury or risk of disease. Besides, poor transport conditions or procedures reduce the value of livestock across the enire supply chain.

Animal farms typically feature large open pastures or paddocks to provide freedom for animals to graze. However, as the size of the pastures or paddocks increases, so too does the difficulty in locating and herding the cattle. In such cases, herding typically involves the utilization of a lot of workforce and time which leads to high costs.

The traditional methods of extension approaches for livestock management have less accountability and effectiveness in terms of time management, larger audience coverage and greater impression on people. Using ICT tools could alter India's livestock, agricultural, and rural artisan economies. (Sasidhar and Sharma, 2006). ICT tools are being used to disseminate information and knowledge, inspiring people to act and improve the livestock sector through mobilisation and action. For instance, information on nutritional awareness, sanitation, immunization, maternal mortality, calf mortality, its causes, anticipation and treatment of sickness can be circulated far afield via ICTs.

Major development In Livestock sector using ICT

The last decade has seen major improvements, including automated feeding systems, milking robots, and manure management, and maximizing production efficiency through instrumentation, animal breeding, genetics, and nutrition. Despite this progress, significant challenges remain. Intensive livestock management is necessary to meet the increasing demand for animal products, but the confined and crowded nature of livestock housing makes it difficult for farmers to closely monitor animal health and welfare (Helwatkar, 2014). As climate change intensifies, the risk of disease, heat stress, and other health issues among livestock animals will increase (Bernabucci, 2019).

This in turn will create a greater urgency to identify health issues and disease outbreaks preemptively or early on, understand disease transmission, and take preventative measures to avoid large-scale economic losses (Thornton, 2010 & Neethirajan, 2017). These issues, as well as escalating concerns over animal welfare, transparency, and environmental sustainability, have led to growing interest in digitalizing livestock agriculture through precision livestock farming technologies (Klerkx, *et al*., 2019) agriculture through precision livestock farming technologies (Klerkx, *et.al*., 2019).

Precision livestock farming (PLF) technologies utilize process engineering principles to automate livestock agriculture, allowing farmers to monitor large populations of animals for health and welfare, detect issues with individual animals in a timely manner, and even anticipate issues before they occur based on previous data. Examples of recent developments in PLF technologies include monitoring cattle behaviour, detecting vocalizations such as screams in pigs, monitoring coughs in multiple species to identify respiratory illness, and identifying bovine pregnancy through changes in body temperature (Neethirajan, 2017). PLF technologies can also help farmers monitor infectious diseases within livestock agriculture, improving food safety and availability (Neethirajan, 2018). The use of PLF technologies will ultimately improve animal health and welfare while reducing food safety issues and maximizing efficient resource use (Jorquera-Chavez, 2019).

The use of PLF technologies, particularly biometric sensors, would contribute to consistent, objective, and regular welfare monitoring of livestock in real time, allowing farmers expeditiously to identify problems and implement preventative measures to avoid critical failures. Precision livestock farming technologies allow for non-invasive sampling, helping farmers and researchers to obtain realistic measures that can be used to address welfare concerns (Jorquera-Chavez, 2019). PLF technologies could also help reduce resource use; a more proactive and individualistic approach to animal health ultimately would reduce the need for medications, particularly antibiotics (Neethirajan, 2017).

ICT offers great hope for improving access, quality and efficiency of information dissemination in livestock sector, but there is a need to understand the key issues underlying the problems and to formulate sensible strategies. Here, an attempt has been made to analyse the constraints and their possible solutions towards use of ICTs as a source of reliable and timely information delivery in livestock sector.

The pace at which ICT application is growing in every sector of the world has triggered the development of different ICT applications in the agriculture sector to aid the rapid access to information by farmers, extension services, and other players within the sector (Daniel Ayisi Nyarko *et al.,(*2021), but empirical evidence of actual impacts is scarce. One of the critical factors that contribute to favourable digital extension policies is better impact assessment and documentation, which is at present lacking.

Therefore, there is need to assess the impact of use of information and communication technologies (ICT) among agricultural extension workers and its implications on extension delivery. For that now how ICT impact in the extension in livestock and farmers from these technologies at work will be discussed using case studies.

In order to better understand the challenges that livestock farmers face when using ICTs, an exploratory research methodology was used in Rajasthan's Jaipur district in North-East India. The state Rajasthan was purposefully chosen through criterion sampling because it has a large livestock population and because its residents use various ICT tools in their daily lives to pursue healthier lifestyles. Additionally, Jaipur district was purposefully chosen over other districts in Rajasthan due to its anticipated rate of access to information, availability, use, excellent information network, and livestock wealth index. Jaipur district has 16 tehsils out of these tehsils two tehsils *viz*. Sanganer and Shahpura were selected randomly. In the next stage of sampling, six villages were selected from each selected tehsils and 10 livestock farmers were selected randomly from each village. Thus, total 120 livestock farming were selected for the study who were using ICT tools for accessing information on different aspects of livestock farming.

Another case study on Jalgaon district of Maharashtra with specific objective to assess the current state of mechanisation and automation used in cattle farms and focus will be given on digital technology adoption on livestock farms.

Impact Assessment

Impact assessment is the analysis of the significant change that has occurred due to an action or series of actions (intervention). This involves what has changed, for whom, how vital the change was, how long the change will last and in what ways our actions have contributed to that change. It is important to assess the impact of the intervention to determine the success of the intervention, how it has impacted the beneficiaries and the local community, and also to use the findings of the assessment for recommending changes in the policies. It also helps us to be accountable to the funding agencies or institutions for which we are working. Impact assessment tries to establish a causal relationship between inputs and changes in terms of magnitude or scale or both. Based on effect, the impact of any intervention can be (Rogers 1995, Airaghi *et al*., 1999, Kelley *et al.*, 2008). 1. Positive or negative. 2. Direct or indirect. 3. Primary or secondary. 4. Intended or Unintended. 5. Short/ Medium/ Long term. Generally, the flow or sequence of a project/ programme/ scheme would be as follows;

Further considering the measures of efficiency, consistency and effectiveness, the same can be illustrated as given in Fig.

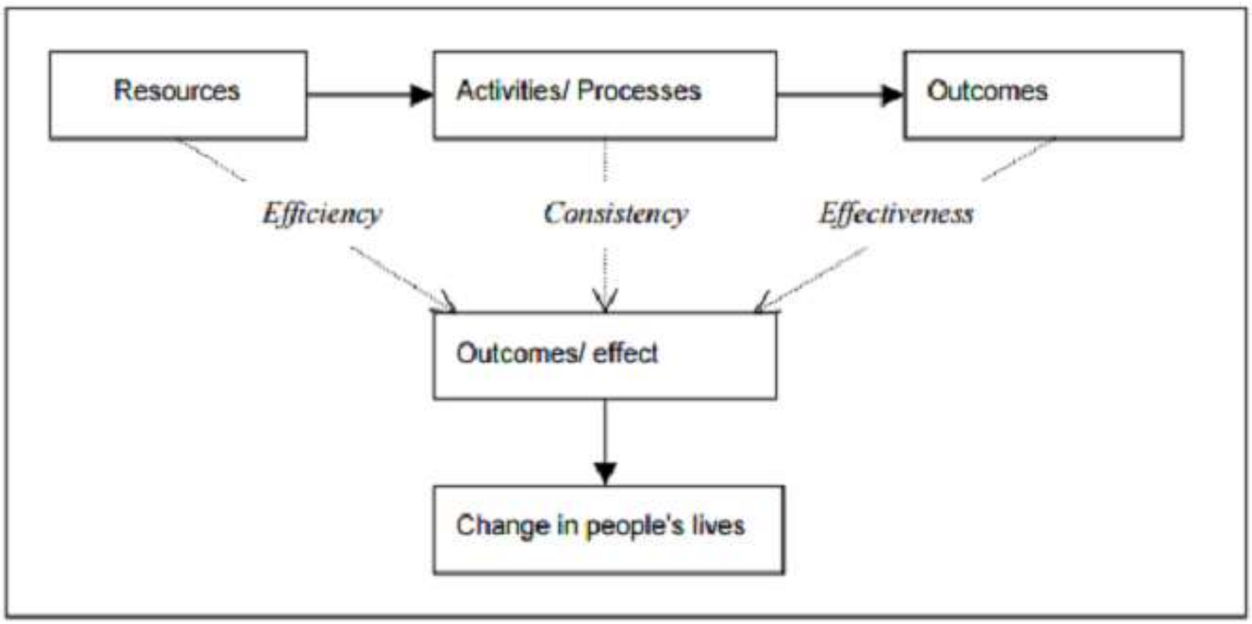


Fig. The Research and Development impact continuum. (Source: Roche, 1999)

Some of the reasons for carrying out impact assessment, which also a sort of evaluation of projects or programmes (Suvedi and Stoep, 2016):

- Should the government and donors continue to fund extension programs?
- Are the extension programs effective?
- How would you improve or terminate ineffective extension programs?
- What new programs should be implemented to meet the needs of farmers, or to address changes of the rural agricultural clients you intend to serve?

Digital Impact Assessments

Now-a-days through ICTs people can obtain the latest up-to-date information, learn and practice sustainable farming. All these studies on different ICT applications specifies the unique ways of it in out reaching larger farmer masses. The five main trends that have been the key drivers for the use of

ICT in agriculture, particularly for poor producers: low-cost and pervasive connectivity, adaptable and more affordable tools, advances in data storage and exchange, innovative business models and partnerships and the democratization of information, including the open access movement and social media. These drivers are expected to continue shaping the prospects for using ICT effectively in developing country agriculture. Thus ICT has emerged as a core driver of the modern knowledge based economy promoting socio-economic development of the country. Thus, the present study is an effort to understand the role played by the ICTs in improving the lives of the farmers.

ICTs have long been recognized as key enablers for bridging the digital divide and achieving the three dimensions of sustainable development: economic growth, environmental balance and social inclusion. However, in order to exploit the latent potential of ICT devices and digital services effectively, the characteristics of the driving forces behind new technologies have to be understood. Digital technology can also be used to deliver e-agriculture, a more streamlined agricultural production system often called “precision agriculture”. e-agriculture has the potential to contribute to a more economically, environmentally and socially sustainable agriculture that meets the agricultural goals of a country or a region more effectively in the following areas:

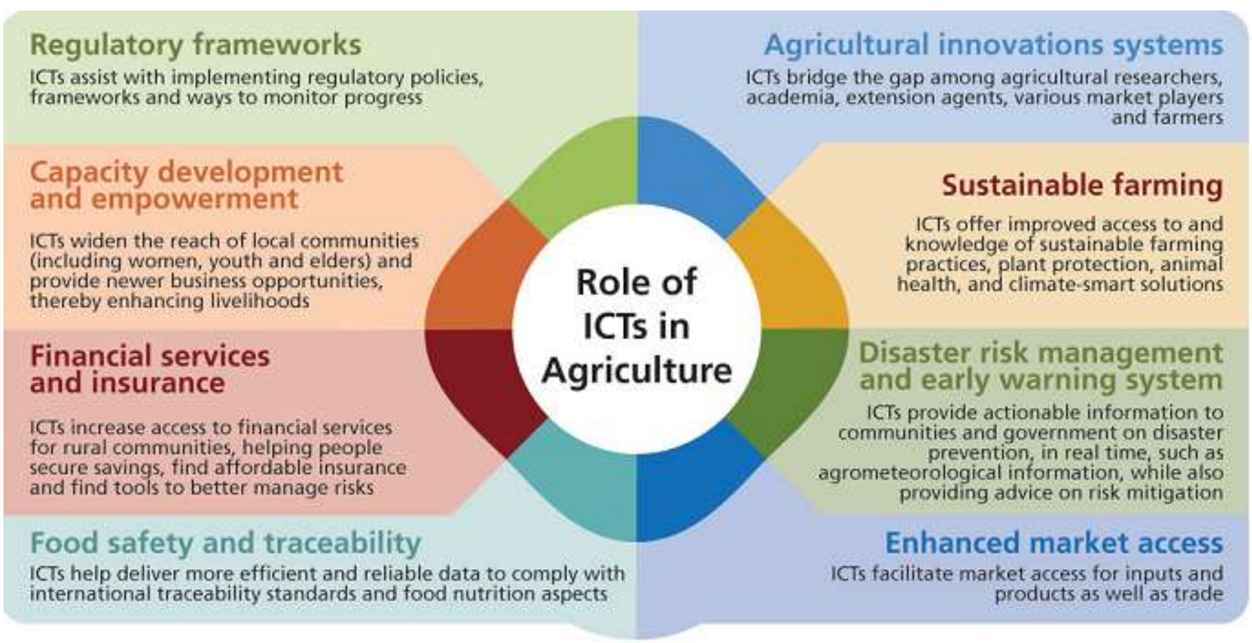


Figure: Role of ICTs in agriculture (Source ITU and FAO 2016)

Periodical studies need to be undertaken to evaluate the ICT initiatives undertaken for further expansion. This paper in detail analyses case studies which teaches several unique ways in which ICTs can help. Current needs of ICT is also analysed and recommendations to promote them extensively amongst the farmers is also envisaged. This current study revealed that ICT initiatives are meeting the selected portions of the population and they have to be popularized to meet the large sections of the community.

This paper explores why measuring the impacts of information and communication technology (ICT) is important for development – and it is statistically challenging. Measuring impacts in any field is difficult, but for ICT there are added complications because of its diversity and rapidly changing nature.

Impact areas Identified

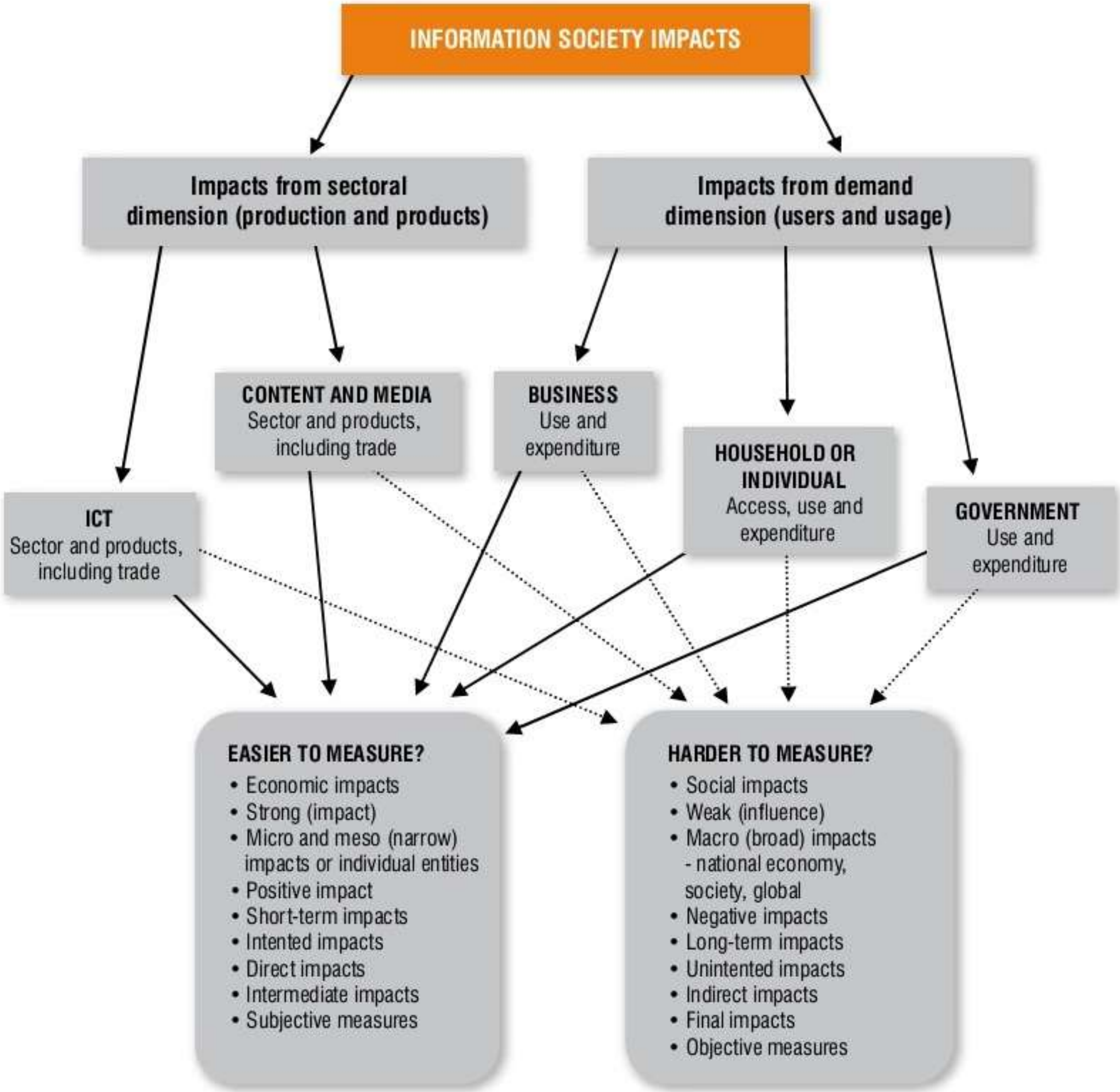
A realistic international performance evaluation and benchmarking (both qualitative and quantitative), through comparable statistical indicators and research results, should be developed to follow up the implementation of the objectives, goals and targets in the Plan of Action, taking into account different national circumstances." (ITU, 2005)

There are significant impacts of ICT.(ITU 2006). Impacts of ICT statistically is far from simple, for several reasons:

- There are a number of different ICTs, with different impacts in different contexts and countries. They include goods, such as mobile phone handsets, and services, such as mobile telecommunications services, which change rapidly over time.
- Many ICTs are general-purpose technologies, which facilitate change and thereby have indirect impacts.
- It is difficult to determine what is meant by "impact". For example, a model proposed by OECD for ICT impacts highlights the diversity of impacts, in terms of intensity, directness, scope, stage, timeframe and characterization (economic, social or environmental, positive or negative, intended or unintended, subjective or objective).
- Determining causality is difficult. There may be a demonstrable relationship and a positive correlation between dependent and independent variables. However, such a relationship cannot readily be proven to be causal.

As per, OECD, 2007 the impacts components of the conceptual model as follows:

- ✓ Impacts of ICT access and use on individuals, organizations, the economy, society and environment;
- ✓ Impacts of ICT production and trade on ICT producers, the economy, society and environment.
- ✓ Impacts of use and production of content (in particular, electronic or digital content, which only exists because of ICT) on the economy, society and environment;
- ✓ Influence of other factors on ICT impacts, for example, skills, innovation, government policy and regulation, and existing level of ICT infrastructure



Information society impacts measurement model (Source: OECD, 2007.)

Heeks and Molla's proposed value chain model as a basis for impact assessments of digital extension projects (Heeks and Molla, 2009) and it is built on a standard input-process-output model to create a sequence of linked resources and processes. In the adapted framework, the components, input, process and output have been substituted by inception, implementation and post-implementation, which are the key stages in the project development. The value chain is divided into four main targets for assessment. Till date most of the impact assessment studies focused on any or all of these components.

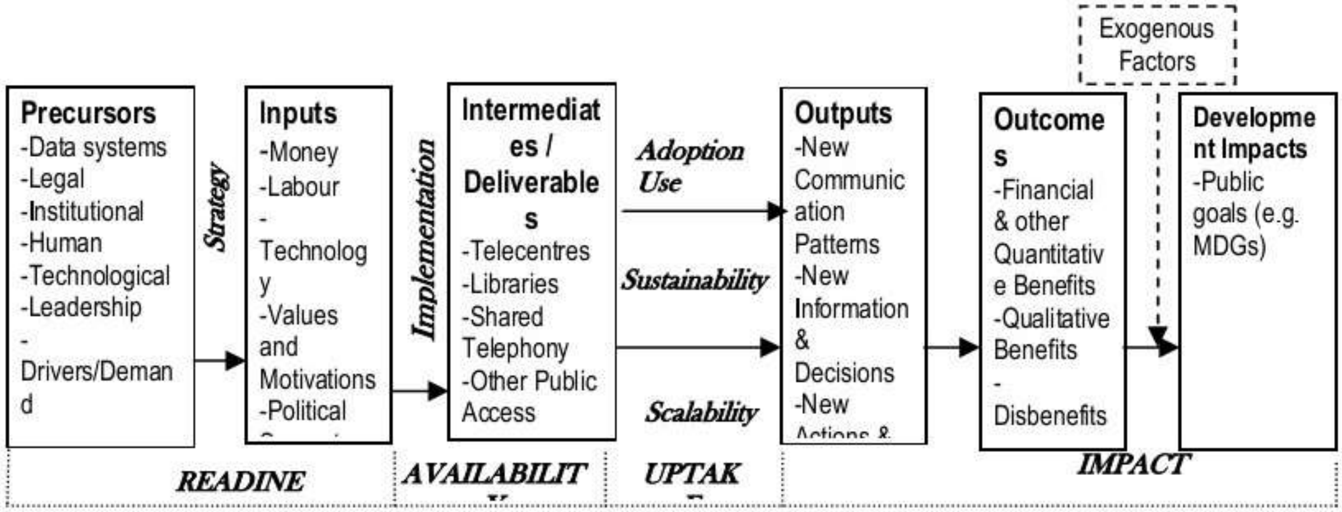


Fig. Value Chain model for Impact Assessment of Digital Extension Project (Source: Heeks and Molla, 2009)

Readiness: "e-readiness" assessment typically measures the systemic prerequisites for any ICT4D initiative e.g. presence of ICT infrastructure, ICT skills, ICT policies, and so on. One could also assess the strategy that turns these precursors into project specific inputs, and the presence/absence of those inputs.

Availability: implementation of the digital extension project turns the inputs into a set of tangible ICT deliverables; one can assess the presence and availability of these intermediate resources.

Uptake: assessment typically measures the extent to which the project's digital extension project deliverables are being used by its target population. Broader assessment could look at the sustainability of this use over time, and at the potential or actuality of scaling-up.

Impact: as the name suggests, only this focus actually assesses the impact of the project and we can divide it into three sub-elements:

Outputs: the micro-level behavioural changes associated with the digital extension project.

Outcomes: the specific costs and benefits associated with the digital extension project.

Development Impacts: the contribution of the digital extension project to broader development goals.

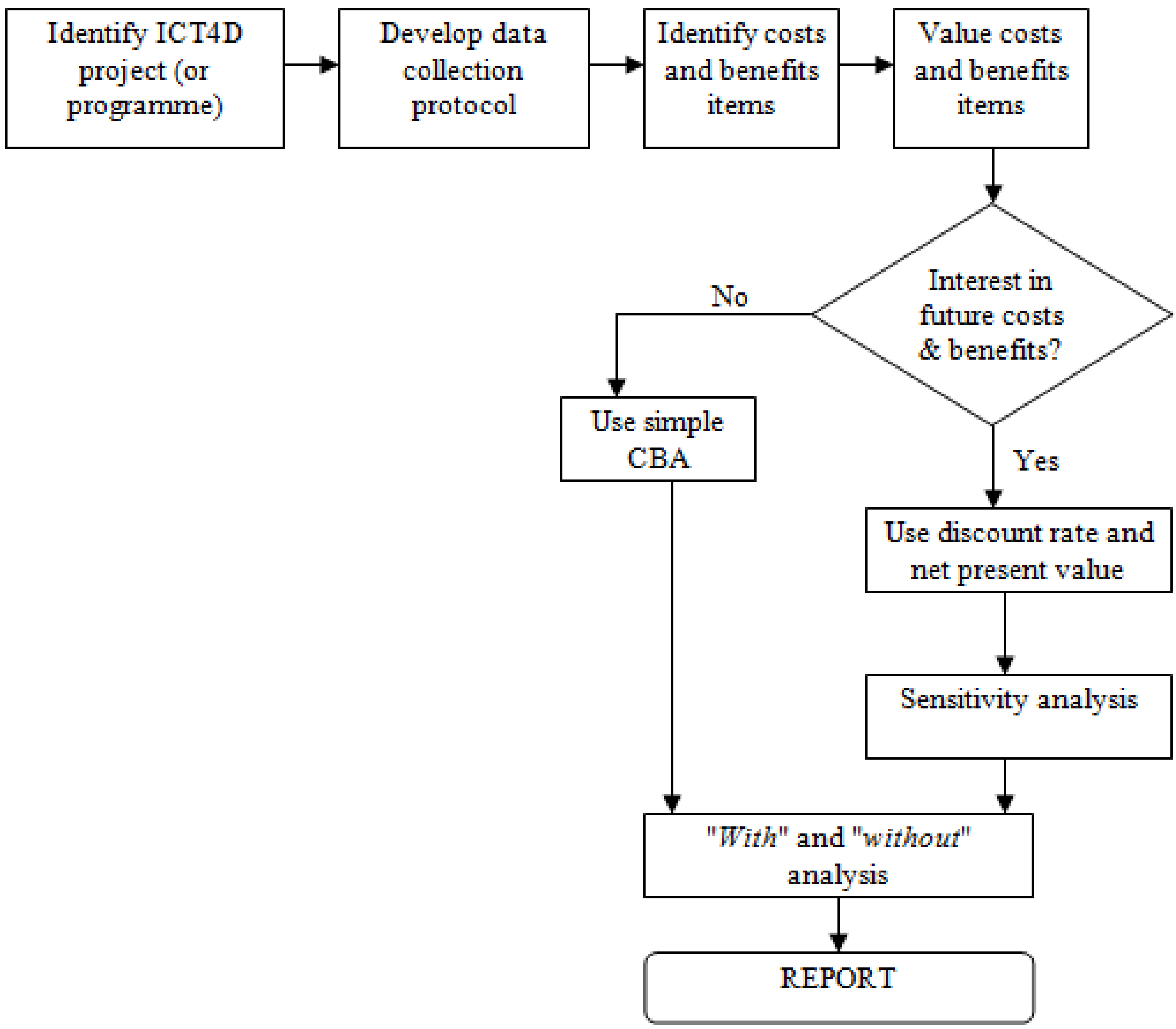
To some extent – and particularly in relation to outputs, outcomes, and development impacts – as you move from left to right along the value chain, assessment becomes more difficult, costlier but also more valuable. That move also represents something of a chronology. In assessing different aspects of the ICT4D value chain has changed over time, with the strong diffusion of ICT4D projects now creating most particular interest in assessment of impacts, as opposed to uptake, availability or readiness

Impact Assessment Frame Works

Assessment frameworks relating to digital extension projects impacts often include (Heeks and Molla, 2009) cost-benefit analysis, assessment of the impact of ICT on livelihoods, Controlled Experiments, Information Economics, Econometric model.

Cost-Benefit Analysis (CBA)

Identifies and quantifies the costs and benefits of Digital Extension projects and offers a logical and consistent framework of data analysis that facilitates assessment, decision-making and cross-project comparison.



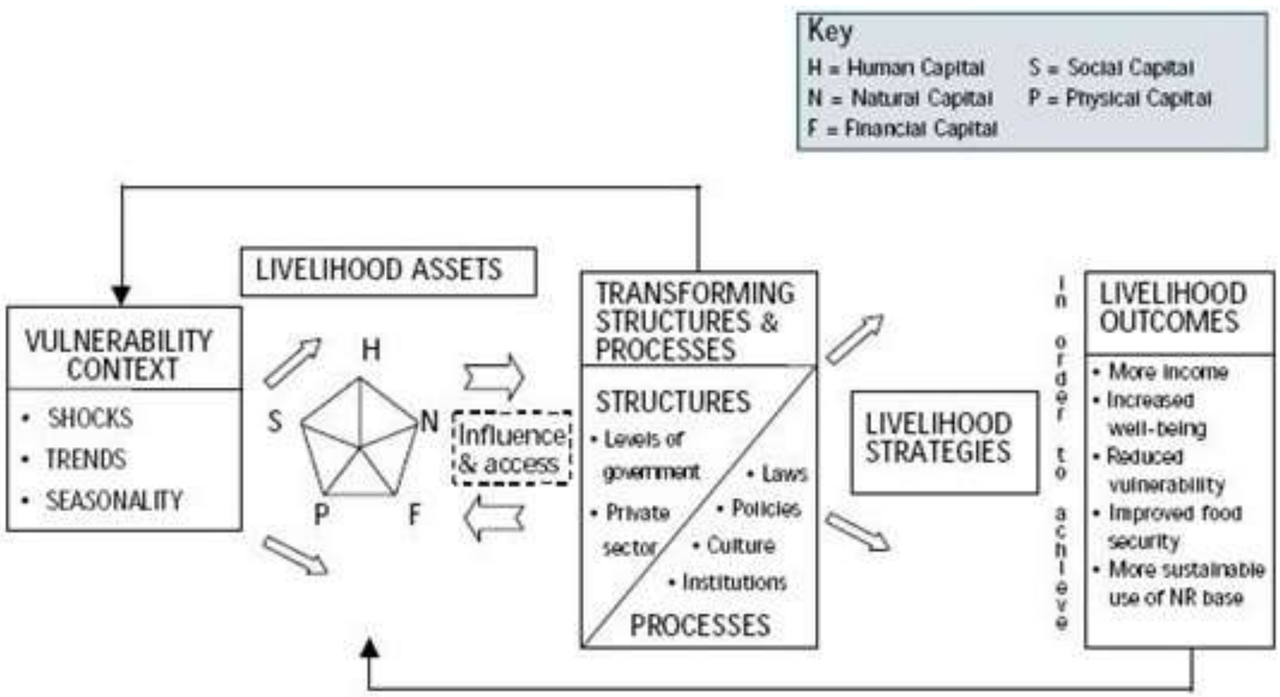
Summarises the generic process of a post-hoc cost-benefit analysis (Source: Heeks and Molla, 2009)

By making explicit link between inputs and outcomes including assumptions, it adds rigour to impact evaluation. CBA can be used to conduct ex-post financial evaluation of implemented projects and/or ex-ante evaluation of alternative investments. Its basic tenet (especially in the context of ex-post evaluation) is to assess the financial sustainability and cost-effectiveness of Digital Extension projects.

The CBA framework uses traditional financial analysis and summary tools such as net present value, discounted cash flow or breakeven point to demonstrate the worth of Digital Extension projects once they are implemented. It is both a decision making (such as continuity, scalability) and communication tool.

Livelihoods Framework

Strongly rooted in development studies, and recognised by extension researchers, the livelihoods framework provides an all-embracing framework for assessing the impact of digital extension on individuals and communities: context, assets, institutions, strategies and outcomes. The livelihoods framework (often known as the sustainable livelihoods/SL framework) developed from the pro-poor and participatory ideologies arising within the development field in the 1980s and 1990s. Its main argument has been that lives of the poor must be understood as the poor themselves understand their own lives as a complex of interacting factors.



Livelihoods Framework (Source: Heeks and Molla, 2009)

Controlled Experiments

Controlled experiments are able to establish causality by having all the independent variables controlled. Therefore, the experimenter can alter a condition and observe the effect. In general, digital extension experiments cannot be controlled to the degree necessary to determine a ‘cause and effect’ relationship. However, where the conditions are limited, a controlled experiment may be possible.

Information Economics

Provides a firm foundation for analysis of the business (commerce/ trade) related impacts of digital technologies. It covers the impact of digital technologies on information failures commonly-found in developing countries and the related characteristics that make commerce slow, costly, risky and intermediated, and make markets and trade relatively slow to develop.

Overall, it is a very useful approach where business is involved, though easier to apply if focused just on one business sector. Information economics takes an information-centric approach to assessment of digital systems, rooted in the information-oriented work of economists such as Stiglitz (1988). This sees development activity in terms of transactions, some interchange of goods or services and it sees information as required to support the decisions and actions integral to all transactions.

Key issues in the application of the impact assessment under this framework include:

Information Failures: which of these are addressed?

Other Characteristics: are process, structural and development characteristics also considered?

Specificity: is assessment narrowed to a particular technology and/or a particular sectoral supply chain?

Price: price is a key item of information in many transactions, aggregating other information (such as production and coordination costs, supply and demand). Comparing price levels and also price fluctuations before and after ICT adoption can be a valuable impact indicator.

Transaction Scope: to what extent does the impact assessment cover the informational aspects of all three stages to a transaction:

Econometric Model

The econometric model attempts to measure the influence of different variables on various dimensions of extension service innovation due to digital technologies. Impacts of product and process innovation can be gathered on five main dimensions.

- Impact on productivity and extension costs.
- Service expansion
- Service Quality
- Skilled activities.

Conclusion

Impact assessment or evaluation is a logical consequence of programme or project implementation. The indicators and the method of evaluations mainly depend on the donors and the researchers" requirements besides the basis premises/ intensions of the project. Although several methods and instruments are available for assessment the cost and simplicity and timeliness are important for choosing the appropriate ones. In any case, the assessment of the impact of digital extension interventions/project should be based on the continuous interaction between technical and socioeconomic processes. Extension organizations should keep evolving the new impact assessment approaches to suit to specific needs of digital extension needs.

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Chapter-9

ADAPTATION OF CLIMATE RESILIENT PRACTICES IN INDIA

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Introduction

Global climate change is widely viewed as one of the most significant challenges society is facing today. Agriculture, upon which society depends for the food, feed, and fiber that enable sustainable livelihoods, is one of the sectors that is most vulnerable to shifts in climate (IPCC 2007; NRC 2010). In particular, arid and semi-arid areas are often challenged by the demands of existing climatic variability, and it is expected that climate change will have significant implications for water resources in these areas (Miller et al. 1997; Sivakumar et al. 2005).

Countries especially like India are highly vulnerable in view of the large population depending on agriculture and excessive pressure on natural resources. Bapuji Rao et al. (2014) found a decline in paddy yield by about 411–859 kg/ha due to a rise in 1^0 C temperatures. The studies conducted by the Indian Agricultural Research Institute (IARI) and other institutions shows the possibility that for every 1°C rise in temperature annual wheat production would decrease by 3% whereas production of rice would decrease by 10% (Aggarwal et al. 2004). Further Pathak et al. (2003) concluded that negative trends in solar radiation and an increase in minimum temperature has resulted in declining trends in productivity of rice and wheat in the Indo-Gangetic plains of India. According to National Rainfed Area Authority of India (NRAA 2013), about 60% of the total cultivated area in India still relies on natural rainfall (rainfed agriculture) and hence changes to rainfall patterns are a significant threat to India's agrarian economy. In addition, drought increases the chance of food insecurity, shortage of drinking water, health problems, migration for work, and debt etc. Udmale et al. (2014) reported that recurring drought is a major challenge in Maharashtra State, Central India.

The vulnerability of communities to climate change is influenced by the ways in which they are affected by climate conditions and by the manner in which they can moderate effects or risks through adaptive strategies (Adger 2006; Fussel and Klein 2006; Smit and Wandel 2006). Although, the choice of adaptation interventions depends on a country’s peculiar circumstances, Vincent (2007) identified the main factors constituting the adaptive capacity of a country to include, economic well-being and stability, demographic structure, global interconnectivity, institutional stability and well-being, and natural resource dependence. According to Smit & Pilifosova (2001, p. 879), “Adaptive capacity is the potential or ability of a system, region, or community to adapt to the effects or impacts of climate change." Adaptive capacity is determined by various factors including recognition of the need to adapt, willingness to undertake adaptation, and the availability of, and ability to deploy, resources (Brown 2010).

The objectives of the present study are to identify farmers perceptions/ knowledge towards climate change (here we focus on one of the implications of climate change in semi-arid areas, i.e. water scarcity leading to droughts), to find out their major farm-level adaptation measures, to find out the relationship between different socioeconomic characteristics of farmers with their adaptation strategies and, suggesting appropriate research/policy issues which can help in facilitating farmers adaptation to climate change. Drought (in this study) is considered to have set in when rainfall and soil moisture availability to plants has dropped to such a level that it adversely affects the crop yield and hence agricultural profitability. Farmers perceptions are the most important predictor of adaptive action. Risk perceptions are an important predictor of adaptive intentions given that researchers have found strong relationships between positive attitudes towards adaptation and higher levels of perceived climate risks (Roesch-McNally et al. 2017; Brody et al. 2008; Arbuckle et al. 2013). Therefore, a higher perception of climate risks will influence an individual's decision to adopt adaptation strategies (O'Connor et al. 1999; Schattman et al. 2016). It is essential to know how perceptions and actions influence one another, to understand what physical changes in climate may prompt a change in farmers' opinion, and by extension, a change in action. Beyond understanding opinions regarding the concept of climate change, understanding perceptions of climate change is of particular importance because it will influence the adaptive behavior that individuals are likely to take. Opinions are views or judgement formed about something (here climate change), not necessarily based on facts, whereas, perceptions are becoming aware through involving senses which results in action/behavior. Identifying the farmers' knowledge and adaptation behavior to climate change is vital in order to facilitate a societal response to the changes in climate that scientists have predicted. Hence, the present study is planned to understand whether or not all factors i.e. farmers internal, external, socioeconomic help adaptive actions towards climate change.

Methods

The study was conducted in the three different states of India viz., Andhra Pradesh, Karnataka and Maharashtra where All India Coordinated Research Project for Dryland Agriculture (AICRPDA) centers are located duly reflecting chronic drought conditions in red and black soils. The selected AICRPDA centers (districts) are Anantapuramu in Andhra Pradesh, Bijapur in Karnataka, Akola and Solapur in Maharashtra. These districts were selected for the study because, here rainfed area is more than irrigated area and rainfall is the most critical factor affecting crop production. The average annual rainfall is 560 mm, 553 mm, 800 mm and 545 mm in Anantapuramu, Bijapur, Akola and Solapur respectively. Climate is semi-arid in Anantapuramu and Bijapur; Akola has a tropical savanna climate bordering humid subtropical climate, while, Solapur has an arid and semi-arid climate. Major crops grown in Anantapuramu are groundnut; sorghum, maize, bajra and wheat are the major crops in Bijapur; cotton, soybean and sorghum are the essential crops grown in Akola; major crops grown include sorghum, wheat and sugarcane in Solapur. The average landholding size in all the districts is less than 2 hectares. The common characteristic across the four locations are farmers are resource poor with low education, meager land holdings, low incomes and low risk taking capacity.

A sample of 240 households at the rate of 60 from each center was selected randomly for data collection representing a minimum of 20% of the population of selected area. One district was selected under each center. From each district one mandal (a mandal is a unit of administration above village and below district level in a state and comprises several villages) and from each mandal two villages were selected. From each village, thirty farmers were selected for data collection. Simple random sampling was followed for selection of villages and farmers. Data was collected using a structured and pre-tested interview questionnaire from the farmers. Focus group discussion (FGD) and interviews were conducted to elicit data from farmers. These tools were helpful in collecting both qualitative and quantitative data. Two FGDs were conducted in each village and each group had ten farmers. The FGDs were not mixed gender. Thirty household interviews were conducted in each village. The main theme on which data collected was about farmers' knowledge on climate change and its' impacts on agriculture. *Eguvapalli* and *Chakraipet* were the villages selected from Anantapuramu, while, *Varkhed* and *Kajaleshwar* were the villages from Akola. *Mangrul* and *Mundewadi* were the villages selected from Solapur, while, *Honnutagi* and *Hadagali* were the villages from Bijapur. Frequency, Percent analysis, correlation and regression coefficients and adaptation indices were used for data analysis.

Results and Discussion

Farmers Perceptions towards Climate Change

Perception of climate change is a necessary prerequisite for adaptation. From table, it is evident that prolonged dry spells, rise in temperatures and rainfall outside rainy season are the major farmers' perceptions towards climate change in all the selected study locations. The focus group discussions suggested that farmers perceive the rainy period to be shorter now, coming at random compared to the previously longer and more reliable periods with heavy rainfall. Farmers perceived the late onset and less frequent more intense rainfall as 'shorter duration rains'. Farmers perceived that the signs for forecasting rain like clouds, wind movement etc. has lost accuracy in recent years, a possible explanation of climate change. It has been observed by the researchers in this study that prolonged dry spells has become a recurrent phenomenon year after year. Therefore, farmers are unsure of when the next rain would occur. In this context, adaptation by water harvesting and storage assumes significant importance for providing critical and supplemental irrigation to the crops as and when required. Another disturbing characteristic of the south west monsoon in the kharif season is heavy rains towards the end of the crop growing period and subsequent damage to the crop produce coinciding with harvesting period. This is untold misery for farmers' after toiling hard for the entire season. Similar studies in Ethiopia and South Africa revealed that farmers experienced increased temperature and decreased rainfall (Bryan et al. 2009). Similar observations of rise in temperatures and decreased rainfall were reported in their studies by Vedwan and Rhoades 2001; Hageback et al. 2005; Dejene 2011. Results of a study conducted in Bundi district of Rajasthan, India revealed farmers' perceptions to climate change as increase in temperatures, decreased rainfall and long dry spells. Studies in several other developing countries indicate that most farmers perceive temperatures to have become warmer and rainfall reduced over the past decade or two (Gbetibouo 2008; Dinar et al. 2008; Mubaya et al. 2010; Deressa et al. 2011).

Table. Farmers Perceptions regarding Climate Change

S. No.	Major Farmers' Perceptions	%*			
		Anantapuramu	Akola	Solapur	Bijapur
1.	Prolonged dry spells.	80	45	63	27
2.	Rise in temperatures.	78	92	50	28
3.	Delayed and shorter rains.	70	63	48	50
4.	Extended breaks in monsoon.	63	43	32	28
5.	Rainfall outside rainy season.	43	41	42	52

*Multiple responses

Farmers Adaptations towards Climate Change

The present study revealed the following adaptations practiced by the farmers towards climate change in the four study locations.

Table indicated that buying insurance, changing planting dates and cropping pattern, diversify to livestock and work as labor were the major adaptation measures followed by farmers towards climate change in the selected four study locations. Usually, farmers in Anantapuramu sow groundnut during July last week every year. But recent trend shows that if one rain occurs during summer month of May or early June, some of the farmers are going for sowing to reap some benefit thinking the worst case scenario may occur during that year i.e., drought. This finding is consistent with similar study by Swanson et al. (2008) which reported that crop insurance was widely used by farmers in foremost region of Canada (which is under similar agro-ecological conditions) and the common feeling was that even though it might not provide sufficient returns for losses incurred it does offer some protection. It has allowed them to continue farming. Agricultural insurance can help people to cope with the financial losses incurred as a result of weather extremes. Insurance supports farmers as one of the adaptation processes and prevents them from falling into absolute poverty. Apart from stabilizing household incomes by reducing the economic risk, insurance can also enhance farmers willingness to adapt, to make use of innovations and invest in new technologies (Anna et al. 2011). Changing crops has been demonstrated in the literature as a common adaptive behavior by farmers in the face of changing circumstances (Kristjanson et al., 2012; Olesen et al. 2011; Westengen and Brysting 2014). In a study in the Ejura-Sekyedumase district of Ghana, it was found that 93% of farmers were of the opinion that the timing of rains is now irregular and unpredictable (Francis et al. 2011).

Some of the values in the table show '0' because these are the absolute values showing absolute percent. Zero means no farmer had adopted that particular adaptation measure in question. Hence, no mean and error values are presented here. Large values are because these are multiple responses taken from farmers.

Agricultural adaptation involves two types of modifications in production systems (this was observed both in the field sites and literature). The first is increased diversification that involves engaging in production activities that are drought tolerant and or resistant to temperature stresses as well as activities that make efficient use and take full advantage of the prevailing water and temperature conditions, among other factors. Crop diversification can serve as insurance against rainfall variability as different crops are affected differently by climate events (Orindi and Eriksen 2005; Adger et al. 2003). The second strategy focuses on crop management practices geared towards ensuring that critical crop growth stages do not coincide with very harsh climatic conditions such as mid-season droughts. Crop management practices that can be used include modifying the length of the growing period and changing planting and harvesting dates (Orindi and Eriksen 2005). Smallholder farmers can adapt to climate change by changing planting dates and diversifying crops (Gbetibouo 2009). Similar reports of planting different crops as an adaptation strategy by 74% of farmers in a study (Ayanwuyi et al. 2010) in Oyo state of Nigeria.

Under diversify to livestock in these dryland regions usually means that the farmers would rear sheep and goat, and sell them as a contingent strategy to tide over the situation particularly, if monsoon fails and drought occurs. Small farmers usually migrate during the event of failure of monsoon to work as contract labour which also serves as one of the adaptation practices in rainfed areas (Ravi Shankar et al. 2013). Water harvesting is one particular practice that has proved to be climate resilient among farmers and reaped rich dividends to them. Farm ponds, percolation tanks and bunds across the slope are a common and welcome sight in the study villages to the researchers. Water harvesting along with the use of modern micro-irrigation practices such as sprinkler and drip irrigation as an adaptation strategy is well established and should be promoted aggressively in similar dry regions of the world. Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) is one government program in India which has clearly made impacts in the lives of rural people by providing 100 days of employment to poor people by way of labor and improving the groundwater resource of the area. Dry regions like Anantapuramu have been benefited enormously by constructing water harvesting pits/structures wherever possible with technical checks. "The rainwater harvested is helping us during periods of dry spell. Groundwater levels are increasing as well, providing us enough for irrigation and cattle rearing'' said a farmer from Anantapuramu. These farm ponds are vital to increase storage of rain water, to improve recharge of bore wells, and to provide wage employment to agricultural labor. Rain Water Harvesting (RWH) increases the amount of water available for agriculture and livelihoods through the capture and storage of runoff, while at the same time reducing the intensity of peak flows following high-intensity rainfall events. It is therefore often highlighted as a practical response to dryness (i.e., long-term aridity and low seasonal precipitation) and rainfall variability, both of which are projected to become more acute over time in some dryland areas (Dile et al. 2013; Vohland and Barry 2009). A global meta-analysis of changes in crop production due to the adoption of RWH techniques noted an average increase in yields of 78%, ranging from –28% to 468% (Bouma and Wosten 2016).

Table. Farmers Adaptations towards Climate Change

S. No.	**Major Farmers' Adaptations**	**%***			
		Anantapuramu	**Akola**	**Solapur**	**Bijapur**
1.	Buy insurance.	93	0	15	25
2.	Change in planting dates and cropping pattern.	87	68	77	45
3.	Planting different crops.	0	0	65	35
4.	Diversify to livestock.	65	0	27	23
5.	Work as labour.	60	0	0	0
6.	Construct water harvesting structures under MGNREGA.	58	0	50	0
7.	Timely availability of inputs.	0	60	0	0
8.	Drought resistant crops.	0	60	0	0
9.	Contingency crop planning.	0	53	0	0
10.	Spray urea.	0	52	0	30

*Multiple responses

MGNREGA: Mahatma Gandhi National Rural Employment Guarantee Act (a Government of India sponsored social security scheme in rural areas).

Computation of adaptation index to assess the extent of farmers' adaptation to climate change

Adaptation was judged through assigning score of 1 for each practice/measure adapted. In the present study, total adaptation measures were 10, and hence maximum adaptation score that could be obtained is 10, while minimum adaptation score that could be obtained by a farmer is 0. The ten adaptation measures in the study were 'buy insurance', 'change in planting dates and cropping pattern', 'planting different crops, diversify to livestock', 'work as labor', 'construct water harvesting structures under MGNREGA', 'timely availability of inputs', 'drought resistant crops', 'contingency crop planning' and 'spray urea'. These were recommended after consulting with scientists, experts in the area and review of available literature. Since all the ten measures were considered under adaptation and analysis was done with this assumption, 'spray urea' in this study was considered as adaptation measure and not as a coping strategy. Adaptation index was computed for assessing the extent of adaptation.

Adaptation index = Adapted measures/Total recommended measures x 100.

The index values were in decimals and were rounded off to the nearest number in the first place. Later, the decimal values were reinstated in table. However, being an absolute measurement there is no point in indicating the error values. The mean adaptation index for the four study locations are presented in table. Farmers in Anantapuramu showed high adaptation when compared with other three locations as they are more receptive (higher perceptions of climate change than other three districts) and already adapting to climate change when compared to other centers. Also, they are accustomed to perpetual droughts year in and out. A higher adaptation index in this study infers higher resilience to combat drought and vice versa.

Table. Adaptation index of farmers

Statistic/Category	**Anantapuramu (n=60)**	**Akola (n=60)**	**Solapur (n=60)**	**Bijapur (n=60)**
Mean Adaptation index	67.3	38.2	32.6	28.9

Correlation and Regression analysis

Coefficient of correlation between farmers' adaptation to climate change and six selected socio-economic variables was computed and compared (table 4). Age was negatively significant at 0.01 level of probability while, education, family size, farm size and annual income were positively significant at

0.01 probability level. The relationship of farming experience with farmers' adaptation to climate change was negative though not significant.

Table. Correlation coefficients between major socio-economic variables and farmers adaptation to climate change (pooled sample) n=240

S. No.	Socio-economic variables	'r' value
1.	Age	-0.318**
2.	Education	0.265**
3.	Family size	0.323*
4.	Farming experience	-0.196
5.	Farm size	0.388**
6.	Annual income	0.592**

***Significant at 5% level of significance; **Significant at 1% level of significance**

Further, in order to determine the combined effect of all the socio-economic variables in explaining variation in farmers' adaptation to climate change, multiple linear regression analysis was carried out and the results are presented in table. Family size, farm size and annual income were found to be contributing positively and significantly at 0.01 level of probability with farmers' adaptation to climate change. Education was found to be contributing positively and significantly with farmers' adaptation while, age was contributing negatively and significantly with farmers' adaptation at 0.05 level of probability.

The more the age, the lesser would be the farmers' adaptation to climate change. With age, farmers become fixed in their thinking patterns and hence the less inclination towards adaptation. The more the farmers are educated, the greater would be the chances of adaptation. This was due to the fact that educated farmers' does not rely on one source of information and would refer to multiple sources and take the best course of action, their adaptation to climate change would be higher. Farmers with higher level of education are more likely to adapt successfully to climate change than those with lower level of education, as high level of education has a link with access to information on improved technologies and production challenges (Daberkow and McBride 2003). The relationship between family size and adaptation was positively significant. As members in a family increase, their risk orientation also increases and, hence the higher the adaptation to climate change. Increasing household size increases the likelihood of adaptation. This finding is in line with the argument, which assumes that a large family size is normally associated with a higher labor endowment, which would enable a household to accomplish various agricultural tasks, especially during peak seasons (Croppenstedt et al. 2003). Farming experience was found to be positive though, not significant. The R^2 value was less than 50 in the study and non-significant farming experience contributed in part to this result. Higher farming experience accounts for increasing the likelihood of taking up adaptation strategies. This is because experienced farmers have more knowledge and wisdom about changes in climatic elements, and on best agricultural practices to adopt. The same understanding holds good for relation between annual incomes with farmers' adaptation to climate change which was positively significant. The greater the farm size, the higher the adaptation of farmers to climate change due to more adaptive capacity. With increase in acreage, the adaptation process hastens and even if some decisions go wrong, the farmer can as well compensate by the large holdings. Gbetibouo (2009) found a positive relationship between farm size and the adaptation to climate change. The author also argued that adoption of an innovation tends to take place earlier on larger farms than on smaller farms. The relative importance of these socio-economic variables reflects both the economic environment and external social relations of farmers that pave the way for collective nature of enhanced adaptation towards climate change. The identified variables help policy makers to provide targeted extension and advisory services to enrich climate change understanding and support appropriate farm-level climate change adaptations.

Table. Regression coefficients of major socio-economic variables with farmers adaptation to climate change (pooled sample) n=240

S. No.	Socio-economic variables	Regression coefficient	Standard error	't' value
1.	Age	-0.487	0.232	-2.09*
2.	Education	0.984	0.477	2.06*
3.	Family size	0.215	0.092	2.33**
4.	Farming experience	0.349	0.288	1.21
5.	Farm size	1.733	0.347	4.99**
6.	Annual income	0.076	0.014	5.34**

R^2 = 0.41; *Significant at 5% level of significance, **Significant at 1% level of significance

Barriers to climate change adaptation

The major barriers to climate change adaptation identified from the study locations were lack of access to credit, labor and access to water. From farmers point of view, awareness about adaptation practices is by itself not sufficient, but has to be supported with capital and labor for successful adaptation. Measures which need attention by policy makers regarding climate change adaptation that were expressed by farmers were pollution control, afforestation and development of irrigation projects. Limits to adaptation are dynamic, site specific and determined through the interaction of biophysical changes with social and institutional conditions. Exceeding the limits of adaptation will trigger escalating losses or result in undesirable changes, such as forced migration, conflicts, or poverty.

Conclusion

Present study suggested major perceptions of climate change among farmers were prolonged dry spells, rise in temperatures, and delayed and shorter rains. Major adaptations towards climate change were insurance, change in planting dates and cropping pattern, diversify to livestock and work as labor. These identified adaptation (crop management) strategies along with those that aim at soil management like conservation tillage, mulching, nutrient recycling etc. and water management like irrigation scheduling, water harvesting etc. too should be promoted and supported by governmental and non-governmental agencies if, farming situations in India has to be made resilient to climate change impacts. Integrated crop, soil and water management measures can be employed to reduce soil degradation and increase the resilience of agricultural production systems to the impacts of climate change. These measures include crop diversification and adoption of drought-resilient econogically appropriate plants, reduced tillage, adoption of improved irrigation techniques (e.g. drip irrigation) and moisture conservation methods (e.g. rainwater harvesting using indigenous and local practices), and maintaining vegetation and mulch cover (IPCC 2019). The numerical value of adaptation index was found to be a good indicator to suggest an area was climate resilient or not.

A better comprehension of farmers perceptions towards climate change, current adaptation decisions, is needed to promote effective futuristic agricultural adaptation policies. Here, even though difficult, we need to account for how the external factors (like policies, infrastructure, information, forecasts) influence farmers' expectations and actual experiences of rainfall. Results from Mitter et. al. (2019) emphasize that not only climate change and adaptation appraisal affect the formation of agricultural adaptation intention and avoidance, but personal, farm and regional characteristics are also of importance as well. This finding supports conceptual and empirical literature proposing that adaptation is often a response to a mix of climatic and non-climatic factors (Mitter et al., 2018).

Agricultural extension and education are crucial to farmers in providing climate resilient knowledge and practices for successful adaptation. Both extension and meteorological organizations should focus and pay attention to the socio-economic contributing factors to adaptation before they embark with their interventions that enhance the productivity and competitiveness of farmers. Emphasis should be given to water harvesting techniques to increase the extent of irrigation coverage. As farm-level adaptation becomes an increasingly important across the world, policies at all levels will need to be accounted for appropriate factors, including perceptions and how perceptions affect human behavior and adaptive actions. Policy responses to droughts based on proactive drought preparedness and drought risk mitigation are more efficient in limiting drought-caused damages than reactive drought relief efforts. Actions required for the enhancement of adaptive capacity are essentially equivalent to those that promote sustainable development and equity. Adaptation through transformation (in the present study diversify to livestock and work as labor) has the potential to become an inclusive, engaging and empowering process that contributes to alternative and sustainable development pathways which needs to be encouraged.

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Chapter-10

TECHNOLOGICAL APPROACHES FOR CLIMATE RESILIENT LIVESTOCK FARMING IN INDIA

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Introduction

Climate change is a serious a challenge not only to agricultural crops but also to the livestock. Livestock are not only the cause but also are affected in multiple ways due to climate change. As global warming is gaining importance, the conservation of indigenous breeds that are hardy and better adapted to even adverse agro-ecologies has been gaining importance. Huge genetic diversity has made the Indigenous breeds more resilient to regional threats like parasites and disease, and extremes of low as well as high temperatures. Each region of India has native indigenous breeds with distinct characteristics, suitable to the local conditions.

Almost 70 per cent of livestock in India is owned by small and marginal farmers, and landless labourers. The animals of these resource poor livestock owners are most vulnerable to climate change and are at greater risk since they do not possess necessary means for adaptation and mitigation. Due to financial constraints and unawareness about latest technologies the livestock systems are even more vulnerable to impacts of adverse climatic conditions.

Impact of climate change on livestock

The climatic change is expected to impact initially fodder availability for the animals, poor availability of pure drinking water, increase in parasitic diseases, and emergence of new diseases, increased infestation of flies / lice, decreased fertility / vitality and reduced productivity. Under such circumstances, the native breeds of livestock would be far more adaptive to the extreme weather situations than exotic/ hybrid. In ruminants like goat, heat stress can significantly affect meat yield, quality and composition. Many farmers are switching to organic farming and native crops as they are better suited to changing climate of increasing temperature and uncertain rainfalls and livestock are an integral part of this type of farming system.

Climate can affect livestock both directly and indirectly. Direct effects include factors of climate, like air temperature, humidity, wind velocity and influence animal performance such as growth, productivity and reproduction efficiency. Indirectly, climate can also affect the quantity and quality of pasture, forage and grain; distribution of livestock diseases and parasites, agro-ecological changes, etc. Indian livestock productivity has been severely affected by vector-borne livestock diseases which are known to be climate sensitive. The direct effects of climate change could translate into the increased spread of existing vector-borne diseases and parasites, accompanied by the emergence and circulation of new diseases. The impacts of climate change also depend on the rainfall which generally affects crop and grassland productivity, ultimately affecting livestock productivity and profitability.

Economic viability/ efficiency of livestock production depend on quantity and quality of feed/ fodder and water availability. An estimate suggests that about 10% of cropland is used for producing animal feed/ fodder/ other crop residues used for feeding livestock. The future of livestock production systems depends on the continued productivity of these various feed-producing areas – all of which are potentially affected by climate change. The effects of climatic interaction with soil characteristics and its direct effect on plants influences the distribution of the various other biological components of the agro-ecosystem – pests, diseases, herbivorous animals, pollinators, soil microorganisms, etc. – all of which in turn influence plant communities. Pressure on feed resources and other constraints to traditional livestock-keeping livelihoods have promoted the spread of agro-pastoralism (i.e. livelihoods that involve some crop production in addition to livestock keeping) at the expense of pastoralism. In production systems where animals are fed on concentrates, rising grain prices (may be driven by climate change) increase the pressure to use animals that efficiently convert grains into meat, eggs or milk. Thus, within such systems climate change may lead to greater use of poultry and pigs at the expense of ruminants, and greater focus on the breeds that are the best converters of concentrate feed under high external input conditions. Increases in the price of grain may also contribute to the further concentration of production in the hands of large-scale producers.

As performance levels (rate of body weight gain, milk production, egg production) increase, the vulnerability of the animal increases and, when coupled with adverse environment, the animal is at a greater risk. Combination of an adverse environment with high performance pushes the level of vulnerability and consequent risk to even higher levels. Inherent genetic makeup and type of management also play important role in deciding the risk level. In general, livestock systems under intensive management will be at lower risk than crop-livestock systems.

Climate change and diseases

Climate is characterized not merely by averages, but also by short-term fluctuations, seasonal oscillations, sudden discontinuities and long term variations, all of which can influence disease distribution and impacts. Disease related threats can be both acute or chronic and can be caused by the direct effects of disease or indirectly by the measures used to control disease. The most severe recent epidemics in India in terms of the numbers of livestock lost have involved quite a narrow range of diseases: most notably foot-and-mouth disease, avian influenza, Blue tongue, African swine fever, classical swine fever and contagious bovine pleuropneumonia.

Technological approaches for climate resilient livestock farming

Adaptation to climate change is more than adaptation to heat but in Indian context elevated temperature and in particular extreme heat events are very important. It is difficult even with the most technologically advanced nations to select animals for extreme climatic conditions without a major reduction in performance. Therefore there is a need to focus on how changing climate impact the animal's overall environment. A number of interacting factors like precipitation (variation and extremes), soil moisture, feed resources, parasite exposure, solar load, temperature (variation and extremes) and water availability are also very important.

a) Feeding management

Modifications in nutritional management are used to reduce the internal heat load on animal. The animals use more energy for digestion of poor quality feed, like crop residues and proportionately higher amount of heat per unit feed intake is produced. This extra heat also is to be lost from body to maintain thermal balance. Similarly the particle size of fodder affect the amount of heat produced per unit weight of dry matter consumed because of higher specific dynamic action values. Several other simple and economically viable feeding technologies like wetting of straws, incorporation of good quality green during summer are available. Increasing the nutrient density by replacing poor quality roughage with concentrate, feeding properly chaffed dry fodder, hydration of dry straws during hot dry period and supplementation of good quality green fodder reduces the internal heat load on animal body and thus help in minimizing the impact of climate. Some of the feed additives like antioxidants, minerals and plant products are used in poultry and high producers. Even age old simple technology of chaffing the fodder, which reduce internal heat load, is not practiced in certain parts of the country.

b) Improved animal housing

In the intensive system of production the animals are mostly fully housed for attainment of maximum productivity. In tropical and sub-tropical climate animal shelters are designed to curtail the heat load on animals from external macro-environment and providing congenial micro-environment in animal houses. Design, height and orientation of shelters, choice of roofing material, provision of open space for ventilation and space per animal are some of the important aspects to attain cooler microenvironment. Shading and louvered roof are used for poultry housing.

c) Heat ameliorative measures

During the period of high temperatures the use of water can be used to bring down the micro-environmental temperature within the animal shelters and increase the evaporative heat loss from animal body. Use of air cooling systems is very efficient but more expensive. In India limited information is available on animal housing for different agro-climatic zones. The lack of knowledge on how to ameliorate the impact of changing climate on livestock production is one problem, but the major problem is the lack of financial resources. Proper housing is an obvious method to minimize the effects of climate.

d) Community animal shelters

The animals in arid zone are out in the fields for grazing during day and are exposed to peak heat. These animals are reared under extensive system of farming and there is scarcity of feed resources in grazing fields. If the community shelters are available in these areas the animals can take rest during peak hot hours. Similarly suitable shelters in flood and cyclone prone areas can save morbidity and mortality losses.

e) Weather forecasting and early warning system

Weather forecasting and early warning are very important to enable the farmers to take preventive measures to protect the animals from extreme weather events like heat wave, cold wave, heavy precipitation events including thunderstorm, cyclone, flood and disease outbreaks. In India presently this component is almost lacking. To make the adaptation measures effective to overcome the effect of climate change this should be brought to international level.

General tips for heat stress management in dairy animals:

- Farmers can quickly identify the animal is in heat stress or not by simply monitoring respiration rate. If the respiration rate is more than 80 breaths per minute, heat stress is a clear indication.
- The more straightforward way to understand when heat stress started is that if human being starts feeling the stress as for animals, it already started.
- Adequate space should be provided during the heat stress period to the dairy animals for effective heat dissipation, especially tie stalls, which are commonly observed at farmers' doorsteps and present-day small commercial dairy farms.
- Shades must be provided, especially during the summer months, to reduce the heat load from radiation. The roof should be reflective. Roof painted with white paint and insulated with puff or straw and covered with seasonal vegetable plants like bottle gourd, pumpkin and ridge gourd grown on earth is quite effective in reducing the inside temperature of the shed.

- The fresh and cool drinking water facility under shaded areas should be ensured for effective heat stress management.
- Holding and milking areas must have adequate ventilation, air circulation, and cooling facilities as less attention has been given to Indian conditions.
- In hot-dry weather, misting is quite effective in cooling the environment, which further helps cool the animals. Fogging is very effective but under closed conditions and when the temperature is high and humidity is low. In fogging, desalinated water is generally recommended; otherwise, nozzle blocking is a common problem.
- In hot-humid conditions, sprinkling for a limited period along with fanning is quite effective. In closed housing for such a cooling system, proper ventilation must be ensured to reduce the humidity buildup.
- Wallowing is very effective for buffaloes due to their black skin colour and fewer sweat glands. Natural ponds are very common in the village area and quite effective amelioration of heat through wallowing. Artificially build 50 ft. wide X 100 ft. long and 4 to 6 ft. depth wallowing pond is suitable for 100 animals.
- Using geothermal energy can be an alternative for cooling closed sheds of the dairy farm by using the earth's temperature at a depth of 15 to 20ft through pipelines for reducing the temperature by 8-10^{O}C.
- In the heat stress period, four to five days of adequate cooling, especially around breeding, can enhance the fertility of dairy animals.
- Optimum body condition score maintenance in different stages of physiological state and especially the animals are going to calve in heat stress period can be an effective strategy.

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Chapter-11

NATURAL FAMING IN LIGHT OF CLIMATE CHANGE

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Introduction

In many semi-arid environments, agricultural intensification, characterized by increasing capital inputs cost to get higher output has been a common strategy for many decades. The success of this strategy at the farm level (including household income) and the country level (meeting food security goals) has been uneven, and increased yield is generally prioritized over other outcomes. In countries like India, which are still dominated by smallholder farms, there are many obstacles to an intensification approach, such as constraints on the ability to purchase inputs and the difficulty in applying this approach at smaller scales. In this respect natural farming (NF) has become a pivot point of discussion among the agricultural scientists, government, farmers, and several other informal groups engaged in agriculture. NF envisages ecological or regenerative agriculture approaches under which the application of any kind of chemicals to soil biosystems are prohibited. It relies more on soil biology than soil chemistry by encouraging multi cropping, round-the-year soil cover, the addition of formulation made up of cow dung and urine to trigger the microorganisms in the soil system. The Economic Survey (2019) categorized alternative farming practices like Natural farming as one of the farming models which highlights elimination of agro-chemical and support sustainable agricultural production with eco-friendly processes in tune with nature. Through NF, soil fertility & soil organic matter is restored, less water is required, and it promotes climate-friendly agriculture system.

Climate Change and Indian Agriculture

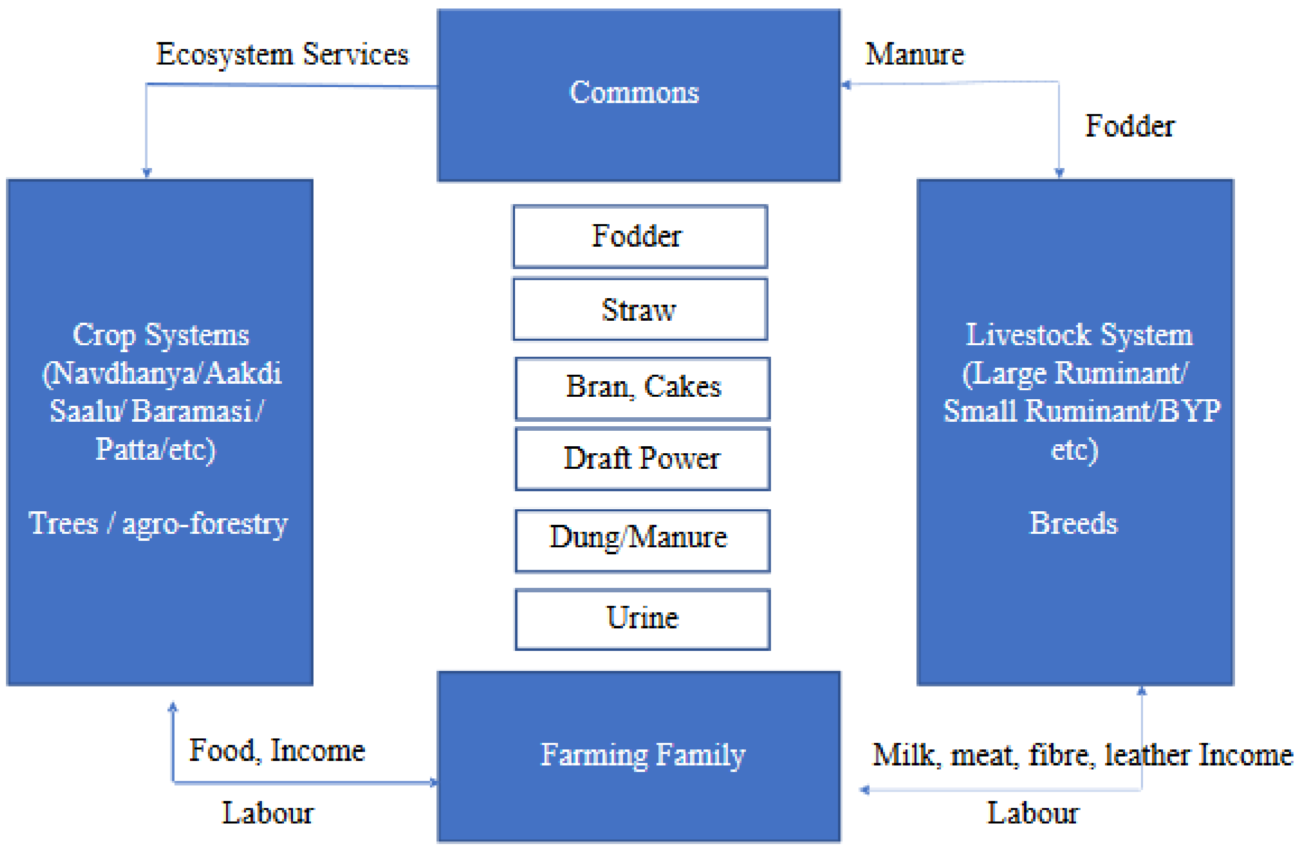
Climate change impacts may reduce income level and stability, through effects on productivity, production costs or prices. Such variations can drive sales of productive capital, such as cattle, which reduces long-term household productive capacity. Agricultural systems can be made more resilient, by implementing measures that are very system- and local-specific. Increasing the efficiency of scarce resource used in productive systems and adaptation measures for crops can include the use of adapted varieties or breeds, with different environmental optima and/or broader environmental tolerances is one perspective.

- Climate resilient production systems can be achieved by
  - Climate – ready crops and livestock
  - Best practices for soil and water conservation

- Manage to enhance adaptive capacity at field, farm and landscape scales
- Increasing the diversity within production systems will help to reduce climatic risks.
- Mobilize social protection to increase resilience of livelihoods in the face of climate change.

A major and urgent area for intervention is increasing the resilience (and thus reducing the vulnerability) of livelihoods, particularly among the poor who are highly dependent on natural resources and exposed to climate risks in NF. NF has potential to reduce fuel consumption, emissions from fertilizer use, and associated emissions from the production of fertilizer and other manufactured inputs. A life cycle assessment suggests a reduction in greenhouse gas emissions could be significant, but empirical data and longer studies are needed to understand NF's potential for emission reductions.

Crop - Livestock - Landscape: A Framework for Natural Farming

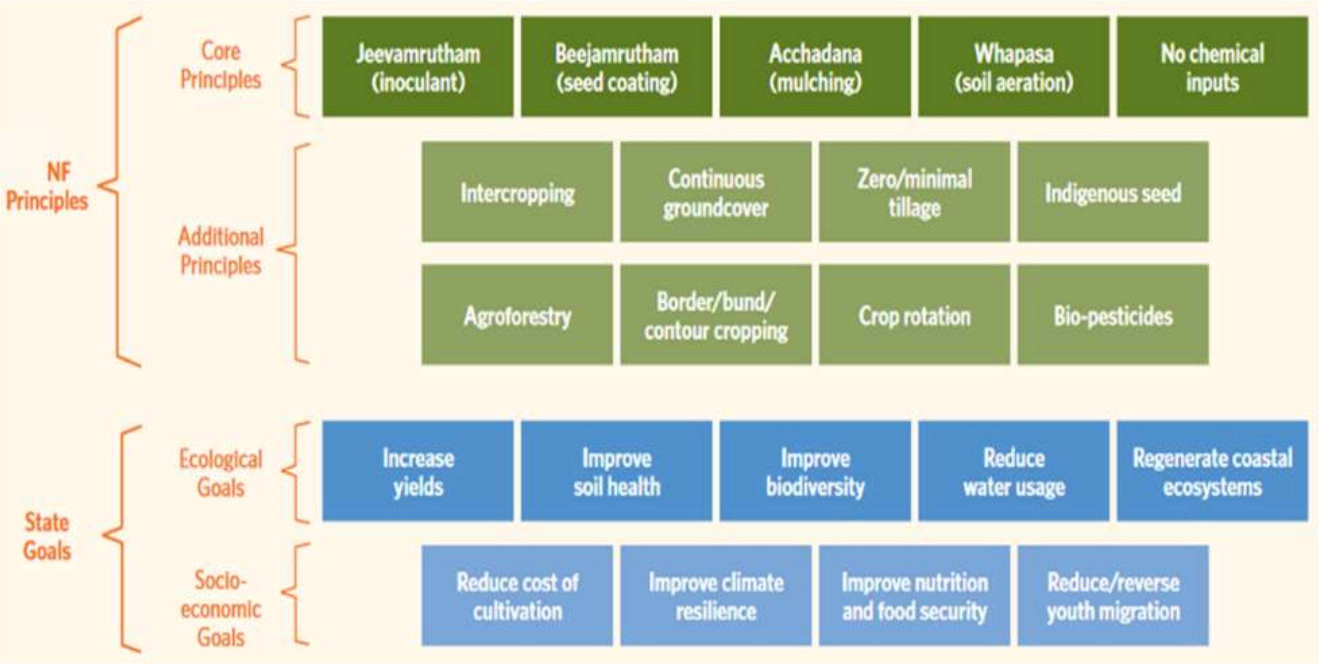


One-third of all humankind for whom farming is a source of livelihood, about 60 percent own livestock. The integration of livestock in the farming system plays an important role in natural farming and helps in restoring the ecosystem. Ecofriendly bio-inputs, such as Jeevamrit and Beejamrit, are prepared from cow dung and urine, and other natural products enhance adaptive capacity at field, farm level.

According to the 20th Livestock Census of India, 2019, rural India generates enormous quantities of bio-waste including animal waste, crop residue, etc. which can be easily diverted for natural farming input preparation. The indigenous Indian cow dung also contain higher amount of calcium, phosphorus, zinc and copper than the cross-breed cow (Garg and Mudgal 2007; Randhawa and Kullar 2011). Cow dung harbours a rich microbial diversity, containing different species of bacteria (Nene, 1999). Cow dung microorganisms have shown natural ability to increase soil fertility through phosphate solubilization. Cow dung has antifungal substance that inhibits the growth of coprophilous fungi (Dhama et al., 2005). It also contains 24 different minerals and micro-nutrients. The indigenous cow also contains higher amount of calcium, phosphorus, zinc and copper than the cross-breed cow. Cow dung harbours a rich microbial diversity, containing different species of bacteria (Bacillus spp., Corynebacterium spp. and Lactobacillus spp.), protozoa and yeast (Saccharomyces and Candida) (Nene 1999; Randhawa and Kullar 2011).

Principles and Goals

NF practice consists of four core elements: 1) jeevamrutham, a soil inoculant made of cow dung, urine, pulse flour, jaggery, and soil; 2) beejamrutham, a seed coating made of similar ingredients; 3) acchadana, mulching; and 4) whapasa, soil aeration.



Source: La Via Campesnia, 2016; Bishnoi and Bhatia, 2017; Mishra, 2018; Khadse et al., 2018; Reddy et al., 2019; RySS, 2019; Bharucha et al. 2020; Biswas, 2020; Gupta and Jain, 2020; Ranjeet et al. 2020

- **Beejamrit** is an ancient, sustainable agriculture technique. It is used for treatments of seeds, seedlings or any planting material. It is effective in protecting young roots from fungus.

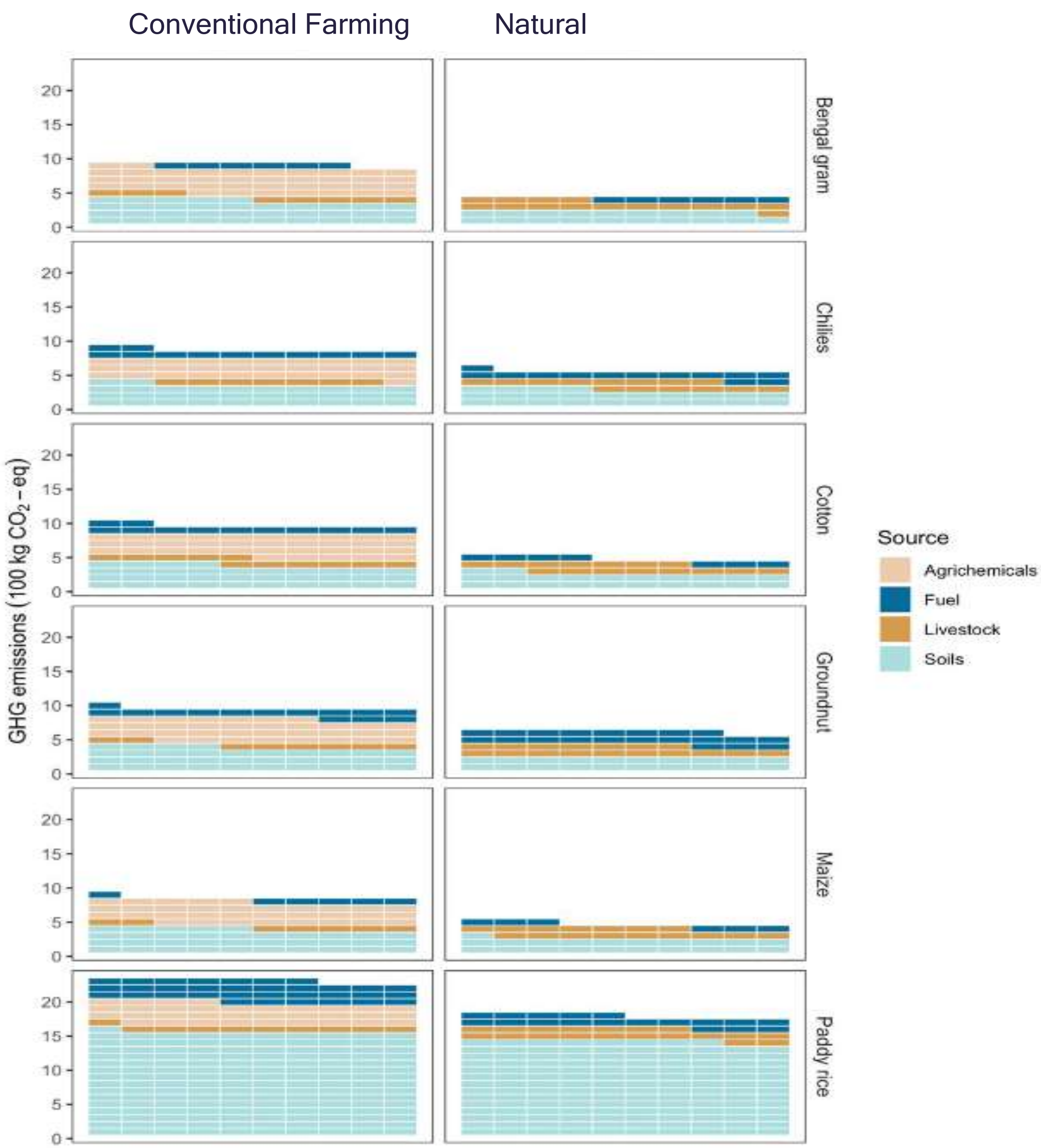
Beejamrit is a fermented microbial solution, with loads of plant -beneficial microbes, and is applied as seed treatment. It is expected that the beneficial microbes would colonize the roots and leaves of the germinating seeds and help in healthy emergence of the plants. Inputs needed: 5 kg cow dung, 5 litre cow urine, 50-gram lime, rhizospheric soil-50g or handful, 20 litre water (for 100 kg seed or depending on seed size).

- **Jeevamrit** acts as a bio-stimulant by re-establishing and promoting the activity of existing farmers' friendly soil microbes which in turn help in efficient recycling of nutrients present in the soil and makes them available to plants. Inputs needed: 10 kg of fresh cow dung, 10 litre cow urine, 2 kg jaggery, 2 kg of any pulse flour preferably besan, handful of rhizospheric soil and 200 litre water.
- **Acchadana/ Mulching** is the process of covering the topsoil with plant material such as leaves, grass, twigs, crop residues and straw etc. In natural farming, the term mulching refers to the use of organic and biodegradable plant materials. However, mulching may also include covering the soil surface using live crops with fast growth and short life spans. Mulching has multiple benefits such as decomposition of mulch material helps in increasing the organic matter content of the soil, conserves moisture in the soil through lowering of soil temperature, prevents soil erosion and also weed growth.
- **Whapasa** means the mixture of 50% air and 50% water vapour in the empty space between two soil particles. It is the soil's microclimate on which soil organisms and roots depend for most of their moisture and some of their nutrients. It increases water availability, enhances water -use efficiency and helps crop growth in drought conditions. The basic principle for Whapasa formation is irrigation should be done six inches outside the shadow circumference of any plant/tree formed at 12 noon during the day time.

Natural farming and Climate change

NF techniques reduce the impact of agriculture on the climate system as compared to the same crops grown under conventional techniques. Based on management activities carried out on typical farms, the carbon footprint of NF farms was lower than that of the conventionally grown crops (Rosenstock et al., 2020). Natural Farming offers a solution to various problems, such as food insecurity, farmers' distress, and health problems arising due to pesticide and fertilizer residue in food and water, global warming, climate change and natural calamities.

Relative sources of GHGs in conventional and NF farming is given below.



Source: Rosenstock et al., 2020

NF include an eco-friendly cultivation process and chemical-free harvests, reasons enough for many farmers to exert extra time and effort in growing naturally farmed goods. Soil is responsible for providing nutrients to the crops planted in it. Natural farming provides food of good quality due to proper soil management. The use of animal manure to improve the health of the soil supplies the crops with necessary nutrients like nitrogen, phosphorus, and potassium. Biodiversity can also be developed and nurtured through natural farming. The place where natural farming operates is an ideal habitat for various species because it allows them to breathe clean air that makes them naturally healthy and resistant to illness. Natural farming fights against climate change. Admittedly, the use of synthetically made fertilizers and pesticides to cultivate crops and livestock contributes a huge amount of greenhouse gases such as nitrous oxide, carbon dioxide, and methane. However, the soil of naturally cultivated farms can store carbon, keeping it from contributing to the worsening problem of global warming. Aside from reducing the impact of climate change, natural farming can also improve the composition of water by decreasing the amount of preservatives which usually contaminates the water. Natural Farming, as the name suggests, is the art, practice and, increasingly, the science of working with nature to achieve much more with less.

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