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Assessing the impact of climate change on agriculture and livelihood in Dhule district, Maharashtra, and identifying adaptation opportunities

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Abstract
The Dhule district in Maharashtra faces severe climate change-induced impacts, particularly affecting agriculture and livelihoods. This research aims to propose adaptation measures, recommend mitigation strategies, and establish a sustainable framework for resilience-building. Using mixed methods, including surveys, interviews, and focus groups, the study engages local communities and stakeholders. Ethical considerations are prioritized, and partnerships with organizations like the Lupin Human Welfare and Research Foundation are crucial. The research explores the impact of climate change on weather patterns, agriculture, and livestock production, identifying key challenges and adaptation practices. Findings reveal fluctuations in rainfall, changes in crop patterns, and shifts in livestock populations. Recommendations include promoting climate-resilient practices, enhancing community awareness, and fostering sustainable development pathways.

Keywords: Climate change, agriculture, livelihood, adaptation, mitigation, Dhule district, Maharashtra, sustainable practices, resilience-building, community engagement

Introduction
The Dhule district of Maharashtra, India, stands at the forefront of the climate crisis, bearing the brunt of erratic weather patterns and rising temperatures. As a predominantly agrarian region, the impact of climate change on agriculture reverberates throughout the district, affecting not only crop yields but also the livelihoods of local communities. Despite the severity of these challenges, there remains a stark lack of awareness and tailored adaptation strategies, exacerbating the vulnerability of Dhule's residents.

Climate change-induced shifts in rainfall patterns and temperature extremes have triggered a cascade of adverse effects on agricultural productivity. From fluctuating crop yields to dwindling water resources, farmers in Dhule face multifaceted challenges that threaten their economic stability and food security. The once-predictable monsoon season has become increasingly erratic, leading to water scarcity and crop failures. Moreover, rising temperatures have accelerated soil degradation and pest infestations, further compromising agricultural sustainability.

In light of these pressing concerns, there is an urgent need for comprehensive research and intervention strategies to bolster the resilience of Dhule's agricultural sector and safeguard the well-being of its communities. By identifying localized impacts, assessing adaptation needs, and fostering stakeholder collaboration, it is possible to chart a path towards sustainable development in the face of climate uncertainty.

By shedding light on the intricate interplay between climate change, agriculture, and livelihoods, this research seeks to inform policy decisions, guide adaptation efforts, and pave the way for a more sustainable future in Dhule district and beyond. Through proactive measures and community empowerment, it is possible to mitigate the adverse effects of climate change and build a resilient foundation for generations to come.

Research Design and Methodology

Research Design

The mixed-method approach combines qualitative and quantitative data collection methods.

- **Data Collection Methods:** Surveys, Interviews & Focus Groups
- **Data Analysis:** Quantitative & Qualitative Data
- **Needs Assessment:** determine the most critical challenges and adaptation requirements of the local communities.
- **Stakeholder Engagement:** Local communities, governmental agencies, NGOs, and other relevant stakeholders
- **Tailored Interventions:** Promoting climate-resilient agricultural practices, providing training on sustainable water management, and developing early warning systems for extreme weather events.
- **Awareness and Capacity Building:** Educate the community about climate change and its impacts. Capacity-building programs will be conducted to equip them with the knowledge and skills to implement adaptation measures.

Ethical Considerations

- Ethical Issues and Resolution Plan:
- Anticipated ethical issues include informed consent, privacy, power imbalances, and data handling.
- To resolve them, we will obtain informed consent, ensure privacy, involve community representatives, securely handle data, and conduct regular ethical reviews.
- Committed to safeguarding the rights and well-being of participants and maintaining the project's integrity.
- Ethical guidelines will be strictly adhered to throughout the research and intervention phases, prioritizing responsible and ethical practices.

Project Site Information

Organization: Lupin Human Welfare and Research Foundation (LHWRF). District: Dhule, Maharashtra, India.

Tehshils: Sakri, Shindkheda, Shirpur, Dhule (2 to 3 villages per tehsil). State: Maharashtra.

The data collection method used by the three types of sampling techniques

Snowball sampling: This could include locating and involving marginalized or remote community members. The total sample size comprises 10 villages, out of which 2 villages are categorized as remote and tribal.

Stratified Sampling: Divided the population into different strata based on specific characteristics such as age and geographical location within the Dhule district. This technique ensures that the sample represents the diversity present within the community, enabling a comprehensive understanding of the varying perspectives and experiences related to climate change impacts. Purposive Sampling: Identifying and selecting key stakeholders, such as agricultural experts from Krishi Vigyan Kendra, and officials from the agriculture department of Dhule district, including District and Tehsil Agriculture Officers. Their valuable insights will contribute to a holistic understanding of the local context and specific challenges.

Dhule District Sampling Details

- Total no of Farmers: 40
- Total no of Tehsils: 04
- Total no of Villages: 10

Data Collection Plan

Tehsil	Villages	Data Collection Method
Dhule	1. Deobhane 2. Sadgaon 3. Wani	01 FGDs 10 Farmers Interview
Sakri	1. Deur 2.Akkalpada 3. Ghanegaon	01 FGDs 10 Farmers Interview
Shindkheda	1. Hatnur 2. Patan	01 FGDs 10 Farmers Interview
Shirpur	1. Rohini 2. Jaitpur	01 FGDs 10 Farmers Interview

Key Findings, Observations & Recommendations

1. Impact of climate change on weather pattern

Overall Trends: From 2009 to 2023, Dhule district experienced fluctuations in annual rainfall, ranging from as low as 106 mm in 2015 to as high as 387 mm in 2013. This variability underscores the dynamic nature of precipitation patterns in the region.

Rainy Days: The number of rainy days fluctuated annually, indicating variations in the duration and intensity of rainfall events. While some years recorded a higher number of rainy days, such as 2011 with 58 days, others, like 2015, had fewer rainy days, totaling only 24.

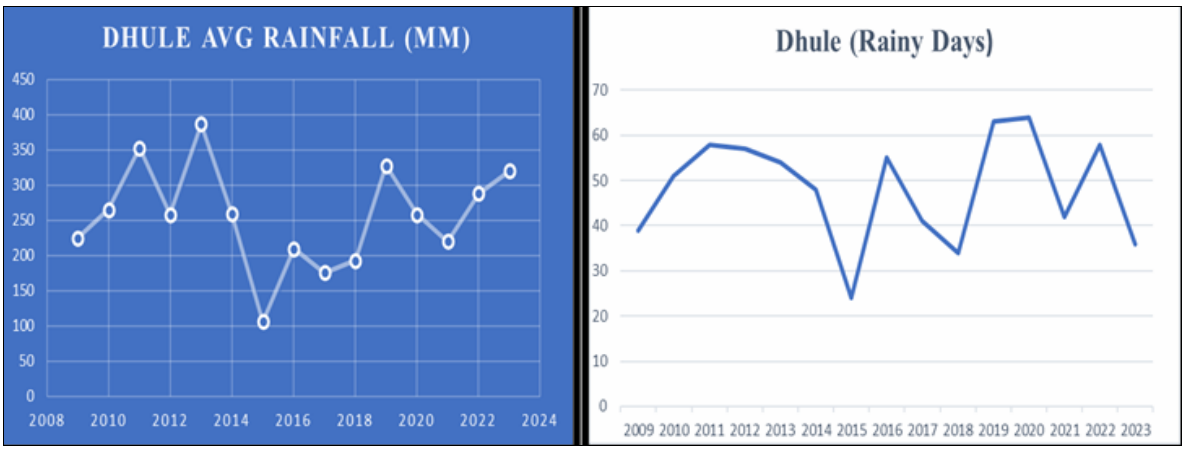

Fig 1: Analysing the rainfall pattern in Dhule district (2009 to 2023)

Anomalies and Extremes: Certain years, such as 2013 and 2019, stand out for their above-average rainfall, while others, like 2015 and 2017, experienced below-average precipitation. These anomalies highlight the susceptibility of the Dhule district to extreme weather events and the potential impact of climate change on rainfall patterns.

Impact on Agriculture and Water Resources: Fluctuations in rainfall can significantly impact agricultural productivity, water availability, and hydrological cycles in Dhule district. Years with below-average rainfall may lead to drought conditions, affecting crop yields and groundwater recharge, while above-average rainfall may increase the risk of flooding and soil erosion.

Implications for Climate Change: The observed variability in rainfall patterns underscores the need for climate change adaptation strategies in Dhule district. Increasing the frequency and intensity of extreme weather events may necessitate measures such as water conservation, crop diversification, and infrastructure development to mitigate risks and build resilience to climate- related challenges.

Impact of climate change on agriculture and livestock production

Production in 000 MT

Cotton Production: Generally, cotton production increased across all four blocks over the observed period, signifying its resilience and potential adaptation to changing climate conditions.

Bajra and Sorghum Decline: Bajra and sorghum production experienced significant declines in all blocks, indicating potential challenges in cultivating these traditional crops in the face of evolving environmental factors.

Maize Moderation: Maize production showed a mixed trend across the blocks, with some witnessing moderate decreases while others remained relatively stable, suggesting varying impacts of climate change on maize cultivation.

Pulses and Groundnut Decline: Pulses and groundnut production declined sharply across all blocks, reflecting challenges in sustaining legume crops under changing climatic conditions.

Chickpea and Wheat Fluctuations: Chickpea and wheat production exhibited fluctuations, with some blocks experiencing notable decreases while others saw moderate increases, highlighting the diverse impacts of climate change on different crops.

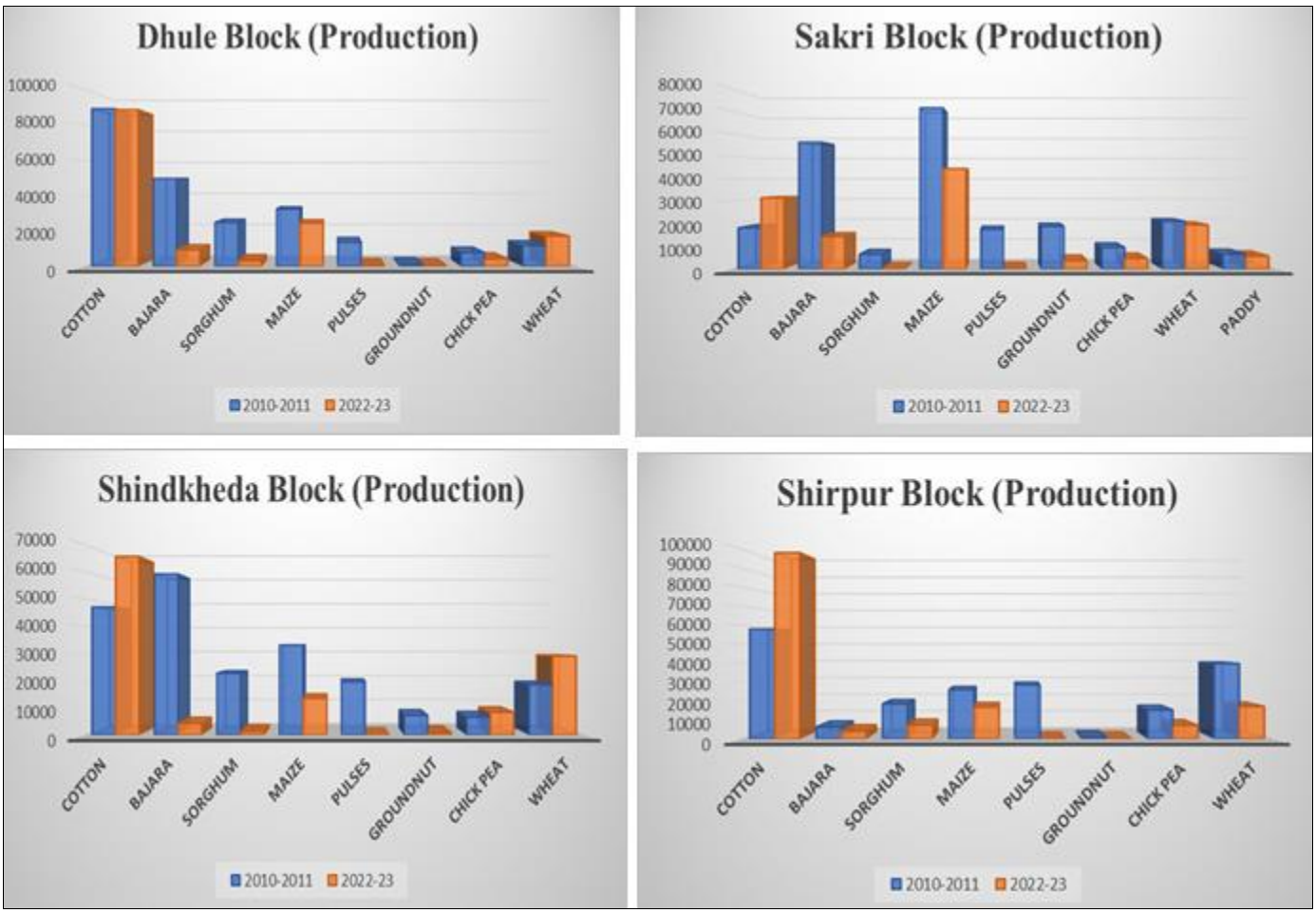

Fig 2: Four blocks in Dhule district regarding changes in crop production over time

Cotton experienced a significant increase in production, with a percentage change of approximately 33.92%. This suggests a notable expansion in cotton cultivation and productivity in the Dhule district.

Bajra (Pearl Millet), Sorghum, Maize, Pulses, and Groundnut witnessed substantial decreases in production, with percentage

changes ranging from -39.07% to -83.84%. This decline indicates potential challenges or shifts in agricultural practices for these crops over the observed period.

Chick Pea and Wheat also experienced decreases in production, with percentage changes of -37.82% and -9.12%, respectively.

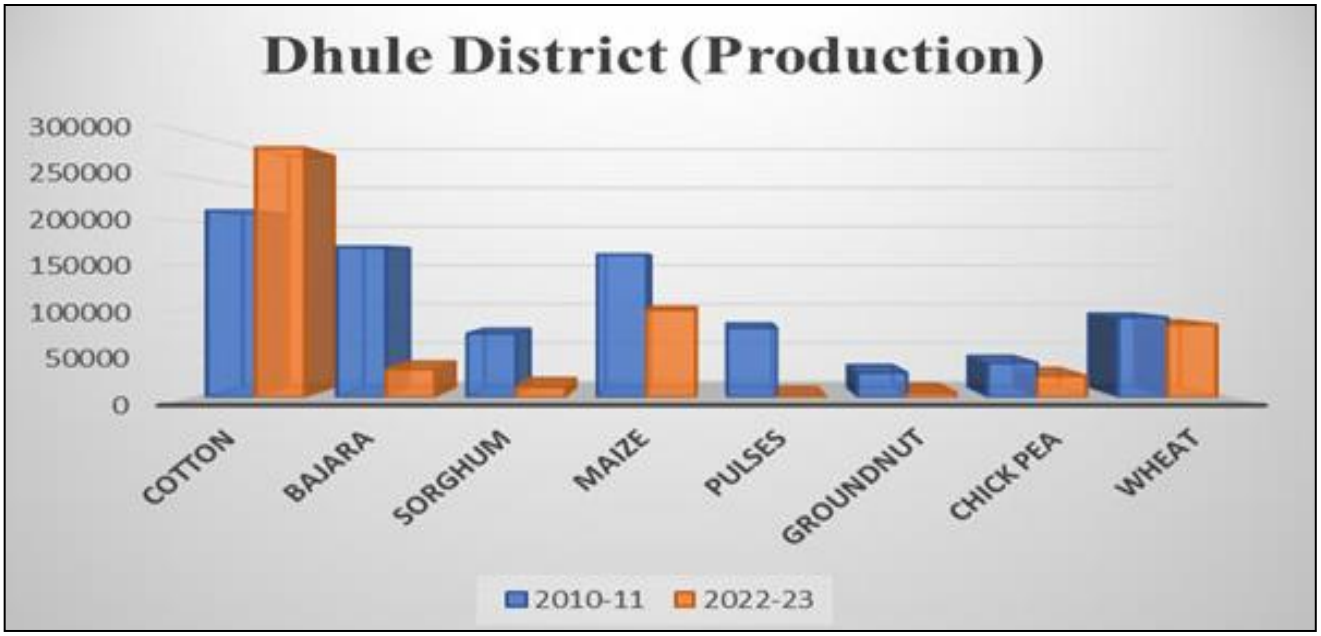

Fig 3: Production data in Dhule district from 2010-11 to 2022-23

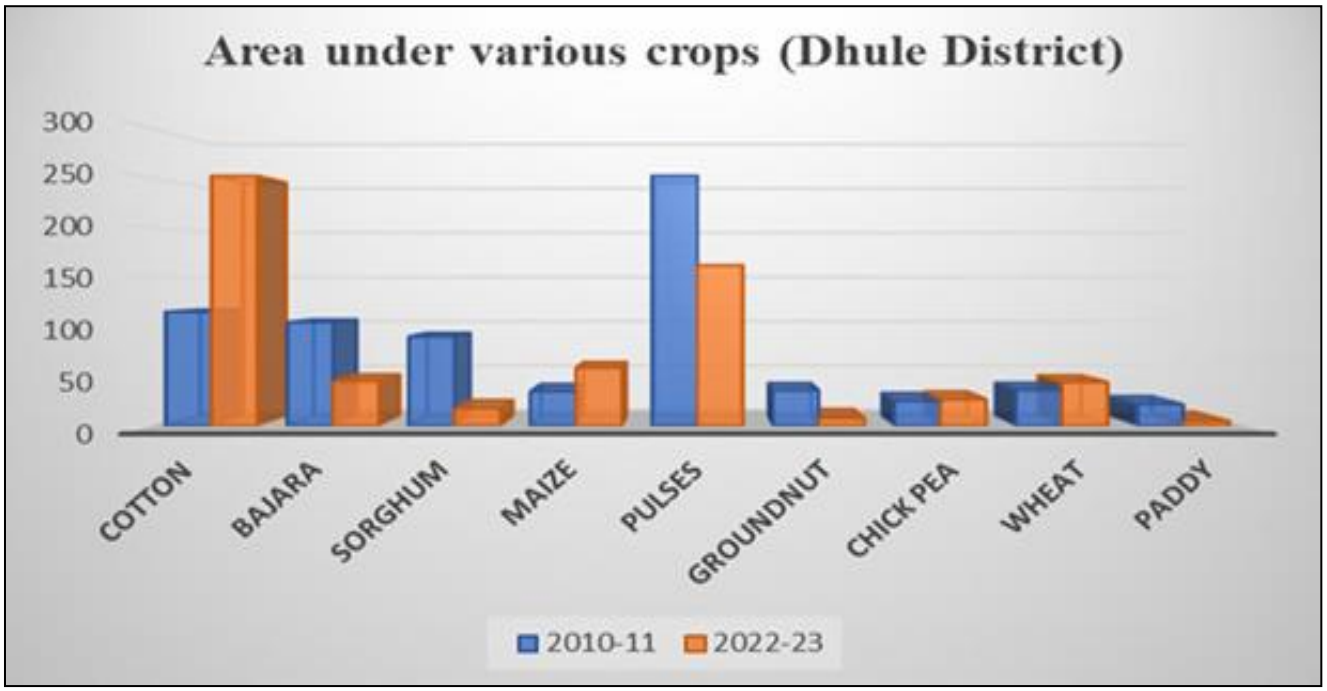

Fig 4: The area under various crops (Cropping pattern) from 2010-11 to 2022-23

Bajra and Sorghum: There has been a notable decline in the area under cultivation for both Bajra and Sorghum. Bajra cultivation decreased from 104.5 thousand hectares to 45.1 thousand hectares, while Sorghum decreased from 90 thousand hectares to 17.4 thousand hectares.

Maize: The area under Maize cultivation has shown an increase, rising from 34.7 thousand hectares to 58.5 thousand hectares.

Wheat and Paddy: Both Wheat and Paddy cultivation areas have witnessed an increase. Wheat cultivation area rose from 36 thousand hectares to 44.08 thousand hectares, whereas Paddy cultivation area increased from 21.5 thousand hectares to 4.8 thousand hectares.

Pulses (Groundnut, Chick Pea): Groundnut and Chick Pea: There has been a significant decrease in the cultivation area for both Groundnut and Chick Pea. Groundnut cultivation area decreased from 35.8 thousand hectares to 7.7 thousand hectares, while Chick Pea cultivation area remained relatively stable, increasing slightly from 25 thousand hectares to 26.6 thousand hectares.

Overall, the data indicates a substantial shift in crop patterns, with a remarkable increase in cotton production at the expense of a decline in cereal and pulse cultivation.

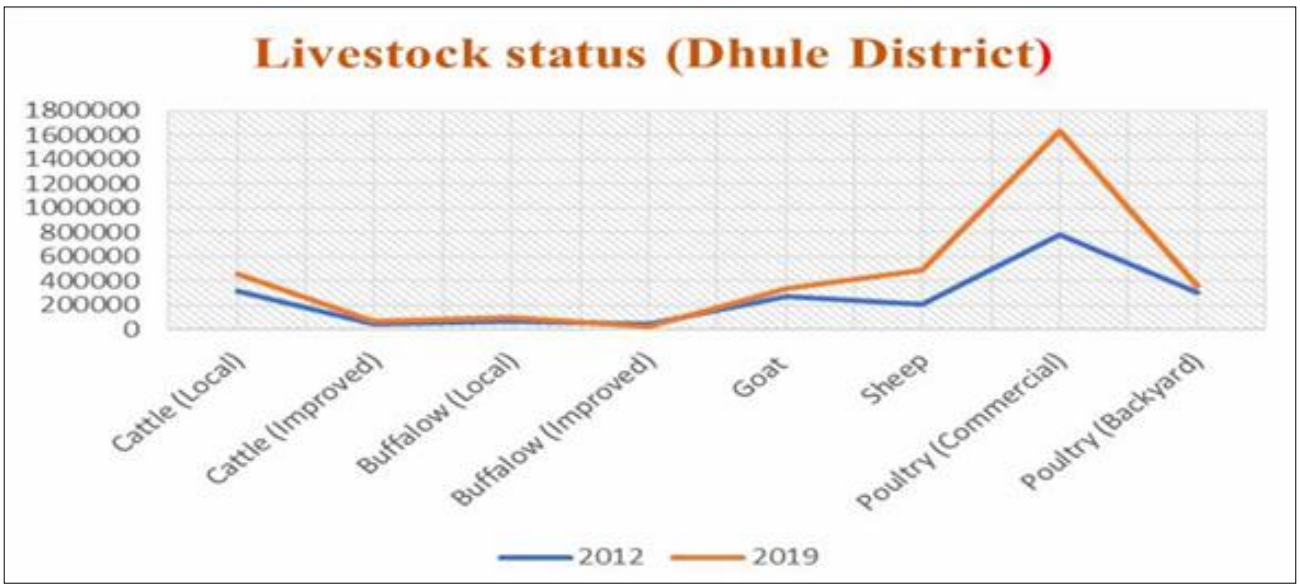

Fig 5: Livestock status of Dhule district from 2012 to 2019

Increase in Cattle and Buffalo Population: Between 2012 and 2019, both local and improved cattle populations experienced significant growth, along with a notable increase in local buffalo numbers. However, the population of improved buffaloes witnessed a decline, indicating potential shifts in breeding practices or environmental influences.

Goat and Sheep Population Growth: The goat and sheep populations exhibited steady growth over the observed period, reflecting the importance of small ruminants in the agricultural landscape of Dhule district. This growth may also indicate resilience to environmental stressors or increased demand for meat and dairy products.

Poultry Expansion: Commercial poultry farming experienced a remarkable surge in numbers, more than doubling in population. Backyard poultry also saw growth, albeit at a slower pace.

This expansion suggests changing dietary preferences, economic opportunities, and the adaptability of poultry to diverse environmental conditions

Climate Change Implications: The observed trends in livestock population dynamics may be influenced by climate change-induced factors such as temperature fluctuations, water availability, and disease prevalence. Shifts in rainfall patterns and temperature extremes could impact fodder availability, breeding cycles, and overall animal health.

Impact of climate change on agriculture and allied based livelihood and recommendations based on climate change ad amputations water availability

Key Findings & Observations

- The number of farmers utilizing bore wells and wells for irrigation has increased.
- 80% of farmers acknowledge a significant decline in the groundwater table.
- There hasn't been a notable shift in the number of farmers transitioning from open irrigation to drip irrigation.
- Only 30% of farmers perceive sufficient water availability for farming, compared to 60% a decade ago.
- 40% of farmers express interest in adopting drip irrigation methods.
- All farmers recognize a significant alteration in rainfall patterns over the past 5 years.
- 60% of farmers have adjusted their cropping patterns due to limited water availability, moving from irrigated to rainfed agriculture.
- Farmers universally report a reduction in yields by 30% to 40% due to water scarcity.
- Farmers unanimously agree on the importance of drip irrigation for water conservation.
- 60% of farmers face financial constraints in installing drip irrigation systems.
- While 60% of farmers acquire drip systems through government subsidies, they often receive low-quality equipment.

Recommendations

- **Promotion of Drip Irrigation:** Launch targeted awareness campaigns to highlight the benefits of drip irrigation among farmers in Dhule. Strengthen government subsidy programs to ensure farmers have access to high-quality drip irrigation equipment.
- **Address Financial Constraints:** Explore options for providing financial assistance or affordable financing schemes to help farmers overcome the financial barriers associated with installing drip irrigation systems.
- **Implement Water Management Strategies:** Develop tailored water management plans that consider changing rainfall patterns and declining groundwater levels.
- Encourage the adoption of water-saving techniques like mulching and rainwater harvesting alongside drip irrigation.

1. Invest in Research and Development

Allocate resources to research initiatives aimed at improving water management practices (drip irrigation technology) to make it more efficient and affordable for farmers in Dhule.

2. Provide Capacity Building and Training

Organize training programs and workshops to educate farmers on the proper installation, operation, and maintenance of drip irrigation systems.

3. Conduct Awareness Campaigns

Collaborate with local organizations and extension services to launch awareness campaigns using various communication channels.

Ensure that farmers understand the long-term benefits of drip irrigation through informative workshops and demonstrations.

4. Facilitate Collaborative Efforts

Foster partnerships between government agencies, NGOs, and private stakeholders to streamline efforts in promoting drip irrigation and sustainable water management practices.

Establish support networks to provide ongoing assistance and guidance to farmers adopting drip irrigation methods.

These recommendations aim to address key challenges and promote the adoption of drip irrigation as a sustainable water management solution in the Dhule district

Soil Quality

Key Findings & Observations

- 60% of farmers regarded their soil quality as good A decade ago, whereas now only 10% share this view.
- Approximately 60% of farmers now consider their soil to be very hard, a stark contrast to conditions 10 years ago.
- The primary reasons cited by farmers for soil hardening, in descending order, include excessive use of chemical fertilizers, pesticides, and irrigation, along with low utilization of organic materials like cow dung, FYM, or vermicompost.
- 80% of farmers report a decline in soil productivity, resulting in reduced yields.
- 80% of rainfed farmers practice monocropping, while 50% of irrigated farmers adopt the same, leading to soil fertility depletion.
- While farmers are aware of soil testing, the absence of nearby laboratories and delays in receiving reports from government facilities hinder their ability to access timely soil analysis results.
- Nearly 90% of farmers engaging in intensive tillage practices experience soil layer loss.

Recommendations

1. Promote Sustainable Soil Management Practices

- Encourage farmers to reduce reliance on chemical fertilizers and pesticides by promoting the use of organic alternatives such as compost, vermicompost, and organic manures.
- Provide training and extension services to educate farmers on sustainable soil management techniques, including crop rotation, cover cropping, and mulching, to improve soil structure and fertility.
- Aware farmers of applied recommended dose of fertilizers on their farm

2. Facilitate Access to Soil Testing Services

- Establish accessible soil testing laboratories or mobile soil testing units in rural areas to provide farmers with timely and accurate soil analysis reports.
- Collaborate with local agricultural extension services and NGOs to conduct soil health assessment camps and awareness programs to promote the importance of soil testing.

3. Encourage Crop Diversification and Intercropping

- Promote crop diversification and intercropping practices among rainfed and irrigated farmers to enhance soil biodiversity, improve nutrient cycling, and reduce soil erosion.
- Advocate for the cultivation of leguminous cover crops and green manures to replenish soil nitrogen levels and improve overall soil fertility.

4. Implement Soil Conservation Measures

- Introduce soil conservation measures such as contour plowing, terracing, and agroforestry to mitigate soil erosion, especially in sloping or vulnerable areas.
- Provide financial incentives and technical support for the adoption of conservation tillage practices and soil erosion control structures to safeguard soil health and prevent land degradation.

5. Advocate for Policy Support and Research Investments

- Advocate for the integration of soil health and conservation considerations into agricultural policies, programs, and extension services at the district and state levels.
- Allocate resources for research and innovation in soil science, agronomy, and agroecology to develop context-specific solutions for improving soil quality, fertility, and resilience in the Dhule district.

Yield & Cost of Cultivation

Key Findings & Observations

- The primary reasons identified by surveyed farmers for the reduction in yield include
- Pest and Disease Attacks
- Limited Water Availability
- High Temperatures
- Less Water Availability has been a persistent issue for over a decade according to 70% of surveyed farmers.
- Approximately 70% of farmers reported a yield decrease ranging from 20% to 30% in major crops such as cotton, maize, wheat, chickpeas, and onions over the past 10 years.
- There is a declining trend in the cultivation of cereals like bajra and sorghum, as well as in pulses.
- Moreover, there has been a significant decrease in the cultivation of local food varieties like desi varieties over time.
- 90% of farmers reported an increasing cost of cultivation, particularly in managing the following factors:
- Weed Management
- Pest & Disease Management
- Fertilizers
- Labor Costs

Recommendations

Integrated Pest and Disease Management

- Implement integrated pest and disease management strategies that include cultural, biological, and chemical control methods.
- Provide training and extension services to farmers on identifying pest and disease symptoms and implementing appropriate management practices.

Water Resource Management

- Invest in water conservation techniques such as rainwater harvesting, drip irrigation, and soil moisture management to optimize water availability for crops.
- Promote the use of drought-tolerant crop varieties and water-efficient irrigation practices to mitigate the impact of limited water availability on crop yields.

Climate-Resilient Crop Varieties

- Introduce and promote the cultivation of climate-resilient

crop varieties that are adapted to high temperatures and water scarcity.
- Collaborate with agricultural research institutions to develop and disseminate improved crop varieties that exhibit tolerance to heat stress and water deficit conditions.

Crop Diversification and Rotation
- Encourage farmers to diversify their cropping systems and adopt crop rotation practices to reduce the risk of pest and disease outbreaks and improve soil health.
- Promote the cultivation of alternative crops that are better suited to changing climatic conditions and have lower water requirements.

Promotion of Indigenous Crop Varieties
- Support the conservation and revival of indigenous crop varieties, including desi varieties of cereals and pulses, which are often more resilient to local environmental stresses.
- Raise awareness among farmers about the nutritional and cultural significance of indigenous crops, fostering their preservation and cultivation.

Capacity Building and Extension Services
- Strengthen extension services and farmer training programs to enhance agricultural knowledge and skills related to climate change adaptation and crop management.
- Provide access to timely and relevant information on weather forecasts, pest and disease outbreaks, and best agricultural practices through mobile-based advisory services and community workshops.

Market Access and Value Chains
- Facilitate market linkages and value chain development for climate-resilient crops to ensure farmers receive fair prices for their produce.
- Support the establishment of farmer cooperatives and collective marketing initiatives to improve bargaining power and market access for smallholder farmers.

Policy Support and Investment
- Advocate for policies and incentives that promote sustainable agriculture, including subsidies for climate-resilient inputs, insurance coverage for crop losses, and investment in agricultural infrastructure.
- Engage policymakers and stakeholders in dialogue to address the underlying drivers of crop yield reduction and develop evidence-based policy interventions to support farmers.
- By implementing these recommendations, farmers can enhance their resilience to climate change, improve crop productivity, and sustainably manage their agricultural systems in the face of evolving environmental challenges

Pest and disease dynamics
Key Findings & Observations
- 100% of farmers agree that there is an increase in pest and disease pressure on their farm fields.
- New pest incidences have emerged and are currently in severe conditions, such as pink bollworms in cotton, Armyworms in maize, and Bollworms in chickpeas.
- Due to the severity of pest and disease outbreaks, farmers resort to using numerous chemicals for control. However, it is increasingly challenging to manage conditions due to the resurgence of pests against these chemicals.
- Similar challenges are observed in vegetable and orchard cultivation among farmers.

Recommendations
Integrated Pest Management (IPM) Practices
Crop Rotation and Diversification
(These two practices are already explained in previous recommendations)

Biological Control Agents
Facilitate the use of biological control agents such as predatory insects, parasitoids, and microbial pesticides to suppress pest populations and minimize reliance on chemical pesticides.

Establish community-based rearing and distribution programs for beneficial insects and natural enemies to enhance their effectiveness in pest management.

Early Warning Systems
Develop and implement early warning systems for pest and disease outbreaks based on meteorological data, pest monitoring networks, and remote sensing technologies.

Provide timely alerts and advisory services to farmers through mobile applications, SMS notifications, and community radio broadcasts to enable proactive pest management decisions.

Responsible Pesticide Use
Promote the judicious use of pesticides by educating farmers about proper application techniques, dosage rates, and safety precautions to minimize negative environmental and human health impacts.

Encourage the adoption of alternative pest control methods such as pheromone traps, botanical extracts, and biopesticides as sustainable alternatives to chemical pesticides.

Farm-Level Monitoring and Surveillance
Establish farmer-led monitoring and surveillance networks to track pest and disease dynamics, share information, and coordinate response efforts at the community level.

Encourage collaboration between farmers, extension agents, researchers, and agricultural authorities to monitor pest populations, assess pest resistance, and evaluate the efficacy of pest management interventions.

Research and Innovation
Invest in research and innovation to develop new pest management technologies, resistant crop varieties, and environmentally friendly pest control strategies tailored to local agroecosystems.

Foster partnerships between research institutions, universities, agricultural companies, and farmer organizations to leverage expertise and resources for pest management research and development

Livestock
Key Findings & Observations
- 65% of farmers reported a significant reduction in the livestock population in villages over the last decade.
- The primary reason observed for this decline is the scarcity of fodder and forage crops, leading to a decrease in livestock population.
- Currently, due to improper feed management, there is a

noticeable decline in the breeding quality of cattle.
- The natural capacity of milk productivity among milking animals has been downgraded as a result

Recommendations

Fodder and Forage Crop Cultivation
- Encourage farmers to cultivate fodder and forage crops suitable for local agroecological conditions to ensure year-round availability of nutritious feed for livestock.
- Provide technical support, including training and extension services, on improved cultivation practices, seed selection, soil fertility management, and irrigation techniques for fodder production.
- Silage Making and Hay Preservation
- Promote the adoption of silage-making and hay preservation techniques to conserve surplus fodder during peak growing seasons for use during periods of scarcity and lean months.
- Conduct demonstrations and capacity-building programs on silage preparation, storage methods, and nutritional value assessment to enhance feed efficiency and livestock productivity.

Integrated Livestock-Crop Systems
- Advocate for the integration of livestock and crop production systems through agroforestry, alley cropping, and rotational grazing to optimize resource utilization, enhance soil fertility, and diversify income streams for farmers.
- Facilitate collaborative initiatives between crop and livestock producers to promote synergies between agriculture and animal husbandry, such as using crop residues as feed supplements and leveraging livestock manure for soil fertility improvement.

Livestock Breeding and Health Management
- Strengthen livestock breeding programs and genetic improvement schemes to enhance the resilience, productivity, and quality of indigenous and exotic breeds adapted to local climatic conditions and market demands.
- Provide veterinary healthcare services, disease prevention measures, vaccination campaigns, and deworming treatments to mitigate livestock diseases, improve reproductive health, and reduce mortality rates among animals.

Feed Management and Nutritional Supplements
- Educate farmers on balanced feed formulation, rationing techniques, and nutritional requirements for different categories of livestock, including lactating cows, growing calves, and breeding bulls.
- Promote the use of locally available feed ingredients, mineral supplements, and protein sources to address nutrient deficiencies, optimize feed conversion efficiency, and enhance animal performance and resilience.

Community-Based Livestock Management

Establish community-based livestock management committees or cooperatives to collectively address fodder scarcity, coordinate feed procurement, bulk purchase inputs, and share best practices for sustainable livestock production.

Foster peer-to-peer learning, farmer field schools, and knowledge exchange platforms to facilitate information sharing, problem-solving, and innovation adoption in livestock management and animal husbandry.

Market Linkages and Value-Added Products

Facilitate access to livestock markets, value chains, and agribusiness opportunities for smallholder farmers through market information, price transparency, contract farming arrangements, and collective marketing initiatives.

Promote the development of value-added products such as dairy products, meat processing, and leather goods to increase the economic viability of livestock farming and generate additional income for rural communities.

Greenhouse gas emissions in the agriculture sector & and their mitigation strategies

Key Findings & Observations
- In Dhule district, the primary crop during the kharif season is cotton, with approximately 80% of rainfed farmers and 60% of irrigated farmers practicing the burning of cotton stakes after harvesting.
- For other crops like wheat and maize, about 30% of farmers reported burning the crop residue.
- When categorizing residue burning by crop type, approximately 70% of burning occurs in cotton crops, while the remaining 30% is distributed among other crops. This practice significantly contributes to carbon emissions in the agricultural sector of Dhule district.
- Another significant contributor to greenhouse gas emissions is the high application of chemical fertilizers and pesticides and open irrigation practices

Recommendations

Promotion of Sustainable Agricultural Practices
- Encourage the adoption of sustainable agricultural practices such as zero tillage, conservation agriculture, and crop rotation to reduce the need for residue burning and minimize carbon emissions
- Provide training and extension services to farmers on alternative residue management techniques, including mulching, composting, biochar preparation, and application incorporation of crop residues into the soil.

Adoption of Climate-Smart Agricultural Practices
- Encourage farmers to adopt climate-smart agricultural practices such as conservation tillage, agroforestry, and integrated crop-livestock systems.
- Promote the use of organic fertilizers, biopesticides, and biofertilizers to reduce reliance on chemical inputs and minimize greenhouse gas emissions from agricultural activities.

Promotion of Renewable Energy Sources
- Encourage the adoption of renewable energy technologies such as solar-powered irrigation pumps, biogas digesters, and biomass briquettes for cooking and heating purposes.
- Provide subsidies, incentives, and technical support to farmers for installing renewable energy systems and transitioning to clean energy alternatives.

Improvement of Water Use Efficiency
- Implement water-saving technologies such as drip irrigation, sprinkler irrigation, and rainwater harvesting to improve water use efficiency and reduce water consumption in agriculture.
- Promote the use of soil moisture sensors, weather-based irrigation scheduling, and efficient irrigation scheduling techniques to optimize water use and minimize water wastage.

Afforestation and Reforestation

- Launch afforestation and reforestation programs to increase tree cover, enhance carbon sequestration, and mitigate the impacts of climate change.
- Establish community-based nurseries, agroforestry models, and watershed management projects to restore degraded lands, conserve biodiversity, and enhance ecosystem resilience.

Enhancement of Livestock Management Practices

- Promote improved livestock management practices such as rotational grazing, silvopastoral systems, and feed supplementation to reduce methane emissions from enteric fermentation.
- Introduce fodder cultivation, pasture improvement, and manure management techniques to enhance feed efficiency, reduce greenhouse gas emissions, and improve soil fertility.

Implementation of Carbon Farming Techniques

- Explore carbon farming techniques such as cover cropping, crop diversification, and no- till farming to enhance soil organic carbon sequestration and mitigate greenhouse gas emissions.
- Provide training, technical assistance, and financial incentives to farmers for adopting carbon farming practices and participating in carbon offset programs

Integration of Climate Change Adaptation and Mitigation Strategies

- Integrate climate change adaptation and mitigation strategies into agricultural planning, policymaking, and development programs to achieve synergistic benefits and maximize resilience.
- Foster multi-stakeholder partnerships, knowledge sharing, and collaboration among government agencies, research institutions, civil society organizations, and local communities to address climate change challenges holistically.

Table 1: Sustainable framework for long-term resilience-building and cli mate change adaptation

Component	Actions	Agencies
Capacity Building and Awareness	Organize farmer field schools and demonstration plots. Train extension workers and community leaders as climate change ambassadors Distribute educational materials on climate change impacts and adaptation	Government/ NGOs/CSR Funds
Water Resource Management	Promote a low-cost drip irrigation system Provide subsidies for drip irrigation systems Promote drought-resistant crops & varieties Partner with research institutions to develop low- cost irrigation solutions	Government/ NGOs/CSR Funds
Soil Health and Conservation	Introduce conservation tillage practices to reduce soil disturbance and erosion Promote Agro-Horticultural & Agro-Forestry models to improve soil fertility and mitigate erosion Promote Vermicomposting, Composting & organic manure application methods to reduce the use of chemical fertilizers Offer subsidized soil testing services and nutrient management advice	Government/ NGOs/CSR Funds
Crop Diversification and Livelihood	Promote the intercropping & mixed cropping farming practices Promote an integrated farming approach (Cultivation of vegetables & fruits) Promote Livestock based farming	Government/ NGOs/CSR Funds
	Conduct Agribusiness workshops on market linkages and value chains. Farmer producer organizations (FPOs) strengthen for collective marketing.	
Ecosystem Restoration and Biodiversity	Launch community-led conservation initiatives to protect biodiversity hotspots. Promote indigenous knowledge systems and traditional conservation practices. Collaborate with indigenous communities for sustainable forest management	Government/ NGOs/CSR Funds
Policy Support and Governance	Advocate for climate-resilient policies and increased budget allocations Strengthen local governance structures for effective implementation Promote inter-agency coordination and multi-stakeholder partnerships	Government/NGOs

Table 2: Sustainable Development Components and Aligned SDGs

Component	Aligned SDG(s)
Capacity Building and Awareness	SDG 4: Quality Education SDG 6: Clean Water and Sanitation SDG 13: Climate Action
Water Resource Management	SDG 6: Clean Water and Sanitation SDG 13: Climate Action
Soil Health and Conservation	SDG 2: Zero Hunger SDG 15: Life on Land SDG 13: Climate Action
Crop Diversification and Livelihood	SDG 2: Zero Hunger SDG 8: Decent Work and Economic Growth

Ecosystem Restoration and Biodiversity	SDG 11: Sustainable Cities and Communities SDG 15: Life on Land
Policy Support and Governance	SDG 13: Climate Action SDG 16: Peace, Justice, and Strong Institutions SDG 17: Partnerships for the Goals

Acknowledgment

"Lupin Human Welfare & Research Foundation (LHWRF) is the social responsibility arm of Lupin Limited, founded by Dr. Desh Bandu Gupta in 1988. In its journey spanning over three decades, the foundation has covered over 1.45 million beneficiaries in over 5000 villages in 23 districts spread across nine states in India. Over the years, the foundation has largely focused on building sustainable livelihood opportunities and triggering economic growth in some of the most backward and underdeveloped districts of India. It has adopted a family-centered approach and initiated measures that help them break the vicious circle of poverty, positively impacting their lives and livelihoods. To ensure that economic development is substantiated by social upliftment and an improvement in quality of life, the organization has been working relentlessly in the areas of health and education at the grassroots level. Structured efforts have been made to upgrade the local infrastructure, build awareness, catalyze positive behavior change, and facilitate access to healthcare services for the most marginalized and underserved communities. The foundation works extensively with various government and non-government partners, international development agencies, and like-minded philanthropic organizations to mobilize additional resources and extend its reach to several more isolated and underserved populations, covering a large majority of landless tribal, scheduled caste, and minority populations in target geographies. As one of the parts of the organization's livelihood strategies Better Cotton Initiative is the major project where 95156 smallholder farmers are engaged in sustainable cotton production".

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