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ISBN 978-3-031-83245-1 ISBN 978-3-031-83246-8 (eBook)
https://doi.org/10.1007/978-3-031-83246-8

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

Achieving sustainable goals is not possible without understanding the aspirations of about one-fourth workforces of the world who are dependent on agricultural systems for foods and livelihood options. The evolving challenges of food security, environmental degradation, climate change, and rural development in India call for innovative approaches that harmonize agricultural productivity with sustainable land use practices. In this context, the district of Murshidabad, located in the heart of West Bengal, offers a rich case study that encapsulates both the challenges and the potential solutions faced by agrarian communities across the nation. This book, *Sustainable Land Use Practices and Agricultural Innovations in India: A Case Study from Murshidabad District of West Bengal*, is the culmination of years of research, fieldwork, and deep engagement with farmers, local stakeholders, academicians, and agricultural experts.

The seed for this work was planted during our early experiences and interactions with rural farming communities, where we were born, grew, and observed the resilience of the people in the face of changing environmental and economic conditions. The urgency to balance the pressures of population growth, food security, agricultural income, and environmental conservation such as soil erosion, pollution, floods, and drought became increasingly evident. This led us to explore innovative and sustainable land use practices that could empower farmers while ensuring long-term environmental stability.

Through this book, our aim is to provide a comprehensive examination of how sustainable agricultural innovations can be effectively implemented in rural India by land size classes. The case study of Murshidabad serves as a focal point to highlight the specific challenges faced by small and marginal farmers, as well as the potential solutions that can emerge through collaborative efforts between farmers, policymakers, academicians, researchers, policy think tank, and agricultural scientists.

At its core, this book seeks to address the critical question: How can we increase agricultural productivity and profitability without further straining the environment? Through a blend of theoretical analysis and practical insights, we hope to offer a road map for achieving sustainable agricultural development and suitable land use measures through innovation processes, not just in Murshidabad, but across India and other regions facing similar challenges.

This book is written for a diverse audience—students, researchers, policymakers, and anyone interested in sustainable land use, agricultural innovation practices, livelihoods, and rural development. I hope that readers will find it useful as a resource for understanding the nuances of sustainable land use and its practical application in real-world scenarios.

We would like to take this opportunity to express our gratitude to the many individuals and institutions who contributed to this project. The farmers of the Murshidabad generously shared their experiences and insights, which became the foundation of this work. We are also indebted to our colleagues and mentors who provided invaluable feedback and guidance during the research process.

In conclusion, this book is a reflection of our belief that the path to sustainable development lies in the intersection of innovation, community engagement, and environmental stewardship. It is our hope that this work will inspire further research, discussions, and actions towards building a sustainable future for agriculture in India.

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Contents

Introduction

Background of the Study

As per a recent estimation of World Bank, agricultural sector has engaged about 26% of global workforce and contributes 4.3% of world's gross domestic product (GDP). In 2023, the GDP share from agriculture in South Asia was 15.98% (World Bank) against the employed workforce of 41.61% (International Labour Organization, 2022). The agricultural income includes forestry, fishing, and agriculture. According to National Sample Survey Office (NSSO), during 2022–2023, about 45.76% of India's total workforce was involved in agriculture and shared 15% of GDP. At national and regional level, the contribution of agriculture in GDP and workforces is decreasing, but still this sector is important for poverty alleviation, reducing hunger, climate change mitigation, and the generation of employment horizontally and vertically at global stage irrespective of intensive and extensive nature of agricultural practices. The intensive subsistence form of agriculture does not require dedicated skills and training; therefore, Africa, South and Central Asia, and countries from Central and South Americas still depend on traditional farming practices. The technological, institutional, and infrastructural development are, no doubts, eliminating workforce directly from agriculture horizontally, but use of automation, precision agriculture, and high tech farming processes increases new avenue for employment vertically. To face global threats and challenges like climate change, disaster, desertification, soil erosion, land pollutions, and food security, the entire agricultural system should be rationalized; therefore, we need agricultural innovation (AI). The AI is a process of developing and applying convenient techniques, technologies, ideas, and practices to improve farm output, sustainability, efficiency, and adjust global challenges and threats. The basic tenet of AI is to use the land for present need without compromising the future fertility. And, from here sustainable land use (SLU) is the first essential premise of AI.

The SLU is not only key of AI rather sustainable development goals (SDGs) have also been focused on this. The SLU emphasizes balanced distribution and the preservation of environmental resources—including water and soil—along with efficient, responsible practices that integrate economic, social, and environmental considerations. The main and key components of SLU are agroforestry, crop rotation, crop diversification, conservation of water, management of tillage, urban greenery, organic farming, and soil health based farming practices. Conversely, the sustainable land use management (SLM) involves planning, governance, and long-term management of land resources which will be beneficial to people of today and tomorrow. The SLM also integrates and balances the social, economic, and environmental existence for well-being. The fundamental focus of SLM includes policies, regulations, and practices to use land in sustainable manner. As like SLU, the SLM also has various components such as zonation of land for planning, integrated land use systems, community participation, environmental impact assessment, and sustainable forestry and agriculture for productivity and efficiency. Keeping in mind of its aims, objectives, and focus, the AI in this study includes SLU and SLM as integral part of discussion under 'sustainable land use practices' (SLUP).

Sustainable Land Use Practice, Agricultural Innovation, and SDGs

The needs of this study also become relevant because of SDG objectives. AI and SLU are integral parts of this long-term goals to enhance economic growth and development, food security, climate resilient agriculture, and natural resources management. The following SDGs are important regarding SLUP:

1. SDG-1 focuses on sustainable land use through AI. To enhance agricultural productivity in any region, the crop rotation, crop diversification, precision agriculture, conservation of tillage, agroforestry, soil, and water efficiency are essential. The goal of zero hunger can be reached through increasing agricultural productivity.
2. SDG-6 stresses on clean water and sanitation through reducing pollutions and efficient water management in agriculture and households. Focusing on water efficiency, the land use management can be enhanced in semiarid and low rainfall regions.
3. SDG-8 focusses on decent work and economic growth by efficient use of land for economic development. The rural economy of small landholders may be enhanced through advancement in agriculture after technological innovation.
4. SDG-9 targets industry, innovation, and infrastructural expansion after vertical farming, hydroponics, aerophonic, smart agriculture, and market horticulture. Sustainable industrial growth may be possible when AI boosts digital platform (mobile application, software, etc.) making agricultural system more robust against climate change and land pollution.

5. SDG-12 aims at responsible consumption and production based on efficient and ensured agricultural system. Innovation in food storage, waste, consumption, and sustainable production system reduces carbon footprint from land use processes.
6. SDG-13 focuses on climate action only after sustainable land use and agricultural innovation like afforestation, agroforestry, and reforestation. The sustainable land use practices in cultivation process have reduced the emissions of greenhouse gases, resultantly an agricultural system become climate resilient.
7. SDG-14 points at life below water. This goal targets water-based agriculture, fishing and restricted water, and land pollution. The SLU avoids the use of chemical fertilizer, on the one hand, and the Al restricts the farming system from unsustainable chemical process along canal, river, and irrigation sources on the other hand.
8. SDG-15 explains about life on land. To make sustainable life practice of plants and animal including agriculture, it is required to halt desertification, land pollution, soil erosion, alkalinity, and salinity problem. The SLUP can boost economic prosperity if existing land resources get due concern from management, planning, attention, and focus.

The adaptation of SLU and leveraging of AI can promote agroforestry, precision agriculture, regenerative farming, and climate-resilient agriculture.

The title of this book can be looked under following two heads, namely sustainable land use in agriculture and agricultural innovation. In the following section, existing literatures from these fields have been analysed with sources and findings. The literatures from the world, India, and local levels are presented coherently.

Sustainable Land Use in Agriculture

World

Tanrivermis (2003) examined that the intensification of agricultural land use geared up by agricultural mechanization, use of agri-chemicals, rapid population growth, industrialization, urbanization leads to the deterioration of soil quality as well as the environment. Therefore, he suggested new legal and institutional regulations which integrate agricultural policies and environmental concerns for sustainable land use management.

A study by Zhao et al. (2008) discussed the concepts and aims of sustainable agricultural development in China with reference to land use practices. They pointed out some obstacles of sustainable agricultural innovation, i.e., water use shortage, cultivated land loss, inappropriate usage of fertilizers and pesticides, and environmental degradation which limit appropriate land use practices. To promote sustainable land use practice, the need of the hour is the requirement of long-term policy intervention along with positive public response towards appropriate measures.

A study on ‘Multifunctional Urban Agriculture for Sustainable Land Use Planning in the United States’ by Lovell (2010) discussed that how urban agriculture offers a viable alternative in city areas for improving sustainability of land use. The study looks forward for viable alternatives such as new strategies, policies, and program through government funding to protect and improve complex urban ecosystem though sustainable land use practices. To face climate change impact on urban life, climate-resilient agriculture with agricultural innovation will attribute positively.

The benefit of agroforestry practices for the sustainable land use system in Nigeria has been discussed by Alao and Shuaibu (2013). They concluded that optimal use of land for agriculture along with forestry production not only increases food and sustainable wood production but also improves the soil quality.

Mockel (2015) highlighted the importance of standard tested technologies and methods such as integrated pest protection, organic farming, precision farming, and conservation tillage to make sustainable land use in agricultural. The high level of emission from agriculture, environmental pollution, and productivity barrier makes European agricultural land use less fertile. Apart from positive check on pollution, introduction of efficient technologies is equally essential for sustainable land use.

India

Jayakumar and Arockiasamy (2003) analysed the land use land cover change of the Eastern Ghats in Tamil Nadu. They suggested some remedial measures, i.e., regular testing of soil, selection of crops based on soil properties and climatic condition, crop rotation, land management, and application of manure and pesticides for the optimum and sustainable utilization of land resources.

The consequence of agricultural expansion by overexploitation of forest causes serious ecological and environmental problems in Kerala (Kumar, 2005). Agroforestry holds promise in order to mitigate these problems. Therefore, it has been suggested that the state should provide attention for the adoption of agro-forestry practices to protect sustainable land use over irregular expansion of agricultural practices.

Srivastava et al. (2016) proposed a commercial ecological agriculture with least disturbing, resilience building, resource use efficient, labour and skill intensive, low input, and diversified system to achieve land use sustainability in existing agroecosystem. By doing this, it would improve and restore the soil quality as well as increase the productivity.

A study on ‘Impact of Sustainable Land-Use Management Practices on Soil Carbon Storage and Soil Quality in Goa State, India’ by Paramesh et al. (2021) recommended sustainable agriculture with alternative land use system in the hills and sequential cropping in coastal plains to enhance soil organic carbon, improve soil quality and, increase farmer’s income at various capacity.

Crop diversification, an important dimension of agricultural development, benefits us ecologically, environmentally, economically, and sustainably over time and space (Rahaman, 2021). Crops diversification across land size classes provides sustainable land use practices across the blocks in Malda district of West Bengal and promotes regenerative agricultural system across the district.

West Bengal

A study by Jana et al. (2015) on 'Multiplier Effect of Home Gardening' in sustainable land use practice found that the food and nutritional security, employment generation, and maintaining soil health are the best possible outcome from annual and perennial cropping, shrub, and fisheries. The households with a high level of education using modern inputs generate more revenues from sustainable agricultural practices i.e., home gardening.

In a study, Ghosh and Chakma (2018) measured the sustainability of agricultural land use applying ecological footprint method. The study revealed that agricultural production relative to population demand of food represents a higher sustainable agricultural system, while crop-wise assessment explored some negative aspects with respect to land utilization and cropping pattern. Hence, the study urged necessary shifting of existing cropping pattern for agricultural sustainability.

Parihari et al. (2021) assessed the land suitability for appropriate crop suggestion using GIS-based sustainable agricultural production. In the study, they found that rice is a highly suitable crop in the given land followed by wheat, sugarcane, and cashew. For effective cropping measures and sustainable production, along with mapping, the proper and timely intervention is required keeping in mind temporal and spatial changes.

The pattern and impact of agricultural land use practices on livelihood assets of farmer in Malda district (Mandal & Saha, 2013) revealed that the socioeconomic conditions and regional economy have great impacts on changing land use pattern of local farmers irrespective of other essential criterion.

Agricultural Innovation

World

Feder and Umali (1993) conducted a review on 'adoption of agricultural innovation and the impact of policy intervention that promotes technology adoption'. The study revealed that all types of technology, market structures, and the nature and duration of the policy intervention under different agro-climatic regions directly impact technological adoption in green revolution technology diffusion at different stages of agriculture.

The role of agri-technological innovation for climate adaptation in agriculture in Ontario, Canada, was explored by Smithers and Blay-Palmer (2001). They concluded the study by recommending that technological innovation in agriculture be promoted, but only after accounting for climate adaptation.

Ariza et al. (2013) tried to develop a framework for measuring innovation and its key determinants in agriculture firms in Colombia. Based on three main tools, i.e., Innovation Matrix, Innovation Index, and Econometric Model, they have classified the technological level of every innovation as the major, intermediate, and minor level of advancement.

A study by Lapple et al. (2015), titled 'Measuring and Understanding the Drivers of Agricultural Innovation: Evidence from Ireland,' found that farm size, production intensity, access to credit, and agricultural education positively drive agricultural innovation. In contrast, older farmer age and off-farm employment act as barriers to innovation.

In a case study of Nigeria, Ogunniyi et al. (2017) revealed that the households implementing agricultural innovation led by agricultural research programs had a better livelihood, productivity, and more diversified income.

India

A study conducted on 'Agricultural Innovations Among Indian Farmers' by Roy (1968) discovered that the diffusion of agricultural innovation is strongly related to social status, education, and personal contact with the outside world, overshadowing the fragmentation, commercialisation, specialisation, and farm efficiency effects. Socioeconomic status and exposure of mass media also play vital roles to innovation practices in agriculture.

Ali (2016) found that smallholder vegetable growers having land size less than 2 ha are more inclined towards adaptation of innovative agricultural practices, i.e., crop rotation, usage of green manure, diversification crops, sorting and grading of production, and market and price analysis.

Tanti et al. (2022) discussed the importance of agricultural innovation in adopting institutional roles, such as subsidies on farm machinery, credit facilities, extension supports, and field demonstration of technologies by smallholder farmers for climate-smart agriculture.

A study on 'An Empirical Analysis on Adoption of Precision Agricultural Techniques Among Farmers of Punjab for Efficient Land Administration' conducted by Khanna and Kaur (2023) revealed that several constraints such as non-awareness of innovative techniques by framers, financial limitation, issue related to cost, etc., are the main hurdles for the non-adaptability of innovative agricultural techniques and practices.

West Bengal

Ghosh (2010) has claimed that the mechanization of farms is strongly determined by irrigation, access to institutional credits, size of landholdings, and proportion of HYV and fertilizer-intensive crops. The mechanized form of agriculture has the ability to promote innovation in which young age farmers are more adaptive than old block farmers.

The failure of three institutional factors, i.e., comprehension, customization, and generalization of Technology Transfer Training (TTT) is responsible for the lag in the process of technology adoption by farmers (Chandra et al., 2018). The AI is compromised when institutional barrier hinders the use and availability of modern and updated technologies.

Reddy et al. (2020) argued in a study that adopting innovative approaches in sustainable intensification, diversification, market reforms, and access to livelihood capitals can lead to the inclusive sustainable intensification of agriculture in West Bengal.

A study by Reddy et al. (2020), titled 'Inclusive Sustainable Intensification of Agriculture in West Bengal, India: Policy and Institutional Approaches,' highlights that the absence of coherent and comprehensive policies and programs is a key constraint contributing to unsustainable agricultural practices. To promote and adopt inclusive, sustainable agricultural innovations, synergy among various formal and informal institutions including panchayat Raj institutions is needed.

Nature of Problems

One of the major problems facing India today is the decreasing man–land ratio. In this situation, the land must be utilized properly and preciously to its full capacity. Another major problem of Indian agriculture is the small and fragmented landholding, as is the case of the Murshidabad district. It directly influences agricultural land use as the size of the landholding decides the degree of risk for the farmers. The identification of suitable cropping patterns for specific regions governs the overall success of agricultural innovation. The cropping pattern reveals that most of the farming land in the study region is covered by food crops. Rice, wheat, maize, gram, etc., are important staple crops that are found in the district. With the development of irrigation and other technological factors, commercial food crops, fruits, and vegetables are gradually occupying land under cash crops. These changing scenarios in cropping patterns indicate the changes in overall agricultural innovation.

Agriculture occupies an important place in India's economy, especially in West Bengal, where it contributes 21.87% (State Economy, Govt. of West Bengal, 2019–2020) to the state domestic product (SDP). In West Bengal, agriculture remains the backbone and crucial to the state economy as around 70% (Statistical Abstract of West Bengal, 2019) of rural lives, directly and indirectly, depend on it.

Besides the structural transformation of the state economy, the contribution of agriculture in SDP follows a declining trend from 41.16% in 1970–1971 to 21.87% in 2019–2020 (Rahaman, 2020). Therefore, the development of this sector is the primary concern for planners and geographers to find out means and ways for overall development.

In India, agricultural innovation was paved over for the first time when the first 5-year plan (1951–1956) was initiated. Agriculture was given as the first priority in the third 5-year plan. The primary aim was to increase food production and raw materials for different industries substantially. The government realizes that the nation needs to focus on rapid growth of agricultural sector to sustain and maintain a higher tempo of industrial development. But in true sense, agricultural innovation in India enlightens the academic discussion shortly after introducing the 'Green Revolution' in the country.

Green revolution brings high-yielding variety (HYV) seeds, new implements and machineries, extended irrigation facilities, and improved fertilizers and pesticides to Indian agriculture. Previously, Indian agriculture was characterized by a subsistence farming system, primitive cultivation techniques, and low yields. On the brighter side, the green revolution helps stabilize the country's food crisis and reaches beyond sufficient food production. At the cost of bumper production and productivity, soil sustainability drastically reduced; as a result, salinity, alkalinity, and loss of fertility have become the new reality of the green revolution in India. The introduction of HYV seeds in the country has doubled the yields of crops, especially the food grain crops, but this has led to inter-regional disparities in Indian agriculture (Chakravarti, 1973). The bumping drawback of the green revolution, the evergrowing population, and the new food security policy have slowed down agricultural contribution to the national economy (Misra & Puri, 2011).

The sudden innovation in agriculture due to the green revolution has created many problems in rural India. The rapid change in production caused economic imbalance among the farmers, thereby creating interregional agricultural disparities. In order to enable planning and execution, the government has started counting the agricultural situation of the country. This led to the initiation of the first-ever comprehensive Agriculture Census in 1970–71. The Agriculture Census has been conducted every 5 years since then to measure the extent and pattern of the agricultural situation in the country. The primary purpose of the first Agriculture Census was to collect statistics related to the various aspects of agriculture to improve farmers' income and living standards. Soon after the second Agriculture Census, it came to light that there was a horizontal expansion of agricultural land use as the barren lands, uncultivated lands, and culturable wastelands were brought back to cultivation.

Once again, in 1992, the agricultural innovation and land use pattern got reshaped as liberalization, privatization, and globalization (LPG) brought new market opportunities to the farmers. As a result, the vertical expansion of agriculture begins. Farmers started shifting from traditional to export-oriented crops, as evident from various research publications (Rahaman, 2020).

In the Murshidabad district, 80.28% of people (District Census Handbook, 2011) are still living in rural areas where agriculture is the principal occupation. About 75% of the total geographical area in this study region is under the net show area. However, the major problem is that more than 96% of the landholders are marginal and small farmers. Thus, it becomes essential to point out the major problems of the farmers regarding agricultural land use and how these problems can be solved through better agricultural land use planning. Therefore, this study will examine the changing pattern of sustainable agricultural land use intensity and highlight how these changing patterns from traditional to commercial crops lead to overall success in agricultural innovation.

Previously available literature suggests that an increase in agricultural land use through proper land utilization and remunerative cropping patterns significantly impacts the structural transformation of agricultural innovation. While judging these findings, it may be noted that these studies are done in various micro-locations in the country or at the district or state levels using either primary household data or secondary data relating to different time periods. Since agricultural land use is a continuing process that changes over time and across space, it is necessary to investigate such studies for different regions of the country using both aggregate and household data. This study is set in this broader framework in the Murshidabad district of West Bengal. It may be noted that there exists hardly any study on this subject for the district.

According to the 2015–16 Agriculture Census, Murshidabad district of West Bengal became home for more than 96% of farmers having a land size of fewer than 2 ha. Traditional low-intensive, subsistence, and low-commercial agriculture boost their income and livelihood at a plodding pace. The district identifies several constraints, such as decreasing groundwater table, climate change and variability, irregular monsoon rainfall, lack of inputs and technological adaptation, instability and volatility of prices of different crops, slowed down public investments, etc. In this context, this work on 'Sustainable Land Use Practices and Agricultural Innovations in India: A Case Study from Murshidabad District of West Bengal' has become a subject of exciting discussion.

Significance of the Study

The increasing pressure of population creates crucial problems on the limited land resources. Therefore, it is very significant to study the use and misuse of land, its exploitation, and conservation for the welfare of human beings, society, and the country. It can only get through proper planning of land resources which suggests that optimum utilization of land resources must contribute to the maximum of its capacity and must serve some valuable purpose to the society. It has been observed that rapid population growth during the last few decades creates changes to the utilization pattern of land by converting agricultural land into settlements, forests into cropland, and others. The scope of this study encompasses important elements of land use related to agricultural land use intensity, cropping pattern, cropping intensity, crop productivity, and innovations of agricultural and land use planning. Land use planning must emphasize the sustainable use of land for various purposes. Every piece of land should be checked and adequately utilized; otherwise, once it is changed into settlements, it will never return to the farmers. India supports more than 18% of the world's population, but it has only about 2.4% land area of the world. Thus, such a vast population is a matter of consideration which clearly indicates the need to enhance the agricultural innovation process to meet these challenges. Therefore, this study has attempted to focus on changes in land use patterns with the main focus on agricultural land use and how these changes lead to the innovation process of agriculture in the selected study area.

Choice of the Topic and Study Area

The scale of problem is fundamental in geographical studies. In agricultural geography, data is collected and observations are generalized. A district-level study would provide a frame at the micro-level on which further research can be based. Keeping this in mind, the Murshidabad district of West Bengal has been chosen as an area of investigation. Several considerations influence the choice. Firstly, little work has been done to assess the significance of various physio-socio-economic factors concerning agriculture in the Murshidabad district. It is felt that such a study at the micro-level would provide a valuable approach for obtaining a complete understanding of the problems of agriculture in the region. Secondly, Murshidabad district has a significant location with respect to agriculture in the state and country. The district is a good representation of geology, physiography, climate, drainage, natural vegetation, soils, and other socio-economic phenomena. Therefore, the study of agricultural land use will help to a certain extent to understand the agricultural geography of the district. Thirdly, the district has a varied physical base, i.e., it represents significant variations in topography. Thus, it is possible to evaluate the influence of various physical elements on agricultural land use. All these considerations have led to the choice of Murshidabad district as the region for this study in order to understand the agricultural land use of the region from a time–space perspective.

Research Question

Agricultural land use is an essential dimension of the agricultural innovation of a region. It is directly related to the pattern of the cropping system as well as the intensity of cropping. Hence, the improvement in the agricultural land use pattern assumes better agricultural output across different land size categories in the district. Here is the research question:

> In the present context, can changing agricultural innovation ensure sustainable land use practices in Murshidabad district?

Objectives

This study is committed to answering the research question raised by the researchers. For this purpose, five objectives and three hypotheses have been framed. This study aims to examine the pattern of change, various factors influencing it, and its contribution to the overall innovation of agriculture. The specific objectives of the study are the following:

1. To examine the status of sustainable agricultural land use and cropping pattern changes under different land size categories at the block level.
2. To measure the level of agricultural innovation across land size class categories at the block level.
3. To estimate the impact of input–output dimensions of agricultural innovation on agricultural land use across land size classes at the block level.
4. To find out the major factors influencing agricultural innovation and sustainable land use practice under different land size classes in the sampled villages.
5. To suggest some policy-based interventions for sustainable agricultural land use and agricultural innovation in Murshidabad district.

Hypotheses

The following three hypotheses set as null are to be tested for rejection under the assumption that they are true:

1. **Ho**: There is no significant difference in the amount of change in agricultural land use across different land size categories.
2. **Ho**: Agricultural input negatively correlates with agricultural output under different land size classes.
3. **Ho**: Agricultural land use is not significantly related to overall agricultural innovation across land size categories.

Database

This work is constituted from both primary and secondary sources of data.

Primary Data

Twenty-six (26) villages have been carefully chosen for micro-level study. Here one village is selected from each block. Only villages populated by the maximum number of cultivators in the 2011 Census of India have been selected for the study. The systematic random sampling is used to determine 30 agricultural households from each village. The representativeness (as used by NSSO, Agriculture Census, and others) is the only criterion for selecting 30 sample sizes. Thereby, a total of 780 households have been surveyed through scheduled questionnaires.

Secondary Data

Secondary data is obtained from the following sources:

1. Agriculture Census of India
2. Input Survey, Govt. of India
3. Census of India
4. National Sample Survey
5. Statistical Handbook of Murshidabad
6. Office of the DDA Admin., Murshidabad
7. Office of the Horticultural Department, Murshidabad
8. Office of the Soil Testing Laboratory, Murshidabad
9. Reports on Strategic Research and Extension Plan of Murshidabad (SREP)
10. Agricultural Technology Management Agency (ATMA), Murshidabad
11. District Irrigation Plan Book, Murshidabad

Data for a few variables which are not available for the census year 2015–16 have been extrapolated. For the extrapolation, first, the data of the Agriculture Census 2005–06 and 2011 were interpolated, and then the average of the last 3 years was taken as actual data for 2015–16. The same technique is used for the 2006–07 and 2011–12 Input Survey data to get the 2016–17 data.

$$\text{Interpolation} = \frac{\text{Base year data} + \left(\text{Recent year data} - \text{Base year data}\right)}{\text{Number of years}\left(\text{Here five}\right)}$$

Here, for Agriculture Census data, the base year is 2005–06, and the recent year is 2010–11. For Input Survey data, the base and recent years are 2006–07 and 2011–12, respectively.

For the data split, the number of households and gross cropped area are taken as the base of the block.

Methodology

Qualitative and quantitative methods have been used for data analysis and mining in the study.

Qualitative Techniques

Strengths, weaknesses, opportunities, and threats (SWOT) analysis is a purely qualitative technique used in Chap. 6.

Quantitative Techniques

1. The UNDP method is applied to compute index value and composite standardized score. We know that Human Development Index (HDI), Gender Inequality Index (GII), and Multidimensional Poverty Index by UNDP and agricultural development in India (ministerial report) have been prepared by using the UNDP method. The standardization technique of the UNDP method is mentioned below:

   - For positive variables

$$\frac{(\text{Actual Value} - \text{Minimum Value})}{(\text{Maximum Value} - \text{Minimum Value})}$$

   - For negative variables

$$\frac{(\text{Maximum Value} - \text{Actual Value})}{(\text{Maximum Value} - \text{Minimum Value})}$$

The minimum value would be 0, and the maximum would be 100 if the data is in percentage form. Otherwise, the maximum and minimum values are considered from the table value when the data is in absolute numbers.

2. Yang's Yield Index used to compute productivity indices

Name of the crops	The area under crop in the block	Yield in quintal/ha		Crop yield in the block as the percentage of the district	Percentage multiplied by area (in ha)
		Average yield in the block	Average yield in the district		
1	2	3	4	5 = col. 3/ col. 4 * 100	6 = col.5 * col. 2

3. Gibbs-Martin's technique is used to calculate the crop diversification index. The index is computed as follows:

$$\text{Crop Diversification Index} = 1 - \frac{\Sigma X^2}{(\Sigma X)^2}$$

Here, X is the percentage of the total cropped area occupied by an individual crop at a point of time. The index value of this technique ranges from 0 to 1. The crop diversification seems to be higher when the index value approaches 1, while the value reaching near 0 reflects a specialization of crop cultivation.

4. To calculate cropping intensity, the following formula is used:

$$\text{Cropping Intensity} = \frac{\text{Gross Cropped Area}}{\text{Net Area Sown}} \times 100$$

5. Karl Pearson's correlation of coefficient is used to check the degree of association between input and output dimensions of agricultural development. The equation for the calculation of Karl Pearson's coefficient of correlation is given below:

$$\mathbf{r} = \frac{\Sigma(\mathbf{X} - \bar{\mathbf{X}})(\mathbf{Y} - \bar{\mathbf{Y}})}{\sqrt{\Sigma(\mathbf{X} - \bar{\mathbf{X}})^2 \, \Sigma(\mathbf{Y} - \bar{\mathbf{Y}})^2}}$$

where $\bar{\mathbf{X}}$ is the mean of **X** variable, and $\bar{\mathbf{Y}}$ is the mean of **Y** variable

6. .The multiple linear regression model, focusing on the ordinary least square (OLS) method used for the estimation of the model's parameter, is statistically formalized as follows:

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_{p-1} x_{i,p-1} + \varepsilon_i$$

where y_i represents the outcome or dependent variable, β_0 is the intercept (the mean of y when all $x_k = 0$), each β_k ($k = 1, 2, \ldots, p - 1$) represents a slope or estimated coefficient concerning the explanatory variables x_i ($i = 1, 2, \ldots, n$ unit of observations), and ε_i is the random error with a prior expectation of 0 and variance σ^2.

7. ANOVA, Karl Pearson's correlation coefficient and T-test have been used to test a significant level of framed hypotheses.

Data are processed in Excel and SPSS spreadsheets. Jamovi 2.3.2, IBM SPSS Statistics 20, and Excel have been used to calculate and run the statistical tests. Moreover, the maps and charts are prepared in ArcMap 10.5 and Excel.

Chapter Outline

This study comprises six chapters, excluding the introduction and conclusion.

The introductory section discusses the background, literatures, the statement of problem, the significance of the study, the choice of the topic and area, the research question, objectives and hypotheses, and the database and methodology for a meaningful shape of the study.

Chapter 1 deals with the overview of the study area. Here, different aspects of the physical and cultural set-up of the Murshidabad district are presented with various maps and diagrams and related data.

Chapter 2 contains the sustainable land use dynamics and cropping patterns under different land size categories in the Murshidabad district. After that, agricultural land use transformation is analysed and discussed in a spatial context across land size categories at two points of time at the block level. The last section deals with the reasons for agricultural land use changes through field survey data.

Chapter 3 analyses input and output determinants of agricultural innovation. A detailed account of the variables of input and output determinants of agricultural innovation is discussed first, and then the degree of association between them is analysed. The last section discusses the overall agricultural innovation concerning the input and output aspects at spatial context under different land size classes in two points of time.

Chapter 4 is devoted to understand the relationship between sustainable agricultural land use and agricultural innovation in the district. The association between agricultural land use and agricultural innovation is measured statistically through multiple regression analysis under different land size categories. Following this, a section on unit-wise change of these two domains is explained at the block level across land size classes, where the input and output dimensions of agricultural innovation are measured with comparisons of per unit change of sustainable agricultural land use.

Chapter 5 presents an analysis based on a household survey to check the sustainable agricultural land use and innovation relation further at the micro-level. The first section describes the physical, socio-economic, and demographic characteristics of the sample villages, and then the agricultural situation of these villages is explained in the next section.

Chapter 6 assesses the issues and challenges of agricultural innovation with respect to existing policies, programs, schemes, and projects introduced by the government for the district. Here, strengths, weaknesses, opportunities, and threats (SWOT) are discussed to identify key factors of agriculture in particular and the innovation process in general. A highlight of area-specific (village-level in this case) constraints faced by the farmers using a rating scale is discussed in the next section. Lastly, the evidence-based policy intervention has been suggested to sort out existing problems.

The study sums up with a summary of findings, suggestions, and conclusions.

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Chapter 1
Overview of the Study Area

Contents

The preceding introductory section discusses the background, importance, nature of problem, research question, objectives and hypotheses, database, and methodology for a meaningful shape of the study. This chapter analyses the different human and

H. Rahaman, S. Ansari, *Sustainable Land Use Practices and Agricultural Innovations in India*, https://doi.org/10.1007/978-3-031-83246-8_1

physical aspects of the study area, i.e., Murshidabad district. The first section of this chapter deals with the background of the district, where the location of the study area, a brief history, and present administrative divisions are presented. The physical features such as physiography, geological structure, drainage pattern, beels, and soil of the study area are discussed in the second section. Subsequently, the aspects like climate, flora and fauna, demographic profile, economic elements, and transport have been interpreted in the following section. Various maps and diagrams have been put up to illustrate the data in the next sections.

1.1 Background of the District

1.1.1 Location of the Study Area

The Murshidabad district, the northernmost district of the presidency division, is located in the middle part of West Bengal, lying between 23° 43′ 30″ and 24° 50′ 20″ North latitudes and 87° 49′ 17″ and 88° 46′ 00″ East longitudes (District Census Handbook, 2011) (Fig. 1.1). It is entirely situated in the north of the Tropic of Cancer. The lower flow of river Ganga, bifurcated to Padma and Bhagirathi near

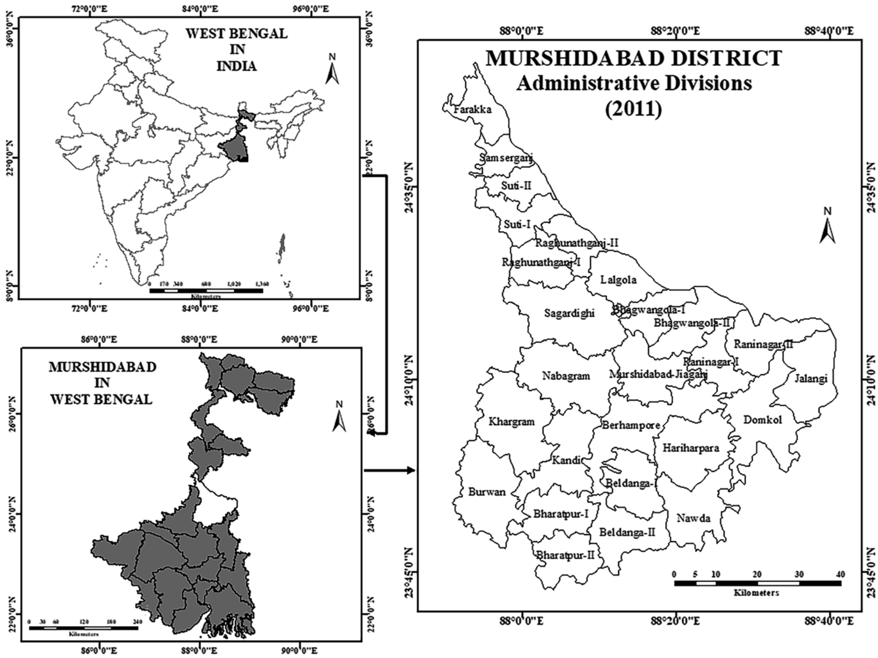

Fig. 1.1 Location of Murshidabad district. (Source: Base Map from Census of India)

Debipur of Suti-II block, creates a natural boundary of the district. The blossoming flow of the Padma River forms the northern and eastern borders of the district, separating the district from Malda district to the north and Bangladesh to the east. It is bounded by Burdwan and Nadia districts to the southern side. The state of Jharkhand (Pakur and Sahibganj districts) and Birbhum district form the western boundary of the district. The district covers 125.35 km of international borders with Bangladesh of 10 CD blocks, of which 42.35 km is on land. The remaining distance is covered by riverine boundaries (Padma River and her connected streams).

It is the seventh biggest district of West Bengal (covering 6.13% of the total geographical area of the state), spreading over an area of 5324 km^2, out of which rural and urban areas cover 5195.11 and 128.89 km^2, respectively (Census of India, 2011). The district's headquarters is Berhampore, situated at 24° 05′ 54″ North latitude and 88° 16′ 06″ East longitude.

1.1.2 Brief History of the District

The Murshidabad district has a long history that dates back to ancient India. During the fifth century AD, some portion of the present district belonged to the territory of the Gupta Empire. Then after, Sasanka ruled over almost the whole district during the seventh century AD. The capital city of his empire was Karnasubarna, which is presently located at the Kandi-Subdivision of the district. The historical literature pointed out that different dynasties ruled the district from seventh to seventeenth century AD. According to the Khalimpur copperplate inscription, the foundation of the Pal dynasty was led by Gopal around 750 AD. It lasted until 1144 AD, when Vijay Sen defeated Madan Pal, the last ruler of the Pal dynasty. The Sen dynasty was the last Hindu-ruled dynasty before the invasion of the Sultanate Empire by Bakhtiyar Khalji. After the termination of sultanate rule, Shahi dynasties and Sher Shah Suri ruled briefly over the district.

Thereafter the Mughal Empire's era began, which ruled till 1757 AD when Siraj-ud-Daulah, the last sovereign ruler of Bengal, lost the battle of Plassey to the East India Company. In 1765 AD, with the grant of Diwani, the East India Company took over the revenue management authority for the whole of Bengal. Soon after taking control, they shifted the centre of power from Murshidabad to Calcutta. It is interesting to mention that the district was initially known as Makhsudabad (meaning the selected city). In 1704 AD, Nawab Murshid Quli Khan renamed the town Murshidabad and transferred the capital city from Dacca (now Dhaka, Bangladesh) to Murshidabad. The unit and boundaries of the district were finalized in 1879. Since then, the present set-up of Murshidabad district has remained the same along with the boundaries.

1.1.3 Administrative Divisions

The Murshidabad district is comprised of 26 CD blocks and seven municipalities under five sub-divisions for the sake of smooth administrative functions. These five sub-divisions are Sadar, Kandi, Jangipur, Lalbagh, and Domkal. The Sadar sub-division comprises eight police stations responsible for maintaining law and order in five blocks and two municipalities, namely Berhampore, Beldanga-I, Beldanga-II, Nawda, Hariharpara, Berhampore (M), and Beldanga (M). Similarly, Kandi, Khargram, Burwan, Bharatpur-I, and Bharatpur-II are the five blocks along with Kandi municipality that come under the security of five police stations in Kandi sub-divisions. Jangipur sub-division comprises six police stations for seven blocks and two municipalities. These are Farakka, Samserganj, Suti-I, Suti-II, Raghunathganj-I, Raghunathganj-II, and Sagardighi. Jangipur and Dhuliyan are the two municipalities situated in this sub-division. The five blocks administered by six police stations in the Lalbagh sub-division are Lalgola, Bhagwangola-I, Bhagwangola-II, Murshidabad-Jiaganj, and Nabagram. Adding to this, two municipalities are also there: Murshidabad and Jiaganj-Azimganj. The Domkal sub-division comprises four police stations that bring law and order in four blocks, i.e., Domkal, Jalangi, Raninagar-I, and Raninagar-II (see Annexure A.1).

In the district, the highest institution for local governance is the Murshidabad Zilla Parishad or District Council. Every community development block corresponding to the Zilla Parishad is the Panchayat Samiti. A total of 254 gram panchayats and 4245 Gram Sansads fall under the jurisdiction of Zilla Parishad in the district, covering 1886 inhabited villages. There are 128 wards classified under seven different municipalities. The municipalities are responsible for the functioning of urban governance. Annexure A.1 reveals that the district has 72 census towns (according to the 2011 census) found in all the sub-divisions except for the Domkal sub-division.

1.2 Physical Setting

1.2.1 Physiography

The river Bhagirathi, flowing from northern to southern, plays a vital role in the study area, which divides the district into two topographical divisions, i.e., Rarh area (western part of Bhagirathi) and Bagri (east of Bhagirathi). The western part of the river reveals rugged terrain, locally known as Rarh, and a flat and rolling plain on the eastern side known as Bagri. These two physiographic divisions are almost equal in size but strikingly different in their relief, geology, soil, etc. The Rarh region is comprised of Farakka, Samserganj, Suti-I, Suti-II, Raghunathganj-I, Raghunathganj-II, Nabagram, Khargram, Burwan, Kandi, Bharatpur-I, and Bharatpur-II blocks, while the rest of the blocks are in the side of the Bagri region (Fig. 1.2).

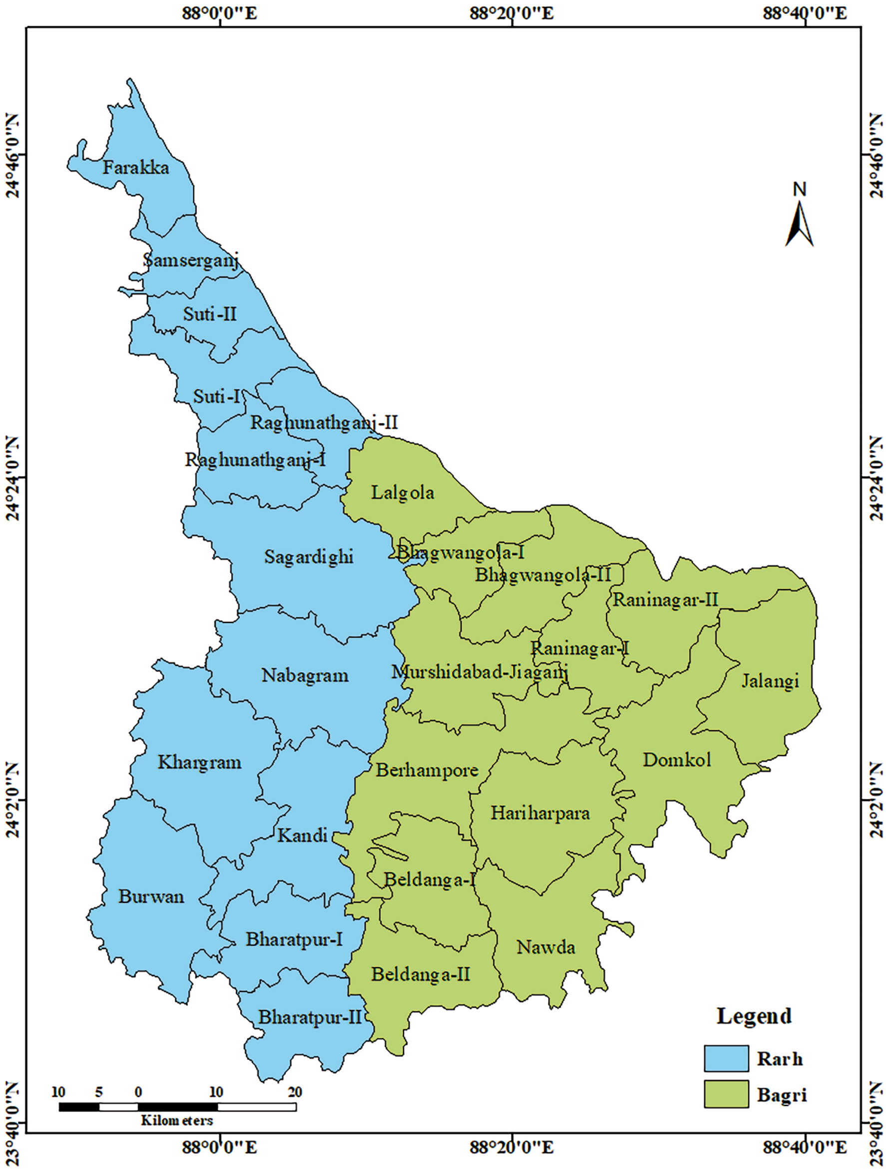

Fig. 1.2 Physiographic divisions of Murshidabad district. (Source: Based on Annexure A.1)

The western part of the study region, the Rarh, represents undulating and rugged terrain and is intercepted by several swamps and beds of old rivers. It is composed of mostly clay and laterite clay type of soil and is primarily a continuation of the sub-Vindhyan region. The altitude of this region is comparatively higher than the eastern region. As we move further, the elevation rises towards the west edge,