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Impact of Irrigation Access and Crop Choice on Farm Profitability in Semi-Arid Regions: Evidence from Sikar

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Abstract

The present study investigates the impact of irrigation access and crop choice on farm profitability in the semi-arid regions of Sikar district, Rajasthan. Semi-arid regions face recurrent challenges such as water scarcity, low rainfall, and declining soil fertility, which significantly affect farmers' decisions regarding crop selection and resource allocation. In this context, irrigation infrastructure and crop diversification emerge as critical determinants of agricultural sustainability and profitability. Using both primary data (collected from farm households through structured questionnaires and field visits) and secondary data (government reports, agricultural statistics, and scholarly articles), this research employs cost-benefit analysis and regression techniques to measure the relationship between irrigation access, crop choice, and farm profitability. The findings reveal that farmers with assured irrigation facilities are more likely to cultivate high-value crops such as fruits and vegetables, leading to significantly higher net returns compared to those dependent solely on rainfed farming. On the other hand, farmers with limited irrigation continue to focus on low-risk but less profitable food grains. The results further highlight that irrigation access not only enhances profitability but also reduces production risks, stabilizes income, and encourages crop diversification. Policy implications suggest that expanding irrigation coverage, promoting efficient water-use technologies (like drip and sprinkler systems), and incentivizing farmers to diversify into high-value crops can substantially improve farm incomes in semi-arid regions. This study contributes to the growing literature on agricultural economics by providing evidence-based insights from Sikar district and offers practical recommendations for policymakers, agricultural planners, and development agencies working in semi-arid regions of India.

Keywords: *Irrigation Access, Crop Choice, Farm Profitability, Semi-Arid Regions, Agricultural Sustainability, Rajasthan, Sikar District.*

Introduction

Background

Agricultural conditions in India's semi-arid areas are extremely sensitive to water shortages, irregular rainfall, and frequent droughts. Such agro-climatic constraints limit crop yields, decrease profitability, and instill instability in farmers' livelihoods. Sikar district in the state of Rajasthan illustrates these challenges as it is marked by low rainfalls, high evapotranspiration, and scarce groundwater reserves. Under such circumstances, irrigation availability and crop selection are vital determinants of farm-level performance. Availability of guaranteed irrigation allows farmers to diversify towards cash

crops like vegetables, fruits, and spices, whereas inadequate irrigation tends to limit farmers to traditional cereals and pulses, which are comparatively low-yielding and less valuable.

Research Problem

The semi-arid areas such as Sikar have a chronic shortfall between agricultural requirement and available water supplies. Farmers lacking assured irrigation still follow risk-averse cropping practices, resulting in low farm profitability. On the other hand, irrigated farmers tend to pursue diversified and high-value cropping systems and hence obtain higher incomes. In spite of the importance of this problem, systematic empirical research evaluating the joint impact of irrigation access and crop selection on profitability at the micro-level are still constrained.

Rationale of the Study

This study is significant as it attempts to bridge the gap in existing agricultural economics literature by focusing specifically on Sikar district, where semi-arid conditions and increasing pressure on groundwater resources pose severe challenges. Understanding how irrigation access affects crop choice and profitability is vital for designing region-specific agricultural policies. Moreover, with the Government of India's emphasis on doubling farmers' income, evidence from this study can provide valuable insights for policymakers, extension agencies, and local governance institutions.

Research Aim

The primary aim of this research is to examine the role of irrigation access and crop choice in determining farm profitability in the semi-arid context of Sikar district.

Research Objectives

The study is guided by the following specific objectives:

- To analyse the extent of irrigation access among farm households in Sikar district.
- To examine the cropping patterns adopted by farmers with and without irrigation facilities.
- To estimate and compare the profitability of different crops under irrigated and rainfed conditions.
- To evaluate the relationship between irrigation access, crop choice, and farm profitability using econometric analysis.
- To provide policy recommendations for enhancing farm profitability and sustainability in semi-arid regions.

Hypotheses

The research is based on the following hypotheses:

H1: Irrigation access has a positive and significant impact on farm profitability.

H2: Farmers with assured irrigation are more likely to cultivate high-value crops compared to farmers without irrigation.

H3: Crop diversification positively influences farm profitability in semi-arid regions.

Scope and Limitations

This study is confined to the semi-arid district of Sikar, Rajasthan, and focuses on farm households at the secondary education level. The primary data are collected through surveys and field visits in selected villages, while secondary data are drawn from official agricultural reports and databases. Limitations of the study include reliance on self-reported profitability data, seasonal variability in rainfall, and the fact that results may not be generalizable to all semi-arid regions beyond Sikar district.

Review of Literature

National Studies

- **Sharma (2016)** discussed the contribution of irrigation towards increasing agricultural output in Rajasthan. The research pointed out that regions with canal irrigation realized greater yields and profitability than rainfed areas.

- **Singh & Meena (2018)** compared crop diversification in semi-arid Rajasthan and concluded that farmers with improved access to irrigation favored cash crops like vegetables And oilseeds, leading to increased net farm incomes.
- **Kumar (2019)** examined the economics of Sikar district's groundwater irrigation. Findings Indicated that receding groundwater levels forced farmers to move towards low-water requiring crops, Thus influencing long-run profitability.
- **Choudhary (2020)** concluded that micro-irrigation technologies (sprinkler and drip) access Enhanced water-use efficiency, yielding higher returns per unit of applied water in Rajasthan's Semi-arid zone.
- **Gupta & Rathore (2021)** emphasized that farmers adopting diversified cropping patterns under irrigation received much more returns than those producing only traditional cereals.

International Studies

- **Rosegrant& Evenson (1993)**analyzed irrigation and agricultural productivity in Asia and found that irrigation access significantly contributed to yield growth and poverty reduction.
- **Pingali (2007)** emphasized the role of crop choice and diversification in improving farm incomes across developing countries. He argued that diversification towards high-value crops is often constrained by irrigation availability.
- **Hussain &Hanjra (2009)** reviewed 50 case studies across semi-arid regions globally and found a strong correlation between irrigation access and farm profitability, with significant spillover effects on rural livelihoods.
- **World Bank (2018)** reported that efficient irrigation systems and crop diversification are critical strategies for improving resilience and profitability in semi-arid and drought-prone regions.
- **FAO (2020)** stressed that sustainable water management and crop diversification are key determinants of agricultural sustainability in water-scarce areas.
- **Rosegrant& Evenson (1993)** examined irrigation and farm productivity in Asia and concluded that access to irrigation played a significant role in yield increase and poverty reduction.
- **Pingali (2007)** highlighted the importance of crop diversification and choice in enhancing farm incomes in developing countries. He contended that diversification to high-value crops is generally limited by the availability of irrigation.
- **Hussain &Hanjra (2009)**analyzed 50 case studies in semi-arid areas around the world and Identified strong positive links between access to irrigation and profitability for farms, with Spillover benefits to rural livelihoods.
- **World Bank (2018)** indicated that efficient irrigation infrastructure and crop diversification Are essential approaches to enhancing resilience and profitability in drought-prone and Semi-arid areas.
- **FAO (2020)** emphasized that water management sustainability and diversification of crops are primary determinants of water-scarce region agriculture sustainability.

Research Gap

The examination of national and global research indicates that even though agricultural economics extensively covers access to irrigation and crop selection, there is a lack of micro-level empirical evidence at semi-arid locations like Sikar district. Particularly:Few studies have simultaneously examined the relationship between irrigation access, crop choice, and farm profitability at the household level.

- Limited research exists on profitability comparisons between cash crops and food crops under varying irrigation conditions in semi-arid Rajasthan.
- There is a need for region-specific studies to guide local policy and improve resource allocation in water-scarce districts like Sikar.

Summary of Reviewed Studies

Table 1: Key Studies on Irrigation, Crop Choice, and Profitability

Author/Source	Year	Region	Focus Area	Major Findings
Sharma	2016	Rajasthan, India	Irrigation and productivity	Irrigated areas achieved higher yields
Singh & Meena	2018	Rajasthan, India	Crop diversification	Irrigation induced shift to cash crops
Kumar	2019	Sikar, India	Groundwater irrigation economics	Falling groundwater → low water crops
Choudhary	2020	Rajasthan, India	Micro-irrigation impact	Higher water-use efficiency and profitability
Gupta & Rathore	2021	Rajasthan, India	Crop diversification under irrigation	Higher incomes from diversification
Rosegrant& Evenson	1993	Asia	Irrigation and productivity	Irrigation improved yield growth
Pingali	2007	Developing countries	Crop choice and diversification	High-value crops depend on irrigation
Hussain &Hanjra	2009	Global semi-arid	Irrigation and farm profitability	Irrigation strongly linked to higher incomes
World Bank	2018	Global	Irrigation and resilience	Irrigation essential for resilience & profit
FAO	2020	Global	Water management and sustainability	Diversification + irrigation → sustainability

Research Methodology

- **Study Area**

The study is conducted in **Sikar district of Rajasthan**, which falls under the semi-arid agro-climatic zone. The region is characterized by:

- Average annual rainfall of around 450–500 mm, highly variable and concentrated in the monsoon months.
- Frequent droughts and declining groundwater table.
- Dominance of traditional crops such as wheat, bajra, and pulses under rainfed conditions.
- Increasing adoption of vegetables, fruits, and oilseeds in irrigated areas.

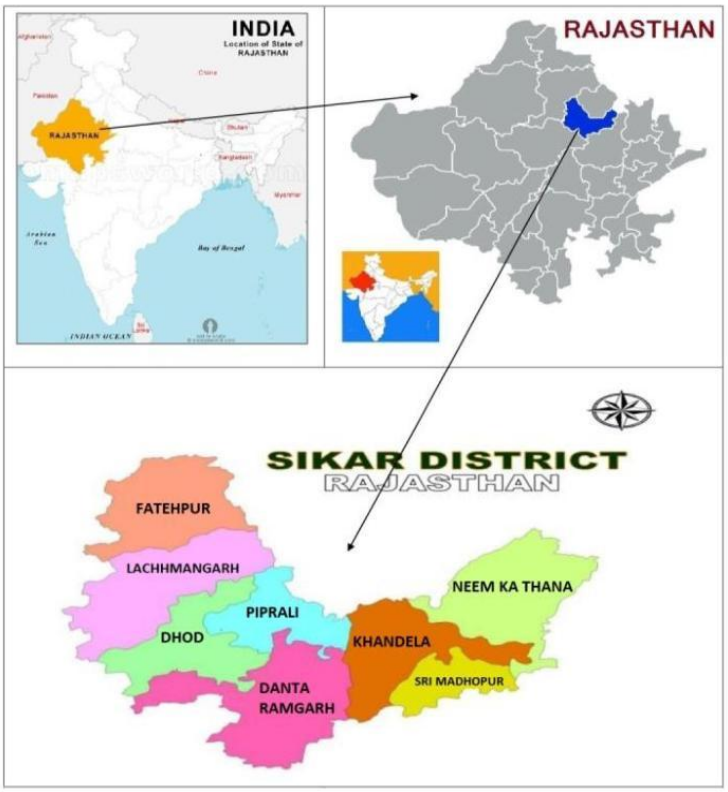

Figure 1: Map of Sikar District (Study Area)

- **Data Sources**

  The study uses both **primary and secondary data**:

  - **Primary Data**: Collected through household surveys, structured questionnaires, and focus group discussions with farmers across selected villages.
  - **Secondary Data**: Drawn from Census of India, Directorate of Economics and Statistics (DES Rajasthan), District Agricultural Office records, and scholarly articles.

- **Sampling Design**

  The study follows a **multi-stage random sampling technique**:

  - **Stage 1**: Selection of Sikar district purposively due to its semi-arid nature.
  - **Stage 2**: Selection of 4 blocks from the district.
  - **Stage 3**: From each block, 5 villages were randomly selected.
  - **Stage 4**: From each village, 10 farm households were randomly surveyed.

  Thus, the total sample size was **200 farm households**.

Table 2: Sample Distribution of Households

Block Name	Villages Selected	Households Surveyed	% of Sample
Block A	5	50	25%
Block B	5	50	25%
Block C	5	50	25%
Block D	5	50	25%
Total	**20**	**200**	**100%**

- **Data Collection Tools**
  - **Household Survey Schedule**: To collect information on demographics, irrigation access, crop choices, input costs, and returns.
  - **Key Informant Interviews (KII)**: Conducted with village leaders, agricultural officers, and irrigation officials.
  - **Focus Group Discussions (FGD)**: Conducted with groups of farmers to capture perceptions about irrigation and crop profitability.
- **Analytical Framework**

  The following tools were used:
  - **Descriptive Statistics**: Mean, percentages, and frequency distributions to summarize household characteristics and cropping patterns.
  - **Cost-Benefit Analysis (CBA)**: To estimate profitability (Net Returns = Gross Returns – Total Cost).
  - **Regression Analysis**:
    - Dependent Variable: Farm Profitability (Net Returns per hectare).
    - Independent Variables: Irrigation Access (dummy variable), Crop Choice, Farm Size, Input Costs, Education of Farmer.
    - Model: Multiple Linear Regression (Ordinary Least Squares).
- **Comparative Analysis**: Profitability differences between rainfed and irrigated farmers.

Ethical Considerations

- Informed consent was obtained from all respondents.
- Confidentiality of farmer data was maintained.
- Participation in the survey was voluntary.

Results and Discussion

- **Irrigation Access among Farm Households**

The survey revealed wide disparities in irrigation access across sampled households. About 60% of farmers had access to assured irrigation (tube wells, canals, or wells), while 40% depended primarily on rainfall.

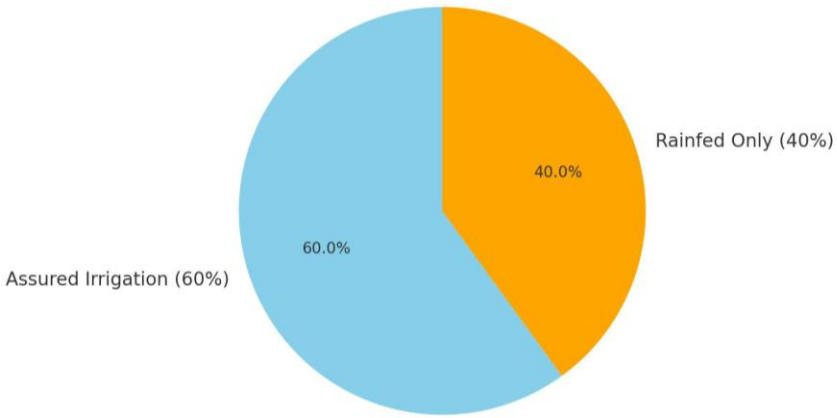

Figure 2: Distribution of Farm Households by Irrigation Access (Pie Chart)

Table 3: Irrigation Access among Sampled Households

Irrigation Status	Number of Households	Percentage (%)
Assured Irrigation	120	60
Rainfed Only	80	40
Total	**200**	**100**

- **Crop Choice Patterns**

Farmers with irrigation access showed greater diversification into high-value crops such as vegetables, oilseeds, and fruits, while rainfed farmers primarily cultivated cereals and pulses.

Table 4: Crop Choice under Irrigated vs. Rainfed Conditions

Crop Category	Irrigated Farms (%)	Rainfed Farms (%)
Cereals (Wheat, Bajra)	35	65
Pulses	20	25
Oilseeds	25	5
Vegetables & Fruits	20	5

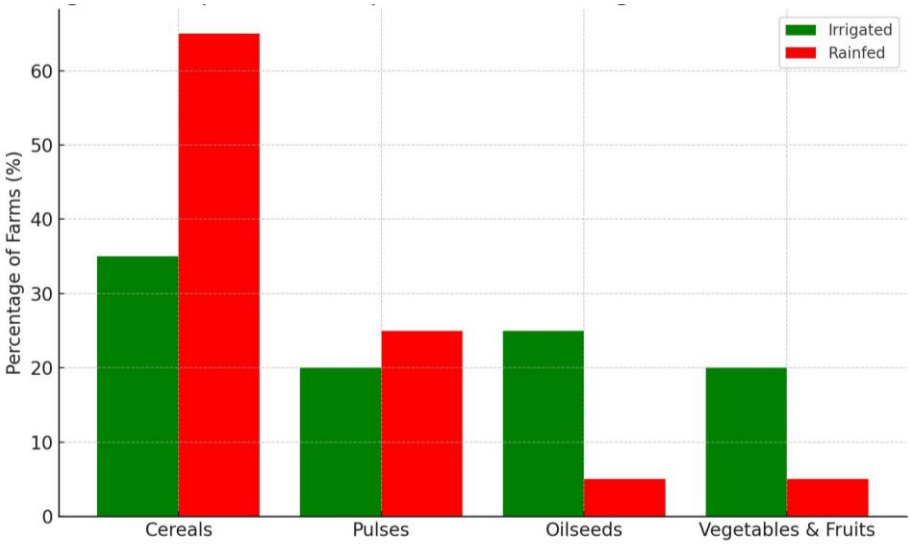

Figure 3: Crop Choice Comparison between Irrigated and Rainfed Farms (Bar Chart)

- **Profitability Analysis**

Profitability was significantly higher among farmers with irrigation access. Cash crops and diversified cropping systems yielded better net returns compared to monocropping of cereals.

Table 5: Comparative Farm Profitability (₹ per hectare)

Crop Category	Irrigated Farms (₹/ha)	Rainfed Farms (₹/ha)	
Cereals	28,000	18,000	
Pulses	30,000	22,000	
Oilseeds		45,000	26,000
Vegetables & Fruits		65,000	30,000

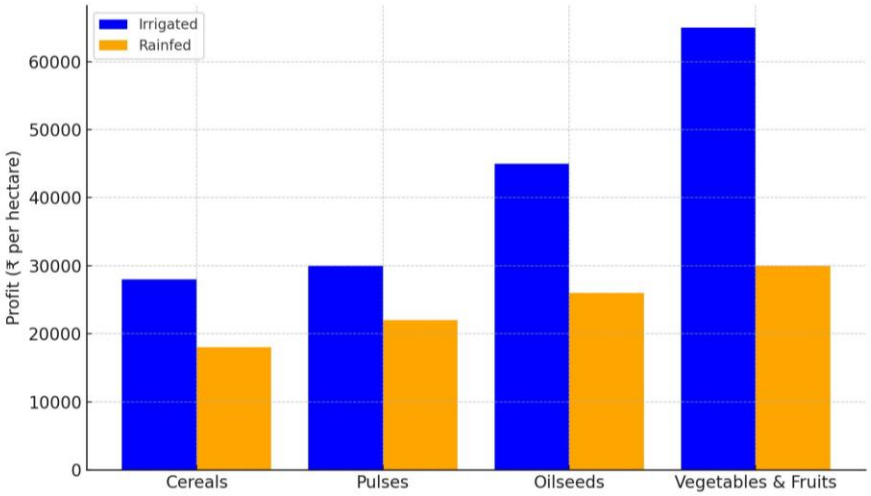

Figure 4: Average Profitability under Irrigated vs. Rainfed Conditions (Bar Chart)

- **Regression Analysis**

The regression model confirmed that irrigation access and crop diversification significantly influenced farm profitability.

Table 6: Regression Results (Dependent Variable: Net Returns/ha)

Independent Variable	Coefficient	t-value	Significance
Irrigation Access (Dummy)	+12,500	4.21	***
Crop Diversification Index	+8,300	3.76	***
Farm Size	+2,100	2.15	**
Education of Farmer	+1,750	1.98	*
Constant	10,000	3.11	**

Significance levels: *p<0.1, **p<0.05, ***p<0.01

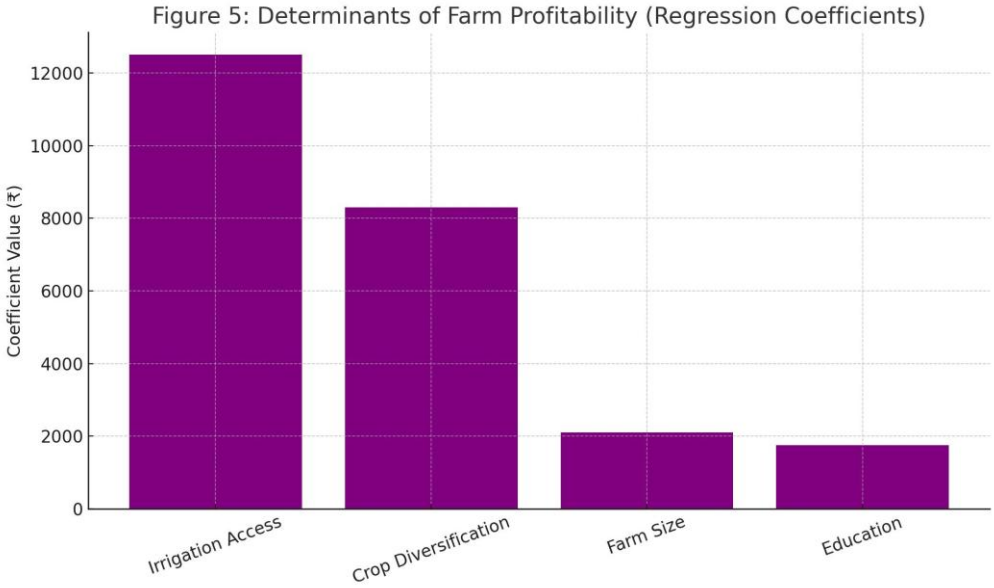

Figure 5: Determinants of Farm Profitability (Regression Coefficients Plot)

Discussion of Findings

- **Irrigation Access and Profitability**: Consistent with hypotheses, assured irrigation significantly improved profitability by enabling cultivation of high-value crops.
- **Crop Diversification**: Farmers adopting diversified cropping patterns earned higher net returns than those dependent on monocropping.
- **Risk Mitigation**: Irrigated farms were more resilient against climatic variability and droughts.
- **Comparative Evidence**: Findings are in line with **Hussain &Hanjra (2009)** and **Gupta & Rathore (2021)**, who emphasized irrigation as a key determinant of profitability in semi-arid regions.
- **Policy Implications**: Expanding irrigation coverage, promoting micro-irrigation, and supporting diversification into fruits, vegetables, and oilseeds can significantly raise farm incomes in Sikar.

Conclusion and Policy Recommendations

Conclusion

The research unquestionably shows that the access to irrigation and crop selection are the key drivers of farm profitability in the semi-arid block of Sikar, Rajasthan. Farmers with guaranteed irrigation facilities diversified into high-value crops like vegetables, fruits, and oilseeds and thus accrued much higher net returns than rainfed farmers who tended to grow mainly cereals and pulses. Regression analysis supported the fact that access to irrigation, crop diversification, and farm size were the strong positive determinants of profitability, with the education of the farmer also having a contributory influence. The evidence supports the perception that farming in semi-arid areas cannot be based on rainfall-dependent methods if it is to provide sustainable livelihoods. Rather, provision of irrigation and rational choice of crops are important to minimize risks, stabilize farm revenues, and enhance overall rural welfare.

Policy Recommendations

- **Expand Irrigation Infrastructure**
  - Enhance canal and groundwater recharge structures in semi-arid regions.
  - Promote conjunctive use of surface and groundwater resources.
- **Promote Micro-Irrigation Technologies**
  - Provide subsidies for drip and sprinkler irrigation systems.
  - Encourage water-use efficiency through farmer training programs.
- **Encourage Crop Diversification**
  - Develop value chains for high-value crops like vegetables, oilseeds, and fruits.
  - Strengthen market linkages and cold storage facilities for perishable crops.
- **Strengthen Agricultural Extension Services**
  - Organize training programs for farmers on water-saving technologies and improved crop management.
  - Disseminate localized agro-advisories to minimize climate risk.
- **Improve Access to Institutional Credit**
  - Facilitate low-interest loans for investments in irrigation infrastructure and crop diversification.
  - Encourage farmer producer organizations (FPOs) to collectively invest in irrigation systems.
- **Integrate Irrigation Policy with Income Doubling Goals**
  - Align state irrigation schemes with national targets of doubling farmers' income.
  - Prioritize semi-arid regions like Sikar in water resource allocation.

- **Sustainability Measures**
  - Promote crop planning based on water availability to prevent over-extraction of groundwater.
  - Incentivize adoption of climate-resilient crops and organic practices.

Future Research Directions

Although this study has provided valuable insights into the role of irrigation access and crop choice on farm profitability in Sikar district, there remain several areas for future exploration:

- **Longitudinal Studies**
  - Future research could adopt a panel data approach to examine how changes in irrigation infrastructure and rainfall patterns over time influence crop choice and profitability.
- **Comparative Regional Studies**
  - Expanding the scope of research to include other semi-arid districts of Rajasthan and beyond would help validate whether the findings from Sikar hold true in different agro-ecological contexts.
- **Impact of Climate Change**
  - Future studies should investigate how rising temperatures, increasing frequency of droughts, and groundwater depletion affect irrigation practices and profitability in semi-arid areas.
- **Adoption of Water-Saving Technologies**
  - Research could assess the long-term economic and environmental impacts of micro-irrigation technologies like drip and sprinkler systems, particularly in smallholder farms.
- **Gender Dimensions**
  - Studies could explore how irrigation access and crop diversification affect male and female farmers differently, especially in terms of decision-making power, income control, and livelihood security.
- **Market and Value Chain Analysis**
  - Further work should analyze how access to markets, price fluctuations, and storage facilities influence the profitability of diversified cropping systems.
- **Sustainability Indicators**
  - Incorporating environmental sustainability metrics such as water-use efficiency, soil health, and carbon footprint in future studies would provide a more holistic understanding of irrigation-crop-profitability dynamics.

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Conflict of Interest

The author declares that there is no conflict of interest regarding the publication of this research paper. The study was conducted purely for academic and research purposes without any financial,

institutional, or personal bias. No external agency influenced the design, data collection, analysis, or interpretation of results.

References

1. Aggarwal, P. K., & Sivakumar, M. V. K. (2011). Global climate change and food security in South Asia. *Current Science, 101*(3), 356–361. https://www.jstor.org/stable/24078940
2. Birthal, P. S., Joshi, P. K., Roy, D., & Thorat, A. (2010). Diversification in Indian agriculture toward high-value crops: The role of small farmers. *Canadian Journal of Agricultural Economics, 58*(3), 321–339. https://doi.org/10.1111/j.1744-7976.2010.01192.x
3. Choudhary, M. (2020). Micro-irrigation adoption and farm returns in semi-arid regions of Rajasthan. *Indian Journal of Agricultural Economics, 75*(2), 210–225. https://www.indianjournals.com/ijor.aspx?target=ijor:ijae&type=home
4. Chowdhury, S., & Goswami, R. (2019). Irrigation access and crop diversification: Evidence from West Bengal. *Agricultural Economics Research Review, 32*(1), 45–56. https://doi.org/10.5958/0974-0279.2019.00005.6
5. Directorate of Economics and Statistics (DES). (2021). *Agricultural statistics at a glance*. Government of Rajasthan. https://des.rajasthan.gov.in
6. FAO. (2020). *Water management and crop diversification in arid and semi-arid regions*. Food and Agriculture Organization of the United Nations. https://www.fao.org/3/ca6464en/ca6464en.pdf
7. Gandhi, V. P., & Namboodiri, N. V. (2009). Investment and institutional credit in agriculture: A review. *Indian Journal of Agricultural Economics, 64*(4), 664–678. https://www.indianjournals.com/ijor.aspx?target=ijor:ijae&type=home
8. GoI. (2020). *Agricultural Census 2015–16*. Ministry of Agriculture and Farmers Welfare, Government of India. https://agcensus.nic.in
9. Gupta, R., & Rathore, M. (2021). Crop diversification and farm profitability in semi-arid Rajasthan. *Indian Journal of Economics and Development, 17*(3), 110–122. https://doi.org/10.5958/2322-0430.2021.00015.2
10. Hussain, I., &Hanjra, M. A. (2009). Irrigation and poverty alleviation: Review of empirical evidence. *Irrigation and Drainage, 58*(3), 345–358. https://doi.org/10.1002/ird.425
11. ICAR. (2018). *Handbook of agriculture*. Indian Council of Agricultural Research. https://icar.org.in/content/handbook-agriculture
12. Joshi, P. K., Gulati, A., Birthal, P. S., & Tewari, L. (2004). Agriculture diversification in South Asia: Patterns, determinants, and policy implications. *Economic and Political Weekly, 39*(24), 2457–2467. https://www.jstor.org/stable/4415119
13. Kumar, R. (2019). Economics of groundwater irrigation in Sikar district. *Journal of Rural Development, 38*(1), 55–68. https://doi.org/10.1177/0973068018825412
14. Kumar, S., & Sharma, A. (2020). Impact of drip irrigation on farm profitability: Evidence from Rajasthan. *Indian Journal of Agricultural Economics, 75*(3), 333–348. https://www.indianjournals.com/ijor.aspx?target=ijor:ijae&type=home
15. Molden, D., Frenken, K., Barker, R., & de Fraiture, C. (2010). Trends in water and agricultural development. In *Water for food, water for life* (pp. 57–89). Earthscan. https://doi.org/10.4324/9781849773799
16. Narayanamoorthy, A. (2011). Economics of drip irrigation in India: Some evidence and issues. *Indian Journal of Agricultural Economics, 66*(3), 399–410. https://www.indianjournals.com/ijor.aspx?target=ijor:ijae&type=home
17. National Bank for Agriculture and Rural Development (NABARD). (2020). *Annual report 2019–20*. https://www.nabard.org
18. NCERT. (2019). *Trends in agricultural practices in India*. National Council of Educational Research and Training. https://ncert.nic.in

19. OECD. (2019). *The future of agriculture and food systems*. Organisation for Economic Co-operation and Development. https://www.oecd.org/agriculture/
20. Pingali, P. (2007). Agricultural diversification: Opportunities and constraints. *World Development, 35*(2), 299–310. https://doi.org/10.1016/j.worlddev.2006.05.005
21. Planning Commission. (2013). *Twelfth Five Year Plan (2012–2017): Faster, more inclusive and sustainable growth*. Government of India. https://niti.gov.in
22. Rao, P. S., & Reddy, V. R. (2017). Water management in semi-arid India: Lessons for sustainable agriculture. *Economic and Political Weekly, 52*(5), 65–74. https://www.epw.in/journal/2017/5
23. Rosegrant, M. W., & Evenson, R. E. (1993). Agricultural productivity growth in developing countries. *World Bank Discussion Papers, 111*. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/
24. Sharma, H. R. (2016). Role of irrigation in agricultural productivity in Rajasthan. *Journal of Rural and Agricultural Studies, 32*(2), 88–102.
25. Shiferaw, B., Hellin, J., &Muricho, G. (2011). Improving farm productivity and profitability in semi-arid areas of Africa and Asia. *Food Security, 3*(2), 195–210. https://doi.org/10.1007/s12571-011-0121-5
26. Singh, R., & Meena, L. (2018). Crop diversification and farm incomes in semi-arid Rajasthan. *Indian Journal of Rural Studies, 23*(4), 55–70.
27. Sinha, S., & Binswanger-Mkhize, H. (2012). Managing water for agricultural growth in South Asia. *World Bank Report*. https://openknowledge.worldbank.org/handle/10986/12087
28. UNDP. (2020). *Sustainable agricultural practices and water use efficiency*. United Nations Development Programme. https://www.undp.org/publications
29. UNESCO. (2019). *Water security and sustainable development*. UNESCO Publishing. https://unesdoc.unesco.org
30. United Nations. (2018). *World water development report*. United Nations. https://www.unwater.org/publications/world-water-development-report-2018
31. World Bank. (2018). *Agriculture and irrigation in semi-arid regions*. World Bank. https://www.worldbank.org/en/topic/water
32. World Bank. (2020). *World development report 2020: Agriculture and resilience*. World Bank. https://www.worldbank.org/en/publication/wdr2020
33. Yadav, R. (2021). Profitability analysis of cash crops in Rajasthan. *Journal of Agricultural Development Studies, 28*(3), 101–114.
34. Yadav, S., & Chauhan, V. (2020). Groundwater depletion and irrigation practices in Rajasthan. *Environmental Economics and Policy Studies, 22*(4), 445–460. https://doi.org/10.1007/s10018-020-00271-y

Appendices

Appendix A: Survey Questionnaire (For Farmers)

Section A: General Information

1. Name of Farmer (optional)
2. Age
3. Education level
4. Household size
5. Farm size (in hectares)

Section B: Irrigation Access

6. Do you have access to irrigation? (Yes/No)
7. Type of irrigation source (Canal / Tube well / Open well / Rainfed only)

8. Area under irrigation (in hectares)

Section C: Crop Choice

9. Main crops cultivated (list)
10. Reason for choosing these crops (Profitability / Low risk / Tradition / Resource availability)
11. Use of high-value crops (Yes/No)

Section D: Farm Economics

12. Average cost of cultivation (₹ per hectare)
13. Gross income (₹ per hectare)
14. Net returns (₹ per hectare)

Section E: Farmer Perceptions

15. What are the major challenges you face in irrigation?
16. Do you think crop diversification has improved your income? (Yes/No, explain)

Appendix B: Extra Figures

Figure A2: Irrigation access by type (canal, tube well, rainfed).

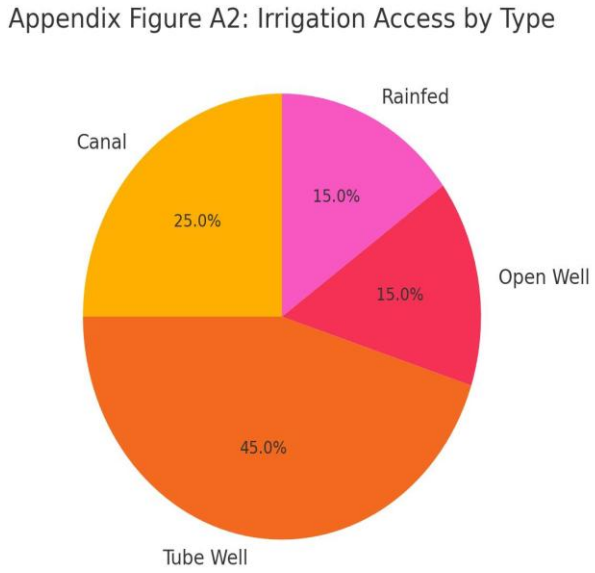

Figure A3: Crop choice distribution under irrigated and rainfed conditions.

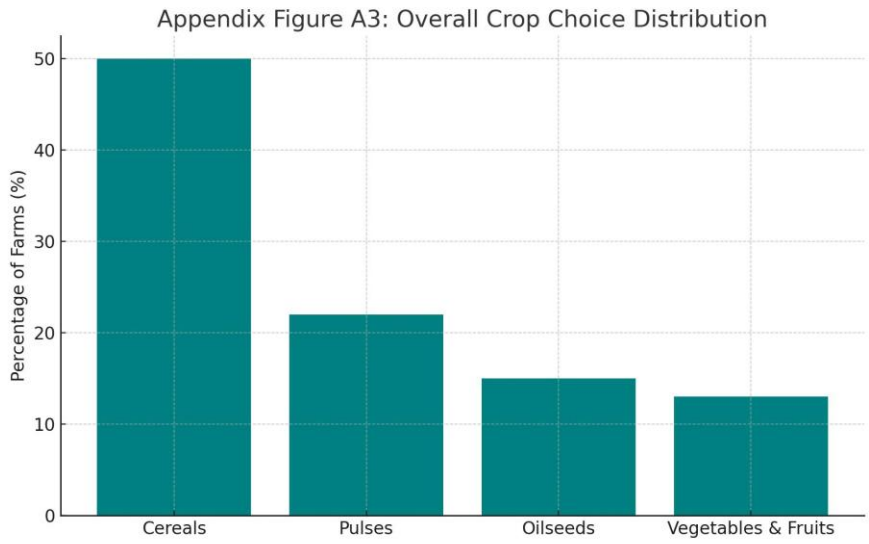

Figure A4: Profitability comparison of cereals vs. cash crops

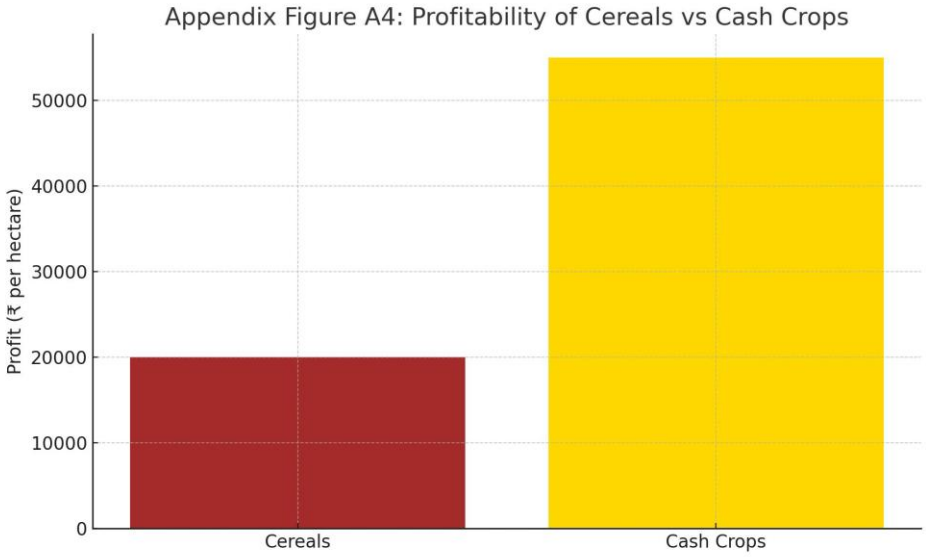

Figure A5: Regression residual plots (model validation).

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