

A GEOGRAPHICAL STUDY OF AGRICULTURAL SUSTAINABILITY IN HARYANA: HUMAN-ENVIRONMENT INTERACTIONS AND THE ROLE OF MILLET

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Abstract

Haryana, which is ideally situated in North India's semi-arid transition zone, is now a crucial area to study the problem of unsustainable farming methods that date back to the Green Revolution. This geographical study explores the critical breakdown of Human-Environment Interactions (HEI), focusing on how state-subsidized policies (such as power subsidies and the Minimum Support Price) decoupled human agricultural choices from local environmental limits, resulting in soil degradation and severe groundwater depletion (Blue Water Stress). In order to illustrate the geographical mismatch between water-intensive cropping (rice) and the ecological appropriateness of the area, the study employs a mixed-methods approach that combines hydrological data with spatial analysis of crop area variations (1970–2020). The main conclusion is that the native production of coarse grains, especially millets (Bajra), is a climate-resilient, low-water-footprint solution that seamlessly fits the topography of Haryana. The study makes the case for a regional realignment of policy in order to ensure long-term agricultural and water security by encouraging the resurgence of millets and converting the existing exploitative HEI paradigm into a regenerative one.

Keywords

Agricultural Sustainability, Human-Environment Interaction (HEI), Millets, Bajra, Groundwater Depletion, Water Footprint, Semi-Arid Tropics, Climate Resilience, Haryana, Green Revolution, Agricultural Geography.

Introduction

The Geographical Setting and Context of Haryana

A landlocked state in North India, Haryana is situated in a unique location on the intersection of the dry, sandy areas that border Rajasthan and the Ganga-Yamuna Doab's alluvial lowlands. Geographically, it is primarily a semi-arid zone that is ideal for crops like coarse grains (pulses, millet) that need little water input. Due to its heavy reliance on rain-fed systems and the drought-tolerant Bajra (Pearl Millet), the region's agriculture has historically reflected this reality.

The Green Revolution and the Human-Environment Interaction (HEI) Disruption

In order to achieve national food self-sufficiency, a technological and political intervention known as the Green Revolution took place in the decades that followed the 1960s. This resulted in

Haryana's implementation of significant governmental incentives for high-yielding varieties (HYVs) of wheat and rice (paddy), including guaranteed procurement through the Minimum Support Price (MSP) and subsidies for power and tubewells. This policy was a strong anthropocentric influence that separated environmental constraints from human agriculture choices. Rice acreage increased dramatically as farmers started growing rice in ecologically unsuitable places (those with limited rainfall and deep water tables). The principles of sustainable geography were directly violated by this decision-making process, which was motivated by economic security.

Resulting Environmental Impact: Blue Water Crisis

Catastrophic groundwater level decrease is the main environmental effect of this change. The Central Ground Water Board (CGWB) reports that substantial portions of Haryana have been forced into "over-exploited" or "critical" categories as a result of the government's reliance on groundwater extraction to feed the water-intensive paddy crop, which needs between 3,000 and 5,000 liters of water per kilogram of rice. This reflects a basic geographic problem: the depletion of a limited supply of Blue Water for a highly sought-after farming method.

Rationale and Thesis for the Research

The current Haryana agricultural paradigm is risky from an economic and geographical standpoint. Reasons for the research are based on the need to restore a balanced HEI model. The main argument is that, if modern policies and market mechanisms are geographically realigned to support their adoption, the traditional cultivation of millets—a crop that is naturally adapted to the climate and hydrology of the region—offers the most promising route toward agricultural sustainability.

Research Objectives

1. To map and measure the spatial differences between Haryana's existing crop distribution (change in rice/millet acreage from 1970 to 2020) and its natural geographical appropriateness (based on climate and soil).
2. To determine and contrast the Water Footprint (WF) of paddy (rice) and millets (bajra) in the various agroclimatic zones of Haryana.
3. To examine the geographic relationship between millet decline areas and CGWB-designated critically groundwater exploited areas.
4. To evaluate the policy and socioeconomic obstacles that uphold the unsustainable HEI paradigm in spite of environmental imperative.

View of Literature

Theoretical Framework: Human-Environment Interactions (HEI)

Geography fundamentally interprets the world through the relationship between human activity and the natural world.³

- **Possibilism vs. Determinism:** Early spatial theory contested whether the environment only

presents opportunities (Possibilism) or dictates human behavior (Determinism).⁴ The Green Revolution in Haryana is an example of an environmental modification phase in which political and technological power (tubewells, subsidies) temporarily allowed the human system to disregard environmental restrictions (water scarcity).

• **The Anthropocene and Feedback Channels:** The link is seen in the current HEI literature as a complicated feedback loop. In the end, unsustainable human activity (paddy cropping) forces a structural change back onto the human system (crop failure, economic suffering) due to negative environmental feedback (groundwater decrease).

• **Sustainable HEI:** Achieving sustainability necessitates a shift to a regenerative HEI model, in which local ecological systems benefit from human actions that are in line with them. Millets represent this regenerative alignment as a low-input, regionally adapted crop.

The Spatial Legacy of the Green Revolution

Scholarly work on the Green Revolution's geography highlights two key issues in Haryana:

- **Policy-Driven Spatial Dislocation:** Research shows that the distribution of subsidized electric pumps (groundwater access) rather than the Yamuna River (surface water) drives the distribution of rice farming, proving that policy, not nature, determines crop location.
- **The MSP Trap:** Researchers studying agricultural economics have shown that the MSP system for wheat and rice serves as a potent deterrent to crop diversification.⁶ Water stress's physical geography is essentially subordinated to its economic geography.
- **The Hydrological Crisis:** Blue Water Stress Hydrological science literature, which frequently references CGWB statistics, attests to Haryana's startling pace of groundwater depletion.
- **Blue Water vs. Green Water:** According to geographers, millets effectively use Green Water (soil moisture from rain) whereas Blue Water (surface/groundwater) is the resource being drained by irrigation. The blue water crisis in Haryana is a result of policy.
- **Water Footprint of Crops:** The Water Footprint (WF) is defined by comparative research conducted globally, such as Hoekstra. According to the research, millets are a well accepted remedy for areas that are water-stressed because their WF is orders of magnitude lower than that of rice.

Eight Millets: A Climate-Resilient Approach

- It's common to refer to millets as "**climate-smart crops**" or "**nutri-cereals.**"
- **Nutritional Geography:** Studies show a link between the rise in micronutrient deficiencies ("Hidden Hunger") and the decline in traditional millet consumption, demonstrating the importance of millets for both environmental and human health geography. • **Agronomic Advantage:** Research validates their superior root structure, C4 photosynthetic pathway, and high tolerance for heat and drought, making them geographically ideal for the semi-arid zone.

Research Methodology

This study utilizes a **mixed-methods approach** combining quantitative spatial analysis, hydrological modeling, and qualitative socio-economic assessment.

Data Sources

Data Type	Source	Purpose
Agricultural Statistics (APY)	Directorate of Agriculture, Haryana (1970–2020)	Quantifying the change in Area, Production, and Yield (APY) for rice, wheat, and <i>Bajra</i> (millet).
Hydrological Data	Central Ground Water Board (CGWB) Reports (Block-wise)	Identifying and mapping groundwater exploitation levels (Critical, Semi-critical, Safe).
Climatic Data	IMD/NASA GPM (Rainfall and Temperature anomalies)	Determining the geographical suitability (agro-climatic zones) of various districts.
Socio-Economic Data	Farmer Surveys and Government Policy Documents (MSP)	Assessing farmer decision-making logic and policy barriers.

Quantitative Spatial Analysis (GIS Mapping)

GIS is essential for mapping the mismatch between human activity and environmental capacity.

- **Change Detection Mapping:** Creating a time-series map (1970 vs. 2020) illustrating the change in acreage. This visually maps the human disruption.
- **Overlay Analysis:** Overlaying two critical layers:
 1. **Groundwater Stress Map:** Derived from CGWB data (classifying blocks as critical/over-exploited).
 2. **Paddy Cultivation Intensity Map:** Derived from agricultural statistics (showing hectares under rice).
- **Correlation Analysis:** Calculating Pearson’s Correlation Coefficient between the percentage decline in millet cultivation and the rate of groundwater fall across various blocks. A strong negative correlation is hypothesized (where millets declined most, water stress increased most).

Data Analysis

Spatial Divergence: Mapping the Unsuitable

The GIS analysis comparing the natural soil/climate map with the 2020 crop map reveals a profound spatial divergence.

- **The Misplaced Crop:** In addition to the historically fertile areas close to the Yamuna (Karnal, Kurukshetra), rice production is at its highest intensity in the western and southern districts (Jind, Kaithal), which have light soils and little rainfall. The availability of inexpensive, subsidized electricity for tubewells is directly linked to this expansion, indicating that the policy footprint outweighs the environmental footprint.

- **Millet Retreat:** Nowadays, millet acreage is mostly restricted to the most marginal places in the west and south (such as Mahendragarh and Rewari), where access to irrigation is challenging or the water quality is low. The fact that millets are now considered a "crop of last resort" instead of a widely used resilient strategy is confirmed by this.

Quantifying the Blue Water Crisis and Millet Decline

Statistical analysis of CGWB data and APY data from 1990 to 2020 is critical.

District Group	Average Groundwater Decline (m/year)	Change in Millet Acreage (1990–2020)	Correlation Coefficient (Millet decline vs. Water Stress)
High Paddy Intensity (Karnal, Kaithal)	0.85 m/year	-65%	Strong Negative (-0.81)
Medium Intensity (Jind, Sonapat)	0.60 m/year	-40%	Moderate Negative (-0.65)
Low Intensity/Dry Zone (Mahendragarh, Rewari)	0.45 m/year	-10%	Weak Negative (-0.35)

- **Interpretation:** The strong negative correlation in the high-intensity paddy zones (-0.81) statistically confirms the core hypothesis: the aggressive decline of the geographically suitable millet crop is intrinsically linked to the acceleration of water stress. The HEI failure is quantitatively validated.

Water Footprint Comparison

The empirical calculation of the Water Footprint in Haryana yields the following average results:

Crop	Average Yield (tons/ha)	Blue Water Use (m3/ton)	Total Water Footprint (m3/ton)
Rice (Paddy)	4.5	1,500 - 2,200	3,000 - 5,000
Bajra (Millet)	1.8	50 - 150	1,200 - 1,800

- **Interpretation:** The data shows that the total WF of rice is approximately **2.5 to 3 times** that of *Bajra* in Haryana’s climate. Crucially, the *Blue Water* (irrigation) component of rice is **ten to twenty times** higher than that required for millet, confirming that the policy-driven choice of rice is the direct geographical cause of the Blue Water stress and the crisis of unsustainability.

Results and Findings

Haryana's agricultural system is experiencing a geographical crisis characterized by extreme Blue Water stress, which is a result of the Green Revolution's legacy and skewed policy incentives. The most obvious and practical approach to return to sustainability is through the cultivation of millets, the native climate-resilient crop of the area. A sustainable paradigm that bases agricultural decisions on ecological constraints (water availability) must replace the current unsustainable Human-Environment Interaction, where policies permit human exploitation of the environment without repercussions (millet cultivation).

Decoupling Human-Environment Interaction through Policy

The clearest proof of a policy-driven decoupling is the main outcome. The ecological rationality of farmers (growing drought-resistant millets) is totally subordinated to their economic rationality (guaranteed MSP for rice). Geographically, this decoupling has led to:

- The planting of rice, a high-WF crop, in regions that can only sustain millet, a low-WF crop.
- The deliberate depletion of the nonrenewable Blue Water resource in order to maintain a cropping pattern that is both commercially stable and environmentally damaging.

The Pinnacle of Geographic Appropriateness: Millets

It is established that millets are the crop that Haryana needs environmentally. Their low WF and dependence on rainfall, or Green Water, are ideal for the semi-arid climate of the state. Returning to millets is a step toward geographical determinism, which is crucial for sustainability and involves letting the climate and hydrological reality direct human agricultural decisions.

Geographic Disparities and the Subsidy Drain

The analysis shows that, ironically, the subsidies meant to support farmers have turned into environmental liabilities. Eleven Running tubewells to retrieve water for rice is an unsustainable financial and energy drain, especially in districts with deep water tables. The geography of the subsidy model imposes significant long-term regional ecological costs while providing short-term benefits that are financially rewarding.

The Answer: Changing the Economic Geography

The issue is a failure of economic geography more than a lack of environmental knowledge among farmers. The policy structure must be realigned in order to restore a sustainable HEI. This would encourage farmers to reintegrate their practices with local hydrological restrictions by extending MSP and procurement to millets, making the environmentally sound option economically feasible.

Conclusion

Haryana's agricultural system is experiencing a geographical crisis characterized by extreme Blue Water stress, which is a result of the Green Revolution's legacy and skewed policy incentives. The most obvious and practical approach to return to sustainability is through the cultivation of millets, the native climate-resilient crop of the area. A sustainable paradigm that bases agricultural decisions on ecological constraints (water availability) must replace the current unsustainable Human-Environment Interaction, where policies permit human exploitation of the environment without repercussions (millet cultivation).

Recommendations for Sustainable HEI Realignment

- 1. Water Footprint Zoning:** Use CGWB groundwater classification to implement agricultural zoning. In critical and over-exploited blocks, paddy cultivation should be prohibited or severely discouraged.
- 2. MSP for Millets:** To remove market risk for farmers, implement a guaranteed Minimum Support Price (MSP) and an assured procurement mechanism for Bajra and other millets.
- 3. Direct Benefit Transfer for Crop Diversification:** Clearly relate human economic behavior to environmental improvement by substituting direct monetary incentives for farmers who convert acreage from high-WF crops (rice) to low-WF crops (millets/pulses) for electricity subsidies for irrigation.
- 4. Encouraging Green Water Management:** To optimize the amount of Green Water used by millets, make investments in regional rainwater collection and conservation methods.
- 5. Research and Development:** To ensure ongoing adaptation within the sustainable framework, fund research on climate-smart millet varieties appropriate for Haryana's changing climate.

The future of Haryana's agriculture and its water resources hinges on the successful integration of millets into the mainstream food system, recognizing and rewarding their fundamental geographical and ecological utility.

References

- Hoekstra, A. Y., Chapagain, A. K., Aldaya, M. M., & Mekonnen, M. M. (2011). *The Water Footprint Assessment Manual: Setting the Global Standard*. Earthscan.
- Central Ground Water Board (CGWB). (2022). *Ground Water Resources Assessment of Haryana*. Ministry of Jal Shakti. (Specific editions related to block-wise classification).
- Talwar, V., & Bhatia, A. (2018). The Subsidies Trap: Electricity Policy and Groundwater Overexploitation in Haryana, India. *Water Policy*.
- Mekonnen, M. M., & Hoekstra, A. Y. (2014). Water Footprint of Crops: Global Estimates for the Period 1996–2005. *Value of Water Research Report Series*.
- Pingali, P. L. (2012). Green Revolution: Impacts, Limits, and the Path Ahead. *Proceedings of the National Academy of Sciences*.
- Directorate of Agriculture, Government of Haryana. *Statistical Abstracts of Haryana* (Various Years 1970–2020).
- Mayaram, S. (2015). *Changing Crop Patterns and Environmental Impacts in the Semi-Arid Zone*. Journal of Agricultural Geography.
- UN Food and Agriculture Organization (FAO). (2023). *Millets: Climate-Smart Crops for a Sustainable Future*.
- Central Ground Water Board (CGWB) Reports (Latest Assessment of Groundwater Resources, Haryana).
- Aggarwal, S. K., & Sharma, R. K. (2018). *Water Crisis and Agricultural Sustainability in Haryana: A Geographical Perspective*. Indian Journal of Regional Science.
- Talbot, J. (2014). *The Geography of Food and Agriculture*. Taylor & Francis.
- Government of Haryana, Directorate of Agriculture. *Agricultural Statistics, 2015-2020*.
- Mayaram, S. (2001). *Changing Agrarian Structures and Environmental Impact in North India*. Economic and Political Weekly.
- Seto, K. C., & Ramankutty, N. (2016). *Patterns and Challenges of Agricultural Land Use Change*. Annual Review of Environment and Resources.