# HOUSEHOLD-LEVEL TARGETING UNDER WATER RATIONING POLICY: EVIDENCE FROM AGRICULTURAL PUNJAB

[1]Suhana GREWAL
[1]University of Edinburgh
Email: [1]suhanagrewal0407@gmail.com

## ABSTRACT

Uniform water rationing remains a dominant policy response to groundwater scarcity in Punjab's agricultural sector. While administratively simple, such policies overlook substantial heterogeneity in farm structure, crop choice, and realized productivity across households, leading to misallocation and avoidable output losses. This paper develops a household-level matching framework that ranks agricultural households for priority access to irrigation under rationing regimes using a small set of observable characteristics. Drawing on microdata from the 77th Round of the Situation Assessment of Agricultural Households (2019), restricted to Punjab, the study constructs a composite heterogeneity score combining realized crop output, cropping intensity, and land fragmentation. Households are classified into priority tiers that can be directly mapped onto differentiated rationing rules, such as variations in pumping hours. Rather than offering causal identification, the framework provides a transparent, low-cost screening tool that can improve allocative efficiency without increasing total water extraction. The approach highlights how modest reallocation within existing rationing regimes can recover productivity gains while preserving equity objectives.

**Keywords**: *groundwater scarcity; agricultural water rationing; irrigation allocation; farm heterogeneity; agricultural households; allocative efficiency; productivity losses; water policy; Punjab agriculture; India*

## 1. INTRODUCTION

Water scarcity has emerged as a binding constraint on agricultural production across India, pushing legislative authorities to rely on rationing mechanisms alongside or instead of price-based instruments. In practice, rationing is typically implemented uniformly across agricultural land through restrictions on groundwater water availability or electricity supply for irrigation pumps (Punjab Government, 2020). Although these policies are defensible on equity and administrative grounds, they implicitly assume homogeneity in productivity and operational structures among agricultural households.

The state of Punjab in India presents a marked case where this assumption fails. Although comprising less than 1.5% of India's geographical area, Punjab is responsible for ~18% of the nation's wheat production and ~12% of its rice production, earning it the title of India's "Food Bowl" (Gulati et al, 2021). Despite ~99% of gross cropped area in Punjab being irrigated, constraints in water availability and periodic rationing have exposed stark heterogeneity in how irrigation is accessed, leading to misallocation of water (Khara, 2017).

Currently, Punjab's agricultural water usage is shaped by free or flat-rate electricity for irrigation pumps, making the marginal cost of groundwater extraction effectively zero for farmers. In practice, mounting fiscal and groundwater pressures have led to implicit rationing through restricted pumping hours, applied uniformly across farms (Gill, 2019). Whereas these policies curb extraction, they ignore differences in productivity across households, resulting in misallocation (Gupta, 2023). A Pareto improvement can only be achieved if water allocation rules account for household-level heterogeneity in productivity and land structure.

This paper argues that uniform rationing generates misallocation by constraining water access for households where marginal productivity of water is high, while protecting households that are equipped to absorb scarcity. Building on this premise, the study proposes a simple household-level matcher that ranks farms for priority access under water scarcity, aiming to improve efficiency without dismantling rationing itself.

## 2. LITERATURE REVIEW

The paper contributes to three strands of literature. First, it relates to work on efficiency of agricultural water use by heterogeneous farmers, which documents the large productivity differences that exist across farms facing similar resource constraints (Chang et al., 2025). Second, it complements studies on groundwater governance in Punjab that highlight the unintended consequences of free electricity and uniform rationing (Gupta, 2023; Gill, 2019). Third, it connects to broader research on rationing of common pool resources, which highlights that equity-oriented rules may produce efficiency losses when agents differ in productivity (Sudarshan, 2020).

This paper focuses on policy feasibility instead of sole exploration on structural or causal models of optimal water allocation. It aligns with recent calls for transparent, data-light tools that can inform targeting decisions in settings with limited monitoring capacity.

## 3. RESEARCH QUESTION

This study explores the research question: **"Which agricultural households should be prioritized under water rationing regimes, given differences in irrigation access, crop structure, and land fragmentation?".**

The question guides the study to systematically classify agricultural households into policy-relevant priority groups using a small set of observable farm characteristics and thereby determine how rationed electricity for water pumping can be reallocated to reduce inefficiency from misallocation.

## 4. DATA

The dataset has been extracted from the "*Land and Livestock Holding of Households and Situation Assessment of Agricultural Households*" conducted in December 2019 (Ministry of Statistics and Programme Implementation, 2019). Although the dataset is temporally older, it captures stable household characteristics that evolve slowly with time, rendering it an appropriate source. The microdata has been state-restricted to Punjab and cleaned to retain variables related to the operational characteristics of landholdings and crop activity. These variables include:

- Household identification (`hhid`).

- Number of parcels operated (`n_parcels`): Proxy for land fragmentation.
- Number of crops cultivated (`n_crops`): Proxy for crop diversification.
- Total crop output (`total_output`): Proxy for realized agricultural production.
- Irrigated area (`irrigated_area`): Land receiving assured water supply.

The sample is restricted to households active in agricultural production to ensure relevance.

# 5. METHODOLOGY

## 5.1 CONCEPTUAL FRAMEWORK

The matcher, developed using R, is designed as a scoring framework that ranks households based on their likely marginal gains from additional water access. Instead of directly modeling water demand, it combines observable realized production outcomes with structural farm characteristics to approximate heterogeneity in water productivity.

## 5.2 CONSTRUCTION OF THE HETEROGENEITY SCORE

### Stage 1: Realized Output Aggregation

Crop-wise production quantities are summed across all crops grown by a household to obtain realized output. This captures actual performance rather than planned or self-reported intensity that current policies rely on (Sudarshan et al, 2020).

### Stage 2: Cropping Intensity Measure

The number of distinct crops grown by each household is used as a proxy for cropping intensity. This figure varies between 1-5 for all households, with 98.32% of the values falling between 1-3. To prevent outliers from dominating the score, this measure is capped at a minimum upper bound (3). This has been done to ensure that after a threshold, additional crops do not inflate a household's water productivity, accounting for the diminishing marginal relevance of additional crops for water prioritization.

### Stage 3: Land Fragmentation Penalty

Households in the dataset operate anywhere between 1-10 land parcels, and multiple parcels are flagged as fragmented. Fragmentation is treated as a constraint because dispersed plots raise water requirements, preventing them from achieving economies of scale as a result of two factors (Mukhtar, 2024).

First, are conveyance losses, which are the amounts of irrigation water lost from pipes or canals during transport from the source to farm fields. These costs increase as water is delivered to multiple parcels (Manjunatha et al, 2013). Secondly, fragmentation causes friction in coordination between all land operators, which reduces how efficiently water is utilized.

### Stage 4: Composite Score

The household-specific heterogeneity score is constructed by combining normalized productivity with cropping intensity and adjusting for land fragmentation through the derived formula:

$$Heterogenity\ Score = \frac{Productivity\ Index \times Crop\ Intensity}{1 + Fragmentation}$$

The score is normalized to lie between 0 and 1, enabling comparison across households.

## 5.3 PRIORITY CLASSIFICATION

Households are ranked based on their

heterogeneity score and classified into priority tiers.

***Table 1:*** *Priority Classification of Households*

| | |
|---|---|
| **Group 1** | **Low priority:** relatively efficient households |
| **Group 2** | **Medium priority:** mixed structural characteristics. |
| **Group 3** | **High priority:** structurally vulnerable households. |

## 6. RESULTS AND POLICY INTERPRETATION

The matcher generates an ordinal ranking of households that can be mapped to rationing rules.

**Group 3 households**, for whom water is most productivity-limiting, should be prioritized for additional pumping hours or relaxed rationing, as marginal increases in water access are likely to translate into realized output.

**Group 2 households** have mixed structural characteristics and should receive the standard rationing allocation, serving as the baseline against which reallocations to other groups are evaluated.

**Group 1 households** are relatively efficient, with lower marginal gains from additional water. They can absorb tighter rationing with small productivity losses, making them suitable for stricter limits.

Importantly, the framework does not require novel data collection; it may be implemented using existing administrative datasets and updated periodically as farm characteristics majorly change.

## 7. LIMITATIONS & DISCUSSION

This study does not claim causal identification between water productivity and land fragmentation or crop intensity. The heterogeneity score is a screening device rather than an estimate of structural water productivity. However, given the decentralized and often informal structure of Punjab's agricultural system, the model's external validity is limited (Khosa, 2024).

Future extensions could incorporate temporal variation to examine whether these classifications persist over time. Moreover, the classifications can be examined against income or consumption outcomes, to assess whether higher-ranked households indeed translate water access into greater economic returns (Srivastava et al, 2015).

## 8. CONCLUSION

The matcher generates an explicit priority ordering that can be directly mapped to rationing rules when water is scarce. In Punjab, where uniform restrictions are imposed for equity or perhaps administrative simplicity, the framework offers a low-cost way to reallocate limited water across households to improve productivity without increasing total extraction. Therefore, the tool identifies households for pilot intervention under rationed water regimes, and can be easily extended to other geographical settings, including states like Rajasthan and Haryana that follow similar equity-based water rationing systems.

Broadly, the framework speaks to a central tension in common pool resource management in Punjab. The current irrigation policy designed to ensure equity through uniform rationing may achieve average efficiency but still generates misallocation. The matcher explicitly ranks households based on observable heterogeneity, illustrating present productivity losses which can be reduced through modest reallocation rules that recover surplus without dismantling rationing itself.

## 9. DECLARATIONS

All authors declare that they have no conflicts of interest.

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