WP-2025-002

Unwatering the Fields: Analyzing Incentives for Crop Diversification amid Groundwater Crisis in India

Disha Gupta and Archisman Mitra

Indira Gandhi Institute of Development Research, Mumbai

March 2025

Unwatering the Fields: Analyzing Incentives for Crop Diversification amid Groundwater Crisis in India

Disha Gupta and Archisman Mitra

Email(corresponding author): disha@igidr.ac.in

Abstract

Groundwater depletion has become a serious concern in north-western India, particularly in Punjab and Haryana, largely due to the dominance of paddy cultivation and unsustainable irrigation practices driven by agricultural electricity subsidies. This paper aims to assess the effectiveness of current incentive strategies for crop diversification in this region introduced by the government for the reduction of groundwater over-extraction. Using the plot-level cost of cultivation data for the period 2017-18 to 2019-20, obtained from the Ministry of Agriculture & Farmers Welfare, Government of India, we show that the current proposed incentives are inadequate for shifting from water-intensive paddy to less water-intensive crops, mainly due to the higher profitability of paddy cultivation in terms of high yields and lower production costs as compared to other crops. We find that the average proportion of area under paddy that would shift to less water-intensive maize or cotton in Punjab with the current policy would be about 17–20 percent, which is 33 percent lower than the 30 percent target area set by the government. The area that would shift to non-paddy crops in Haryana would be about 11–16 percent, which is even lower. Our results show that the cash incentives required for crop diversification could be as high as 2.5 times the amount offered under the current scheme in order to shift to even the most profitable non-paddy crop. Our study highlights challenges in the implementation of the crop diversification scheme and propose alternatives.

Keywords: Groundwater Depletion, Crop Diversification, Government Policies, Cash Incentives, Water

JEL Code: Q25, Q28, Q58, O13

Acknowledgements: We would like to thank Marie-Charlotte Buisson, Alok Sikka, and participants of the Monash Environmental Economics Workshop, and the IWMI Economics Seminar Series for their valuable comments and feedback. Archisman Mitra acknowledges the financial support provided under the CGIAR Initiative on National Policies and Strategies (NPS), which is grateful for the support of CGIAR Trust Fund contributors. All remaining errors are our own. All opinions, findings, and conclusions expressed in this article are those of the authors and do not necessarily reflect the views of the organizations that authors are affiliated with.

Unwatering the Fields: Analyzing Incentives for Crop Diversification amid Groundwater Crisis in India

Disha Gupta* and Archisman Mitra†

Abstract

Groundwater depletion has become a serious concern in north-western India, particularly in Punjab and Haryana, largely due to the dominance of paddy cultivation and unsustainable irrigation practices driven by agricultural electricity subsidies. This paper aims to assess the effectiveness of current incentive strategies for crop diversification in this region introduced by the government for the reduction of groundwater over-extraction. Using the plot-level cost of cultivation data for the period 2017-18 to 2019-20, obtained from the Ministry of Agriculture & Farmers Welfare, Government of India, we show that the current proposed incentives are inadequate for shifting from water-intensive paddy to less water-intensive crops, mainly due to the higher profitability of paddy cultivation in terms of high yields and lower production costs as compared to other crops. We find that the average proportion of area under paddy that would shift to less water-intensive maize or cotton in Punjab with the current policy would be about 17–20 percent, which is 33 percent lower than the 30 percent target area set by the government. The area that would shift to non-paddy crops in Haryana would be about 11–16 percent, which is even lower. Our results show that the cash incentives required for crop diversification could be as high as 2.5 times the amount offered under the current scheme in order to shift to even the most profitable non-paddy crop. Our study highlights challenges in the implementation of the crop diversification scheme and propose alternatives.

Keywords: Groundwater Depletion, Crop Diversification, Government Policies, Cash Incentives, Water

JEL Codes: Q25, Q28, Q58, O13

*Assistant Professor, Indira Gandhi Institute of Development Research; Email: disha@igidr.ac.in
†Regional Researcher, International Water Management Institute; Email: a.mitra@cgiar.org

Acknowledgements: We would like to thank Marie-Charlotte Buisson, Alok Sikka, and participants of the Monash Environmental Economics Workshop, and the IWMI Economics Seminar Series for their valuable comments and feedback. Archisman Mitra acknowledges the financial support provided under the CGIAR Initiative on National Policies and Strategies (NPS), which is grateful for the support of CGIAR Trust Fund contributors. All remaining errors are our own. All opinions, findings, and conclusions expressed in this article are those of the authors and do not necessarily reflect the views of the organizations that authors are affiliated with.

1 Introduction

Water is at the core of the current climate crisis. Agriculture accounts for about 72 percent of the world's fresh water withdrawals (FAO, 2023), and increasing water scarcity, together with climate change, is putting global food security at risk. To adapt, irrigation will be essential, but practicing it sustainably will require farmers worldwide to make more efficient use of scarce freshwater resources, especially groundwater, along with the enormous amounts of energy used to pump it.

India is globally the largest user of groundwater for irrigation (UN-Water, 2022). Farm power supply is highly subsidised in most regions of the country, giving farmers little to no incentive for water conservation (Badiani-Magnusson and Jessoe, 2019). The situation is most severe in northwestern India, particularly Punjab, which has the highest groundwater extraction rate, followed closely by Haryana (CGWB, 2024), the region that will be the focus of our study. Policymakers and government have made efforts to address the issue groundwater depletion through several policy instruments. The first-best policy is volumetric pricing of farm electricity that could lead to water conservation since it requires farmers to pay for each unit of electricity used for water extraction, incentivizing them to use these scarce resources optimally (Gupta, 2024). However, studies suggest that implementing water pricing could be challenging due to its political infeasibility and potential negative implications, especially for small farmers (Fishman et al., 2023; Mitra et al., 2023). Thus, alternative second-best approaches have been explored for improving water use efficiency in agriculture, such as cash incentives for voluntarily saving electricity below a pre-specified threshold (Fishman et al., 2016; Mitra et al., 2023), delay in paddy sowing and transplantation under the Sub-soil Water Act of 2009 (Tripathi et al., 2016), alternate wetting and drying (Chakravorty et al., 2023), direct seeding of rice, micro-irrigation technologies such as sprinklers and drip irrigation (Fishman et al., 2023), and laser land leveling (Jat et al., 2009; Lybbert et al., 2018). While these approaches are easier to implement, some can be costly and may have unintended negative environmental consequences (Agarwala et al., 2022; Mishra et al., 2017).

In this paper, we examine the effectiveness of the crop diversification scheme introduced by the governments of Punjab and Haryana in shifting cultivation away from water-

intensive paddy to less water-intensive crops to address the issue of groundwater depletion in the region. Under the crop diversification scheme, the government offered a cash incentive per unit of area for shifting cultivation away from paddy, along with assured procurement for the less water-intensive crops cultivated under this scheme at the Minimum Support Price (MSP). A cash incentive of Rs. 23,500 per hectare and Rs. 7,000 per acre (approximately equivalent to Rs. 17,300 per hectare) was announced in Punjab and Haryana, respectively. The Punjab government aimed to diversify 30 percent of the paddy area to alternative crops. In particular, we are interested in assessing whether these cash incentives would indeed result in the diversification of the targeted area away from paddy in order to save water. We also compute the optimal cash incentive structure required for diversifying different proportions of the paddy area toward less water-intensive crops. Finally, we explore alternative ways of implementing the crop diversification scheme to meet the target in a more cost-effective manner.

All the policy instruments mentioned earlier, including volumetric pricing, delay in transplantation, alternate wetting and drying, direct seeding of rice, or using sprinklers and drip irrigation, aim to improve water use efficiency by reducing the amount of water applied to the crop while keeping the current cropping patterns intact. However, the groundwater situation is very serious in this region, partly due to the cultivation of water-intensive paddy crop. The crop diversification scheme is different from the other approaches as it aims to encourage farmers to cultivate crops that have lower water requirements, leading to real water savings, by providing cash incentives to compensate for lower returns from the cultivation of these crops. Additionally, they perhaps try to shield farmers from market risk by promising to procure these crops at MSP.

The analysis in our paper is based primarily on the plot-level and state-level cost of cultivation data for the period 2017-18 to 2019-20 from the Ministry of Agriculture & Farmers Welfare, Government of India. To assess whether a farmer shifts away from paddy cultivation, we compare the actual profit from cultivating paddy on each plot with the average profits that could have been earned by cultivating less water-intensive crops in the *kharif* season, given the procurement of these crops at MSP. We assume that the decision to cultivate any crop is solely based on the profits earned from its cultivation, and the entire plot area is allocated to the most profitable crop. We aggregate the area of plots whose cultivation would shift away from paddy based on profit comparisons to determine

the proportion of the area shifted, taking into account the incentives announced under the scheme. We also make these profit comparisons for various combinations of cash incentives and use the brute force approach for elimination and finding the most profitable and cost-effective cash incentive structure for diversifying 30 percent of the paddy area. Since we do not have information about the returns from cultivating less water-intensive crops on actual paddy plots, we construct two measures for profit comparison: i. the weighted mean of state-level profits from cultivating less water-intensive crops (all-India measure), and ii. the weighted mean of profits from cultivating these crops in each agro-climatic zone in Punjab and Haryana (state-specific measure).

This paper shows that incentives under the current crop diversification scheme are insufficient to incentivize farmers to diversify the targeted area to reduce overextraction of groundwater resources in northwestern India. We find that the average proportion of paddy area that would shift to less water-intensive maize or cotton in Punjab is about 17–20 percent, which is 33 percent lower than the target set by the state government. Similarly, in Haryana, the average area that would shift out of paddy is about 11–16 percent, which is even lower. These results are obtained by making comparisons with the state-level measure of the average profits from cultivating less water-intensive crops. On the other hand, using the all-India measure for comparison, we find that only 14 percent of the paddy area in Punjab and 8 percent in Haryana would shift even to the most profitable less water-intensive crop, *arhar*. The proportion of area that would shift to other less water-intensive crops is even smaller, given their lower profitability.

Further, we compute the amount of cash incentive that should be paid to farmers for different levels of target areas. We find that the amount to be offered increases steeply for shifting up to 30 percent of paddy area to less water-intensive crops. Beyond that, while greater amounts are required to encourage the farmers to shift, the cash incentive increases at a decreasing rate as the targeted area becomes larger. Using profit comparison with the all-India measure, we show that a cash incentive of Rs. 50,100 per hectare in Punjab and Rs. 43,300 in Haryana needs to be offered to encourage the diversification of 30 percent of paddy area to even the most profitable less water-intensive crop, which is about 2.5 times the amount currently offered under the current scheme.

Finally, our results suggest that there would be cost savings of 7–11 percent for the Punjab

government and 1.5–3 percent for the Haryana government if a differential cash incentive based on farm size were offered to farmers instead of providing a constant amount to all. However, it is important to note that while differential cash incentives reduce the cost burden of the policy, their implementation poses several challenges, especially in terms of identifying and targeting beneficiaries, and higher transaction costs.

Our study contributes to the growing literature that assesses various policy instruments that can be used for mitigating the issue of groundwater depletion. Several studies have proposed potential solutions to reduce overextraction of water resources, including volumetric pricing, alternate wetting and drying, micro-irrigation technologies, delayed transplantation, cash incentives for optimal electricity usage, direct seeding of rice, and laser land leveling (Fishman et al., 2016; Gupta, 2024; Larson et al., 2016; Lybbert et al., 2018; Mitra et al., 2023; Tripathi et al., 2016). These studies show mixed evidence regarding the effectiveness of these policy instruments for water conservation. However, there is limited literature discussing crop diversification as one of the potential solutions (Devineni et al., 2022; Singh et al., 2024; Bhogal and Vatta, 2021).

Devineni et al. (2022) recognizes the cultivation of water-intensive crops in Punjab and Haryana as one of the major reasons for rapid groundwater depletion in these areas. They suggest modifying the current Public Distribution System (PDS) strategy of procuring grains from specific regions to address this issue. Using hydro-economic analysis and geo-spatial data, results from their study suggest that "optimal" cropping patterns resemble those that existed in the pre-Green Revolution era. Punjab and Haryana are suitable for cultivating less water-intensive crops like pearl millet, maize, sorghum, and finger millet, while other states should be targeted for the cultivation of water-intensive paddy. They conclude that it is possible to design a spatial cropping pattern even under rain-fed cultivation in a manner that meets PDS targets for maintaining food security while achieving a net gain in national farm revenue.

A recent report published by ICRIER suggests offering a cash incentive of Rs. 30,000–40,000 per hectare for farmers who shift their cultivation to non-paddy crops, with the central and state governments contributing equally to this subsidy amount (Singh et al., 2024).[1] The authors also suggest ensured procurement of these crops at MSP, as one of the factors

[1]While the authors mention that they use the cost of cultivation data for the computations, the exact methodology followed for determining the suggested cash incentive is unclear.

driving the preference for paddy cultivation is its lower market risk.

Our paper makes three contributions to the literature. Firstly, we use the most recent plot-level cost of cultivation data to determine that the cash incentives offered under the current scheme are insufficient to shift the targeted area away from paddy cultivation. We provide estimates of the cash incentives required for crop diversification. These are likely to be lower bounds, as our results are based solely on profit comparisons. We argue that the actual cash incentives to be offered could be significantly higher if we also account for the market risk and production risk associated with cultivating alternative crops. This is the first study to provide estimates of the cash incentives required for crop diversification using disaggregated data, making comparisons with counterfactuals based on all-India and state-level measures.

Secondly, we determine the different levels of cash incentives required to shift from paddy to each of the eleven less-water intensive crops across varying proportions of targeted areas. We show that for lower targeted areas, much higher cash incentives are required to encourage the shift away from paddy cultivation. This finding highlights the need for crop-specific policy interventions rather than one-size-fits-all approach, although there may be trade-off as implementation could be challenging.

Thirdly, we propose an alternative approach for implementing the crop diversification scheme to enhance its cost-effectiveness for the government. In particular, we assess potential cost savings through differential cash incentives based on land size. Furthermore, we emphasize the importance of investing in research to improve the productivity of less water-intensive crops rather than relying solely on cash incentives, as this may offer a more sustainable way to achieve the objective of the policy in the longer term.

The rest of the paper is organized as follows. Section 2 provides context by describing the groundwater situation in northwestern India, the policy instruments used for water conservation, and a comprehensive overview of the crop diversification scheme in Punjab and Haryana. Section 3 outlines the data used in this study. Section 4 discusses the methodology for assessing whether the incentives under the current scheme are sufficient, along with potential improvements and challenges in implementing such a policy. Section 5 presents the results of the analysis. Section 6 discusses the limitations of the study and offers possible explanations for the findings. Section 7 concludes the paper.

2 Context

Indian agriculture relies heavily on groundwater for irrigation. Much of this dependency is driven by changing cropping patterns and sub-optimal government policies, especially highly subsidised inputs such as farm power. Given that farmers barely pay any charges for the electricity used for groundwater pumping, they do not use the scarce water resources efficiently, leading to a situation where groundwater extraction exceeds its natural recharge.

This problem is more severe in northwestern India, especially in Punjab, where farm power is free since 1997, and in Haryana, where it is highly subsidised, requiring farmers to pay a small monthly fee dependent on the horsepower rating of their water pumps (Gupta, 2023; Shah et al., 2012). As a result, more than 75 percent of the blocks in Punjab and 62 percent in Haryana are categorized as "over-exploited" (CGWB, 2024).[2] Figure 1 shows the states of Punjab and Haryana on the map of India, and the categorization of blocks by groundwater status. Areas marked in red are classified as over-exploited.

[Insert Figure 1 here]

While in the 1980s, the cultivation of less water-intensive crops like maize, cotton, and pearl millet was dominant in these regions, four decades later, paddy cultivation is dominant in the *kharif* season from July to October. In 1984-85, the area under maize and cotton cultivation was 303.8 thousand hectares and 472.4 thousand hectares, respectively, in Punjab while that under water-intensive paddy was 1,644.2 thousand hectares. By 2022-23, the paddy area had increased to 3,167.8 thousand hectares while, maize and cotton areas shrunk to 93.3 thousand hectares and 248.9 thousand hectares, respectively. Similar trends existed in Haryana. The area under paddy expanded from 557.3 thousand hectares to 1,661.3 thousand hectares, while that under pearl millet declined from 748.3 thousand hectares to 526.2 thousand hectares over the same four decades.[3] Huge farm

[2]The Central Ground Water Board (CGWB) defines over-exploited blocks as administrative units where groundwater extraction exceeds natural recharge.

[3]The data on area under various crops in Punjab and Haryana for the year 1984-85 is taken from the Land Use Statistics published by Department of Agriculture & Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India. Please refer to: https://desagri.gov.in/document-report-category/land-use-statistics-at-a-glance-archive/. For 2022-23, data is taken from the Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India. For details, please see: https://data.desagri.gov.in/website/crops-apy-report-web. Last accessed in February, 2025.

power subsidies and the dominance of paddy cultivation, coupled with assured procurement of rice at MSP, have together contributed to increased groundwater overextraction over the years.

Several policy instruments have been used to tackle this situation and studies show mixed results.[4] For instance, based on a pilot intervention in Punjab in 2018 where farmers were given cash incentives for saving electricity below a pre-specified allocation, Mitra et al. (2023) shows a reduction of at least 7.5 percent in electricity consumption and irrigation hours without any negative impact on paddy yields. On the other hand, Fishman et al. (2016) examine the impact of a similar intervention in Gujarat in 2012 and finds no such reduction in electricity and water use.

Delay in transplantation of paddy is another policy instrument used for reducing water extraction since initial water requirements are fulfilled by the monsoon instead of groundwater pumping. Tripathi et al. (2016) finds a reduction in groundwater depletion in Punjab as a result of delaying sowing and transplantation of paddy till the onset of monsoon under the 2009 Sub-soil Water Act.

Using micro-irrigation technologies is another approach that could enhance water savings. A randomized control trial based in Andhra Pradesh, India, found an improvement in irrigation efficiency for farmers who were randomly given subsidies to adopt drip irrigation compared to the control group (Fishman et al., 2023). However, there were no savings in groundwater extraction due to a simultaneous increase in the irrigated area which offset the water savings of the drip irrigation adopters.

Laser land leveling is another approach for saving water since leveled fields require less water for irrigation. Lybbert et al. (2018) use experimental data from selected districts in eastern Uttar Pradesh in 2011 and 2012 to evaluate the impact of targeted subsidies for laser land leveling and find that farmers who adopted the technology reduced groundwater extraction by 25 percent, leading to improved water use efficiency.

Under alternate wetting and drying (AWD), a perforated and hollow plastic pipe is installed vertically in the farmer's paddy plot to observe the soil moisture level and identify the timing of subsequent water applications (Chakravorty et al., 2023; Howell et al., 2015).

[4] Balasubramanya (2025) provides an overview of the groundwater situation in South Asia and an excellent review of the literature on groundwater management approaches, highlighting potential research pathways for better policymaking.

Based on a randomized control trial in Bangladesh, Chakravorty et al. (2023) shows that farmers who adopt AWD use 19 percent less water under the volumetric pricing of water. However, for the overall sample, they find no significant reduction in water use from AWD adoption.

While the above approaches primarily target a reduction in irrigation water application, the actual savings can be limited if the current cropping pattern of water-intensive crop cultivation is kept unchanged. An effective reduction in groundwater extraction that leads to an improvement in the water table could be made possible through a crop diversification strategy provided there are sufficient returns in terms of net gain in profitability and the procurement of these crops at MSP (Sarkar and Das, 2014).

The Crop Diversification Programme was first introduced by the Indian government under the Rashtriya Krishi Vikas Yojana (RKVY) in Punjab, Haryana, and Uttar Pradesh in 2013-14 to encourage farmers to shift area under water-intensive paddy cultivated in the *kharif* season to less water-intensive crops such as maize, cotton, pulses, etc.[5] The primary objective of this scheme was to improve soil fertility, reduce water depletion, and improve farmers' incomes. The government proposed diverting at least 5 percent of the paddy area to alternative crops, which was equivalent to 0.14 million hectares in Punjab, and 0.06 million hectares in Haryana. They set aside a budget of Rs. 500 crores for the same. They also provided support for farm mechanisation to facilitate the transition to these crops. However, the scheme did not achieve its intended target due to a lack of markets for the alternative crops, the assured procurement of paddy at MSP that reduced the market risk unlike these crops, and ineffective implementation.

The Haryana government launched the revamped "*Mera Pani Meri Virasat*" scheme (translates to "my water, my heritage") in May 2020 to promote crop diversification in the state for water conservation. Under this scheme, a cash incentive of Rs. 7,000 per acre was offered to farmers who shifted area under paddy cultivation to less water-intensive crops.[6] The government's proposal was to shift 50 percent of the paddy area to alternative crops in year 2000. A higher cash incentive of Rs. 10,000 per acre for 3 years was offered for adopting agro-forestry instead of paddy farming by planting at least 400 trees per acre.

[5]Please see the detailed guidelines for the Crop Diversification in Original Green Revolution States: https://www.nfsm.gov.in/Guidelines/CDGuidelines.pdf. Last accessed by the authors in July 2024.

[6]For details on "Mera Pani Meri Virasat" scheme, please see: https://agriharyana.gov.in/data/SchemeDoc/mera_pani_meri_virasat.pdf.

Additionally, the government provided assured procurement of less water-intensive crops cultivated under the scheme at MSP. In May 2021, the Haryana government extended the cash incentive of Rs. 7,000 per acre to include farmers not growing any crop in their field during the paddy season under the new scheme, "*Kheti Khaali, Fir Bhi Khushali*" (translates to "farm is empty, yet there is happiness").[7] A crop-specific cash incentive of Rs. 2,400 per acre for maize cultivation and Rs. 3,600 per acre for the cultivation of pulses, such as *moong*, *urad*, and *arhar*, was introduced by the state government in 2022, with a target of bringing 62,500 acres under maize and 32,500 acres under pulses.[8] The government proposed to replace 0.1 million hectares of paddy area with alternative crops under this scheme. However, only half of the target of 0.53 million hectares was achieved in 2022.

A similar crop diversification strategy was announced in Punjab in 2021. The National Bank for Agriculture and Rural Development (NABARD) under the National Adaptation Fund for Climate Change (NAFCC) project planned to offer a cash incentive of Rs. 23,500 per hectare to farmers who shift from paddy to the cultivation of maize and cotton.[9] The Punjab government set a target of diversifying 1 million hectares out of a total of 3.1 million hectares under paddy in a period of five years.[10] This was roughly equivalent to diversifying 30 percent of the paddy area. In 2024, the Crop Diversification scheme was revised, and farmers in Punjab were offered a cash incentive of Rs. 17,500 per hectare for shifting away from paddy cultivation.[11]

In our paper, we have assumed a cash incentive of Rs. 23,500 in Punjab, and Rs. 7,000 per acre in Haryana, even though a lower cash incentive was most recently announced in Punjab. This is done to show that a higher cash incentive is also insufficient to meet the target. We have assumed that the targeted area is 30 percent of the area under paddy for both the states. We discuss in the later section, the amount of paddy area that needs to be diversified to resolve the issue of groundwater depletion in this area.

[7]For details, please refer to: https://haryanacmoffice.gov.in/21-may-2021-0.

[8]For details on crop-specific cash incentives, please see: https://agriharyana.gov.in/CDPOriginalGreen.

[9]For details, please see: urlhttps://indianexpress.com/article/cities/ludhiana/in-11-punjab-districts-farmers-who-cultivate-maize-instead-of-paddy-to-get-financial-aid-7242290/.

[10]For details, please see: https://tinyurl.com/punjabcropdiversification

[11]For details, please see: https://economictimes.indiatimes.com/news/economy/agriculture/farmers-to-get-rs-17500/hectare-for-switching-from-paddy-to-other-crops-punjab-minister/articleshow/111890064.cms?from=mdr.

3 Data

In this paper, we use the plot-level data for Punjab and Haryana obtained from the cost of cultivation surveys that are conducted by the Commission for Agricultural Costs and Prices (CACP), Ministry of Agriculture & Farmers Welfare, Government of India. We use the data for the three-year block period from 2017-18 to 2019-20, since this is the most recent block period data that is publicly available.[12] The publicly accessible data provides plot-level information for only the principal crops in each state. It includes data on area under cultivation, output produced, and inputs quantities and costs for labour, machine, irrigation, seeds, fertilizers, insecticides, land etc. for each of the principal crops by season.

Three-stage stratified random sampling procedure is employed by the CACP for collecting the plot-level data. In both Punjab and Haryana, there are three zones corresponding to different agro-climatic zones. Within each zone, the number of tehsils (first stage unit) sampled is determined based on the proportion of area dedicated to the selected principal crops in that zone of a particular state. Tehsils within a zone are selected with a probability proportional to the area under the selected principal crops and with replacement. For each tehsil, a village (second stage unit) is again sampled with probability proportional to the area under the selected crops. Within each village, operational holdings are categorized into five size classes as follows: size group 1 for operational holdings less than 1 hectare, size group 2 for area between 1-2 hectares, size group 3 for area between 2-4 hectares, size group 4 for area between 4-6 hectares, and size group 5 for area greater than 6 hectares. For each size-class group, two plots (third stage unit) are selected using simple random sampling without replacement.

Since we are interested in crop diversification of area under cultivation away from water-intensive paddy, and paddy is cultivated in the *kharif* season in both the states, we will focus on crops grown in the *kharif* season only. There are three principal crops cultivated in the *kharif* season in Punjab, namely, paddy, maize, and cotton; while in Haryana, farmers cultivate paddy, pearl millet and cotton. The total number of plot-year observations in our sample are 1601 for paddy, 109 for maize and 191 for cotton in

[12]The plot-level CACP data can be downloaded from: https://eands.da.gov.in/Plot-Level-Summary-Data.htm. Last accessed by the authors in October 2022.

Punjab, and 574 for paddy, 392 for cotton and 317 for pearl millet in Haryana (Table 1).

[Insert Table 1 here]

For computing different measures of profits for alternative crops, we use data on the input costs and value of agricultural output from the state-level CACP reports on cost of cultivation and production data given by Ministry of Agriculture & Farmers Welfare, Government of India, for the three years considered in our study.[13]

Additionally, in our analysis, we use the data on year-wise Minimum Support Prices (MSP) for principal crops, as announced by the Government of India based on recommendations from the CACP.[14] The government sets the MSP as 1.5 times of A2FL cost of cultivation which is the aggregation of the total paid-out cost incurred by farmers and the value of family labour.

4 Methodology

This analysis aims to examine the extent to which the farmers in Punjab and Haryana would shift away from paddy cultivation at different cash incentive levels provided that the less-water intensive non-paddy *kharif* crops cultivated under this scheme are procured at their respective Minimum Support Prices (MSP). For this, we assume that a farmer will shift away from paddy cultivation on a particular plot if the profit from cultivating paddy on that plot is lower than the average return that can be earned from cultivating any other non-paddy crop, such as maize, cotton, pulses, etc. This average return is the sum of the cash incentive offered by the government and the profit from these less water-intensive *kharif* crops assuming that they are procured at MSP. Since we do not observe the counterfactual, that is, the actual profit that could have been earned from cultivating any non-paddy crop on a particular plot where the farmer is currently cultivating paddy, we compare the profit from paddy cultivation on any given plot with the average profit from cultivating alternative less water-intensive crops with procurement at MSP, in order to determine whether there would be a shift in cultivation or not.

[13]For the state-level CACP reports, please see: https://desagri.gov.in/document-report-category/cost-of-cultivation-production-estimates/. Last accessed by the authors in July 2023.

[14]For details on the MSP data, please see: https://desagri.gov.in/wp-content/uploads/2023/07/MSPEnglish_websitestatistics-1-1.pdf. Last accessed by the authors in July 2023.

We construct two measures of average profit that could be earned by cultivating alternative crops which are used as counterfactuals in the analysis: i. all-India measure which is the area-weighted mean of the average state-level profits from cultivating less water-intensive crops, and ii. state-specific measure which is the weighted mean of the average profits from cultivating these crops in each agro-climatic zone in Punjab and Haryana.

For computing the all-India measure, we consider all the eleven non-paddy principal crops cultivated in the *kharif* season across all the states in India, namely, black gram (*urad*), cotton, finger millet (*ragi*), green gram (*moong*), groundnut, maize, pearl millet (*bajra*), pigeon pea (*arhar*), sesame, sorghum (*jowar*), and soybean. The average state-level crop-specific profits (in rupees per hectare) for these alternative crops is computed as the difference between the value of agricultural output at MSP, that is, the average revenue earned by the farmer if these crops are procured at MSP,[15] and the cost of cultivating that particular crop. We then compute the all-India weighted average of the state-level profits for each of these crops. The weights are based on the share of area under cultivation of these crops in each of these states.

It is important to note that not all the eleven non-paddy crops considered here are cultivated in all the states, and CACP data is recorded for only the principal crops that are cultivated in each of the states. For instance, the principal crops cultivated in Punjab in the *kharif* season are paddy, maize and cotton, while that in Haryana are paddy, pearl millet and cotton, and thus we have data on value of output and input costs for only these crops. However, the crop diversification scheme covers a larger set of less water-intensive non-paddy crops, and the all-India measure allows us to construct a counterfactual for returns that could be earned by the farmers in Punjab and Haryana for the wider range of crops that may not be actually cultivated in these two states.

The second measure used for profit comparison is the state-specific average profit that could be earned by cultivating non-paddy crops. For constructing this measure, we first identify the non-paddy crops cultivated in each of the agro-climatic zones in Punjab and Haryana. We compute the weighted average profits from cultivating these less-water intensive non-paddy crops for each zone, where weights are based on the share of area

[15]For some cases, value of agricultural output at MSP was less than that at the market price. We have taken the larger value among the two, given that the objective of the government to procure these non-paddy crops at MSP is to cover the market risk faced by the farmers.

under cultivation in the zone. In some zones, multiple non-paddy crops are cultivated. For instance, in all the three zones of Haryana, farmers cultivate cotton as well as pearl millet in the *kharif* season in addition to paddy (Table 2). For such zones, we consider the average profits from cultivating the non-paddy crop which is dominant based on the number of plots on which it is cultivated in the study period. In Punjab, the alternative non-paddy crop cultivated in zones 1 and 2 is maize while farmers cultivate cotton in zone 3. In Haryana, we consider average profits for pearl millet in zone 1 while that of cotton in zones 2 and 3, based on the above criteria (Table 2). This measure allows us to make comparisons using the actual profits made from cultivation of alternative non-paddy crops in both the states, considering different crops in each zone that would be more likely to replace paddy under such a scheme.

[Insert Table 2 here]

We use three alternative cost definitions for computing profits from cultivation of paddy and non-paddy crops in our analysis. First is the paid-out cost which includes cost of attached labour, casual labour, owned and hired animal labour, owned and hired machine labour, seeds, insecticides, manure, fertilizer, irrigation charges for owned and hired pumps, rent paid for leased-in land, land revenue and miscellaneous cost. Second is the A1 cost. In addition to all the components of the paid-out cost except rent paid for leased-in land, it includes depreciation on implements and farm buildings and interest on working capital. The third cost definition that we consider is A2FL which includes rent paid for leased-in land and cost of family labour in addition to all the components of A1 cost.

In order to estimate the proportion of area that would get shifted away from paddy in response to various cash incentives, we first determine the total area that would get shifted for each size class using plot-level data for both the states. We compare the profit per hectare from paddy cultivation on each plot with the average return per hectare from non-paddy crops, using the all-India and state-specific measures, for various cash incentives.[16] If the former is lower than the latter, we assume that the cultivation on entire plot area

[16]The publicly available plot-level cost of cultivation data does not have information on depreciation on implements and farm buildings and interest on working capital needed for calculating the A1 and A2FL costs. So, we compute plot-specific profit per hectare excluding these two components. However, we subtract the (crop-specific) state-level estimates of these two components (given in the state-level reports of the CACP) from the computed state-level returns from cultivation of each crop to get at our final estimate of comparison.

would be shifted to non-paddy crop since it is more profitable to cultivate than paddy. We will refer to this as the *shifting criteria* for any plot.

Once we know whether a particular plot (where paddy is currently cultivated) would shift or not, we estimate the total area that would be shifted to non-paddy crops in each of the states for every size class in all the three years. To do this, we calculate a year-wise weighted sum of the area of all such plots that meet the *shifting criteria* within each size group, where weights are taken as the sampling weights as defined by the CACP in conducting cost of cultivation surveys.[17] We finally take the three-year average of the total area shifted in every size class in both the states to get the estimate of the average area that will get shifted out of paddy. We do this computation for several cash incentives. We consider cash incentives ranging from Rs. 0 to Rs. 100,000 in the intervals of Rs. 100 which is equivalent to 1000 different combinations of cash incentives offered to the farmers. For each possible cash incentive in this range, we compute the total paddy area that will get shifted to non-paddy crops by aggregating the area shifted in every size class at that particular (and same) cash incentive offered to farmers of all the size classes. From here, we also compute the proportion of total paddy area that will get shifted away from paddy cultivation. This allows us to find out the amount of cash incentives required for different proportions of shifts in paddy area that could be targeted under the scheme and the government expenditure[18] needed for implementing the crop diversification policy.

The next objective is to assess whether a size class based targeted cash incentive scheme can achieve a similar shift in paddy area but with lower government expenditure. Here we explore the relationship between the proportion of paddy area that will get shifted and the government expenditure on the crop diversification scheme when farmers of different size classes receive varying cash incentives. We employ the brute force approach

[17]The sampling weights are defined as: $(A \times M_{ijk})/(t \times A_{ij} \times m_{ijk})$ where M_{ijk} refers to the number of operational holdings on which a particular crop is cultivated in size class k of village j and tehsil i; m_{ijk} refers to the number of holdings sampled out of M_{ijk}; A is the area under all the selected crops in the zone; A_{ij} is the area under all the selected crops in village j and tehsil i; and t is number of sampled tehsils in the zone.

[18]The expenditure made by the government for implementing crop diversification scheme is the product of cash incentive and the area shifted away from paddy. For simplifying the computation, we round-off the proportion of shifted area to two decimal places, resulting in 100 possible proportions ranging from 0 to 1. Then, if multiple cash incentives lead to the same proportion of area shift, we select the incentive profile with the lowest government expenditure. This results in a smooth function of the minimum government expenditure required to achieve any proportion of paddy area shift at 0.01 intervals.

to compute the total area that will get shifted for all possible combinations of cash incentives across the five size groups. In the case of varying cash incentives ranging from Rs. 0 to Rs. 100,000 in the intervals of Rs. 100, there would be 1000 possible cash incentives to farmers of each of the five size groups resulting in a total of 1000 trillion possible combinations of cash incentives.[19] We compute the total area that would shift and government expenditure incurred by aggregating these values for all the size groups for each possible combination of cash incentives.[20] Using this method, we determine the cash incentive scheme, varying across five size classes, that minimizes government expenditure for any targeted proportion of area (which is also rounded-off to two decimal places i.e., in the interval of 0.01).

However, it may be difficult to implement the size group based cash incentive if these vary without any pattern. To simplify targeting, we consider monotonically differentiated cash incentive scheme with only one possible jump or drop. For example, if Rs. 1000 per hectare is offered to size groups 1 and 2, and then the incentive increases to Rs. 30,000 per hectare for size groups 3, 4 and 5, it is monotonically increasing cash incentive scheme with one jump. Conversely, it could drop to Rs. 500 per hectare for size groups 3, 4 and 5, making it a monotonically decreasing scheme with one drop. This jump or drop can occur at any size group but is limited to one change. Employing the brute force approach as before, we calculate the proportion of shift in paddy area and the required government expenditure for all monotonically differentiated cash incentive schemes, i.e., in the algorithm, we drop any combination that violates the conditions for monotonically differentiated cash incentive scheme with only one break-point. We compare the varying cash incentive schemes (without any restriction and with monotonically increasing or decreasing incentive) against the constant cash incentive scheme to estimate potential savings in government expenditure for specific target proportions of shift in paddy area.

[19] 1000 possible cash incentives such as Rs. 0, 100, 200, and so on, and varying them for farmers of each of the 5 size groups (for instance, Rs. 0 to farmer of size group 1, Rs. 200 to size group 2, Rs. 100 to size group 3, Rs. 200 to size group 4, Rs. 300 to size group 5 and so on) makes it 1000^5 combinations which is equivalent to as many as 1000 trillion (or 1,000,000,000,000,000) combinations.

[20] To manage time and computer memory requirements, we employed an algorithm that added one size class after another and in each step, removed redundant combinations before adding possible combinations with the next size class, to reduce the overall number of combinations that we check. These redundant combinations are achieved by rounding-off the shifted area to the nearest hundred hectares (to get multiple combinations giving the same shift in area approximated to the nearest hundred hectares), and then keeping only those combinations that minimize the government expenditure.

5 Results

In this section, we first discuss the results based on profit comparison between paddy plots with the all-India weighted average profits made by the cultivation of the non-paddy (less water-intensive) crops for both the states assuming that the latter are procured at MSP. This is followed by a comparison with the state-wise average profits earned by cultivating non-paddy crop that is dominant in each of the agro-climatic zones in Punjab and Haryana.

5.1 Are the current incentives enough to shift to non-paddy crops?

Under the crop diversification scheme, a cash incentive of Rs. 23,500 per hectare in Punjab and Rs. 7000 per acre (which is roughly equivalent to Rs. 17,300 per hectare) in Haryana along with procurement of non-paddy crops at MSP was announced for shifting area under paddy cultivation to other less water-intensive paddy crops like maize, cotton, pulses, etc. We have used this initial announcement for our analysis in the paper.

Table 3 presents results for the average proportion of area that would shift out of paddy to less water-intensive crops, assuming that farmers are given the announced cash incentive per unit of area and that the non-paddy crops are procured at their respective MSPs. In order to examine the proportion of area that is likely to shift out of paddy, we make a profit comparison with all the eleven less water-intensive principal crops, namely, black gram (*urad*), cotton, finger millet (*ragi*), green gram (*moong*), groundnut, maize, pearl millet (*bajra*), pigeon pea (*arhar*), sesame, sorghum (*jowar*), and soybean, that are cultivated in the *kharif* season across India. Among these crops, the cultivation of *arhar* and cotton emerges as the most profitable alternatives while the cultivation of *jowar* and *ragi* as the least profitable options, taking into account the announced benefits of the crop diversification scheme. Considering A2FL cost for profit computation and assuming that farmers could earn the average all-India weighted profit for cultivating the non-paddy crop, we find that an average of 5 to 14 percent of area could get shifted away from paddy to less water-intensive crops in Punjab (Columns 1 and 4 of Table 3) while an average of 2 to 8 percent of area can get shifted in Haryana. In particular, even if the farmers cultivate the most profitable non-paddy crop *arhar*, only about 14 and 8 percent

of area under paddy in Punjab and Haryana, respectively, gets shifted to *arhar* cultivation under the current scheme. This is much lower than the government's target of shifting 30 percent of the area under paddy cultivation to non-paddy crops in order to tackle the issue of groundwater depletion in Punjab. Results are qualitatively similar when profit computation is done using A1 and paid-out costs where no more than 16 percent of the area can get shifted away from the more water-intensive paddy in Punjab (Columns 2 and 3 of Table 3) and the maximum area that can get shifted to less-water intensive crops in Haryana is only 10 percent (Columns 5 and 6 of Table 3).

[Insert Table 3 here]

Apart from paddy, the other principal crops that are cultivated in *kharif* season in Punjab are maize and cotton, and those in Haryana are pearl millet and cotton.[21] If we assume that alternatively, farmers cultivating paddy can earn the average profit of a farmer growing the dominant non-paddy crop in each zone, we find that the average proportion of area that would shift away from paddy to either maize, pearl millet or cotton is still lower than the targeted area. The average proportion of area under paddy that would shift to less water-intensive maize or cotton in Punjab is about 17–20 percent (Figure 2a), which is 33 percent lower than the targeted area for reducing over-exploitation of groundwater in the state. Similarly, in Haryana, the average area that would shift out of paddy is about 11–16 percent which is even lower (Figure 2b). These results imply that the current policy of giving a cash incentive of Rs. 23,500 per hectare in Punjab and Rs. 17,300 per hectare in Haryana for each unit of area shifted to less water-intensive crops along with procurement of these crops at MSP is not sufficient to shift the targeted area away from paddy for the management of groundwater resources in these two states.

[Insert Figure 2 here]

5.2 How much cash incentive is required for crop diversification?

Since the average profit that farmers could earn from cultivating various less-water intensive crops is different, the cash incentive required to shift from paddy to these crops

[21] There are three agro-climatic zones each in Punjab as well as Haryana. In terms of non-paddy less water-intensive *kharif* crops, maize is the dominant crop in two out of three zones in Punjab, while cotton cultivation dominates in the remaining zone. Similarly, in Haryana, cotton is the dominant non-paddy crop in two zones, while pearl millet in the third one.

also varies. Figure 3 shows the average proportion of area under paddy cultivation that would get shifted to less water-intensive crops at various levels of cash incentives in both the states assuming that the government procures these non-paddy crops at MSP. The two solid dark blue graphs are for the most profitable non-paddy crop, *arhar* and for the least profitable, *jowar*. All the dotted lined graphs between them are for the other non-paddy crops mentioned earlier. Note that, in this computation, all types of farmers would be offered the same amount of cash incentive for shifting out of paddy. We get these results from making comparisons between profits earned by cultivating paddy on each plot with average all-India profits earned by cultivating various non-paddy crops computed at A2FL cost.[22] In order to shift up to 30 percent of area under paddy to non-paddy crops, the amount of cash incentive increases steeply. But for shifting more than 30 percent of the area away from paddy, though farmers need to be offered larger cash incentive per hectare, the amount increases at a decreasing rate (Figure 3). The average cash incentive required to shift 30 percent of area under to paddy to jowar is Rs. 80,000 per hectare and to arhar is Rs. 50,100 per hectare in Punjab (Figure 3a). Similar is the situation in Haryana. For shifting the targeted area from paddy to *jowar*, farmers should be given an average amount of Rs. 73,200 per hectare and an amount of Rs. 43,300 per hectare for shifting to *arhar* (Figure 3b). While the incentive to shift to different crops varies but our results show that the cash incentive required for crop diversification could be as high as 2.5 times the amount currently offered under the current scheme in order to shift to even the most profitable non-paddy crop.

Under the current crop diversification scheme, the average cost of the policy for the government assuming that the farmers who would shift 30 percent of the area from paddy to less water-intensive crops ranges from Rs. 44.5 billion to 70.8 billion in Punjab and Rs. 18.5 billion to 31.2 billion in Haryana (Figure 3).[23] This is much higher as compared to the cost that the government would incur if it continues to provide cash incentives of Rs. 23,500 and Rs. 17,300 per hectare in Punjab and Haryana, respectively under the

[22]In the remaining paper, all the results are discussed using profits computed at A2FL cost because this cost definition captures all the paid-out cost by the farmer in cash and kind, and also the imputed family labour cost. In addition, this definition is also used by the government for recommending MSP. The results are qualitatively similar using the other cost definitions (A1 cost and paid-out cost) as defined earlier, unless stated otherwise.

[23]The average cost for the policy implementation by the government is the amount of cash incentive per hectare given to farmers times the area shifted away from paddy to less water-intensive crops measured in hectares.

current scheme where the targeted shift in area for reduction in groundwater depletion is not met in either of the regions.

[Insert Figure 3 here]

When the decision to shift to cultivation from paddy to less water-intensive crops is based on comparison with the average profit that could be earned from cultivating the dominant non-paddy crop in each zone, we find that a cash incentive of Rs. 35,000 per hectare in Punjab and Rs. 36,500 per hectare in Haryana is required to shift the targeted area of 30 percent away from paddy cultivation (Figure 4). This amount is 49 percent higher than the cash incentive announced under the current policy in Punjab and more than double the incentive offered in Haryana.

Further, it will cost about 31.1 billion rupees to the government in Punjab to shift the targeted area out of paddy cultivation which is approximately three times the average cost of policy under the current scheme where only 17 percent of the paddy area would get shifted to maize and cotton (Figure 4a). In Haryana, the average cost of the policy to the government for shifting 30 percent area away from paddy cultivation will be about 15.6 billion rupees which is five times under the present scenario where only 11 percent of the paddy area would get shifted to less water-intensive pearl millet and cotton (Figure 4b). Our results show that a much higher cash incentive is required to shift the targeted area from paddy to less water-intensive crops in both states, assuming procurement is done at MSP. This also results in a higher cost of policy implementation for the government compared to the currently announced scheme.

[Insert Figure 4 here]

5.3 Can heterogenous cash incentives reduce policy implementation costs?

Under the current scheme, the government offers a fixed and homogenous cash incentive of Rs. 23,500 per hectare in Punjab and Rs. 17,300 per hectare in Haryana along with procurement of non-paddy crops at MSP to all the farmers who shift away from paddy cultivation. However, offering a differential or heterogenous cash incentive based on farm size groups could lower the cost burden of this policy. There are several ways to improve targeting given the budget for this scheme, for instance, it could be based on farmers'

income. In our paper, we propose an alternative way to target farmers using size classes based on the landholding size because: i. it is easier to observe and record area under cultivation by each farmer; ii. the third-stage of sampling in the CACP data is based on land size. If farmers across different size classes are offered a heterogenous cash incentive based on land size, we find that the cost of policy to shift about 30 percent of area under paddy cultivation to least-profitable crop *jowar* decreases from Rs. 70.8 billion to 66 billion in Punjab when profit comparison is made using the all-India average profit that could be earned from cultivating non-paddy crops. Even if cultivation is shifted from paddy to the most profitable non-paddy crop, there would still be cost savings. In this case, the policy cost reduces from about Rs. 44.5 billion to 39.5 billion for shifting the targeted area away from paddy. This amounts to roughly 7–11 percent of the cost burden of the policy incurred by the government in Punjab. However, the scenario differs in Haryana, where a differential cash incentive would result in only 1.5–3 percent reduction in policy implementation costs.

It should be noted that implementing differential cash incentives could be challenging if the amounts offered to farmers of different size groups are non-monotonic. For instance, if farmers in size groups 1 and 3 are given higher cash incentives than those in size group 2, identifying these farmers and administering the differential cash transfers would be difficult. To address this, we impose a restriction to ensure that the differential cash incetives are monotonic in nature. If a monotonic differential cash incentives by land size are offered instead of constant transfers as in the current scheme, there are still cost savings when shifting land away from paddy to less water-intensive crops. However, these monetary savings are lower than in the former case of differential cash incentive without any restriction of monotonicity on the transfer amount. Figure 5 illustrates the percentage savings in total government expenditure if a non-monotonic (solid line) and a monotonically varying cash incentive (dotted line) is offered to farmers of different size groups, as compared to a constant cash incentive across all the farmers. This is shown at varying proportions of paddy area shifted to non-paddy crops. For both the less-water intensive crops, arhar and jowar, the percentage cost savings are lower under the monotonic cash incentive as compared to the non-monotic case in Punjab as well as Haryana. Additionally, the cost savings from implementing a differential cash incentive are much higher when targeting lower proportions of land for crop diversification, whereas

targeting larger areas results in relatively smaller savings. The findings are similar when we compare the average profits earned from cultivating the remaining nine less water-intensive crops.

[Insert Figure 5 here]

The results remain qualitatively similar when profit comparisons are based on the average profit that could be earned from cultivating the dominant non-paddy crop in each zone, although the magnitude of cost savings for the government becomes slightly smaller. Offering a differential cash incentive (either monotonic or non-monotonic) to farmers of different size groups reduces the average cost of policy from Rs. 31.1 billion to 29.6 billion in Punjab and from Rs. 15.6 billion to 14.9 billion in Haryana for shifting the target area of 30 percent away from paddy. This translates to approximately 4–5 percent savings in the cost of policy for the government. Figure 6 presents the percentage savings in policy costs when a differential cash incentive is implemented in this scenario. Notably, the savings in policy costs are higher when smaller proportions of area are shifted away from paddy but as more paddy area is reallocated to non-paddy crops, the savings from implementing a differential cash incentive diminish significantly.

[Insert Figure 6 here]

6 Discussion

In our analysis, we have considered a target proportion of 30 percent of the paddy cultivation area to be shifted to less water-intensive crops. This is based on the crop diversification scheme announced by the Punjab government. Note that while Punjab government explicitly set a target area to be achieved under its crop diversification scheme, the Haryana government did not specify such a goal. In this paper, we have assumed a common target of 30 percent for both the states for comparison of results. However, a simple back-of-the-envelope calculation of the average area that needs to be shifted out of paddy to balance annual groundwater extraction with natural recharge suggests that the required target areas should be 33 percent in Punjab and 18 percent in Haryana.

To estimate this, we first calculate the average annual over-extraction of groundwater resources (in billion cubic meters) as the difference between annual extractable ground-

water resources and current annual groundwater extraction, reported by the CGWB.[24] Taking the average crop water requirements for rice, maize, and pearl millet cultivation to be 1250 mm, 500 mm, and 500 mm, respectively (Sharma et al., 2018), we calculate the water savings per hectare when shifting from paddy cultivation to alternative crops like maize or pearl millet. Using these calculations, we determine the proportion of area that needs to shifted in order to reduce the average annual over-extraction of groundwater resources to zero, assuming that this is achieved solely through crop diversification.

Interestingly, Punjab's announced target of 30 percent area diversification away from paddy closely aligns with our estimated requirement for the state. In contrast, even if Haryana were to set a target of 18 percent, at most only half of this would be achieved under the current cash incentives announced by the state government, considering both measures of the average profit of alternative crops used in our analysis.

The profit comparisons in our paper rely on several critical assumptions. We assume profit-maximizing farmers with a narrow definition of profit as the net monetary return from cultivation. However, it is important to recognize that farmers' decisions are influenced by various other factors that we do not consider, including behavioural biases, risk preferences, personal taste, and broader crop planning for the year. For instance, the choice of the *kharif* crop may impact the subsequent cultivation of *rabi* crops such as wheat in the region. Thus, it is important to note that the actual cash incentives required for crop diversification could be significantly higher if we also account for the market risk and production risk associated with cultivating alternative crops. Since incorporating these risk factors is expected to impact the returns from alternative crops negatively, the cash incentive computations in our study are likely to be lower bounds of the actual incentives required to make such a shift possible. Moreover, the actual net returns from non-paddy crops can vary significantly from the average state or India-level profits, depending on factors such as farmer capacity, soil type, plot elevation, irrigation availability, and climatic conditions. The most profitable non-paddy crop will also differ from plot to plot, a detail we lack. Since we do not observe this counterfactual, we rely on average profit comparisons.

[24]Data on groundwater resources is taken from reports on the "Dynamic Groundwater Resources of India" for the years 2017, 2020, and 2022, published by the Central Ground Water Board. For details, please see: https://www.cgwb.gov.in/old_website/Dynamic-GW-Resources.html. Last accessed by the authors in October 2023.

Another important assumption we make is that we do not account for the general equilibrium effects that may arise if a significantly large share of area under paddy cultivation is diversified to other crops in Punjab and Haryana. Such a shift could lead to market oversupply and reduction in prices for certain crops, particularly those with limited demand, like pearl millet. Addressing this would require increased public procurement of other non-paddy crops at minimum support prices, which will have its own implementation challenges and falls beyond the scope of this paper. Additionally, our analysis does not account for the production risks associated with different crops, which significantly influence farmers' crop choices. While price risks may also be relevant, we assume that both paddy and non-paddy crops are being procured at MSP by the government. In this paper, we focus solely on comparing the static returns and do not delve into their variability.

Given these caveats, using the plot-level cost of cultivation data for the period 2017-18 to 2019-20 from the Commission for Agricultural Costs and Prices (CACP), our paper shows that the average proportion of area that would shift out of paddy to less water intensive crops (considering A2FL costs) is 17 percent in Punjab and 11 percent in Haryana which is much lower than the targeted area of 30 percent. In other words, the current cash incentives under the crop diversification scheme are insufficient to achieve the required reduction in paddy cultivation necessary to curb groundwater depletion in this region. This is likely due to the high yields and comparatively lower cost of production for paddy, which make it much more profitable compared to other alternatives. As a result, substantialy higher cash transfers would be needed to incentivize farmers to shift to cultivation of crops with lower water requirements.

We show that the average cash incentives required for shifting out of paddy range from Rs. 50,100 to 80,000 per hectare in Punjab while Rs. 43,300 to 73,200 per hectare in Haryana, which is about 2.5 times of the current cash incentives announced by the state governments, even when targeting a shift to the most profitable less water-intensive crops in these states. Finally, using a brute-force approach, we evaluate nearly 1,000 trillion cash incentive combinations between Rs. 0 and Rs. 100,000 to identify the most profitable combination of cash incentive for the farmers to shift out of paddy while minimizing the government's cost of policy implementation as compared to the current incentive structure. Our results suggest that, instead of offering a uniform cash incentive to all

farmers, a differential cash incentive based on farm size could lead to cost savings of 7–11 percent in Punjab and 1.5–3 percent in Haryana. However, while differential cash incentives reduce costs for the government, their implementation presents challenges, particularly in terms of identifying and targeting beneficiaries.

Figure 7 shows the average paddy yields for plots in Punjab that would shift from paddy cultivation to less water-intensive crops (*arhar* and *jowar*) and average yields of plots that would continue cultivating paddy when cash incentives are offered alongside procurement of less water-intensive crops at MSP. We find that the less productive farmers are more likely to shift from paddy to less water-intensive crops. In Punjab, the average paddy yields for plots that will shift from paddy to *arhar* (the most profitable less water-intensive crop) is 5.29 tonnes/ha, whereas for those continuing paddy cultivation despite incentives, it is 6.73 tonnes/ha. When considering *jowar* (the least profitable less water-intensive crop), the corresponding paddy yields are 4.42 and 6.58 tonnes/ha, respectively. We observe a similar pattern in Haryana. The average paddy yields for plots that will shift to *arhar* and *jowar* are 3.5 tonnes/ha and 3.2 tonnes/ha, respectively, which are lower than the paddy yields on plots that will not get diversified to less water-intensive crops. Since our analysis is based on profitability as the primary criterion for determining crop shifts, plots with lower paddy yields are more likely to shift away from paddy.

[Insert Figure 7 here]

Moreover, farmers who have plots with lower paddy yields require a lower cash incentive to match the profits that they could earn by cultivating less water-intensive crops and shifting away from paddy cultivation than the farmers whose plots have very high paddy yields. As paddy yields increase, the cash incentive required to encourage a shift away from paddy also increases in both the states, as shown by upward-sloping graphs in Figure 8. This is because it is easier to make less water-intensive crops more profitable with lower cash incentives for farmers whose paddy yields are relatively lower.

[Insert Figure 8 here]

The north-western states of Punjab and Haryana were historically dominated by the cultivation of less water-intensive crops, such as maize and cotton, in the 1950s. However, with the Green Revolution in the late 1960s and 1970s, the introduction of high yielding varieties (HVYs) of rice and wheat, along with mechanization, fertilizers, and

other technological advancements, facilitated a shift towards greater paddy cultivation in these states. Paddy productivity is high in Punjab and Haryana, with paddy yields being highest in Punjab and fourth highest in Haryana out of the eleven states, while the cost of cultivation of paddy in the two states is relatively low as compared to other regions (Figures 9a and 9b). In contrast, the yields of less water-intensive crops such as maize in Punjab and pearl millet in Haryana are comparatively low (Figures 9c and 9e), while their costs of cultivation are among the highest when compared to other states while their cost of cultivation is one of the highest when comparing to other regions (Figures 9d and 9f). Moreover, the procurement of paddy at MSP ensures stable returns for farmers, whereas other less water-intensive crops are not currently procured by the government agencies. Given these advantages—higher yields, lower cultivation costs, and assured procurement—farmers are more likely to cultivate paddy over alternative crops.

[Insert Figure 9 here]

7 Conclusion

Relying solely on cash incentives along with reduction in price risk through procurement at MSP may not be the most effective way for shifting area away from paddy cultivation. The yields of less water-intensive crops are low, and sustaining annual cash incentives to make these crops profitable would require a substantial budget, which may not be viable in the long term. The profitability of paddy cultivation is driven by several factors, one of which is new technology, for instance the introduction of HYVs during the Green Revolution era. Therefore, higher investment in research to improve the productivity of less water-intensive crops may provide a more feasible and sustainable pathway for shifting away from paddy cultivation to these crops.

While crop diversification is one way to address the issue of groundwater depletion, shifting away from paddy has several challenges that need to be considered when designing an appropriate policy. Among all states, Punjab contributes the largest share to national paddy procurement. In 2020-21, 20 million metric tonnes of paddy were procured from Punjab out of a total procurement of 89 million metric tonnes, accounting for approximately 23 percent of the national contribution of paddy in total procurement. Telangana

and Andhra Pradesh were the next highest contributors, with shares of 16 percent and 9 percent, respectively, while Haryana, West Bengal, and Chhattisgarh each contributed 7–8 percent. The procurement of paddy serves multiple purposes: stabilizing market prices, preventing excessive fluctuations which could have negative consequences for both farmers and consumers, and ensuring national food security by maintaining buffer stocks for periods of shortages or emergencies. Additionally, the food grains procured by the government are also utilized in the mid-day meal program in which school children of economically disadvantaged backgrounds are provided cooked meals to improve nutrition and promote school attendance. Given that Punjab is the largest contributor to national paddy procurement, a reduction in paddy cultivation can have significant implications for food security in India unless these factors are accounted for.

Designing policy for reducing paddy cultivation to save water and address groundwater depletion in Punjab and Haryana requires a careful balance between environmental sustainability, economic viability, and food security. While cash incentives and procurement of alternative less water-intensive crops at MSP can encourage diversification, these measures may not be sufficient, given the high profitability and relatively lower risk in paddy cultivation. A more effective policy should also focus on investments in agricultural research for improving the productivity of less water-intensive crops. Since there has been a dependence on paddy in Punjab and Haryana for decades, any policy aimed at reducing its cultivation needs to be introduced gradually. This should be accompanied by other behavioral measures such as raising awareness among farmers about the severity of the groundwater situation, encouraging demand for alternative crops, and bringing in crop-specific technological improvements to ensure long-term irrigation sustainability and food security.

References

Agarwala, M., Bhattacharjee, S., and Dasgupta, A. (2022). Unintended consequences of Indian groundwater preservation law on crop residue burning. *Economics Letters*, 214:110446. https://doi.org/10.1016/j.econlet.2022.110446.

Badiani-Magnusson, R. and Jessoe, K. (2019). Electricity Prices, Groundwater, and Agriculture: The Environmental and Agricultural Impacts of Electricity Subsidies in India. In Schlenker, W., editor, *Agricultural Productivity and Producer Behavior*, pages 157–183. University of Chicago Press. https:doi.org/10.7208/chicago/9780226619941.003.0006.

Balasubramanya, S. (2025). Groundwater Use in Agriculture in South Asia: The Role of Technology. *Agricultural Economics*, *Forthcoming*. https://doi.org/10.1111/agec.70004.

Bhogal, S. and Vatta, K. (2021). Can crop diversification be widely adopted to solve the water crisis in Punjab? *Current Science*, 120(8):1303–1307. https://www.jstor.org/stable/27310378.

CGWB (2024). National Compilation on Dynamic Ground Water Resources of India. Central Ground Water Board. Department of Water Resources, River Development & Ganga Rejuvenation, Ministry of Jal Shakti, Government of India. https://cgwb.gov.in/cgwbpnm/public/uploads/documents/17357182991031590738file.pdf.

Chakravorty, U., Dar, M. H., and Emerick, K. (2023). Inefficient water pricing and incentives for conservation. *American Economic Journal: Applied Economics*, 15(1):319–350. https://doi.org/10.1257/app.20210011.

Devineni, N., Perveen, S., and Lall, U. (2022). Solving groundwater depletion in India while achieving food security. *Nature Communications*, 13(1):3374. https://doi.org/10.1038/s41467-022-31122-9.

FAO (2023). AQUASTAT – FAO's Global Information System on Water and Agriculture. Food and Agricultural Organization of the United Nations. https://www.fao.org/aquastat/en/.

Fishman, R., Giné, X., and Jacoby, H. G. (2023). Efficient irrigation and water conservation: Evidence from South India. *Journal of Development Economics*, 162:103051. https://doi.org/10.1016/j.jdeveco.2023.103051.

Fishman, R., Lall, U., Modi, V., and Parekh, N. (2016). Can Electricity Pricing Save India's Groundwater? Field Evidence from a Novel Policy Mechanism in Gujarat. *Journal of the Association of Environmental and Resource Economists*, 3(4):819–855. https://doi.org/10.1086/688496.

Gupta, D. (2023). Free power, irrigation, and groundwater depletion: Impact of farm electricity policy of Punjab, India. *Agricultural Economics*, 54(4):515–541. https://doi.org/10.1111/agec.12773.

Gupta, D. (2024). Pricing Farm Electricity, Water Use and Efficiency: The Case of Paddy Cultivation in Punjab. International Association of Agricultural Economists (IAAE). Conference Paper, August 2-7, 2024, New Delhi, India. https://doi.org/10.22004/ag.econ.344328.

Howell, K. R., Shrestha, P., and Dodd, I. C. (2015). Alternate wetting and drying irrigation maintained rice yields despite half the irrigation volume, but is currently unlikely to be adopted by smallholder lowland rice farmers in Nepal. *Food and energy security*, 4(2):144–157. https://doi.org/10.1002/fes3.58.

Jat, M., Gathala, M. K., Ladha, J., Saharawat, Y., Jat, A., Kumar, V., Sharma, S., Kumar, V., and Gupta, R. (2009). Evaluation of precision land leveling and double zero-till systems in the rice–wheat rotation: Water use, productivity, profitability and soil physical properties. *Soil and Tillage Research*, 105(1):112–121. https://doi.org/10.1016/j.still.2009.06.003.

Larson, N., Sekhri, S., and Sidhu, R. (2016). Adoption of water-saving technology in agriculture: The case of laser levelers. *Water Resources and Economics*, 14:44–64. https://doi.org/10.1016/j.wre.2015.11.001.

Lybbert, T. J., Magnan, N., Spielman, D. J., Bhargava, A. K., and Gulati, K. (2018). Targeting technology to increase smallholder profits and conserve resources: experimental provision of laser land-leveling services to Indian farmers. *Economic Development and Cultural Change*, 66(2):265–306. https://doi.org/10.1086/695284.

Mishra, A. K., Khanal, A. R., and Pede, V. O. (2017). Is direct seeded rice a boon for economic performance? Empirical evidence from India. *Food Policy*, 73:10–18. https://doi.org/10.1016/j.foodpol.2017.08.021.

Mitra, A., Balasubramanya, S., and Brouwer, R. (2023). Can cash incentives modify groundwater pumping behaviors? Evidence from an experiment in Punjab. *American Journal of Agricultural Economics*, 105(3):861–887. https://doi.org/10.1111/ajae.12340.

Sarkar, A. and Das, A. (2014). Groundwater irrigation-electricity-crop diversification Nexus in Punjab: Trends, turning points, and Policy Initiatives. *Economic and Political Weekly*, pages 64–73. https://www.jstor.org/stable/24481208.

Shah, T., Giordano, M., and Mukherji, A. (2012). Political economy of the energy-groundwater nexus in India: exploring issues and assessing policy options. *Hydrogeology Journal*, 20(5):995. https://doi.org/10.1007/s10040-011-0816-0.

Sharma, B. R., Gulati, A., Mohan, G., Manchanda, S., Ray, I., and Amarasinghe, U. (2018). Water productivity mapping of major Indian crops. National Bank for Agriculture and Rural Development (NABARD) and Indian Council for Research on International Economic Relations (ICRIER). https://www.nabard.org/auth/writereaddata/tender/1806181128Water%20Productivity%20Mapping%20of%20Major%20Indian%20Crops,%20Web%20Version%20(Low%20Resolution%20PDF).pdf.

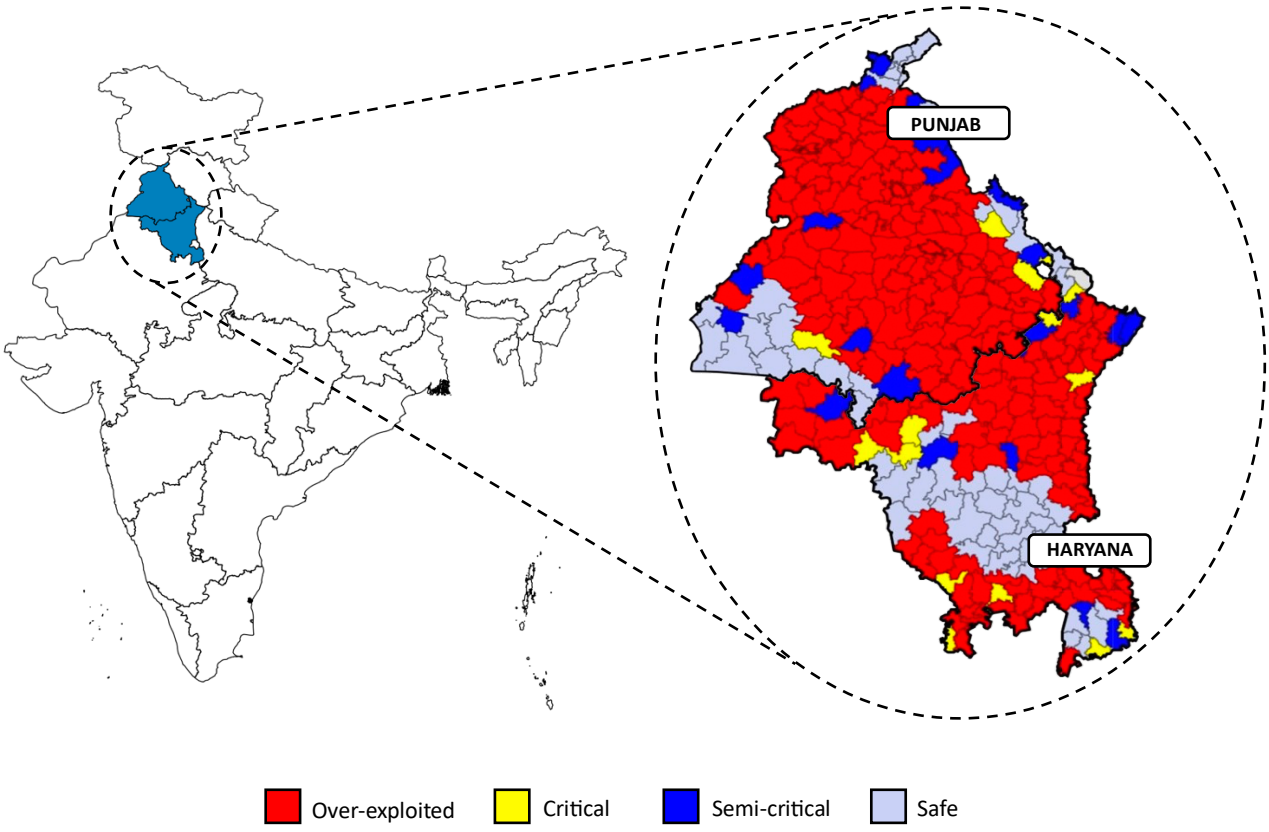
Singh, R., Thangaraj, P., Juneja, R., and Gulati, A. (2024). Saving Punjab and Haryana from Ecological Disaster: Re-aligning Agri-Food Policies. Technical report, Policy Brief 21, Indian Council for Research on International Economic Relations (ICRIER). https://icrier.org/pdf/PB-21.pdf.

Tripathi, A., Mishra, A. K., and Verma, G. (2016). Impact of preservation of subsoil water act on groundwater depletion: the case of Punjab, India. *Environmental management*, 58(1):48–59. https://doi.org/10.1007/s00267-016-0693-3.

UN-Water (2022). The United Nations World Water Development Report. Groundwater: Making the invisible visible. United Nations. https://unesdoc.unesco.org/ark:/48223/pf0000380721/PDF/380721eng.pdf.multi.

Figures

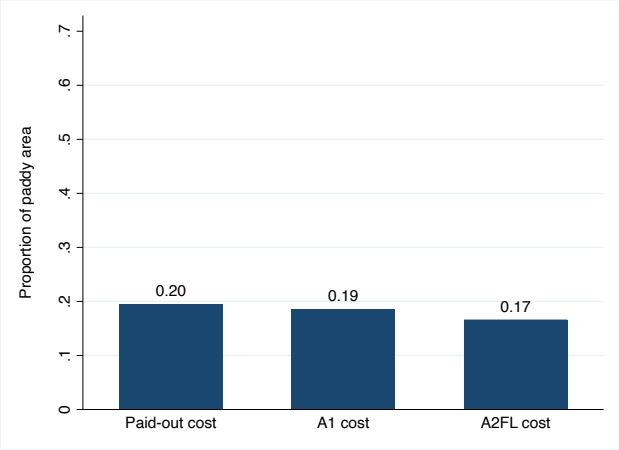
Figure 1: Study area: Punjab and Haryana on the map of India, and categorization of blocks by groundwater situation



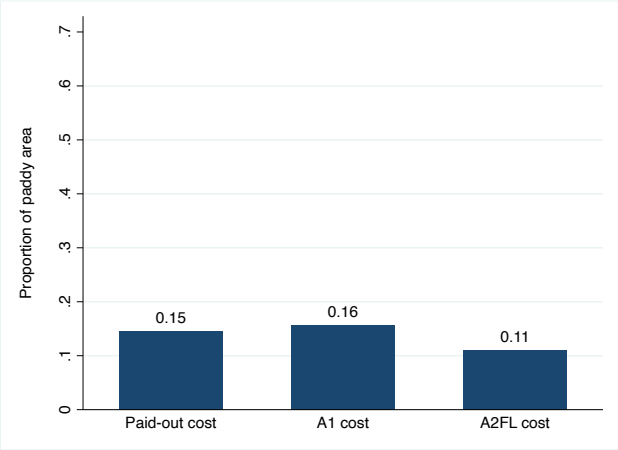
Source: Based on figures and data taken from the Central Ground Water Board reports on: i. Punjab Dynamic Ground Water Resources, 2023, and ii. Haryana Dynamic Ground Water Resources, 2023, both published in January, 2024.

Figure 2: Average area that will shift from paddy to non-paddy crops under the scheme, when compared to average (zone-wise) profits at the state-level

(a) Punjab



(b) Haryana

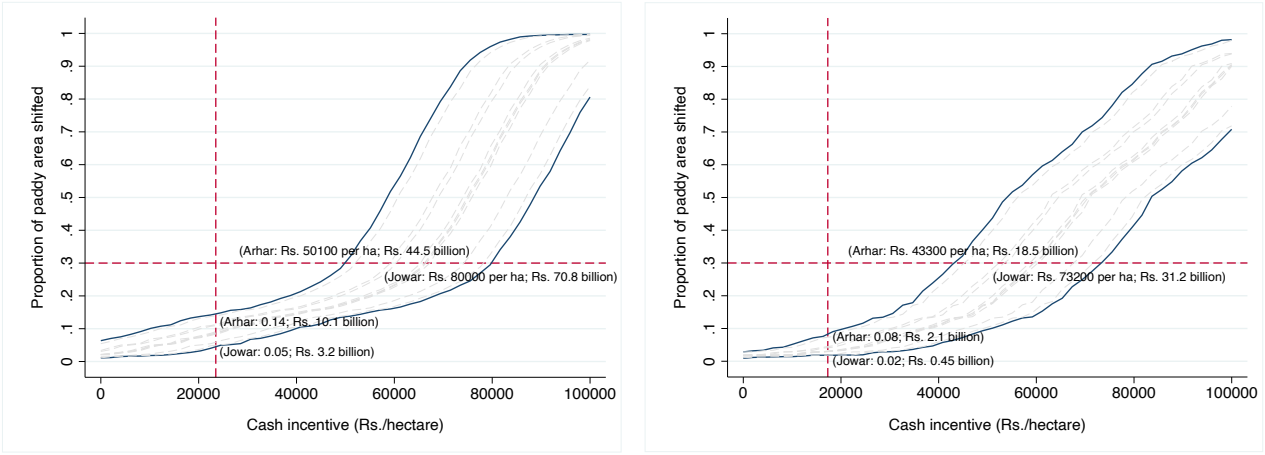


Source: Computed using plot-level cost of cultivation data from the Directorate of Economics & Statistics, Ministry of Agriculture and Farmers Welfare, Government of India; and year-wise data on Minimum Support Prices (MSP) for principal crops, as announced by the Government of India based on recommendations from the CACP.

Figure 3: Average area shifted away from paddy at various levels of cash incentives, when compared to average profits at the all India-level

(a) Punjab

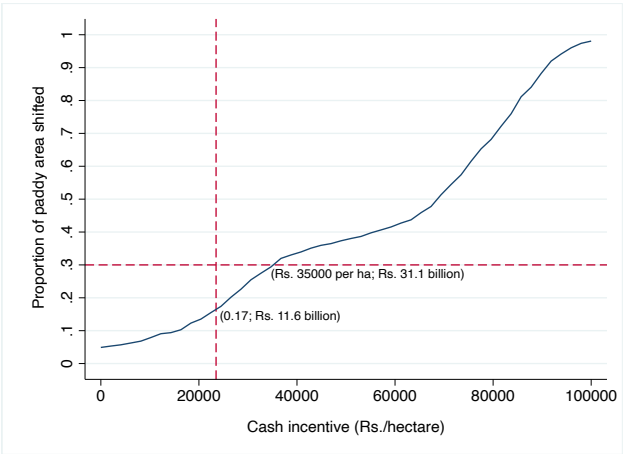
(b) Haryana



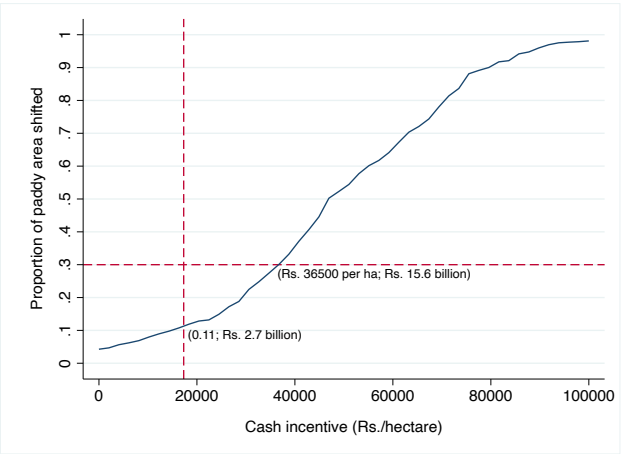
Notes: The left and the right solid blue lines show the average proportion of area that will shift from paddy to *arhar* and *jowar*, respectively at various cash incentives. The dotted grey lines between the two blue graphs are for the other less water-intensive crops. The horizontal dotted red line is drawn at 30 percent area and the vertical dotted red line is drawn at the current cash incentives in the two states, i.e., at Rs. 23,500 per hectare for Punjab and Rs. 17,300 per hectare for Haryana.
Source: Computed using plot-level cost of cultivation data from the Directorate of Economics & Statistics, Ministry of Agriculture and Farmers Welfare, Government of India.

Figure 4: Average area shifted away from paddy at various levels of cash incentives, when compared to average (zone-wise) profits at the state-level

(a) Punjab



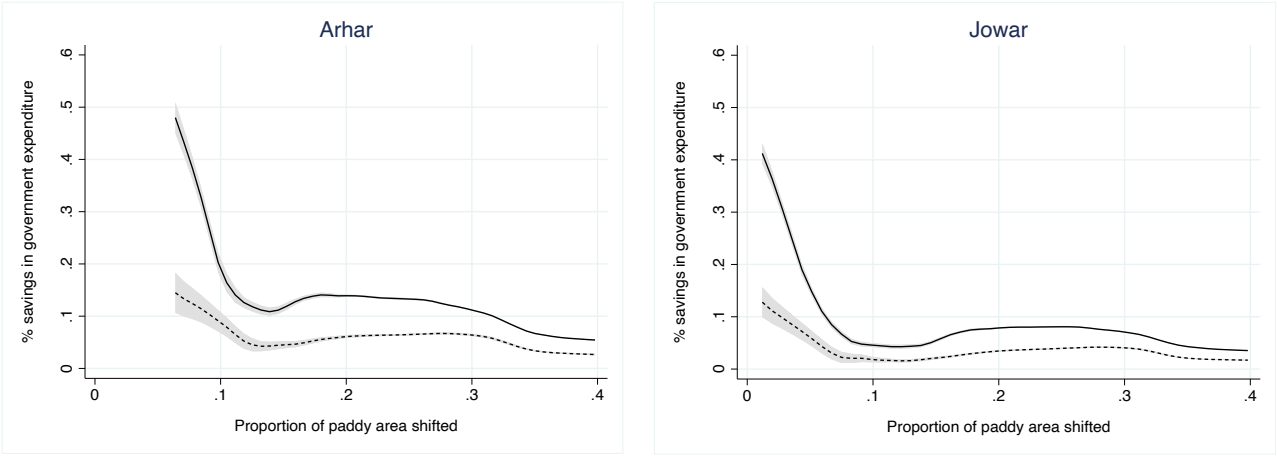
(b) Haryana



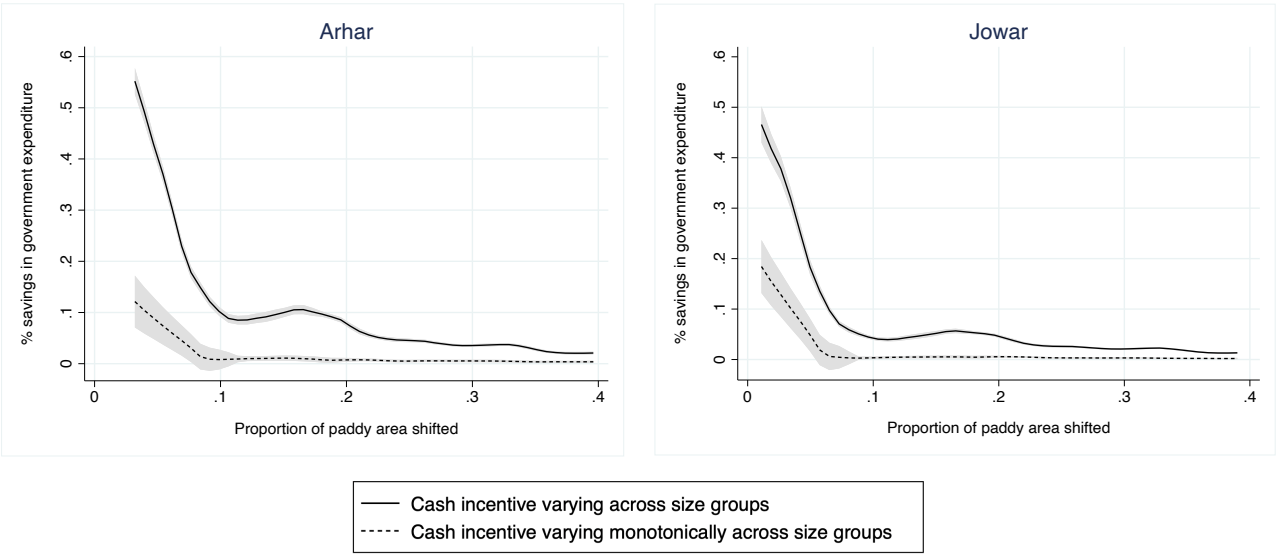
Notes: The solid blue line shows the average proportion of area that will shift from paddy to less water-intensive crops at various cash incentives. The horizontal dotted red line is drawn at 30 percent area and the vertical dotted red line is drawn at the current cash incentives in the two states, i.e., at Rs. 23,500 per hectare for Punjab and Rs. 17,300 per hectare for Haryana.
Source: Computed using plot-level cost of cultivation data from the Directorate of Economics & Statistics, Ministry of Agriculture and Farmers Welfare, Government of India.

Figure 5: Percentage savings for differential cash incentives by size group, when profits on paddy plots are compared to average profits at the all India-level

(a) Punjab

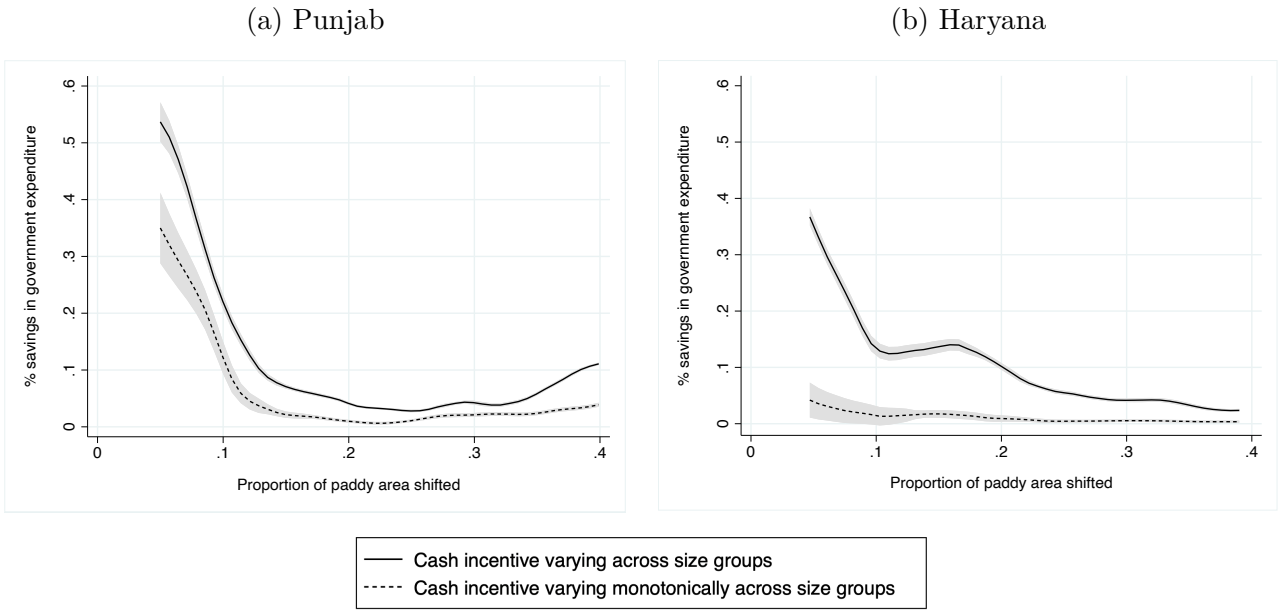


(b) Haryana



Notes: In the case of Haryana, while computing percentage savings in government expenditure when the cash incentive varies monotonically across size groups versus the current scheme of a constant cash incentive, we eliminate several combinations of cash incentives to arrive at the optimal combination by rounding off decimal points at multiple steps in the algorithm. This rounding sometimes results in slightly lower expenditure for the constant incentive scheme, leading to small negative savings—an impossibility caused by approximation. In those few cases, we have set the difference to zero while plotting Figure 4(b).
Source: Computed using cost of cultivation data from the Directorate of Economics & Statistics, Ministry of Agriculture and Farmers Welfare, Government of India.

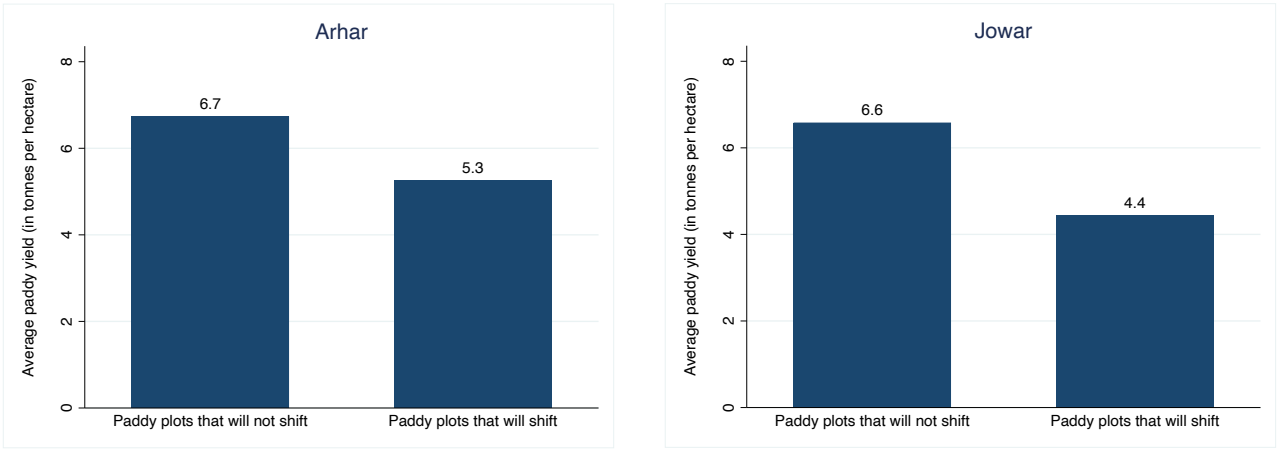
Figure 6: Percentage savings for differential cash incentives by size group, when profits on paddy plots are compared to average (zone-wise) profits at the state-level



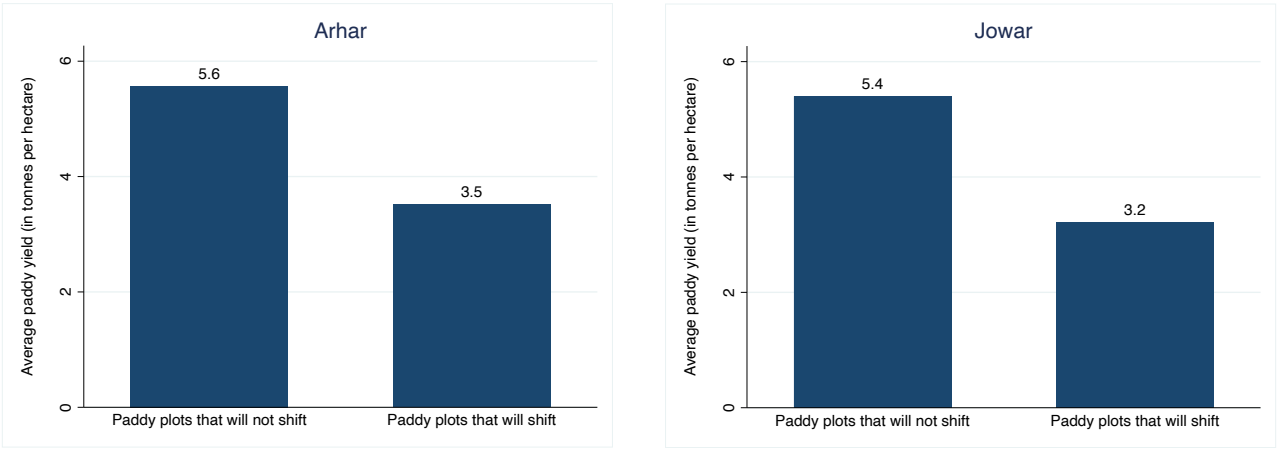
Source: Computed using plot-level cost of cultivation data from the Directorate of Economics & Statistics, Ministry of Agriculture and Farmers Welfare, Government of India.

Figure 7: Average paddy yields of plots that will shift versus those that will not shift out of paddy cultivation under the crop diversification scheme

(a) Punjab



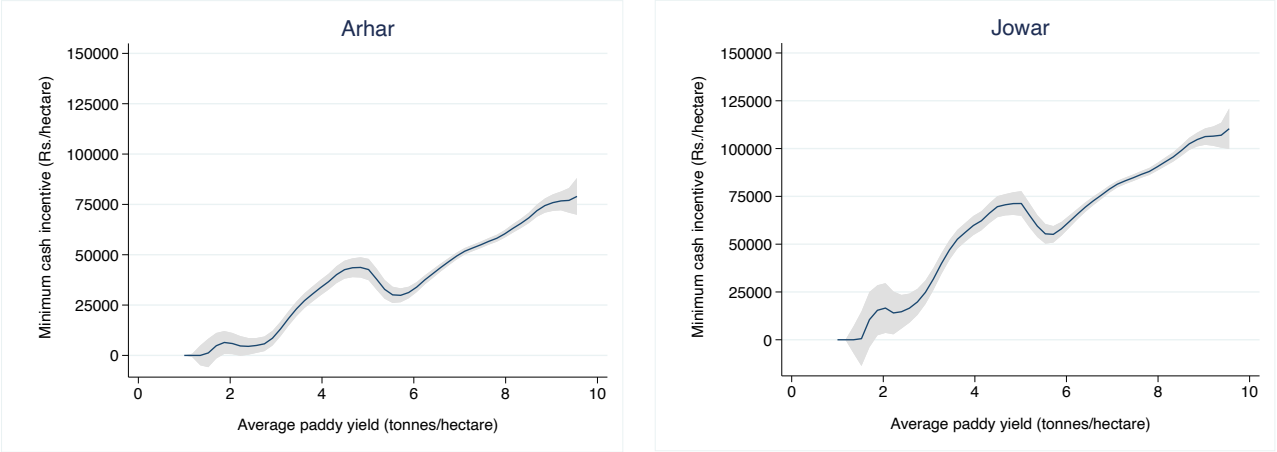
(b) Haryana



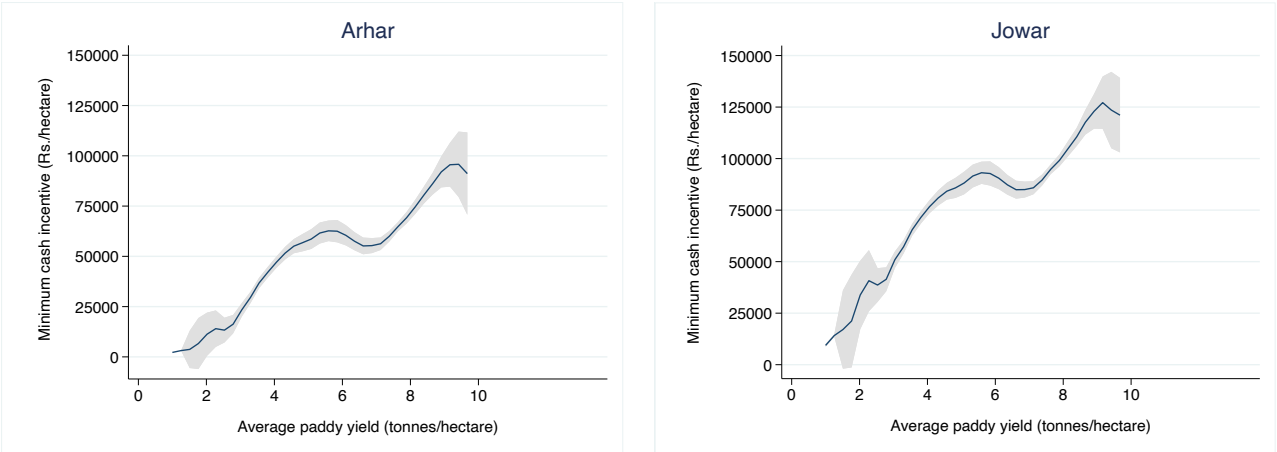
Notes: The left bar in the graphs show the average paddy yield on plots where cultivation will not shift from paddy to less water-intensive, *arhar* or *jowar*, even if a cash incentive of Rs. 23,500 per ha in Punjab and Rs. 17,300 per ha in Haryana is provided to the farmers for making such a shift and the less water-intensive crops are procured at MSP, while the right bars show the average paddy yield on plots where cultivation will shift to *arhar/jowar* under the crop diversification scheme.
Source: Computed using plot-level cost of cultivation data from the Directorate of Economics & Statistics, Ministry of Agriculture and Farmers Welfare, Government of India.

Figure 8: Minimum cash incentive required to shift out of paddy cultivation

(a) Punjab



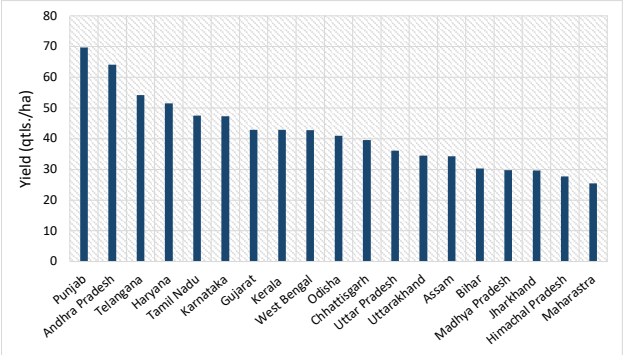
(b) Haryana



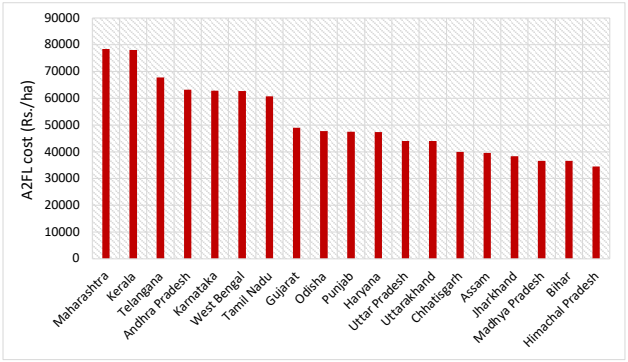
Source: Computed using cost of cultivation data from the Directorate of Economics & Statistics, Ministry of Agriculture and Farmers Welfare, Government of India.

Figure 9: Yields and cost of cultivation for paddy, maize and pearl millet in Punjab and Haryana

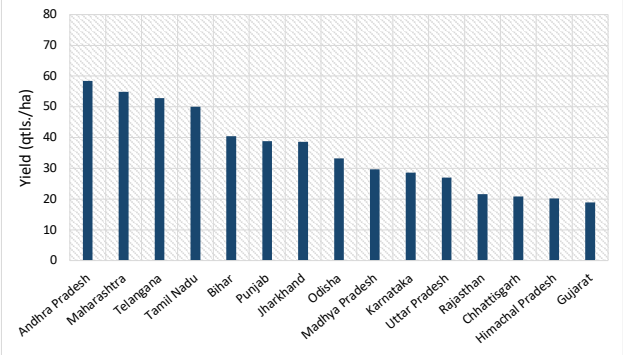
(a) Paddy yield



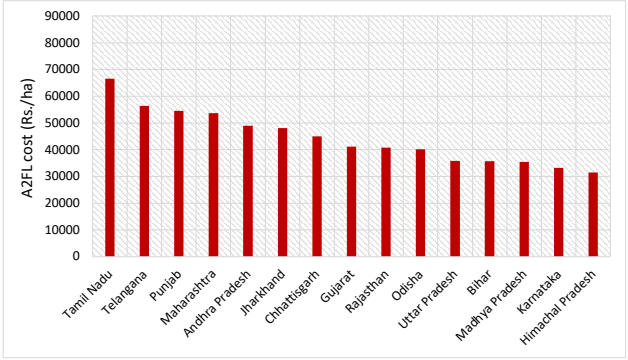
(b) Cost of paddy cultivation



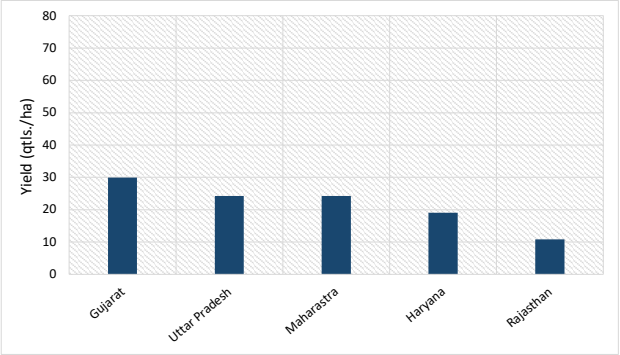
(c) Maize yield



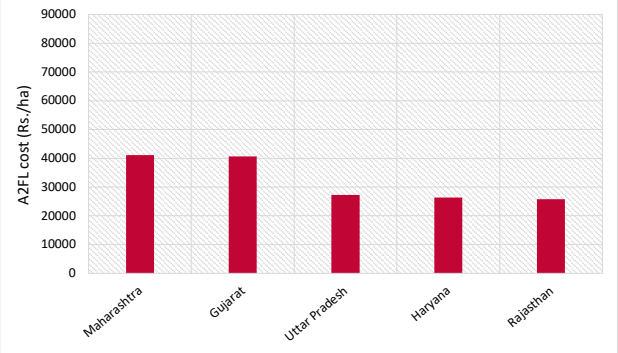
(d) Cost of maize cultivation



(e) Pearl millet yield



(f) Cost of pearl millet cultivation



Source: Computed using cost of cultivation data from the Directorate of Economics & Statistics, Ministry of Agriculture and Farmers Welfare, Government of India.

Tables

Table 1: Number of plots in the sample, by crop and year

State	Year	Paddy	Maize	Cotton	Pearl Millet
Punjab	2017-18	521	33	80	-
	2018-19	540	36	61	-
	2019-20	540	40	50	-
	Total	1601	109	191	-
Haryana	2017-18	184	-	126	120
	2018-19	193	-	131	98
	2019-20	197	-	135	99
	Total	574	-	392	317

Notes: Principal crops cultivated in the *kharif* season in Punjab are paddy, maize, and cotton, while those in Haryana are paddy, cotton, and pearl millet.
Source: Computed using plot-level cost of cultivation data from the Directorate of Economics & Statistics, Ministry of Agriculture and Farmers Welfare, Government of India.

Table 2: Number of plots in the sample, by crop and zone

State	Zone	Paddy	Maize	Cotton	Pearl Millet
Punjab	1	816	104	0	-
	2	415	5	0	-
	3	370	0	191	-
	Total	1601	109	191	-
Haryana	1	15	-	92	152
	2	190	-	276	163
	3	369	-	24	2
	Total	574	-	392	317

Source: Computed using plot-level cost of cultivation data from the Directorate of Economics & Statistics, Ministry of Agriculture and Farmers Welfare, Government of India.

Table 3: Average area that will shift from paddy to non-paddy crops under the scheme, when compared to average profits at the all-India level

	Average proportion of paddy area that will shift with profits computed using three different cost definitions					
	Punjab			Haryana		
	A2FL cost	A1 cost	Paid-out cost	A2FL cost	A1 cost	Paid-out cost
	(1)	(2)	(3)	(4)	(5)	(6)
Jowar	0.05	0.01	0.05	0.02	0.02	0.01
Ragi	0.05	0.02	0.07	0.02	0.02	0.02
Pearl millet	0.06	0.02	0.08	0.02	0.02	0.02
Sesame	0.08	0.02	0.08	0.03	0.02	0.02
Moong	0.09	0.02	0.09	0.03	0.03	0.02
Urad	0.09	0.02	0.09	0.03	0.02	0.02
Soyabean	0.09	0.03	0.10	0.03	0.03	0.03
Maize	0.11	0.04	0.13	0.04	0.05	0.04
Groundnut	0.11	0.04	0.13	0.04	0.05	0.05
Cotton	0.14	0.06	0.16	0.07	0.08	0.09
Arhar	0.14	0.06	0.15	0.08	0.10	0.08

Source: Computed using plot-level cost of cultivation data from the Directorate of Economics & Statistics, Ministry of Agriculture and Farmers Welfare, Government of India.