DISCUSSION PAPER

Empowering Small Farmers Through Water Conservation

A policy roadmap for Punjab and Haryana

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PANJ
Policy Advisory and
Network for Joint Progress

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EXECUTIVE SUMMARY

Both Punjab and Haryana have historically produced a majority of the country's rice and wheat produce. Today, however, both these are at a worrying juncture. Both states extract more water than their respective recharge capacities. Inadvertently, small farmers, with no alternative sources, will be the first ones to bear the brunt of this depletion of groundwater. Taking this into account, this brief proposes policy solutions pertaining to improving access to water for small farmers in the two states and bettering the efficiency of water utilisation. In the short term, we suggest (a) restricting paddy procurement at the Minimum Support Price (MSP) to only farmers with 2 hectares and under. This allows ensuring a fair price to the small farmers, and also encourages crop diversification for large farmers; (b) adopting a tiered approach for electricity subsidy for farmers, with the margin of subsidy reducing depending on the farm size. This will help encourage efficient water use by large farmers, who are one of the major contributors to water over extraction; and (c) restoring village water bodies and implementing rainwater harvesting systems to implement localised solutions to water scarcity. As part of the long-term solutions, we propose (a) promotion of agroforestry through poplar tree boundary plantations. This will give a push to farmers to move away from water intensive crops, will also ensure sustainable incomes; and (b) Formalising groundwater markets under panchayat oversight to ensure better access to groundwater to smaller farmers.

INTRODUCTION

Water, often considered a freely available natural resource, has historically been economically undervalued. However, with increasing population pressures and changing consumption patterns, the sustainability of water resources has become a critical global concern. The recognition of water as an economic good, emphasised in the Dublin Principles (ICWE, 1992), has shifted global discourse to focus on its true value. In India, this shift is particularly relevant, as the country faces acute water challenges driven by rapid agricultural expansion, reliance on groundwater irrigation, and inefficient resource management practices. This has been more prevalent in the agriculturally advance and important states of Punjab and Haryana.

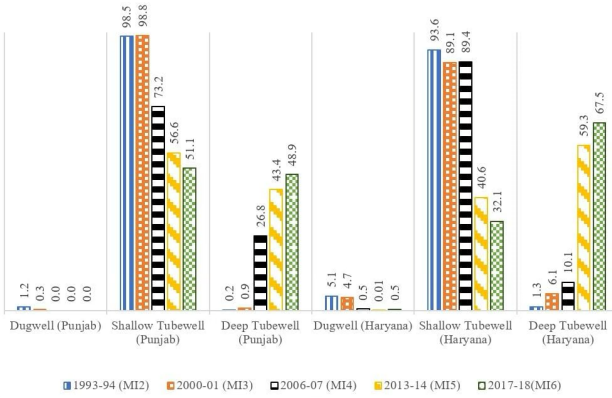
CONTEXT FOR THE PROBLEM

Groundwater irrigation has been a cornerstone of India's agricultural growth, especially in regions like Punjab and Haryana, which played pivotal roles in the Green Revolution. While this transition helped avert food crises in the 1960s and 1970s, it has come at a steep ecological and economic cost. The introduction of modern drilling technologies, combined with heavily subsidised or free electricity for irrigation, has led to uncontrolled groundwater extraction. Punjab and Haryana represent the dual challenges of agricultural growth and resource depletion. Both states depend heavily on the rice-wheat crop rotation, which, while economically profitable, is water-intensive and resource-depleting.

According to the CGWB (2023), Punjab extracts 27.8 billion cubic metre (BCM) of groundwater annually, far exceeding its recharge capacity of 18.8 BCM, while Haryana extracts 11.8 BCM annually against a recharge capacity of 8.7 BCM.

As a result, 77% of Punjab's and 62% of Haryana's groundwater blocks are classified as overexploited, compelling farmers to rely on deeper and more energy-intensive wells. This shift is evidenced by the transition from shallow to deep tubewells, as depicted in Figure 1.

Figure 1: Percentage Distribution of Groundwater Structures in Punjab and Haryana (1993-94 to 2017-18)



Source: *Minor Irrigation Census of Punjab and Haryana, Minor Irrigation Division, Ministry of Water Resources, Government of India, 1993-94—2017-18.*

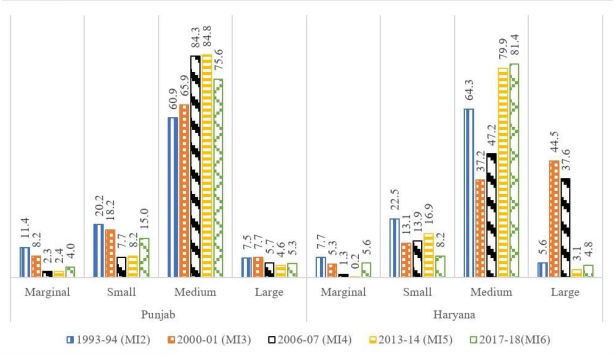
PUNJAB AND HARYANA: ILLUSTRATING THE CRISIS

In Punjab, the share of deep tubewells rose from 0.2% in 1993–94 to 48.9% in 2017–18, while shallow tubewells declined from 98.5% to 51.1% during the same period. Haryana experienced a similar shift, with deep tubewells increasing from 1.3% to 67.5% and shallow tubewells falling from 93.6% to 32.1%. This shift has been incentivised by energy subsidies, with Punjab introducing free electricity in 1997 and Haryana adopting reduced flat tariff rates in 2007. These policies enabled medium and large farmers, who dominate tubewell ownership, to extract groundwater at unsustainable rates.

This rapid shift in the composition of tubewells, driven by energy subsidies and the need to access

deeper groundwater reserves, has disproportionately benefited medium and large farmers, who have the financial capacity to invest in deep tubewell infrastructure, further exacerbating inequities in groundwater access (Figure 2). By 2017–18, medium farmers in Punjab owned 75.6% of tubewells, up from 60.9% in 1993–94, while marginal farmers' ownership fell from 11.4% to 4.0%. In Haryana, medium farmers' share increased from 47.2% in 2006–07 to 81.4% in 2017–18, while marginal farmers' share dropped to 5.6%, highlighting growing inequities in groundwater access.

Figure 2: Percentage Distribution of Groundwater Structures according to Land-size in Punjab and Haryana (1993-94 to 2017-18)

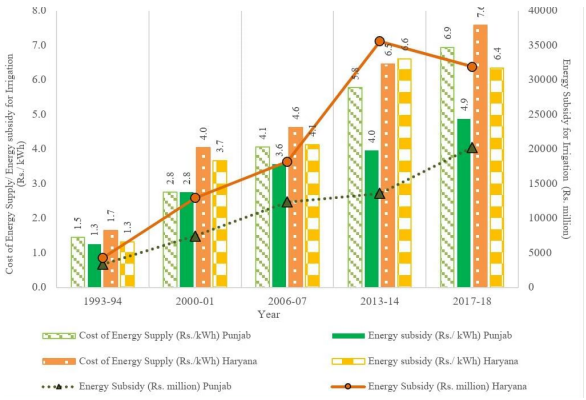


Source: *Minor Irrigation Census of Punjab and Haryana, Minor Irrigation Division, Ministry of Water Resources, Government of India, 1993-94—2017-18.*

The growing inequities in tubewell ownership and access to groundwater have been further compounded by the increasing reliance on energy-intensive irrigation systems, predominantly used by medium and large farmers. This reliance has significantly contributed to the sharp rise in energy subsidies, as deeper tubewells require greater energy inputs to extract groundwater, particularly in states like Punjab and Haryana where groundwater tables continue to decline. This over reliance on energy-intensive irrigation has led to a dramatic rise in energy subsidies (Figure 3).

Between 1993–94 and 2017–18, Punjab's subsidy for irrigation grew from ₹334 crore to ₹2,028 crore, while Haryana's surged from ₹426 crore to ₹3,191 crore, reflecting seven- to twelve-fold increases. The per-unit cost of energy supply for irrigation also rose sharply, from ₹1.45/kWh to ₹6.94/kWh in Punjab and from ₹1.65/kWh to ₹7.58/kWh in Haryana. As groundwater tables fell, farmers increasingly relied on deep tubewells, which require higher energy inputs. These subsidies have strained state finances, with Punjab and Haryana's per-hectare subsidy costs escalating from ₹3,338 and ₹4,262 in 1993-94 to ₹18,993 and ₹31,909 in 2017–18, respectively. In both Punjab and Haryana, per-hectare energy consumption for crops, particularly wheat and paddy, increases in direct proportion to the size of landholdings (Khara and Ghuman, 2023a).

Figure 3: Cost of Energy Supply and Subsidy in Punjab and Haryana (1993-94 to 2017-18)



Source: *1. Computed from Annual Reports on the Working of State Electricity Boards and Electricity Departments, Planning Commission, New Delhi (Various Issues)*
2. Report on the Performance of State Power Utilities, Power Finance Corporation Ltd, Government of India (Various Issues).

The environmental and fiscal challenges in Punjab and Haryana are severe and interconnected, posing significant risks to long-term agricultural sustainability. Over-extraction of groundwater has led to widespread aquifer depletion, soil salinisation, and water pollution,

while rising energy subsidies have strained state utilities, limiting their ability to invest in infrastructure upgrades. Smallholders, who lack the financial capacity to transition to deep tubewells, face restricted irrigation access, further exacerbating resource inequalities. These issues highlight the urgent need for comprehensive policy reforms that ensure equitable access to resources, promote efficiency, and safeguard both fiscal and environmental sustainability. Without timely intervention, the groundwater and energy economies of Punjab and Haryana risk collapse, jeopardising the agricultural future of these states.

Compounding these challenges is the rising number of small and marginal farmers, driven by population growth and the fragmentation of agricultural land. According to the Agriculture Census (2015–16), farmers operating landholdings of 2 hectares or less account for 33% of total farm households in Punjab and 69% in Haryana. These demographic underscores the critical need for targeted and inclusive agricultural policies that prioritise the needs of smallholders, ensuring their livelihoods are safeguarded amidst growing resource constraints and fiscal pressures.

Punjab and Haryana serve as microcosms of India's broader groundwater crisis, illustrating the urgent need for sustainable water management policies. Addressing the twin challenges of water availability and accessibility for small farmers requires a multi-pronged approach that combines short-term relief measures with long-term structural reforms. These policies must prioritise equitable resource access, promote efficient water use, and ensure fiscal and ecological sustainability. By focusing on these states as examples, policymakers can develop and implement scalable solutions that not only safeguard the livelihoods of small farmers but also serve as a model for sustainable water management across India.

PROPOSED POLICY SOLUTIONS

Short-term interventions

1. ***Restricting paddy procurement under the MSP to 2 hectares per farmer:*** It can serve as an effective measure to promote equitable access to MSP benefits and address the pressing issue of groundwater depletion in Punjab and Haryana. This policy ensures that small and marginal farmers, who constitute a significant portion of the agricultural population (33% in Punjab and 69% in Haryana), receive fair prices for their produce, thereby safeguarding their livelihoods. Additionally, this restriction discourages large landholders from over-cultivating paddy, a highly water-intensive crop, thereby incentivising crop diversification. Significant disparities in groundwater irrigation and economic productivity are evident both between and within states in the cultivation of wheat and rice.

In both Punjab and Haryana, there is an inverse relationship between landholding size and irrigation efficiency, suggesting that farmers with smaller landholdings utilise groundwater more efficiently for irrigation compared to their larger counterparts (Khara and Ghuman, 2024b). Shifting 10% of the paddy area cultivated by large farmers to less water-intensive crops can result in significant water savings. In Punjab, rice is cultivated on 3,50,000 hectares, accounting for 10% of the total rice-cultivated area, with an average yield of 4,210 kg/ha (based on data from 2019–2021) (GoP, 2022). Producing 1 kilogram of rice requires approximately 5,337 litres of water (CACP, 2015). By shifting this 10% area to alternative crops, Punjab could conserve around 7.89 billion cubic meters (BCM) of water annually. Similarly, in Haryana, where rice is grown on 2,60,000 hectares, representing 10% of

the total rice-cultivated area, with an average yield of 3,540 kg/ha (GoH, 2022), and each kilogram of rice requiring 3,875 litres of water (CACP, 2015), transitioning this portion to alternative crops could save 3.56 BCM of water annually. This policy not only reduces pressure on groundwater resources but also promotes sustainable farming practices, ensuring a balance between agricultural productivity and environmental conservation (Refer to Appendix A1.1).

2. ***Reorienting the electricity subsidy framework:*** This is a vital step toward ensuring equity, sustainability, and judicious water use in Punjab and Haryana. Under this proposal, marginal and small farmers, will continue to receive a 100% subsidy on electricity to support irrigation. This translates to an average subsidy of approximately ₹30,000 per tubewell per hectare in Punjab and ₹60,000 per tubewell per hectare in Haryana, ensuring affordability and access for smallholders. However, subsidies for larger landholders—semi-medium, medium, and large farmers—will be gradually scaled down to 60%, 50%, and 40%, respectively. This tiered approach aligns subsidy levels with farm size, reducing the fiscal burden on state utilities while encouraging efficient water use among larger farmers, who are major contributors to groundwater over-extraction. By restructuring subsidies in this way, state governments could substantially cut agricultural energy subsidy expenditures by ₹1200 crore in Punjab and over ₹150 crore in Haryana, which can be further reinvested in agricultural development. (Refer to Appendix A1.2)

3. ***Restoring village water bodies and implementing rainwater harvesting systems:*** It offer a localised and sustainable solution to address water scarcity, particularly for small and marginal farmers. Based on MGNREGA 2015 framework, for 8 acres of ponds constructed in each village of Punjab and Haryana, we estimate the total water storage, irrigation potential, construction cost, employment generation under MGNREGA, and self-financing mechanisms. The total cost per village is ₹1.38 crore, with ₹1.15 crore (83.3%) covered by MGNREGA and ₹23.08 lakh for materials. Each village pond system will store 32,000 cubic meters of water, providing irrigation for 26.7 to 17.8 hectares through micro-irrigation techniques.

Additionally, a self-financing model involving community contributions, agro-based income sources, water usage charges, and CSR funds can reduce dependency on government funding. Implementation should be phase-wise, prioritising most overexploited villages first, followed by moderately affected regions. By integrating these efforts with assured buyback schemes for less water-intensive crops, small farmers can benefit from stable incomes and reduced financial uncertainty. This approach of resource conservation and income stabilisation not only enhances agricultural sustainability but also supports the economic resilience of smallholders, ensuring long-term benefits for rural communities in Punjab and Haryana (Refer to Appendix A1.3).

Long-term interventions

1. ***Promoting agroforestry through poplar tree boundary plantations:*** It would present a transformative opportunity for small and marginal farmers by providing economic diversification, environmental sustainability, and income stability. Planting 200 poplar trees per hectare along field boundaries can yield an additional ₹2,40,000 per hectare, with each tree valued conservatively at ₹1,200 (Dhiman, 2024). This approach not only enhances farm profitability but also aligns with global

environmental goals, as poplar trees can sequester approximately 348.61 tCO_2e per hectare (Rizvi et al.,2020) during their lifecycle, generating an additional ₹30,000 per hectare in carbon credits at a rate of USD 0.6 per tonne (₹86.58) (World Bank, 2017).

This dual benefit allows small farmers to reduce dependence on traditional, water-intensive crops while tapping into the growing carbon market. To support adoption, the provision of subsidised planting materials by the state can significantly boost participation and ensure profitability.

Over a seven-year period, the average maturity cycle of poplar trees, farmers adopting agroforestry boundary plantations alongside conventional crops such as paddy and wheat can realise significantly enhanced earnings. In Punjab, adopting agroforestry can generate an additional average income of ₹79,000 per hectare, while in Haryana, farmers can earn an additional ₹87,000 per hectare, compared to those solely growing conventional crops. This initiative not only diversifies income streams but also mitigates climate risks and contributes to sustainable agricultural practices, making it a win-win strategy for both farmers and the environment (Refer to Appendix A1.4).

2. ***Formalising groundwater markets:*** Under panchayat oversight can ensure equitable irrigation access for small farmers, particularly those without tubewells or with fragmented landholdings. At an average cost of ₹66 and ₹105 per hour for hired irrigation in Punjab and Haryana, respectively (CCPC, 2020), this system can make water affordable and accessible. Lowering or managing prices at ₹50 per hour can help farmers save between ₹500 and ₹2200 per hectare of wheat cultivation. Panchayats can regulate such markets by prioritising less water-intensive crops, setting extraction limits based on groundwater depth, and monitoring pricing to prevent exploitation. This approach promotes sustainable water use, supports smallholders' agricultural productivity, and ensures fair access to groundwater resources while curbing over-extraction (Refer to Appendix A1.5).

CONCLUSION

These interventions aim to address immediate inequities while fostering long-term sustainability in water access and usage. Restricting paddy procurement, reforming subsidies, and restoring water bodies provide immediate relief and resource security for small farmers. Meanwhile, promoting agroforestry and formalising groundwater markets offer long-term solutions that diversify incomes, protect resources, and create new revenue streams through carbon credits and regulated water use. Together, these measures form a comprehensive strategy to empower small farmers while ensuring sustainable agricultural practices in Punjab and Haryana.

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APPENDIX: A1. CALCULATION OF PROPOSED SOLUTIONS

A1.1 Impact of limiting paddy procurement upto 2 hectares at MSP and shifting paddy cultivation to alternative crops

Scenario: If farmers with landholdings greater than 2 hectares shift 10% of their net irrigated area under paddy cultivation to alternative, less water-intensive crops, significant water savings can be achieved in Punjab and Haryana. According to the Agriculture Census 2015–16, this corresponds to 3,50,000 hectares in Punjab and 2,60,000 hectares in Haryana.

Water savings

- Punjab
  - Area under paddy: 3,50,000 hectares
  - Average yield: 4,210 kg/ha
  - Water usage: 5,337 litres/kg
  - Water saved: 3,50,000 ha x 4210kg/ha x 5337 litres/kg = 7.89 billion cubic meters (BCM)
- Haryana
  - Area under paddy: 2,60,000 hectares
  - Average yield: 3,540 kg/ha
  - Water usage: 3,875 litres/kg
  - Water saved: 2,60,000 ha x 3540 kg/ha x 3875 litres/kg = 3.56 BCM

Key outcomes

- Water Conservation:
  - Punjab can save approximately 7.89 BCM of water annually.
  - Haryana can save approximately 3.56 BCM of water annually
- Income Security for Small Farmers:
  - Small farmers (with landholdings ≤2 hectares) remain secured under the MSP framework for their limited area of paddy cultivation, ensuring stable incomes while promoting sustainability.

Conclusion

Shifting 10% of the paddy cultivation area by large farmers to alternative crops can significantly reduce water stress in Punjab and Haryana. This strategy secures small farmers' incomes under the MSP system and promotes sustainable water management practices, ensuring both economic and environmental resilience.

A1.2 REORIENTING THE ELECTRICITY SUBSIDY FRAMEWORK

Background and Assumptions

- Number of Agricultural Households (Agriculture Census, 2015–16):
  - Punjab: 1,092,713 households
  - Haryana: 1,628,015 households

- Distribution of Farmers by Landholding Category:
  - Punjab:
    - Marginal and Small: 33%
    - Semi-Medium: 34%
    - Medium: 28%
    - Large: 5%
  - Haryana:
    - Marginal and Small: 69%
    - Semi-Medium: 17%
    - Medium: 12%
    - Large: 2%
- Average Electricity Subsidy per Farmer per Year per Hectare (Khara and Ghuman, 2024b):
  - Punjab: ₹30,000/ha
  - Haryana: ₹60,000/ha

Proposed Revised Subsidy Allocation

- Marginal and Small Farmers: Continue with 100% subsidy to ensure equity and affordability.
- Semi-Medium Farmers: Subsidy reduced to 60%:
  - Punjab: ₹18,000/ha
  - Haryana: ₹36,000/ha
- Medium Farmers: Subsidy reduced to 50%:
  - Punjab: ₹15,000/ha
  - Haryana: ₹30,000/ha
- Large Farmers: Subsidy reduced to 40%:
  - Punjab: ₹12,000/ha
  - Haryana: ₹24,000/ha

Impact on State Exchequer

- Cost of Electricity Subsidy (Without Reorientation)
- Punjab:
  - Large Farmers: 61,690 × ₹30,000 = ₹185.07 crore
  - Medium Farmers: 344,790 × ₹30,000 = ₹1,034.37 crore
  - Semi-Medium Farmers: 529,951 × ₹30,000 = ₹1,589.85 crore
  - Total (Punjab): ₹2,809.29 crore
- Haryana:
  - Large Farmers: 3,086 × ₹60,000 = ₹18.52 crore
  - Medium Farmers: 24,628 × ₹60,000 = ₹147.77 crore
  - Semi-Medium Farmers: 27,679 × ₹60,000 = ₹166.07 crore
  - Total (Haryana): ₹332.36 crore

- Cost of Electricity Subsidy (With Reorientation)
- Punjab:
  - Large Farmers: 61,690 × ₹12,000 = ₹74.03 crore

    - Medium Farmers: 344,790 × ₹15,000 = ₹517.19 crore
    - Semi-Medium Farmers: 529,951 × ₹18,000 = ₹953.91 crore
    - Total (Punjab): ₹1,545.12 crore
- Haryana:
    - Large Farmers: 3,086 × ₹24,000 = ₹7.41 crore
    - Medium Farmers: 24,628 × ₹30,000 = ₹73.88 crore
    - Semi-Medium Farmers: 27,679 × ₹36,000 = ₹99.64 crore
    - Total (Haryana): ₹180.93 crore

**Number of farmers owning tubewells as per land-size have been taken from Sixth Minor Irrigation Census data set*.

Savings to State Exchequer
- Punjab:
    - Without Reorientation: ₹2,809.29 crore
    - With Reorientation: ₹1,545.12 crore
    - Savings: ₹1,264.17 crore annually
- Haryana:
    - Without Reorientation: ₹332.36 crore
    - With Reorientation: ₹180.93 crore
    - Savings: ₹151.43 crore annually

Conclusion

Reorienting the electricity subsidy framework ensures continued support for small and marginal farmers while reducing the fiscal burden on state utilities. This proposal encourages judicious water use by large and medium farmers and promotes equitable access to energy resources, saving ₹1,264.17 crore annually in Punjab and ₹151.43 crore in Haryana. The revised subsidy system represents a more sustainable and equitable approach to resource management, aligning with both environmental and economic priorities.

A1.3 VILLAGE WATER BODY RESTORATION: IMPACT AND COST ANALYSIS (BASED ON MNREGA FRAMEWORK 2015)

Assumptions:

1. Each Pond Size = 20m × 20m top, 14m × 14m bottom, 3m depth
2. Each Pond Water Storage Capacity = 800 cubic meters
3. Total Ponds in 8 Acres = 40 ponds
4. Cost per Pond (2025 Inflation-Adjusted) = ₹3,45,600
5. Water Requirement for Micro-Irrigation: Drip Irrigation = 1,200 m^3/ha/season; Sprinkler Irrigation = 1,800 m^3/ha/season
6. Phase-wise Implementation:
    A. Phase 1 (Most Overexploited Villages) – 40% of total ponds
    B. Phase 2 (Moderately Affected Villages) – 35% of total ponds
    C. Phase 3 (Remaining Villages) – 25% of total ponds

Calculations (For 8 Acres)

Water Storage Capacity: Total Water Storage=800 m^3×40=32,000 m^3

Irrigation Potential
- Drip Irrigation (1,200 m^3 per hectare per season): 32000/1200 =26.7 hectares
- Sprinkler Irrigation (1,800 m^3 per hectare per season) 32000/1,800=17.8 hectares

Cost of 8 Acres of Ponds
- Total Cost=3,45,600×40=₹1,38,24,000
- Labour Cost (83.3%) = ₹1,15,15,392
- Material Cost (16.7%) = ₹23,08,608

Self-Financing Model for Villages
- Irrigation Water Charges (₹50/acre/cycle): ₹50,000 — ₹1,00,000
- Fish Farming: ₹2,00,000 — ₹3,00,000
- CSR/NGO/NRI Support: ₹5,00,000— ₹10,00,000

Total possible Self-Fund Generation: ₹8 - 12 lakh per village

Key Outcomes

- Water Storage: Restoring 8 acres of village water bodies can harvest 32,000 cubic meters of rainwater annually, providing a sustainable and localised water source.
- Irrigation Coverage: 26.7 ha (Drip) or 17.8 ha (Sprinkler).
- Construction Cost per village: The total investment required for restoring 8 acres of water bodies is ₹1.38 crore ensuring long-term benefits for agriculture and water management.

MGREGA Labour Share (83.3%) =₹1.15 crore
Material Share (16.7%) = ₹23.08 lakh

Conclusion

By implementing this model in a phased manner, prioritising overexploited villages first, the scheme ensures sustainable groundwater conservation, enhanced irrigation, and employment generation while reducing financial burden on the government.

A1.4 AGROFORESTRY REVENUE AND BENEFIT ANALYSIS

The analysis uses the triennium average of per-hectare yields for rice and wheat, derived from the Statistical Abstracts of Punjab and Haryana (2019–2021), with MSP values extrapolated from the last 10 years to ensure realistic revenue projections. Cultivation costs are based on CACP estimates. For the agroforestry model, it is assumed that planting 200 Poplar trees per hectare along field boundaries occupies 25% of the field area, reducing crop yields by 25%. Poplar tree values are estimated at ₹1,200 per tree, as reported by Dhiman et al. (2024). This approach accounts for trade-offs between reduced crop yields and additional income from timber sales and carbon credits, providing a structured framework to assess agroforestry's economic benefits.

Punjab: Revenue and Benefits

Revenue Component	Details	Value (₹/hectare)
Revenue from Crops (Traditional System)	Rice: ₹2,48,674 (over 7 years) Wheat: ₹5,16,054 (over 7 years)	**₹7,64,728**
Revenue from Crops (With Agroforestry)	Rice: ₹1,86,506 (adjusted for 25% yield reduction) Wheat: ₹3,87,041	**₹5,73,547**
Poplar Revenue	200 Poplar trees × ₹1,200/tree	**₹2,40,000**
Carbon Credit Revenue	348.61 tCO_2e × \$0.6/ tCO_2e × ₹86.58/USD	**₹30,183**
Total Revenue (With Agroforestry)	₹5,73,547 (crops) + ₹2,40,000 (Poplar) + ₹30,183 (carbon credits)	**₹8,43,730**
Net Benefit	Total Agroforestry Revenue – Traditional Revenue	**₹79,002**

Haryana: Revenue and Benefits

Revenue Component	Details	Value (₹/hectare)
Revenue from Crops (Traditional System)	Rice: ₹2,30,414 (over 7 years) Wheat: ₹4,99,204 (over 7 years)	**₹7,29,618**
Revenue from Crops (With Agroforestry)	Rice: ₹1,72,811 (adjusted for 25% yield reduction) Wheat: ₹3,74,403	**₹5,47,214**
Poplar Revenue	200 Poplar trees × ₹1,200/tree	**₹2,40,000**
Carbon Credit Revenue	348.61 tCO_2e × \$0.6/ tCO_2e × ₹86.58/USD	**₹30,183**
Total Revenue (With Agroforestry)	₹5,47,214 (crops) + ₹2,40,000 (Poplar) + ₹30,183 (carbon credits)	**₹8,17,397**
Net Benefit	Total Agroforestry Revenue – Traditional Revenue = ₹8,17,397 – ₹7,29,618	**₹87,779**

Key Data Sources

- Crop Yields: Statistical Abstracts of Haryana and Punjab (2019, 2020 and 2021 (Triennium))
- MSP and Crop Cost: CACP (2016-2021)
- Poplar Revenue Estimates: Dhiman et al., 2024

- Carbon Credit Calculations: Rizvi et al. 2020

Conclusion

Adopting agroforestry practices by planting Poplar trees along field boundaries significantly enhances farmers' incomes in both Haryana and Punjab. Over seven years: Haryana farmers gain ₹87,779/ha more, and Punjab farmers gain ₹79,002/ha more compared to traditional farming systems. Agroforestry not only diversifies income through Poplar timber and carbon credits but also promotes sustainable farming practices by optimising resource use and mitigating environmental impact.

A1.5 GROUNDWATER MARKET FORMALISATION

Assumptions

- Current water cost for irrigation (informal market):
  - Punjab: ~₹66/hour
  - Haryana: ~₹105/hour (CCPC, 2020)
- Average irrigation hours for wheat per hectare:
  - Punjab: 32 hours
  - Haryana: 40 hours (CCPC, 2020)

Cost Analysis

Unregulated Costs (Current Informal Market Rates)
- Punjab: ₹66/hour × 32 hours = ₹2,112/ha (for wheat irrigation)
- Haryana: ₹105/hour × 40 hours = ₹4,200/ha (for wheat irrigation)

Regulated Costs (Proposed Rates)
- Punjab: ₹50/hour × 32 hours = ₹1,600/ha (for wheat irrigation); Savings: ₹2,112 - ₹1,600 = ₹512/ha
- Haryana: ₹50/hour × 40 hours = ₹2,000/ha (for wheat irrigation); Savings: ₹4,200 - ₹2,000 = ₹2,200/ha

Summary of Savings Through Regulation
- Punjab: ₹512 saved per hectare of wheat irrigation
- Haryana: ₹2,200 saved per hectare of wheat irrigation

Formalising groundwater markets can significantly reduce irrigation costs for farmers in both states, making water more affordable and accessible while promoting equitable and sustainable water usage.

Abbreviations

BCM	:	Billion Cubic Meter
ICWE	:	International conference on water and the
CGWB	:	Central Ground Water Board
MI	:	Minor Irrigation
kWh	:	Kilowatt-hour
Rs.	:	Rupees
GoP	:	Government of Punjab
GoH	:	Government of Haryana
CACP	:	Commission of Agriculture Costs and Prices
kg	:	Kilogram
Ha	:	Hectare
MGNREGA	:	Mahatma Gandhi National Rural Employment
CCPC	:	Cost of Cultivation of Production of Principal
MSP	:	Minimum Support Price
CCEA	:	Cabinet Committee on Economic Affairs
tCO_2e	:	Metric tons of carbon dioxide equivalent
US$	:	United States Dollar

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