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Pindi Balochan: Exhibiting pathway of climate resilience

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In India, green revolution has brought food security through improved varieties and technologies, however, overexploitation has led to soil pollution, environmental degradation, high use of synthetic fertilizers, etc. Pindi Balochan, is one of those villages in Punjab facing these challenges besides climatic variability. To address these challenges, interventions of KVK, Faridkot under National Innovations on Climate Resilient Agriculture (NIRCA) has helped in adoption of climate resilient agriculture through crop residue management, agroforestry, and improved livestock practices. The story of Pindi Balochan reaffirmed that with the right integration of technologies, innovations, traditional knowledge, empowered communities, and supportive policies, even the most vulnerable rural landscapes could transition towards resilient livelihoods, sustainable ecosystems, and long-term climate stewardship.

Keywords: Climate resilient agriculture, Crop residue management, NIRCA, Sustainable ecosystems

PINDI Balochan, a prominent agricultural village situated in Faridkot district, Punjab is a part of India's north-western agrarian belt with paddy-wheat cropping system. Like many parts of Punjab's Malwa region, the village forms a microcosm of both the strengths and vulnerabilities of Punjab's Green Revolution landscape, with high productivity, but also high input dependency, soil degradation, water scarcity and environment pollution. Despite its high productivity, agriculture in Pindi Balochan had increasingly come under stress due to climatic variability and resource depletion. Erratic rainfall, heat waves, declining groundwater levels, and soil nutrient depletion have adversely affected the long-term sustainability of farming systems.

Climatic vulnerabilities

Pindi Balochan village was confronted with a complex set of climatic and environmental challenges that had significantly affected its agricultural sustainability and livelihoods. The region experienced wide temperature fluctuations (4.6–43.8°C). These extremes disrupted crop growth cycles, causing heat stress in wheat during grain filling and increasing the risk of lodging in paddy. Rainfall was both scanty and erratic (averaging only 433 mm) against a potential evapotranspiration of nearly 3,000 mm, which created a severe water deficit to rely heavily on groundwater extraction, leading to further aquifer depletion. Furthermore, practice of crop residue burning contributes to air pollution by releasing large amounts of particulate matter, carbon monoxide, and greenhouse gases.

The soils, predominantly loamy sand, were inherently fragile, prone to leaching, and poor in organic carbon. Continuous paddy-wheat cultivation, coupled with residue burning, has worsened soil health, depleted organic matter, and contributed to greenhouse gas emissions. Seasonal heat waves and prolonged dry spells further compounded the problem, drying soils, lowering fodder availability, and reducing milk productivity in livestock. At the livelihood level, farmers' dependence on rice and wheat, both highly input-intensive crops, left incomes vulnerable to climatic variability, rising production costs, and fluctuating market prices. Taken together, these interlinked stresses underscored the urgent need for climate-resilient agricultural interventions in Pindi Balochan.

KVK interventions

Under the National Innovations in Climate Resilient Agriculture (NICRA) initiative, KVK Faridkot implemented a comprehensive set of technological, ecological, and institutional interventions in Pindi Balochan to address the village's vulnerabilities and transform its agricultural landscape. These interventions were not limited to tackling immediate issues but were strategically designed to improve long-term

Table 1. Agro-climatic profile of Pindi Balochan

Parameter	Description/Value
Location	30.68°N, 74.50°E (Faridkot District, Punjab)
Total cultivated land	1,060 ha
Soil type	Loamy sand
Annual average temperature	24.2°C
Temperature range	4.6°C (winter)–43.8°C (summer)
Average annual rainfall	433 mm
Potential evapotranspiration	≈ 3,000 mm
Cropping System	Paddy-wheat (dominant)
Average holding size	2–5 ha
Livestock	Buffaloes and cows (dairy-linked income)

Table 2. Major climate vulnerabilities before NICRA

Challenge	Impact on agriculture
Erratic rainfall and high temperature	Crop yield variability, heat stress in wheat
Groundwater depletion	Crop yield variability, heat stress in wheat
Residue burning	Air pollution, loss of soil organic carbon
Soil nutrient depletion	Air pollution, loss of soil organic carbon
Livestock heat stress	Decline in milk yield, low fertility
Pest attacks	Crop losses in maize, vegetables, and fruits

sustainability by reducing greenhouse gas emissions and enhancing carbon sequestration.

A breakthrough was achieved through Crop Residue Management (CRM), where the introduction of the Happy Seeder and Zero till Drill enabled wheat to be sown directly into rice residues. This eliminated residue burning on nearly 900 ha, saving around 50 L of diesel/ha and reducing land preparation costs by ₹ 1,650/ha. Alongside this, farmers adopted improved, climate-resilient crop varieties such as PR-126, PR-131, and PR-132 in paddy, and PBW-766 (Sunehri) and PBW-826 in wheat. These varieties stabilized yields at approximately 70–72 q/ha for paddy and 58–60 q/ha for wheat, even under varying weather conditions. To restore soil fertility, balanced fertilization and site-specific nutrient management were introduced, while residue incorporation enhanced soil organic carbon levels.

In livestock management, the use of Urea Molasses Mineral Blocks (UMMB) and balanced rationing improved digestibility, cut methane emissions, and increased milk productivity by 8–12%. Stall feeding reduced open grazing pressure and nutrient wastage, contributing to better fodder efficiency. Efforts in grassland development further secured fodder resources, with rehabilitated pastures and improved fodder varieties increasing dry matter availability by nearly 40 q/ha and reducing dependence on external purchases. Simultaneously, forestry and agroforestry initiatives (4.52 ha) brought significant ecological benefits. Trees planted along farm bunds and common

Table 3. Key NICRA interventions in Pindi Balochan

Intervention type	Practice/Technology	Outcome
Crop residue management	Happy Seeder and Zero Till Drill wheat sowing directly into rice residue; residue burning eliminated on ~900 ha	~85% adoption; ~₹1,650/ha savings; diesel savings (~50 L/ha); major drop in air pollution
Climate resilient varieties	Climate resilient paddy (PR 126, PR 131) and wheat (PBW 766, PBW 826) varieties	Yield stability even under weather stress: ~71 q/ha for paddy; 58 60 q/ha for wheat
Soil fertility enhancement	Balanced fertilization, nutrient management, residue incorporation	Increased soil organic carbon; minimized overuse of N; better soil health
Water conservation	Direct Seeded Rice (DSR), short duration varieties, alternate irrigation practices	Saved 25 30% water (~1,000 1,200 m^3/ha); lower labour & irrigation costs
Livestock and fodder	Urea Molasses Mineral Blocks (UMMB), balanced rations, area specific mineral mixture, stall feeding, silage	Milk yield up by 8 12%; reduced open grazing; lower methane emissions per unit output
Forestry and agroforestry	Trees planted along bunds and community land	Enhanced green cover; carbon sequestration; income diversity for farmers
Institutional innovations	Custom Hiring Centre (CHC) for shared access to machines; scientific advisories (e.g. for heat stress)	Small farmers can afford CRM tools; damage in heat waves mitigated; overall resilience of systems improved

lands enhanced green cover, while agroforestry systems boosted carbon sequestration and provided farmers with diversified sources of income.

During the extreme heat wave of March 2022, timely advisories on potassium nitrate sprays, light irrigations, and livestock management minimized losses across farming systems. While regional wheat yields declined by 4–6 quintals, farmers in Pindi Balochan faced only a marginal reduction of around 2 quintals, indicating enhanced adaptive capacity. Integrated measures, such as zero-till wheat, KNO_3 sprays, silage preparation, and use of foggers and bypass fat, helped sustain crop and livestock productivity despite climatic stress. Even under erratic rainfall, pest attacks, and temperature extremes, these practices reduced vulnerability, stabilized incomes, and safeguarded food and fodder availability. The experience underlines that informed advisories, adaptive technologies, and local capacity-building can significantly strengthen resilience to heat, drought, and biotic stresses, ensuring sustainable production in climate-affected regions.

A major institutional innovation was the establishment of a Custom Hiring Centre (CHC) in the village. The CHC made climate-resilient machinery such as the Happy Seeder, Zero till Drill, and Rotavator available to farmers on a rental basis, ensuring that even small and marginal farmers could access advanced

Smart seeder sown wheat in rice residues

Direct Seeded Rice

Happy seeder sown wheat in rice residues

technologies. This significantly expanded the adoption of CRM practices, reduced residue burning, and supported transitions to Direct Seeded Rice (DSR) and zero-till wheat. By lowering operational costs and promoting collective use of machinery, the CHC strengthened community cooperation and made climate-smart agriculture more inclusive. The CHC earned an income of ₹ 8,24,190/- by providing farm machinery services that promote mechanized and eco-friendly farming practices.

Together, these interventions transformed Pindi Balochan into a model of climate-smart agriculture, where resource conservation, productivity gains, and environmental stewardship went hand in hand.

Table 4. Machinery available at custom hiring centre, Pindi Balochan

Name of machine/Implements	Hiring rate (₹/h)	Hiring rate (₹/ acre)
Happy Seeder	800	1500–1800
Super Seeder	900	1600–2000
Rotavator	700	1200
Zero Till Drill	600	1000
Mulcher	800	1400
Laser Land Leveler	1000	1500
MB Plough (Reversible)	700	1200
Paddy Straw Chopper	900	1500
Seed Drill (Conventional)	500	900
Disc Harrow	600	1000

Impact and resilience

The combined effect of the interventions in Pindi Balochan fundamentally reshaped both agricultural performance and the carbon profile of the village. Crop

Area specific mineral mixture

Preventive vaccination

yields improved significantly, with wheat production rising from an average of 58 q/ha to 62–65 q/ha, while paddy yields stabilized at 70–72 q/ha. Farmers reported that yields became more reliable and consistent even under erratic rainfall, a sign of strengthened resilience. Residue management practices also marked a major shift, with nearly 85% of farmers adopting CRM technologies. This not only prevented residue burning but also helped conserve soil nutrients valued at nearly ₹ 4,000 per hectare, while simultaneously cutting down on air pollution. The shift to reduced tillage and direct seeding resulted in substantial energy and cost savings, lowering diesel use by 50 L/ha. These savings, along with reduced field operations and labour, translated into additional profitability of ₹ 7,000–10,000 per hectare annually.

Livestock and fodder management further enhanced village livelihoods. Grassland development met household fodder requirements, reducing dependence on external purchases and ensuring steady dairy income. Improved feed and rationing techniques boosted milk yields, which in turn improved the daily cash flow of smallholder families. Beyond productivity, the interventions had a measurable impact on the village's carbon balance. Avoiding stubble burning alone reduced carbon dioxide emissions by several hundred tonnes each year. Combined with agroforestry plantations and residue incorporation, these practices added to carbon sequestration, ultimately shifting the village's carbon profile from deficit to surplus. Pindi Balochan emerged as one of the rare examples of a village-level carbon sink.

The impact in Pindi Balochan was multi-dimensional. By avoiding residue burning and saving fuel, along with better soil, tree, and livestock management, the village achieved near carbon-neutral and even carbon-positive status in some models. Farmers gained economically through input savings, higher yields, and better milk production, improving profits by 15–20% over the baseline. Socially, collective adoption of clean and smart technologies built stronger community cooperation and reduced air pollution, leading to better health and a cleaner environment.

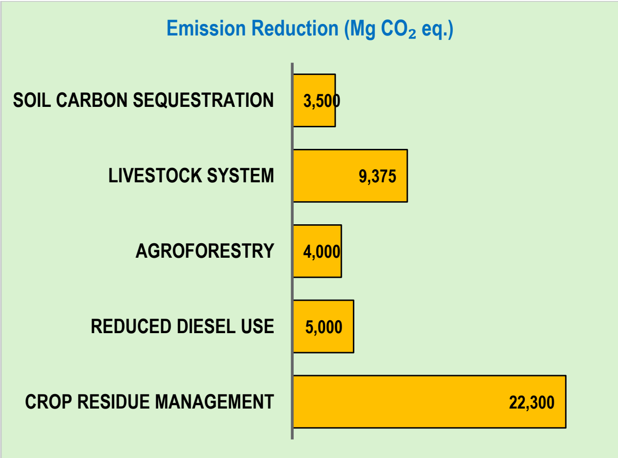
Promotion of Direct Seeded Rice (DSR) and short-duration paddy varieties in Faridkot showed remarkable results under NICRA interventions. DSR reduced irrigation requirements by about 25–30%, saving nearly 1,000–1,200 m^3 of water per hectare, and cut cultivation costs by ₹ 4,000–₹ 5,000/ha compared to puddled transplanting. Adoption of short-duration varieties like PR-126 further enabled early sowing of wheat, helping farmers escape terminal heat stress. Extrapolating these outcomes district-wide, with around 60,000 ha under paddy, potential water savings exceed 60 million m^3 annually, while improving input-use efficiency, reducing methane emissions, and enhancing climate resilience across Faridkot's rice–wheat system.

The study indicated that Pindi Balochan village was found to have significant climate-resilient transformation driven by the adoption of improved agricultural and livestock management practices under the NICRA framework. The village recorded the highest carbon sink potential among all study sites, particularly through interventions in irrigated rice systems where emissions dropped from 59,392 Mg CO_2 eq. to 37,119 Mg CO_2 eq., marking a reduction of nearly 37% due to the adoption of crop residue management practices like the Happy Seeder and alternate wetting and drying. While there was no perennial cultivation intervention, the annual cropping system showed a 42% increase in carbon sequestration, mainly through diversification into sugarcane, berseem, wheat, and vegetables. Interestingly, livestock numbers declined from 845 to 410, creating a net carbon sink (- 9,375 Mg CO_2 eq.) from this sector. The lowest nitrogen fertilizer application rate (120 kg N/ha) was also recorded in this village due to awareness and green manuring, contributing to reduced N_2O emissions. Overall, Pindi Balochan demonstrated how integrated climate-resilient practices, especially crop residue and nutrient management, can substantially mitigate emissions, enhance soil carbon, and lower emission intensity, with the lowest recorded farm-gate emission intensity of 0.43 kg CO_2 eq./kg of rice and 0.44 kg CO_2 eq./kg of milk among all villages studied Another study observed that the farmers in the village showed a high level of conviction toward the adoption of climate-resilient practices. As a result of these interventions, NICRA village Pindi Balochan enhanced its adaptive capacity, improved incomes, and functioned as a model "knowledge hub" for scaling the technologies to broader areas.

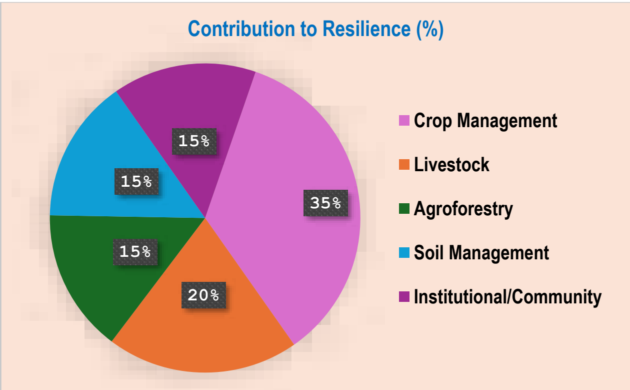
The findings from Pindi Balochan village, highlighted in the Hindustan Times feature "Farmers of Punjab's Climate-Smart Villages Geared Up to Protect Wheat from Heat Stress" (12 March 2023), underscore the village's success as a model under the NICRA initiative.

Farmes there effectively mitigated the adverse impact of rising temperatures on wheat yield by adopting climate-smart practices such as timely sowing, use of short-duration and heat-tolerant wheat and paddy varieties, eco-friendly residue management, and direct-seeded rice (DSR). Progressive farmers like Jaspal Singh reported spraying potassium nitrate as advised by experts to counter sudden heat surges, which significantly reduced yield loss during the 2022 heatwave. While neighbouring areas experienced wheat yield reductions of 4–6 q/acre, Pindi Balochan farmers saw only a marginal loss of about 2 q, demonstrating the effectiveness of these interventions. Our experience shows that the village exemplifies how scientific advisories, timely actions, and farmer capacity-building can enhance resilience to climate-induced heat stress and protect productivity in Punjab's climate-vulnerable regions.

Ultimately, these transformations established resilience in multiple dimensions. Agricultural resilience was achieved through stable yields, while ecological resilience came from improved soil carbon, reduced erosion, and better nutrient cycling. Livelihood



Component-wise carbon emission reduction



Sector-wise contribution to climate resilience

resilience followed with income diversification via forestry and dairy improvements, along with cost reductions. Community resilience strengthened through collective action in machinery sharing, particularly via CHC, and residue management. Another important milestone is that the village has achieved nutritional security, as every household maintains a nutritional garden cultivating indigenous varieties of vegetables organically using vegetable kits. Most importantly, climate resilience was achieved as Pindi Balochan transitioned to a carbon-positive profile, reducing local vulnerabilities while contributing to broader goals of global climate change mitigation.

Way forward

The success of Pindi Balochan charted a clear way forward for scaling and sustaining climate-resilient agriculture across Punjab and beyond. The interventions demonstrated in the village provided practical models for replication, particularly in neighbouring villages of Faridkot and the wider Malwa region, where similar climatic vulnerabilities exist. Scaling up crop residue management, agroforestry, and improved livestock practices could help expand both productivity and environmental gains.

Equally important is building stronger policy linkages, aligning village-level actions with national and state schemes such as the Crop Residue Management (CRM) Scheme, PM-KUSUM for solar-based irrigation, MGNREGA for land and water resource development, and the soil health card programme for balanced nutrient use. Future progress also lies in connecting farmers to carbon credit markets, creating a framework where sequestration services are monetized, and farmers are rewarded for maintaining a carbon-positive profile. Strengthening institutional mechanisms, particularly Farmer Producer Organizations (FPOs), will be vital for collective residue management, bulk input procurement, and better marketing of produce. Most importantly, Pindi Balochan holds the potential to be showcased as a climate-smart village model under NICRA, where integrated interventions not only ensure resilience but also highlight the synergies between sustainability, profitability, and community welfare.

SUMMARY

The journey of Pindi Balochan from a climate-vulnerable settlement to a climate-resilient, carbon-positive village stood as a testament to the transformative power of science-based interventions, farmer participation, and institutional convergence. What began as a response to recurring heat waves, erratic rainfall, and soil degradation gradually evolved into a comprehensive model of sustainable agriculture and rural resilience. By raising crop yields, lowering production costs, securing fodder supplies, and achieving a favourable carbon balance, the village demonstrated that climate-smart agriculture was both an environmental imperative and an economic opportunity. The story of Pindi Balochan reaffirmed that with the right mix of technologies, empowered communities, and supportive policies, even the most vulnerable rural landscapes could transition towards resilient livelihoods, sustainable ecosystems, and long-term climate stewardship.

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