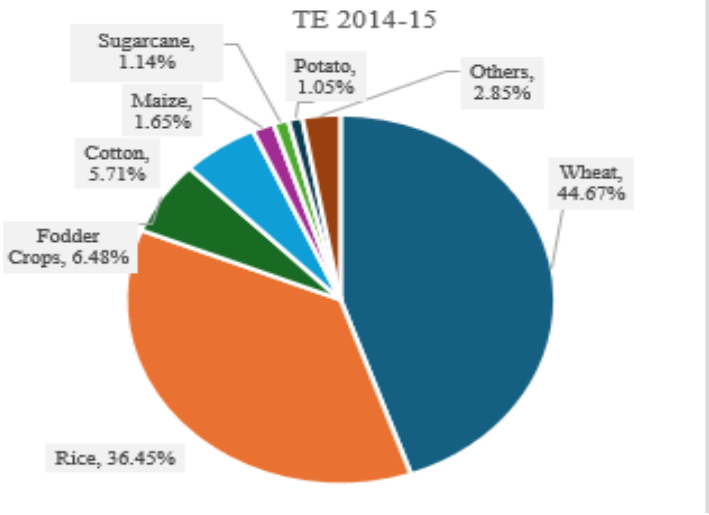
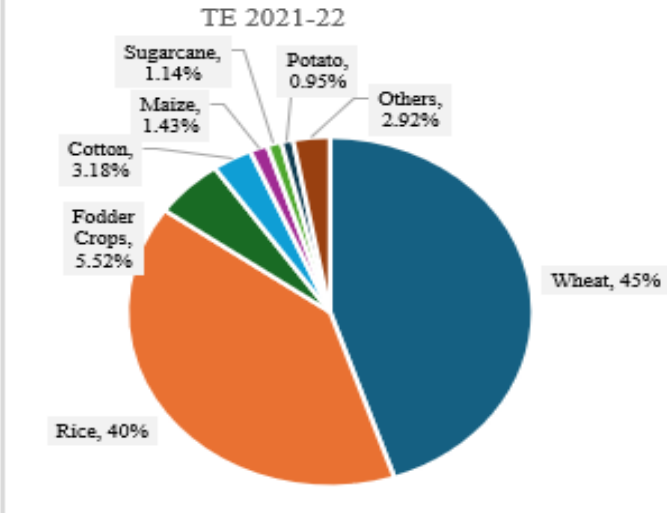
Enhancing Income and Climate Resilience in Punjab Agriculture

Roadmap for Punjab

Concept Note





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vi agenama
understanding rural life

Arcus Policy Research

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ABOUT US

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VillageNama, a conglomerate consisting of a YouTube News & Features channel, an Action Research Lab Centre for Rural Policies & Studies (CRPS), and a Journal of Rural Policies & Studies (JRPS), is mandated to have all stakeholders focus on rural affairs in all its diversities.

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Executive Summary

Punjab has been a key state in contributing to India's food security over time. Although, in 2018-19, income of the agricultural households in Punjab was Rs. 21,705 per month but Meghalaya had the highest income of Rs. 26,973 per month in India, thus Punjab needs to focus more on its agricultural and allied sector.

Punjab has a high-cost of cultivating crops like cotton, oilseeds, barely, etc., when compared to states like Haryana, Madhya Pradesh and Bihar. Punjab has also experienced stagnated or lower yields in major crops like cotton, paddy, barley, and oilseeds. For instance, the cost of cultivation for cotton increased by 7 percent from 2019-20 to 2021-22, while yield decreased by 47 percent.

While Punjab benefits when prices fall, it also loses when prices rise. In, 2023-24, when farmers in Madhya Pradesh and West Bengal were able to sell wheat at around Rs.2400/quintal, Punjab was selling wheat at the MSP of Rs.2275/quintal. It is due to lack of presence of private players in the state that farmers are forced to sell their produce to government at the MSP.

Compared to Haryana, Punjab's GVA from agriculture and allied sectors is less diversified. In the TE 2022-23, around 80% of Punjab's GVA in this sector came from just a few commodities like milk, paddy, wheat, meat, and fodder. Consequently, the state has placed only minimal emphasis on allied activities.

To enhance Punjab's agricultural economy, the state government should aggressively promote milk processing, incentivize private sector involvement, and develop both milk and meat processing industries to increase profitability and target international markets.

In order to reduce paddy's dominance, around 2.4 million hectares of land needs to be diversified to other crops in Punjab. For this, 1.4 million hectares needs to be diversified from the present paddy cultivating area and 1 million hectare needs to be reclaimed from fallow land in the state.

Many districts like S.A.S Nagar, Hoshiarpur, Tarn Taran and Kapurthala do not have a second crops as their cropping intensities are lower than 180 percent. Thus, many districts in Punjab need to have second and third crops.

The prevalence of fake and spurious fertilizers is a much larger issue than anticipated, undermining soil health and crop yields, leading to financial losses for farmers and compromising the integrity of the agricultural supply chain.

Water pollution in Punjab is entrenched, indicating that it is deeply rooted; unless resolved, it poses a severe threat to both farmers and farming.

Agroforestry can be a game changer for crop diversification in Punjab and can be scaled up in a phased manner through the Direct Benefit Transfer (DBT) initiative to benefit farmers.

Under the Parampragat Krishi Vikas Yojana (PKVY), 300 clusters were sanctioned between 2017-2021, with 6,000 farmers in Punjab adopting organic farming. Thus, niche organic pockets are developing in the state but on a very small scale.

Price forecasting and the use of technology are still far from being implemented in Punjab. The state faces challenges in adopting advanced forecasting methods and integrating technology into agricultural practices.

Key Recommendations

Crop diversification is not a silo effort, entire revival package is required in order for the farmers to handheld this diversification drive. The government must ensure quality seeds, price assurance, risk coverage, and develop storage, processing, procurement, and pest management systems to sustain diversification.

Excessive loan waivers and the misuse of agricultural loans for social consumption, such as marriages, are undermining credit culture and financial responsibility in Punjab's farming community.

Developing a real-time distress index using advanced technologies can help policymakers monitor farmers' challenges and implement targeted support strategies more effectively.

Reviving market institutions like Markfed is essential due to its struggles with competition, technological gaps, operational inefficiencies, and severe financial distress.

The widespread use of counterfeit fertilizers in Punjab highlights the need for robust monitoring, farmer education, mandatory billing, and a strong regulatory framework to protect agricultural interests.

Establish Agro Service Centres with custom hiring services and increase subsidies for sustainable farm machinery can boost mechanization in Punjab.

Introduction

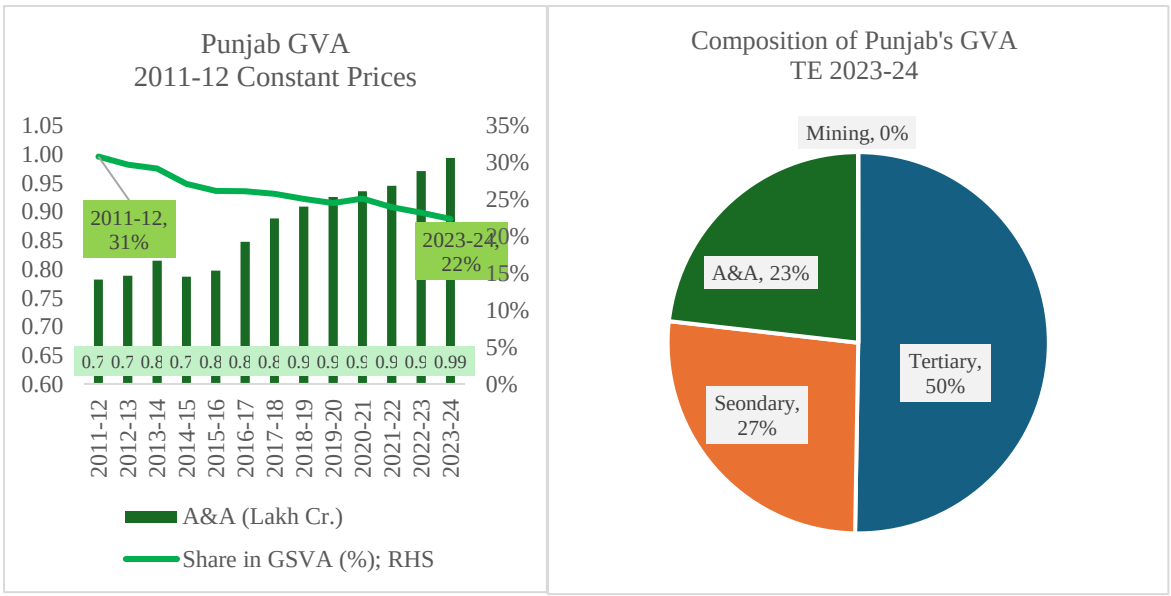
Punjab's total GCA amounts to 7.9 million hectares, with approximately 3.2 million hectares dedicated to paddy cultivation. Paddy is a highly water-intensive crop, contributing to a global water footprint of 784 km³ per year (Chapagain and Hoekstra, 2011). Paddy cultivation has caused several ecological problems, as it results in the highest CO_2 equivalent emissions of any crop, totaling 6718 kg CO_2 eq. ha□ and about 60 percent of these emissions come from methane (CH_4) released during submerged water cultivation (Ranguwal et al., 2023). To address the adverse externalities that have accumulated over time from paddy cultivation, it is imperative for farmers to diversify their cropping patterns.

The Government of Punjab in July 2024 launched an incentive of Rs. 7000 per acre to farmers for cultivating crops other than paddy (Chaba 2024). With this context, this note discusses in brief the agricultural landscape and challenges that exist in Punjab's agriculture crop diversification plans. This note then estimates the extent to which land can be made available for other crops and suggests pathways for increasing acreage under crops other than the dominant paddy-wheat nexus.

Section I: Agricultural Sector in Punjab

The state's overall gross value added (GVA) in *triennium ending* (TE) 2023-24 was Rs. 4.2 lakh crores. Off this, 23 percent was attributed to agriculture and allied sectors (A&A) in the state (Figure 1). Over the years, state's A&A GVA is on an increasing trend, however, the share in overall GVA has been on a continuous decline. In 2011-12, A&A sectors accounted for 31 percent of total GVA which has declined to 22 percent in 2023-24.

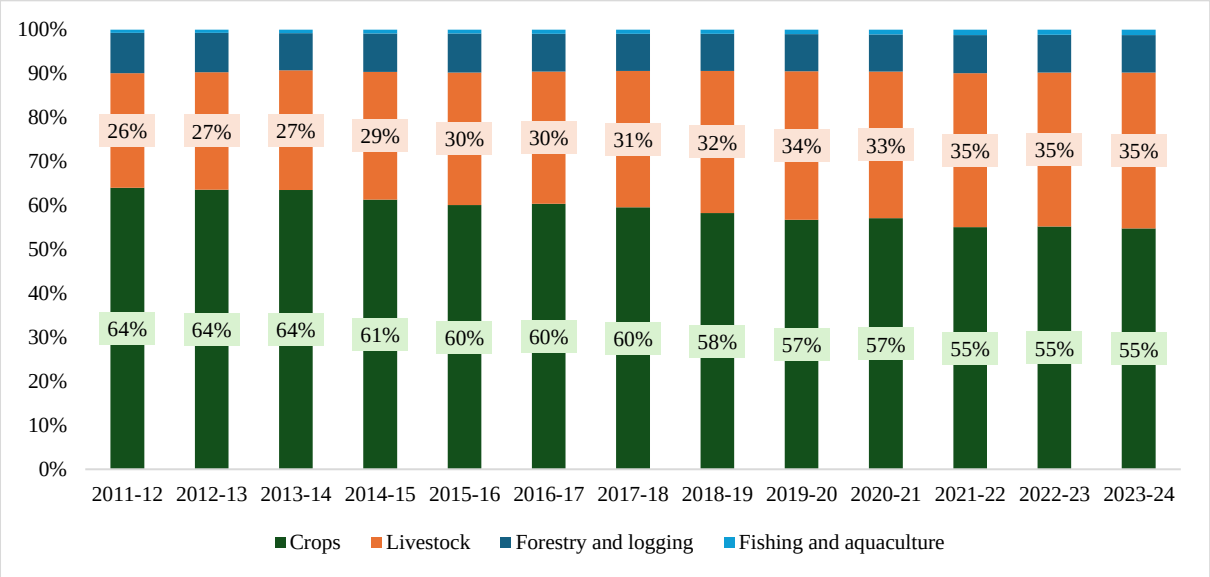
Figure 1: Trends and Composition Punjab GVA



Source: MOSPI

A&A GVA is composed of value-added in crop farming, livestock, forestry and fishing sectors. In 2023-24, crop farming GVA was Rs. 0.54 lakh crores, followed by 0.35 lakh crores for livestock, Rs. 0.09 lakh crores for forestry & logging and Rs. 0.01 lakh crores for fishing & aquaculture. Over the years, the share of crop farming in state's A&A GVA has been reducing. In 2011-12, crop farming accounted for 64 percent of total A&A GVA, this share has decreased to 55 percent in 2023-24. The decrease in crop farming GVA is filled by increase in livestock's GVA. Forestry & logging and Fishing & aquaculture have maintained similar shares during this time period (Figure 2).

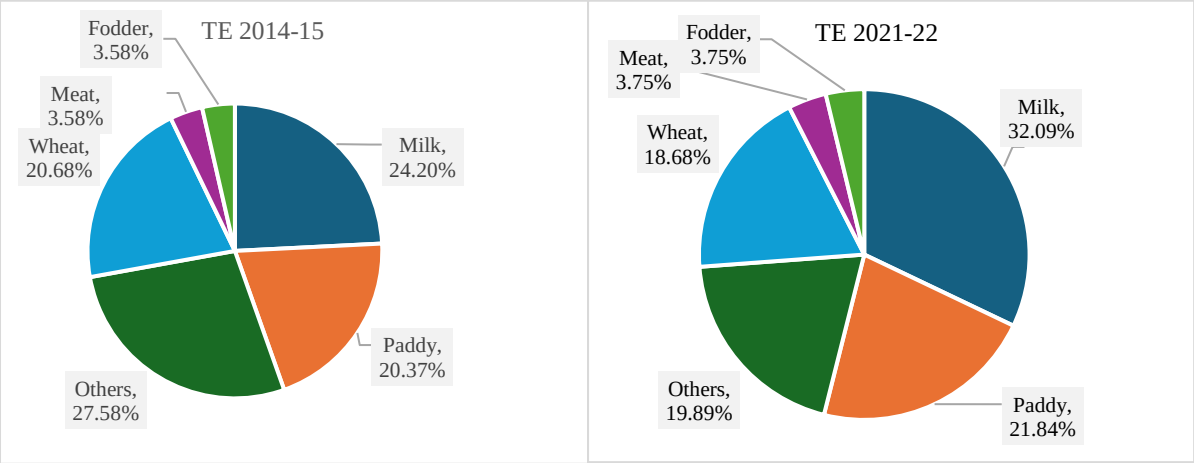
Figure 2: Composition of A&A GVA in Punjab



Source: MOSPI | Note: Estimates using 2011-12 constant prices

From TE 2014-15 to TE 2022-23, Punjab's gross value added (GVA) remained dominated by milk, paddy, wheat, meat, and fodder (Figure 3). Milk has been the largest contributor to Punjab's GVA from agriculture and allied sectors and its contribution grew to 32 percent over the given period. The contribution of paddy has also seen a rise, increasing by almost 2 percent. In contrast, the contribution of wheat has decreased by 2 percent during the same period. Meanwhile, the contribution of meat and fodder has remained steady at almost 4 percent of Punjab's total GVA from agriculture and allied sectors. These shifts highlight the growing importance of milk and paddy in Punjab's agricultural economy, while that of wheat has slightly declined.

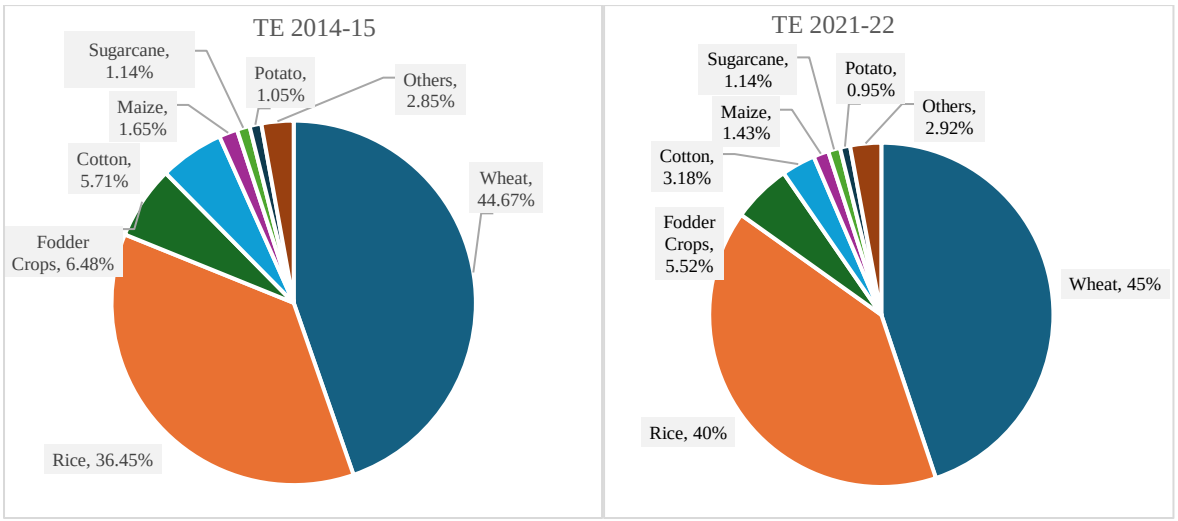
Figure 3: GVA Composition



Source: MOSPI

The total gross cropped area (GCA) for TE 2021-22 in Punjab is 7.9 million hectares and the major crops are wheat, paddy, maize, cotton, sugarcane, bajra, jowar and other horticultural products. Over the years, wheat and paddy have continued to dominate the GCA of Punjab (Figure 4). The share of paddy has significantly increased from 36 percent to 40 percent, while the share of wheat has remained similar around 45 percent. Conversely, during the same period, share in GCA of cotton decreased from 5.71 percent to 3.18 percent, and fodder crops, from about 7 percent to 5.5 percent. Share of maize and potato have also decreased slightly. Sugarcane's share remained similar at around 1.14 percent.

Figure 4: Trends in GCA composition



Source: DES, GOI

Haryana, which is has a similar landscape to Punjab, is more diversified in terms of its land use. During the TE 2021-22, wheat (37 percent), paddy (23 percent), cotton (11 percent), rapeseed and mustard (9 percent), bajra (9 percent), sugarcane (1.5 percent), gram (0.63 percent) and fodder crops (4 percent) constituted around 95 percent of the GCA, making them

the major crops grown in Haryana. Between TE 2014-15 and TE 2022-23, while Punjab's GVA from agriculture and allied sectors grew by 60 percent, Haryana's grew much aggressively by 72 percent.

Table 1: Monthly average income of agricultural households from livestock sector (2018-19)

#	Total AHH incomes in	Nominal CAGR of Livestock Income from 2013 to 2019	AHH incomes from livestock	Real CAGR of Livestock Income from 2013 to 2019	Proportion of Livestock Income from Total Income
India	10,218	13%	1,582	8%	15%
Punjab	26,701	18%	4,457	13%	17%

Source: NSSO's 77th Situation Assessment Survey (SAS) of Agricultural Households | Note: AHH is Agricultural Household

According to the latest round of the NSSO's 77th Situational Assessment Survey (SAS) of Agricultural Households (2018-19), the monthly average income of agricultural households in Punjab was Rs. 26,701 (Table 1). This is significantly higher than the all-India average of Rs. 10,218, making Punjab's agricultural income the second highest in the country. Additionally, farmers in Punjab earn Rs. 4,457 per month from livestock, which is also higher than the all-India average of Rs. 1,582. The livestock income for farmers in Punjab increased at a real compound annual growth rate (CAGR) of 13 percent between 2012-13 and 2018-19, after adjusting for inflation, indicating a robust growth rate in livestock income compared to the national average. These figures highlight the substantial role of livestock in augmenting agricultural income in Punjab relative to the rest of India.

Section II: Constraints or Opportunities for Punjab Agriculture

Punjab faces significant challenges in diversifying its agricultural practices due to a strong reliance on the rice-wheat cropping pattern. This dominance is maintained by stable profits and government procurement mechanisms, making it difficult for farmers to transition to other crops despite the potential for higher profits from options like Moong. Factors such as high price volatility, long gestation periods, lack of incentives, and inadequate storage facilities further hinder diversification efforts. Additionally, the inefficient functioning of mandis and a historical reluctance to adopt crop insurance schemes compound the difficulties in achieving agricultural diversification in the state. This section discusses these challenges in great detail.

Inertia on rice and wheat cropping pattern: More economics than just inertia

DA&FW releases the Cost of Cultivation data for multiple crops. The latest data in this regard is available till 2021-22. Using this dataset, using per hectare costs revenues, the profits earned from a crop can be estimated. Using the A2+FL cost composition and the value of both main and by products we estimate the profits earned between 2017-18 and 201-22 by Punjab farmers for various crops. Based on analysis cultivation of Moong gives the highest profits per hectare in the state (Table 2).

Table 2: Profits (Rs. /Ha) and Profitability (profits as percent cost) of key crops in Punjab

Crops	2017	2018	2019	2020	2021
Moong	-	-	-	70035 (243%)	75403 (253%)
Cotton	40227 (71%)	72076 (116%)	68392 (116%)	62079 (103%)	114274 (180%)
Wheat	63900 (196%)	64974 (174%)	65737 (173%)	65829 (179%)	61962 (164%)
Paddy	81159 (191%)	75887 (157%)	74873 (144%)	87626 (165%)	83613 (142%)
Maize	4323 (9%)	15775 (31%)	6424 (10%)	-7024 (-12%)	10937 (17%)
Sugarcane	183287 (221%)	176682 (164%)	172412 (250%)	-	-
Potato	161439 (193%)	26567 (20%)	121885 (99%)	-	-
Mustard	27854 (98%)	31746 (107%)	21557 (68%)	48393 (134%)	-

Source: Estimated by authors using cost of cultivation data by MoA, GOI | Note: Profit is estimated by subtracting A2+FL cost from the revenue generated from sale of main and by products. Number in parenthesis is the profitability rate, i.e., Revenue/Cost and is expressed as percentage. "- "denotes data unavailability

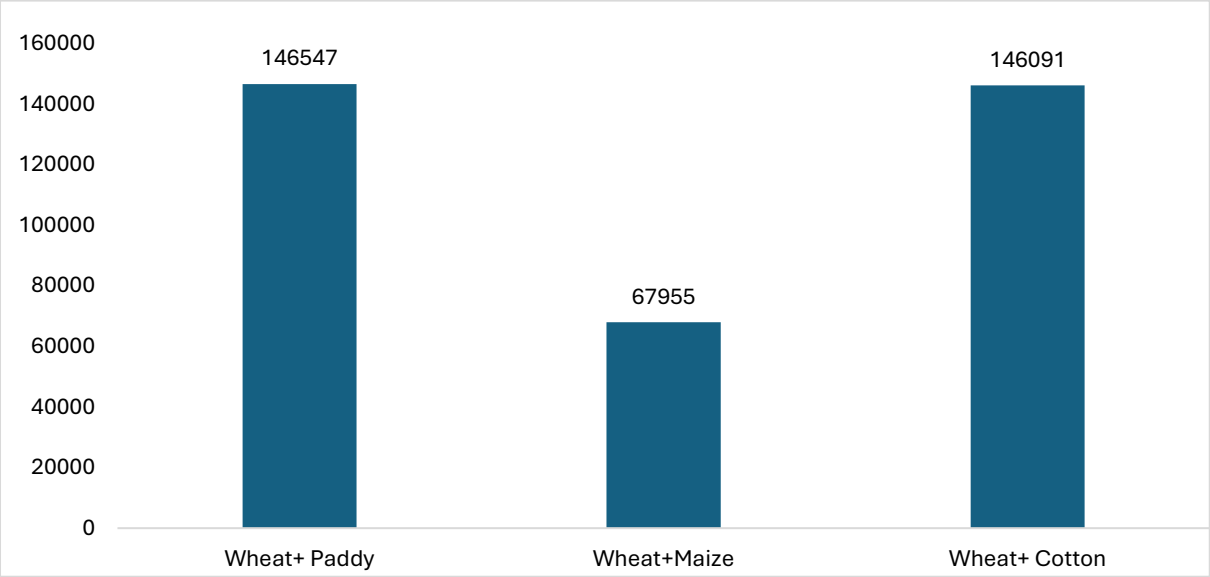
From the above table the following learnings emerge:

1. *For Paddy and wheat, farmer profitability remains high and stable. For paddy, profitability ranges between 150 to 200 percent with profits between 75000 per hectare to 87000 per hectares.*
2. *Moong provides highest profitability rates for Punjab farmers which above 250 percent returns over the cost of production. Cultivation of profitable crops like Moong could help boost and stabilize farmers' incomes in Punjab but currently the GCA for Moong remains less than 1 percent of Punjab's total GCA.*
3. *Profitability from crops such as cotton, maize, potato and mustard are highly volatile with profitability showing large variations across years.*

No other crop combination matches this level of profits unless one considers sugarcane. However, sugarcane requires substantial water, which does not address the issue of the declining water table. In 2021-22, the profitability of Moong increased by 250 percent, showing an increase from 2020-21. Consequently, for a profit-maximizing farmer, the rice-wheat pattern remains the most financially attractive option, leading to a primary reluctance to diversify crops.

Below discussed are profits from various crop combinations (Figure 5). The wheat-paddy combination yields the highest profits at market prices compared to all other crop combinations involving paddy. Punjab's Paddy and wheat generate stable and steadily increasing incomes annually due to government's MSP operations. These operations ensure that almost the entire crop brought by farmers to the APMCs is purchased at guaranteed prices. In contrast, other crops tend to offer relatively unstable and volatile incomes.

Figure 5: Profits from different crop combinations for TE 2021-22 (Rs. /Hectare)



Source: Estimated by authors using cost of cultivation data by MoA, GOI | Note: Profits for TE 2021-22 are calculated as per Table 2, and then the profits for both crops in a combination are added.

While the wheat-cotton combination offers similar profit levels, but farmers are concerned about pests, diseases, untimely rains, high temperatures, hail, and other adverse conditions, that affect cotton production. For instance, the cotton crop suffered damage from mealybugs in 2007, whitefly in 2015, and pink bollworm in 2021. Additionally, unlike wheat and paddy, the input costs for cotton are higher due to the broken extension system and labour-intensive nature of this crop. The market price risk is one of the reasons behind farmers' reluctance to switch to other crop combinations.

Constraints: Soil, land, excessive/fake fertilizer Use, Groundwater levels/pollution, and Climate

Agricultural production relies heavily on natural resources such as land, water, air, and soil, with their quality directly affecting crop productivity. Land is a fundamental input for agriculture, holding a crucial position among all the resources essential for the modern economy (Ramasamy et al., 2005). Punjab's increase share of fallow land, over the years, signifies desertification and lower productivity of land. This may be due to degrading quality of soil, water and air, coupled with increasing natural calamities like floods, drought, etc, that Punjab is facing. Districts such as Bhatinda, Faridkot, Gurdaspur, Jalandhar, and Moga fall under the "Very High" risk category, largely due to their high NAS and low rainfall. These districts are historically prone to droughts, and future projections indicate an increase in drought proneness or a rise in minimum temperatures, exacerbating their vulnerability. Similarly, districts like Firozpur, Mansa, Muktsar, and Sangrur, classified as "High" risk, as they also exhibit high NAS and low rainfall, with a history of high drought or flood proneness. The interplay of these factors—high NAS, low rainfall, and historical climate hazards positions these districts at a heightened risk, necessitating targeted climate adaptation strategies focusing on efficient water management, crop diversification, and socio-economic resilience (Rao et. al. 2013). In 2023, incessant rainfall and overflow of rivers caused flooding of fields and damage to other infrastructure in Punjab. Climate change is causing an increase in the frequency of extreme weather events.

Punjab leads the country in fertilizer consumption, with an annual usage of 375.63 kg of urea and 91.49 kg of diammonium phosphate per hectare (Department of fertilizers, 2023). Overuse of fertilizers and pesticides has increased the levels of anthropogenic pollutants and heavy metals like Nitrate, Iron, Arsenic, Selenium, Chromium, Manganese, Nickel, Cadmium, Lead and Uranium in groundwater, beyond permissible limits (as per BIS) for human consumption. This has increased both carcinogenic and non-carcinogenic risk due to the use of groundwater (Department of water resources, river development & ganga rejuvenation 2024). Moreover, huge prevalence of fake and spurious fertilizers, will not only destroy crops but also pose a serious threat to the consumers of that crop. The prolific agricultural activity in Punjab, particularly following the Green Revolution, has led to a significant shift in cropping patterns over the past fifty years. While agricultural production has increased, this growth has come at

the expense of severe groundwater contamination. As Punjab evolved into the "Bread Basket of India," it simultaneously became known as the "Cancer Capital" of the country.

The categorization of groundwater assessment units in Punjab highlights the alarming state of groundwater resources across the state. According to 2022 report by the Dynamic Ground Water Resources of India[1], Gurdaspur, Jalandhar, Firozpur, and Moga, pockets within Hoshiarpur, Rupnagar, and Sangrur, fall under the "Over Exploited" category, indicating that the rate of groundwater extraction has significantly exceeded the rate of natural recharge, posing severe sustainability issues. Parts of Pathankot, Hoshiarpur, and a few districts in the southwestern region like Bathinda and Fazilka, fall in the “semi-critical” category implying that the groundwater levels are is low but not over-exploited. Only Muktsar and Pathankot districts of Punjab fall under the “safe” category.

Cropping Intensity is falling or low in some districts

Cropping intensity refers to the practice of growing multiple crops on the same piece of land within a single agricultural year, thereby boosting overall crop production. Monitoring cropping intensity can be crucial for evaluating the impact of interventions on irrigation feasibility and the potential for planting during short-season rainfall periods[2]. Punjab has a high cropping intensity of 189 percent or 1.89, as the plains of Punjab are sub-humid alluvial areas with good alluvial soil and moderate to high land capability (Verma and Singh 2006). Over the years, Punjab is dominated by paddy-wheat cropping pattern, leading to increased demand for irrigation water and over-exploitation of groundwater resources. Prior to the Green Revolution, Punjab was not traditionally a rice-growing state. However, with the introduction of controlled irrigation and high-yielding variety (HYV) seeds, the productivity of rice and wheat in Punjab became highest in the country. These two crops have largely replaced the cultivation of coarse cereals, pulses, and oilseeds. Over the years, the area under cotton cultivation has also fluctuated due to issues with the pest attacks, prompting farmers to switch to rice for stable yields and assured income (Rangi and Sidhu 2004).

Hoshiarpur, Jalandhar and Tarn Taran practice double cropping as more than 70 percent of the area are doubled cropped but only by rice and wheat cultivation. On the other hand, Pathankot, Fazilka, Patiala, Mansa, Barnala, Sangrur, Moga, Muktsar and Kapurthala have cropping intensity close to 2, signifying that these districts are growing rice and wheat, along with a short duration variety crop like summer mong, oilseeds, vegetables like potato, tomato, onion, fruits like kinnow, etc.

[1] *Dynamic Ground Water Resources of India, 2022, categorizes the stages of groundwater extraction as Safe (≤ 70%), Semi-critical (> 70% and ≤ 90%), Critical (> 90% and ≤ 100%), and Over Exploited (> 100%).*
[2] *Cropping Intensity = (Gross Cropped Area / Net Sown Area) x 100*

Table 3: Cropping Intensity of Punjab

Cropping Intensity (CI)	Districts	TE 2020-21	% Change CI TE 2014-15 TE 2020-21
<1.50	S.A.S NAGAR	1.3	-8%
>1.50 and <1.80	HOSHIARPUR	1.7	-4%
	JALANDHAR	1.7	-3%
	TARN TARAN	1.8	-1%
>1.80	FIROZEPUR	1.9	-18%
	FATEHGARH SAHIB	1.9	-1%
	RUPNAGAR	1.9	5%
	AMRITSAR	1.9	0%
	BATHINDA	1.9	2%
	S.B.S NAGAR	1.9	1%
	LUDHIANA	1.9	7%
	GURDASPUR	1.9	3%
	FARIDKOT	1.9	0%
	PATHANKOT	2.0	-8%
	FAZILKA	2.0	14%
	PATIALA	2.0	0%
	MALERKOTLA	2.0	
	MANSA	2.0	4%
	BARNALA	2.0	0%
	SANGRUR	2.0	-1%
	MOGA	2.0	0%
	MUKTSAR	2.0	1%
	KAPURTHALA	2.0	1%

Source: Arcus Policy Research based on LUS data for TE2014-15 and TE 2020-21

Thus, Punjab has high cropping intensity but the GCA is mostly dominated by paddy in kharif season and wheat in rabi season. Some districts have witnessed increase in the cropping intensity signify areas where farmers are growing multiple crops on the same piece of land within a single agricultural year.

Districts like Fazilka (14 percent), Ludhiana (7 percent), Rupnagar (5 percent), Mansa (4 percent), Gurdaspur (3 percent), Bathinda (2 percent), Kapurthala (1 percent), Muktsar (1 percent) and SBS Nagar (1 percent) have experienced increased cropping intensity from TE 2014-15 to TE 2020-21, implying that they have initiated diversification but the pace very slow.

Vulnerable yet uninsured

Punjab government has promoted cotton-wheat combination as an alternative to the water-intensive paddy-wheat system but farmers still remain reluctant to switch due to the historical emphasis on wheat and rice cultivation supported by price stability and procurement mechanisms. Floods, hot and humid weather, late sowing coupled wrong cropping pattern of the have made farmers more vulnerable to pest attacks in Punjab. In 2023-24, Punjab government found that moong is a natural host of whitefly, causes pest attacks on nearby cotton fields (Joshi 2023). The damage done by mealybugs in 2007, whitefly in 2015 and pink bollworm in 2021, is making farmers ditch cotton for paddy cultivation (Jagga 2024). The area under cotton was 485,000 hectares in TE 2014-15, which decreased to 250,000 hectares in TE 2021-22. In 2015-16, during whitefly, the cotton yield was lowest since 2000, which was 196 Kg per hectares, decreasing from 544 Kg per hectares in 2014-15. Challenges in cotton cultivation in Punjab extend beyond issues of supply of lower quality seeds and agrochemicals. Weather and market uncertainties are major factors that discourage farmers from taking up cotton farming. Farmers are unaware of pest attacks on cotton and its control due to lack of awareness and government support (Kumar 2023).

Punjab, despite its rich agricultural heritage, has consistently been reluctant to embrace crop insurance schemes. This hesitance dates back from the Individual Approach Basis Insurance Scheme (IABIS) and the Comprehensive Crop Insurance Scheme (CCIS), which the state did not adopt. Over the years, Punjab has only briefly engaged with a few insurance initiatives, such as a pilot seed crop insurance scheme in 1999-2000, the farm income insurance scheme in Sangrur, and livestock insurance in select districts in 2006-2007. As of 2023, while the central insurance scheme Pradhan Mantri Fasal Bima Yojana (PMFBY), launched in 2016, has been adopted by 17 states, Punjab has yet to show interest. Reasons for the state's non-adoption of these schemes include secured irrigation, low indemnity levels, outdated crop size benchmarks, and the burden of ₹1,500 per acre premium (Kaur 2024).

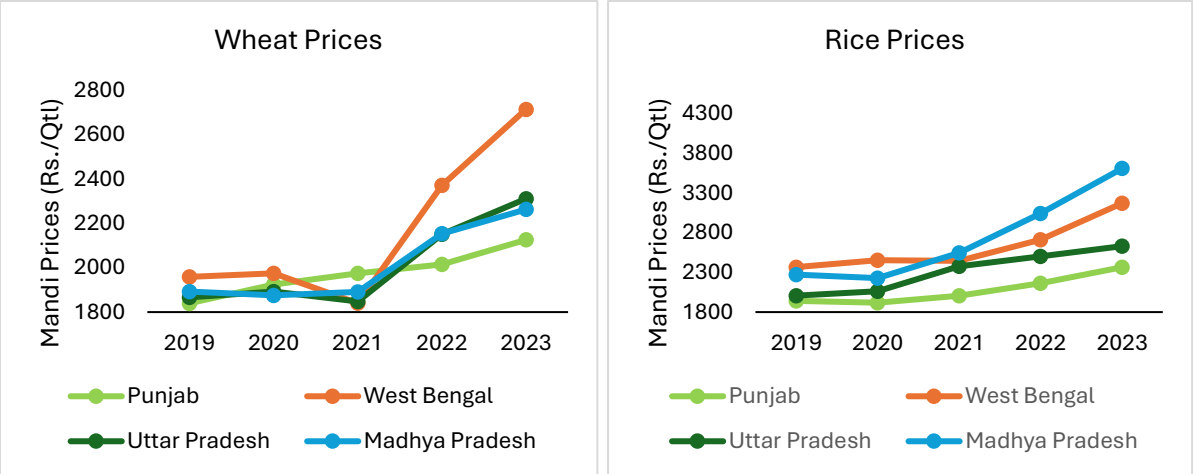
Challenges faced by Livestock Sector

In Punjab, livestock farming faces several significant constraints. The primary issue is the lack of consistent availability of green fodder throughout the year, leading to underfeeding of animals (Kaur and Sidhu, 2010; Kaushal et al., 2011). Other major problems include inadequate quality and supply of feed and fodder, high feed costs, and insufficient veterinary facilities. Farmers also struggle with low milk prices and poor productivity due to traditional feeding practices and lack of scientific management. Additionally, fragmentation of landholdings, scarcity of labor, and limited access to improved seeds and technology further exacerbates these challenges. These constraints collectively hinder the growth and efficiency of livestock farming in the region.

Limited Private Participation: High Intermediation Costs, Low Crop Diversification, and Lack of Focus on Processing

Punjab imposes a 6 percent mandi tax (including development cess) on wheat and non-Basmati paddy, while the tax ranges from 1 to 3 percent for Basmati rice, maize, cotton, fruits, and vegetables. Haryana charges 4 percent on wheat, paddy, arhar, sesame, and green fodder, with a lower rate of 1 to 3 percent for other commodities. Uttar Pradesh applies a mandi fee or user charge of 1 to 1.5 percent on all commodities (APEDA 2022). Thus, high mandi taxs discourages private procurement in the state, forcing farmers to keep selling on MSP.

Figure 6: Mandi Prices (Rs./Qtl) for Wheat and Rice



Source: UPAj, GOI

Farmers in many major wheat and rice-producing states sell their produce at market prices higher than the Minimum Support Price (MSP). In contrast, in Punjab, where private procurement is less prevalent, market prices, though similar to MSP, tend to be lower compared to other states. As a result, Punjab farmers benefit from a stable income when mandi prices fall but miss out on the higher earnings when market prices rise. This cyclical pattern of stagnant wheat and rice prices poses a significant challenge for farmers in Punjab.

Despite Punjab's significant contribution to the country's food production, the state has a limited number of food parks, which is insufficient compared to its agricultural output. With the objective of providing common infrastructure facilities for the food processing industry, particularly for Small and Medium Entrepreneurs (SMEs), food parks are crucial. These parks enable the manufacturing of processed food products from perishable agricultural produce, catering to both domestic and export markets. However, Punjab currently has only three mega food parks, of which only two are functional, and one is still under implementation. This disparity highlights the need for more food parks to adequately leverage Punjab's substantial agricultural produce and boost its food processing industry.

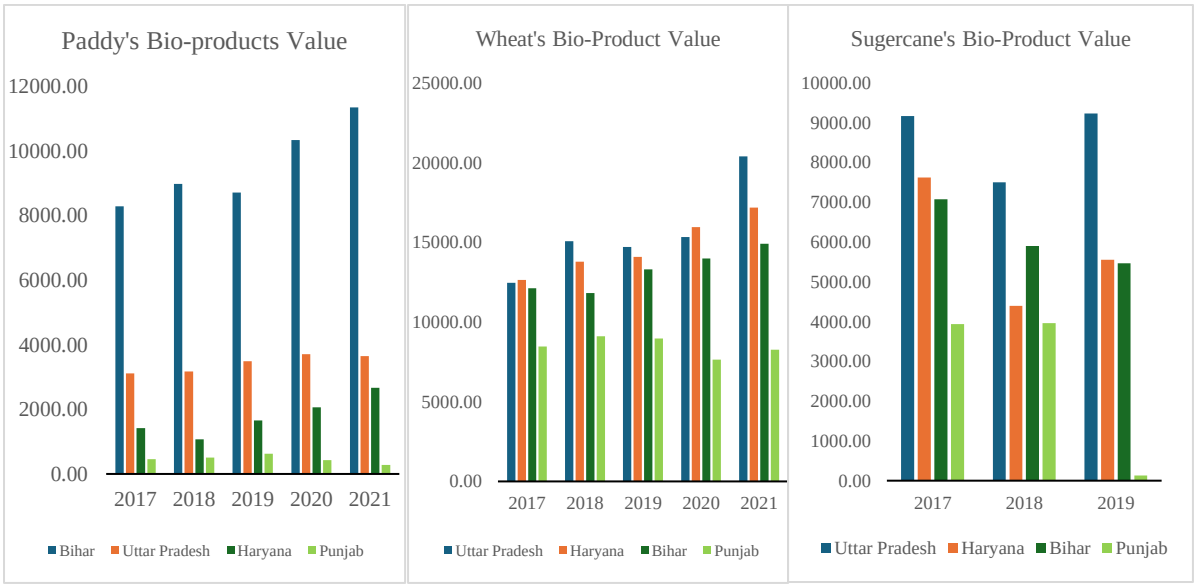
Agroforestry is long losing steam

Agroforestry has faced significant challenges in Punjab, leading to its prolonged struggle for adoption. Farmers encounter high fluctuations in prices on a daily basis, placing their income at substantial risk, and they often receive 30-40% less than market prices. The long gestation period, ranging from 5 to 8 years, further deters farmers. Additionally, the lack of incentives, MSPs, subsidies, and buy-back guarantees makes it difficult for farmers to undertake the risk and switch to agroforestry. The inefficient functioning of mandis forces farmers to deal with middlemen (Arthiyas), incurring extra expenses. Furthermore, the risk of land acquisition due to extended gestation periods and potential conflicts arising from insufficient profit division among the involved parties adds to the hesitation.

Missed opportunities in by-products

Punjab has the lowest value generation from bio-products from wheat, paddy and sugarcane, indicating significant regional variations across Bihar, Haryana and Utter Pradesh (Figure 6). Waste to value is an innovative approach in agriculture that transforms agricultural waste into valuable bio-products, reducing environmental impact. This process not only mitigates waste disposal issues but also generates additional income for farmers. By converting waste into bio-products like organic fertilizers, biofuels, and biodegradable materials, sustainable agricultural practices can be promoted.

Figure 7: Value Bio-Product of Different Crops



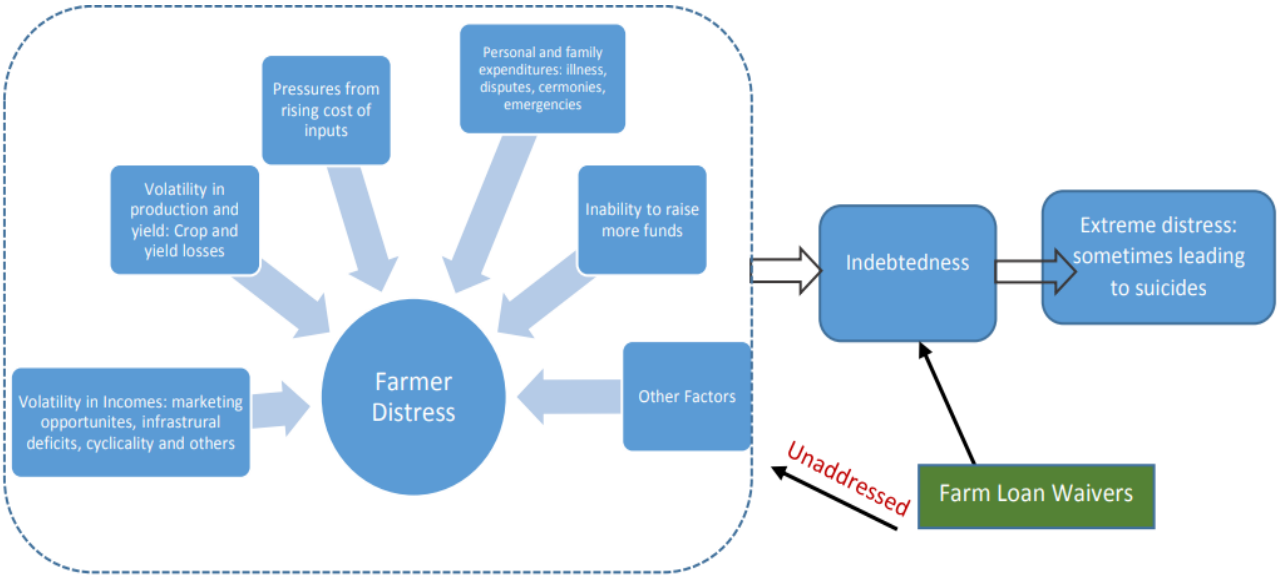
Source: Estimated by authors using cost of cultivation data by MoA, GOI

Focus on farmer's welfare is missing

An Indian farmer faces numerous distortions that render farming an unviable business. Although the agriculture sector is central to India and the widespread acknowledgment of the distress that most farmers endure, there is no standardized measure of farmers' distress in the

country. Farmer distress in India arises from a combination of economic pressures and uncertainties that threaten their livelihoods.

Figure 8: Framework of Farmers' Distress



Source: Discussion Paper titled "Farm Loan Waivers in India: Assessing Impact and Looking Ahead" by Arcus Policy Research

Key factors contributing to this distress include the volatility in crop production and yields, fluctuations in income due to market opportunities, infrastructural deficits, and the cyclical nature of agriculture (Figure 8). Additionally, farmers face rising costs of inputs and personal and family expenses related to illness, emergencies, and other unforeseen events, which further strain their finances. The inability to raise additional funds exacerbates their financial burden, leading many into deep indebtedness. This cycle of distress, when unaddressed, often pushes farmers into extreme despair, sometimes resulting in tragic outcomes like suicides. Although farm loan waivers are occasionally introduced as a relief measure, they tend to address only the symptoms rather than the root causes of the crisis, leaving many underlying issues unresolved.

In conclusion, Punjab's agricultural landscape remains heavily dominated by the rice-wheat cropping pattern due to stable profits and government support. Despite potential benefits, crop diversification and agroforestry face significant obstacles, including high price volatility, long gestation periods, and insufficient incentives. The inefficiency of mandis, inadequate storage facilities, and reluctance to embrace crop insurance further exacerbate these challenges. Addressing these issues is crucial for promoting sustainable agricultural practices and enhancing farmers' incomes in Punjab.

Section III: Diversification: Where and How?

Restructuring and augmenting land use in Punjab's agricultural sector is necessary to address the challenges arising from heavy reliance on paddy cultivation, which covers 41% of the state's gross cropped area (GCA). This overreliance has led to severe groundwater overexploitation, especially in districts like Sangrur, Ludhiana, and Moga. By focusing on districts with low paddy yields, high GCA shares, and critical groundwater conditions, it is possible to identify prime candidates for transitioning to more diverse and sustainable crops.

Restructure and Augment Land Use

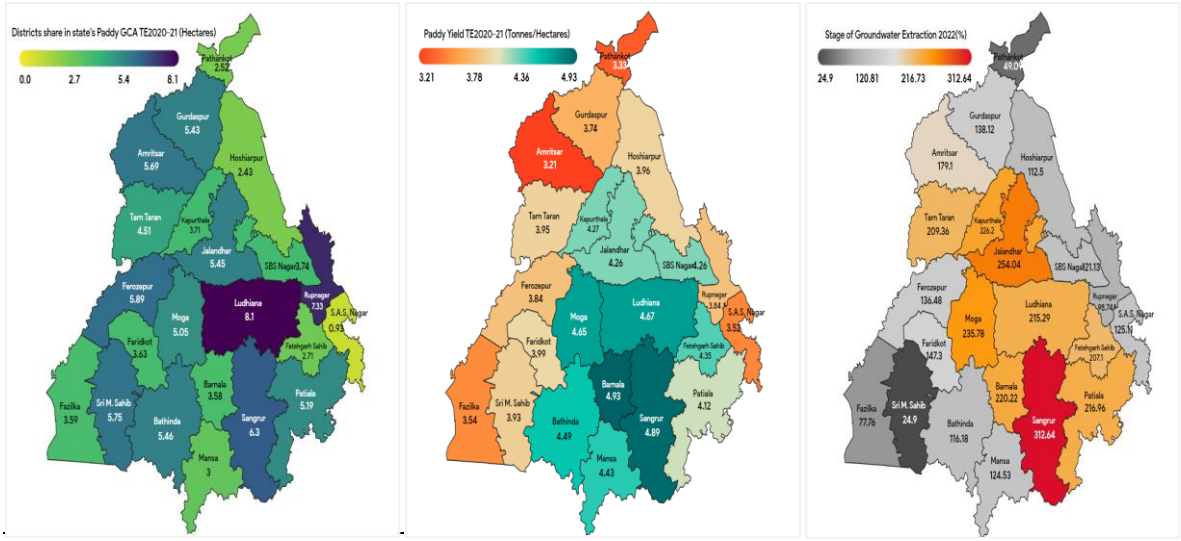
Punjab's agricultural sector faces significant challenges due to its heavy reliance on paddy cultivation, which covers 41 percent of the state's gross cropped area (GCA). An analysis of 22 districts reveals that Ludhiana, Sangrur, and Rupnagar lead in paddy GCA, while Sangrur boasts the highest paddy yield. However, this dominance in paddy cultivation has led to severe groundwater overexploitation, particularly in districts like Sangrur, Ludhiana, and Moga. To promote crop diversification, districts with low paddy yields, high GCA shares, and overexploited groundwater resources are identified as prime candidates for transitioning away from paddy.

Releasing paddy land

To diversify Punjab's cropping pattern from Paddy, 22 districts were analyzed based on their share in state Paddy GCA, Paddy yield, and groundwater extraction[3]. Punjab dedicates 41% of its total GCA to Paddy cultivation. Ludhiana leads with an 8% share of state Paddy GCA, followed by Sangrur, Rupnagar (7% each), Amritsar, Firozpur, and Muktsar (6% each). In 2020-21, India's paddy yield was 4.3 tonnes/hectare, with Punjab achieving 4.2 tonnes/hectare. Sangrur had the highest yield at 4.89 tonnes/hectare, while Amritsar had the lowest at 3.21 tonnes/hectare. Districts like Barnala, Ludhiana, Moga, Bathinda, Mansa, and Fatehgarh Sahib exceeded the state's average yield. The stage of groundwater extraction indicates Punjab's overexploitation of water resources due to Paddy cultivation since the Green Revolution. Districts such as Sangrur, Ludhiana, Moga, Fatehgarh Sahib, Barnala, Patiala, Jalandhar, Kapurthala, Tarn Taran, and Amritsar are overexploited and of particular concern. (Figure 9)

[3]*Stage of GW Extraction = (Existing Gross GW Extraction for all uses/ Annual Extractable GW Resources) *100.* The existing gross ground water extraction for all uses refers to the total of existing gross ground water extraction for irrigation and all other purposes.

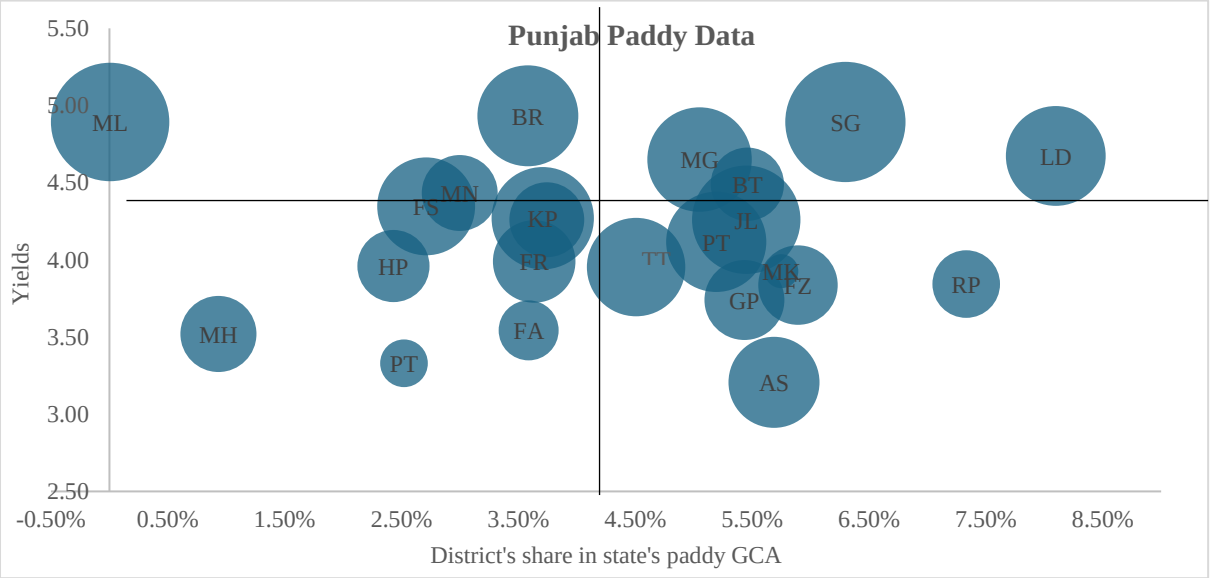
Figure 9: District wise area under paddy, paddy yields and Stage of Ground Water Extraction



Source: Arcus Policy Research based on (a) LUS data for TE 2020-21, (b) Directorate of Economics and Statistics (DES) for TE 2020-21 and (c) Dynamic Ground Water Resources of India 2022

Using these three parameters, our study identified the districts where land can be diversified as they had low paddy yield, high district area shares in state paddy GCA and over exploited groundwater extraction levels. District-wise share in paddy GCA and paddy yields are plotted along with percentage share of groundwater extraction as bubbles in a graph (Figure). Greater size of the bubble implies that more groundwater is being extracted than being recharged, thus the groundwater level is in a critical condition. Districts with low paddy yields and a higher share in paddy GCA are identified in the lower right quadrant of the graph below, where land can be diversified from Paddy.

Figure 10: District wise comparison of Paddy yields, shares in state paddy GCA and State of groundwater extraction level



Source: Arcus Policy Research based on LUS data for TE 2020-21, dynamic ground water resources of India, 2022 and Directorate of Economics and Statistics (DES) for TE 2020-21. | ***Note:*** *AS: Amritsar, BR: Barnala, BT: Bathinda, FR: Faridkot, FS: Fatehgarh Sahib, FA: Fazilka, FZ: Firozpur, GP: Gurdaspur, HP: Hoshiarpur, JL: Jalandhar, KP: Kapurthala, LD: Ludhiana, ML: Malerkotla, MN: Mansa, MG: Moga, MK: Muktsar, PT: Pathankot, PA: Patiala, RP: Rupnagar, MH: S.A.S. Nagar, BSN: S.B.S. Nagar, SG: Sangrur, and TT: Tarn Taran*

From this analysis, 8 districts are identified from where around 13 lakhs hectare of land in Paddy can be used for crop diversification. This corresponds to around 42 percent of the total area under paddy in Punjab.

Table 4: Districts where Paddy land can be reduced (Lakh Hectares)

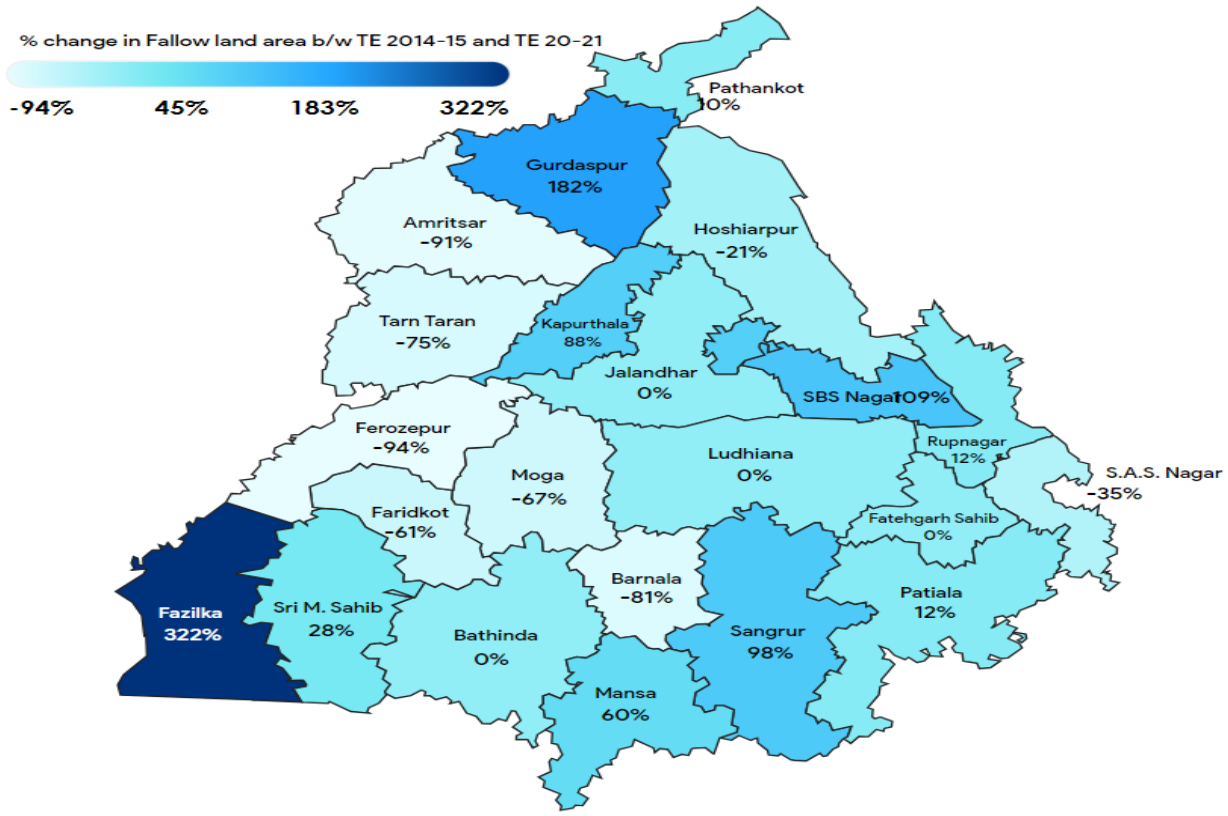
Districts	Land estimated for diversification to other crops
Amritsar	1.8
Ferozepur	1.9
Gurdaspur	1.7
Jalandhar	1.7
Muktsar	1.8
Patiala	1.7
Rupnagar	2.3
Tarn Taran	1.4
Total Area	13.3

Source: Arcus Policy Research based on LUS data for TE 2020-21

Reclaim fallow lands

Punjab's fallow land totalled 92,300 hectares for TE 2020-21, a 29 percent increase since TE 2014-15. This land can be reclaimed to diversify the cropping pattern across various districts. Fazilka saw the highest increase in fallow land at 322 percent, followed by Gurdaspur at 182 percent, Sangrur at 98 percent, and Kapurthala at 88 percent. Mansa experienced a 60 percent increase, while Sri Muktsar Sahib saw a 28 percent rise. Jalandhar, Ludhiana, Bathinda, and SBS Nagar showed no change in fallow land area during this period. Conversely, Amritsar and Tarn Taran saw substantial decreases of 91 percent and 75 percent, respectively, with Moga, Faridkot, and Barnala experiencing reductions of 67 percent, 61 percent and 81 percent (Figure 11).

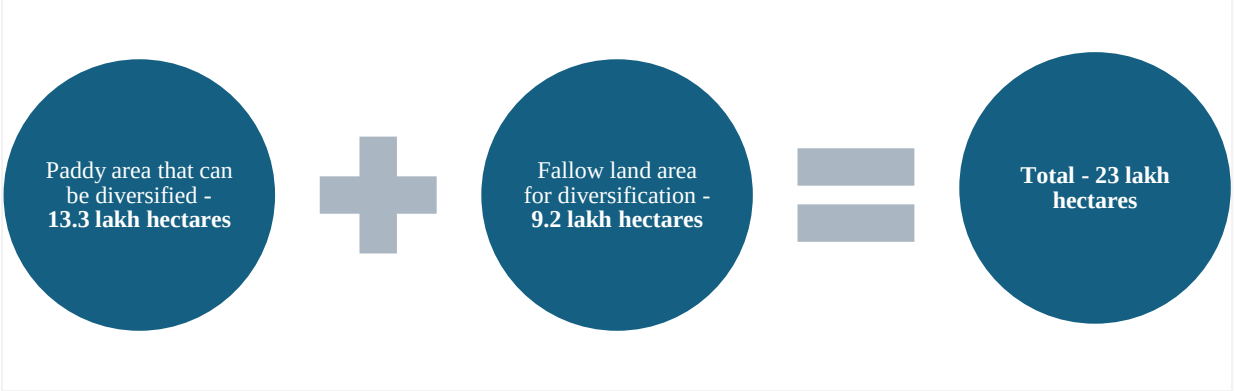
Figure 11: Change in Area under Fallow land between TE 2014-15 and TE 2021-22



Source: Arcus Policy Research based on LUS data for TE 2020-21

Total Paddy area that can be diversified from 8 Punjab districts, which includes Amritsar, Firozepur, Gurdaspur, Jalandar, Muktsar, Pathankot, Patiala, Rupnagar and Tarn Taran, is about 13.3 lakh hectares. Punjab's fallow land of 9.2 lakh hectares, can be reclaimed for the cultivation of diversified crops that are less water-intensive and easy to grow. Thus, land where cropping pattern can be diversified amounts approximately to 23 lakh hectares which is about 30 percent of Punjab's GCA (Figure).

Figure12: Total Area that can be diversified in Punjab



Source: Arcus Policy Research based on LUS data for TE2014-15 and TE 2020-21

Crop Diversification

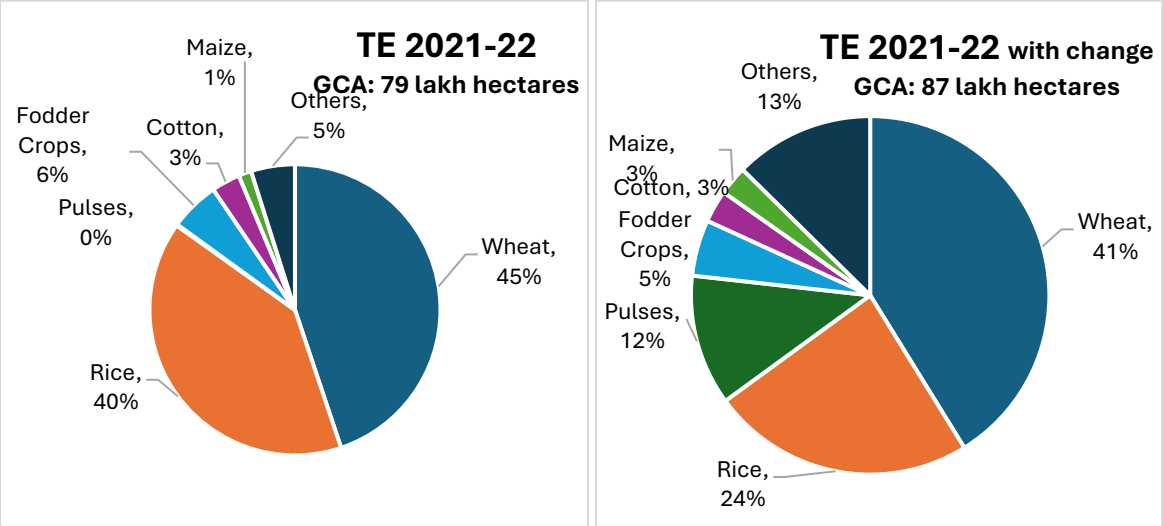
Punjab's agricultural sector is at a pivotal crossroads, where the need for sustainable practices is more pressing than ever. With declining groundwater levels, soil degradation, and the challenges posed by climate change, a strategic shift from traditional paddy-wheat cropping patterns towards diversified agriculture is crucial. This transformation, rooted in crop diversification, agroforestry, and the adoption of modern farming techniques, aims not only to enhance productivity but also to secure the livelihoods of Punjab's farmers. The following analysis outlines a comprehensive approach to achieving these goals, ensuring a resilient and prosperous agricultural future for the state.

Punjab's New Proposed Diversification Plan

To boost agricultural productivity and sustainability in Punjab, decreasing the GCA under paddy can be achieved through crop diversification and agroforestry. With Punjab's high cropping intensity, introducing a third crop is feasible. Potential third crops like Bitter gourd, Sponge gourd, and Sweet Potato can be planted from March to June, providing alternatives to paddy. Thus, following the recommendations listed below, crop diversification can be undertaken in the following manner:

- *In order to diversify area from paddy, districts which had high district Paddy share in state GCA and lower paddy yields, were targeted. Moreover, state of ground water level was also taken into account.*
- *50 percent of the area from paddy is shifted to maize in districts which had high GCA under paddy and low yield but the groundwater extraction level was not very critical. These districts include Muktsar and Rupnagar.*
- *From majority of the districts, 50 percent of the area from paddy is shifted to pulses in districts which had high GCA under paddy, low yield and the groundwater extraction level was very critical.*
- *Punjab's total GCA for TE 2021-22 was around 79 lakh hectares, of that rice constituted 40% of the area, wheat (45 percent), Fodder crops (6 percent), Cotton (3 percent), 1 percent for maize, sugarcane and potato, with only 3 percent in others. (Figure13)*
- *In RHS pie, Punjab's total GCA is around 87 lakh hectares, as 10 percent of the initial area is added for third crop.*
- *As a result, after the shift rice constituted 24% of the area, wheat (41 percent), Pulses (12 percent), Fodder crops (5 percent), Cotton (3 percent), maize (3 percent), with 35 percent in other crops.*

Figure 83: Proposed Diversification plan



Source: Arcus Policy Research based on LUS data for TE 2021-22, dynamic ground water resources of India, 2022 and Directorate of Economics and Statistics (DES) for TE 2021-22.

The reduction in the GCA under paddy in Punjab, achieved through strategic crop diversification and the introduction of agroforestry, highlights a shift towards sustainable agriculture. By reallocating land from paddy to other crops like maize and pulses, especially in districts with high paddy GCA but lower yields and critical groundwater levels, Punjab's agricultural landscape can become more varied. This diversification also considers the addition of a third crop, such as Bitter gourd, Sponge gourd, or Sweet Potato, but is only possible in a phased wise manner over the years. As a result, the share of rice in the GCA dropped from 40 percent to 24 percent, while the area under other crops expanded significantly, illustrating a more balanced and sustainable agricultural practice.

Third crop

In 2019-20, Punjab, with a cropping intensity of 189 percent, ranked all-India fourth. Sikkim had the highest cropping intensity with 210 percent, followed by West Bengal with 192 percent and Telangana with 190 percent. Numerous districts in West Bengal have a cropping intensity greater than 2, suggesting that introducing a third crop can be feasible in Punjab. West Bengal follows several viable cropping options that could be promoted, such as kharif rice-potato-green gram, kharif rice-potato, kharif rice-maize, and vegetables-vegetables. Additionally, improvements were made to some existing cropping systems (like kharif rice, kharif rice-ridge potato, and mixed cropping systems) through enhanced soil and water management, as demonstrated in farmers' fields. Cropping system intensification (CSI) enhanced the profitability of these systems for farmers. In West Bengal, challenges are faced with excess water during the wet (kharif) season leading to waterlogging, and issues such as inadequate quality irrigation water and soil salinity during the dry (rabi) season. These examples from West Bengal can serve as a reference for addressing similar challenges in Punjab. Notably, 19 districts in Punjab have a very high cropping intensity, exceeding 180 percent, making them

suitable candidates for recommending a third crop. Many crops which can be sown from March to June, can serve as a potential substitute of Paddy and act as third crop for these 19 districts of Punjab, that have a very high cropping intensity. These crops include Bitter gourd (Karela), Sponge gourd (Toari), Sweet Potato, Tinda, Turmeric, Cotton, moong, Sesamum (Till) and Jawar. (Annexe 1)

Shift to agroforestry from paddy cultivation

Agroforestry is a promising strategy for crop diversification in Punjab, particularly given the projected increase in demand for pulp, paper, plywood, and other wood-based products in India, which is expected to reach 70 million cubic meters by 2030. As of 2022, Punjab supplies 12 percent of this demand, with an aim to increase to 30 percent by 2030. Therefore, it is crucial for Punjab to focus on expanding its agroforestry practices by increasing green cover and Trees Outside Forest (TOF) areas. Agroforestry is attractive due to the high survival rates and profitability of trees like Poplar and Eucalyptus, which also have low groundwater requirements. The growing market for multi-purpose wood and the interest from the plywood industry present significant opportunities. However, challenges such as price volatility, long gestation periods, lack of financial incentives, and inefficient mandi operations need to be addressed through government interventions.

From this analysis, approximately 13.3 lakh hectares of paddy land across eight districts in Punjab can be diversified into less water-intensive crops. Additionally, reclaiming 9.2 lakh hectares of fallow land could further support this transition. With an estimated 23 lakh hectares, or 30% of Punjab's GCA, available for diversification, the state can significantly reduce its dependence on paddy. By introducing a third crop in districts with high cropping intensity, Punjab can achieve more sustainable agricultural practices, enhance farmers' incomes, and mitigate the environmental impact of paddy cultivation.

Way Forward

The future of Punjab's agricultural sector hinges on a multi-faceted approach that addresses the various challenges farmers face and leverages the state's potential for growth. Key areas of focus include revitalizing cotton farming, converting agricultural waste into valuable products, promoting agroforestry, enhancing paddy yields through innovative techniques, increasing pulse cultivation, and improving the processing and value addition of agricultural products. By implementing targeted interventions and providing necessary support, Punjab can achieve sustainable agricultural development and improve the livelihoods of its farmers.

Waste to Value

Paddy straw can help in generation of biogas in Punjab, reducing stubble burning. Anaerobic co-digestion (AcoD) of paddy straw with other farm residues like green potato waste, mung residue, mint residue, sugarcane bagasse (SCB), spoiled potato waste, poultry droppings, cattle

dung and bio-digested slurry can be a promising technology for enhancing methane production. Thus, government should promote such technologies and research efforts (Tian et al. 2023).

Diversification to maize can serve the dual motive of food and fuel in Punjab. Maize, can be extensively used as poultry feed and dairy animal fodder, which can significantly boost livestock productivity. Maize cultivation should be linked to the processing industry for food and feed, particularly poultry. Maize's versatility extends to its use in cornmeal, corn syrup, corn oil, ethanol, pharmaceuticals, industrial products, alcoholic drinks, and toothpaste, making it a valuable crop (Gulati, Roy, and Hussain 2017). With the growing market for processed foods, Punjab can leverage maize's potential by strengthening value chain infrastructure, incentivizing maize production, and addressing marketing challenges such as moisture content.

According to the "Expert Committee on Roadmap for Ethanol Blending in India by 2025," India needs 4.66 billion liters of ethanol from food grains to meet its blending targets (NITI AayogMoP and NG 2021). To address the potential food security concerns of using rice for ethanol, maize should be the primary source for ethanol production. The average maize yield in Punjab and Haryana is 3.5 tons per hectare. By increasing this yield to at least 6 tons per hectare, profitability can be significantly enhanced. Technologies such as high-yielding single cross hybrid maize cultivars (yielding 6-8 tons per hectare) should be provided to farmers by state agricultural universities and private companies. Given an ethanol yield of 340 liters per ton (ibid), converting several lakh hectares of rice cultivation to maize will contribute substantially to India's "Atmanirbhar fuel" goals. It is suggested that NAFED and the National Cooperative Consumers Federation of India Limited (NCCF) procure maize from farmers at the Minimum Support Price (MSP). These cooperatives would register farmers and coordinate with distilleries to determine their needs. Based on this demand, farmers would produce maize, and distilleries would make advance payments to cooperatives through supply contracts specifying price, quantity, location, and other terms. The distilleries would then convert the maize into ethanol and sell it to Oil Marketing Companies (OMCs), helping these companies meet their emissions reduction targets with corn-based biofuel. A potential challenge is that it could lead to the cultivation of water-intensive spring maize, which could be procured by distilleries.

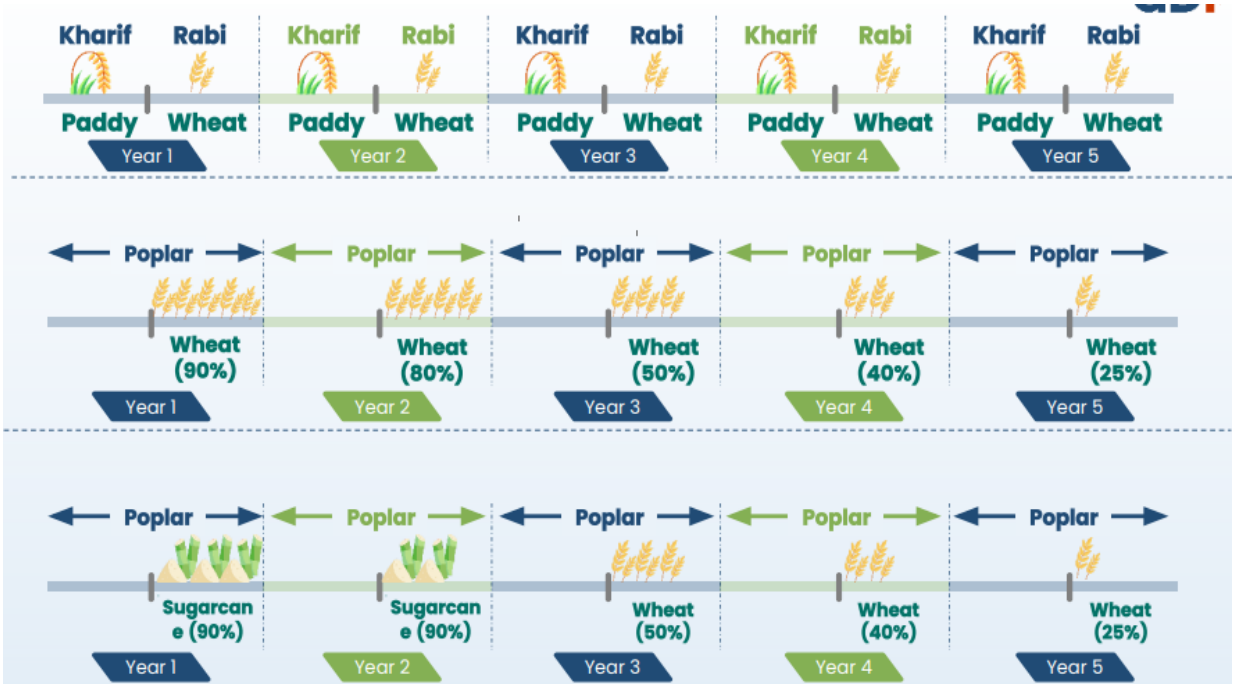
Livestock Sector

Connecting maize farmers with the dairy sector can boost milk production by providing high-quality feed. The government should offer incentives for establishing milk processing units. Inspired by Amul, the dairy sector in Punjab should also target the Middle Eastern market. Since marginal and small farmers dominate the dairy sector, encouraging the formation of Farmer Producer Organizations (FPOs) would be beneficial. Punjab can further enhance cattle farming profitability by developing a strong dairy sector and establishing a meat processing industry, particularly for buffaloes, with a focus on exports. If Punjab can be declared free from foot-and-mouth disease, farmers will be able to secure higher prices for their healthy, non-milching buffaloes intended for slaughter.

Agroforestry

In the traditional farming system, farmers grow paddy during the Kharif season and wheat during the Rabi season, repeating this cycle annually. Agroforestry offers a five-year transition plan (Figure) from the paddy-wheat rotation to simultaneously cultivate only wheat or a combination of wheat and sugarcane.

Figure 14: Transition towards Agroforestry



Source: Arcus Policy Research

Transitioning to agroforestry involves cultivation of wheat on 90% of the land, and poplar trees are gradually introduced. By Year 5, poplar trees occupy most of the land, with wheat cultivation reduced to 25%. This approach aims to diversify farmers' income through timber sales. A more diversified transition plan includes sugarcane along with wheat and agroforestry. In Year 1, sugarcane is grown on 90% of the land, and over the years, poplar trees gradually occupy more area, reaching 75% by Year 5, with sugarcane and wheat sharing the remaining land. This diversified approach enhances farmers' income by combining timber revenue with high-value sugarcane crops, compared to the traditional paddy-wheat system.

The transition plans aim to boost the income and sustainability of farming by introducing agroforestry and diversifying crop choices, reducing reliance on the traditional paddy-wheat cycle. Government incentives are essential for promoting agroforestry, such as providing cash incentives on a "per hectare" or "per farmer" basis, linked to a minimum survival rate of 75-80 percent after 2-3 years. Additional support includes upfront payments for converting land to agroforestry and distributing Poplar and other agroforestry trees for free. The private sector can also play a role by offering assured buy-back and minimum viable prices to mitigate price risks. Special Economic Zones (SEZs) and contract farming can further encourage private sector

participation and protect farmers' interests. Legalizing agreements and establishing dispute settlement mechanisms, along with modifying tenancy models to accommodate agroforestry's longer gestation periods, will ensure a smooth transition and sustainable farming practices.

Paddy yield: technique and technology of production

Paddy yield in Punjab amidst the challenges of water scarcity, soil degradation, and labour shortages can be significantly enhanced through the adoption of innovative agricultural techniques. One approach is the implementation of Direct Seeded Rice (DSR) technology, which offers a sustainable alternative to the traditional puddled transplanting of rice (PTR). This method eliminates the need for raising seedlings in nurseries, puddling, and transplanting, which are labour and time-intensive processes. By adopting DSR, farmers can achieve higher returns over variable costs despite marginally lower yields. The overall reduction in input costs and water requirements makes DSR a viable option for sustainable rice production (Singh, Ranguwal, and Kumar 2024).

To further enhance paddy yields, integrating precision agriculture techniques such as remote sensing and drones can play a crucial role. These technologies enable real-time monitoring of crop health, soil conditions, and pest infestations, allowing for precise and timely interventions. For instance, drones equipped with multispectral sensors which can identify areas with nutrient deficiencies or pest infestations and targeted application of fertilizers and pesticides were tested by Indian Farmers Fertiliser Cooperative (IFFCO) and PAU in Bathinda. This has not only optimized input usage but also minimizes environmental impact. Additionally, implementing precision irrigation systems, such as drip or sprinkler irrigation, can ensure efficient water use and reduce water wastage. By delivering water directly to the plant roots, these systems enhance water use efficiency and improve crop yields.

Moreover, the adoption of advanced agronomic practices such as System of Rice Intensification (SRI) can further boost paddy yields. SRI involves planting younger seedlings at wider spacing, which encourages root growth and enhances the plant’s ability to absorb nutrients and water. This method also emphasizes the use of organic fertilizers and intermittent irrigation to create a favourable soil environment for plant growth. Research has shown that SRI can increase paddy yields by 20-50% while reducing water and input requirements. Additionally, the development and use of high-yielding and disease-resistant rice varieties through genetic modification and conventional breeding can contribute to higher productivity. By incorporating these new technues and technologies, Punjab can achieve sustainable increases in paddy yields, ensuring food security and economic stability for its farmers (Lal et al. 2016).

Carbon is a tradable commodity within the carbon credit system, where one carbon credit represents one tonne of carbon dioxide emissions. This system offers financial incentives to farmers by enabling them to sell carbon credits generated through the reduction of greenhouse gas (GHG) emissions on their farms. Companies with substantial carbon footprints, such as fertilizer producers, mining firms, and oil companies, can purchase these credits from farmers

to offset their emissions. Thus, carbon credits provide farmers with an income for every unit of GHG reduced or sequestered from the atmosphere. Farmers typically receive between USD 15 and USD 30 per tonne, and occasionally even more than USD 40 per tonne of carbon saved or sequestered through agricultural programs. Paddy cultivation in Punjab and Haryana emits approximately 5 tonnes of CO2 equivalent per hectare (Singh and Gulati 2023). By transitioning to alternative crops, farmers can earn up to 4 carbon credits per hectare, translating to about Rs 6,288 to Rs 12,576 at a rate of USD 20 to USD 40 per hectare. Additionally, transitioning from paddy cultivation could save around 2,000 litres of water per kilogram of rice not produced. If 1.2 million hectares were transitioned away from paddy, it could result in a water saving of 14.2 billion cubic meters. The opportunity cost of the conserved water could be calculated and provided to farmers as green credits, offering further financial incentives.

Promotion of pulses

Pulses are crucial for providing high-value food, ensuring nutritional security, and alleviating malnutrition among the poor (Shalendra, Gummagolmath, Sharma, and Patil 2013). Developing various pulse varieties offers a valuable opportunity to promote it as third crop extensively in Punjab's cropping system. Moong, arhar, and mash are key summer/kharif pulses, while gram and lentil can grow during the rabi season. Growing the summer moong variety, which matures in 60 days, can boost pulse production, increase farmers' income, enhance soil fertility, and reduce early rice transplanting, thus saving irrigation water (Sachan et al. 2014). Pulses can be grown in various rotations like summer moong after wheat, potato, toria, raya, barley, arhar – wheat, or intercropping of moong/mash/gram in sugarcane and orchards.

In sum, transitioning to crop diversification, reclaiming fallow lands, and enhancing cropping intensity are strategic steps towards sustainable agriculture in Punjab. Integrating advanced farming techniques, promoting agroforestry, and cultivating less water-intensive crops can significantly reduce reliance on paddy. Additionally, introducing pulses as a third crop, improving paddy yields through modern technologies, and facilitating the processing and value addition of agricultural products are essential. These measures aim to increase farmers' incomes and ensure long-term environmental sustainability in Punjab.

Section IV: Package required to kickstart, grow and sustain crop diversification

Diversification is not a one-time effort; for it to be sustainable, the government must establish a comprehensive ecosystem that supports this transition. The proposed plan to diversify away from paddy, as outlined above, will only be successful if the state implements proper agricultural practices. To encourage the cultivation of pulses, maize, and a third crop, the government must ensure the availability of quality seeds, provide price assurance, and offer adequate risk coverage. Additionally, the development of storage facilities, processing mills, effective procurement systems, and robust pest management practices is essential for sustaining this diversification. Only with these measures in place can Punjab's agricultural sector thrive and maintain the shift towards more sustainable crop patterns.

Farmers in Punjab, borrows expensive and spend agricultural loan on social consumption

Excessive loan waivers are eroding the very foundation of the credit culture within the community. When farmers are repeatedly relieved of their repayment obligations, it not only undermines the principle of commercial honesty but also encourages a culture of defaulting. This shift away from a sense of duty and responsibility towards financial obligations is damaging the trust and integrity essential for the sustainability of the credit system. Moreover, farmers in Punjab are using agricultural loan for social consumption purposes like marriage. Thus, more emphasis on FLW is not required rather consumption behavior of the agricultural households needs to be changed.

Real time monitoring of farmers distress/ welfare

An Indian farmer faces numerous distortions that render agriculture both volatile and unsustainable. The inherent production cycles often lead to unavoidable indebtedness, while the instability of income traps them in a relentless cycle of debt from which it is difficult to escape. A critical step in addressing farmer distress is the creation of a real-time dynamic distress index. This index would integrate high-frequency data on weather, climate forecasts, agricultural commodity prices, and farmers' debt burdens to monitor and predict distress levels in real-time. Leveraging advanced technologies like space technology, artificial intelligence, and blockchain can enhance the accuracy and credibility of data collection and analysis. While tracking distress at the individual farmer level may be challenging due to small landholdings, district-level monitoring can serve as a practical starting point. The involvement of local institutions like Gram Sabhas and Farmer Producer Organizations (FPOs) can further enhance the effectiveness of distress alleviation efforts.

The insights gained from this real-time distress index would empower policymakers to develop and execute timely, targeted support strategies for farmers in distress. Based on the type and extent of distress, interventions could involve a combination of unconditional grants, loan restructuring, or full loan waivers. This approach, grounded in data-driven, real-time analysis, would not only ease the burden on farmers but also provide governments with the ability to efficiently plan and deliver policy measures that are accurately directed toward those most in need.

Cotton Redoing

Cotton is an important commercial crop and it the second largest crop among the Karif crops after Paddy in Punjab. Financial incentives, technical support and extensive research can rescue farmers and promote cotton farming. Growing only recommended varieties and hybrids that are resistant or tolerant to cotton leaf curl viral disease is crucial. For instance, the PAU has recently developed a leaf curl virus-resistance breeding line for cotton crop, which can resist multiple pest attacks, such varieties should be promoted (Goyal 2024). Eradicating alternate hosts of the virus and volunteer cotton plants before sowing can prevent the multiplication and

spread of the disease. It is essential to soak delinted seeds in water for 2-4 hours before planting and to ensure heavy pre-sowing irrigation for good germination and early plant establishment. Completing the sowing between April and May 15 helps in escaping the attack of the American bollworm to a significant extent. Farmers should avoid planting American cotton near orchards and refrain from growing crops like bhindi, moong, arhar, castor, and dhaincha around cotton fields to prevent the simultaneous build-up and spread of pests and diseases (Department of Agriculture and Farmer Welfare, Government of Punjab 2020).

Farmers should be informed about the government's crop diversification programs (CDP) which focuses on educating farmers about crop diversification while offering technical assistance and financial support. More financial support programmes like providing Rs.17500 per hectare to farmers shifting from paddy to other crops should be encouraged in the state.

Farm Mechanization

To enhance farm mechanization in Punjab, it is essential to establish Agro Service Centres for every cluster of 4-5 villages. These centres should provide custom hiring services for high-cost machinery like laser levelers, happy seeders, ridgers, and bed-planters, making advanced equipment accessible to farmers, especially those with small and marginal holdings. Additionally, financial assistance for farmers and cooperatives to purchase or rent farm machinery should be increased and additional subsidies should be provided for machinery that promotes sustainable practices, such as equipment for residue management and water-efficient technologies.

Furthermore, it is crucial to introduce and promote suitable machinery for rice transplanting, sugarcane harvesting, cotton picking, and the cultivation of vegetable and horticultural crops to address labor shortages and ensure timely agricultural operations. Establishing Dairy Machinery Service Centres to provide machinery for fodder sowing, harvesting, and silage/hay making on a custom hiring basis will also help improve the economic viability of dairy operations. These measures will collectively enhance productivity, sustainability, and the overall economic health of Punjab's agricultural sector.

Horticulture

To enhance horticultural development in Punjab, it is imperative to prioritize the expansion of protected cultivation under low-cost net houses. This technology has demonstrated significant benefits, including minimized pesticide use, improved produce quality, and increased yields. To maximize these benefits, the government should extend this technology on a large scale, aiming to cover one lakh small farmers. Sufficient capital assistance should be provided under schemes like Rashtriya Krishi Vikas Yojana (RKVY) and the National Horticulture Mission. Additionally, establishing peri-urban vegetable cultivation with necessary support infrastructure and incentives for mechanization, processing, and export is crucial. This includes promoting varieties suitable for processing and developing the Kandi area as a horticulture belt for fruits like Amla, Guava, and Kinnow, along with organic farming.

Furthermore, to ensure the efficient marketing of horticultural produce, it is recommended to establish collection centres equipped with facilities for washing, grading, packaging, and cooling. These centres should be set up in new areas, with at least one centre per block, through public-private partnerships and Farmers' Marketing Cooperatives. Promoting the development and introduction of new vegetable and fruit varieties suitable for processing and improving irrigation and fertigation technologies will also enhance horticultural productivity. Additionally, efforts should be made to ensure faster transportation of produce across the country through express trains with cold storage facilities, thereby addressing issues of glut clearance and market access.

Seed Capital

To enhance agricultural productivity in Punjab, ensuring the supply of quality seeds and planting materials is essential. The state should implement a seed policy that achieves full coverage with new seeds every 3-5 years for major crops and annually for hybrids. Strengthening the Punjab State Seeds Corporation (PUNSEED) and the Seed Certification Authority is crucial for delivering quality seeds directly to farmers. Additionally, seed testing laboratories need to be modernized to test for Genetically Modified (GM) crops and conduct DNA fingerprinting to verify seed quality.

Producing disease-free planting material using conventional and tissue culture techniques should be prioritized, especially for vegetatively propagated crops. Research on resistant rootstocks for issues like Phytophthora foot rot in citrus should be intensified. Fodder seed production should also be given high priority to enhance milk productivity and reduce costs. The Department of Agriculture should manage fodder seed production within crop rotation systems at seed farms, establishing a reliable seed multiplication system for fodder crops.

Livestock Development

To advance the livestock sector, a multi-faceted approach is required, focusing on enhancing productivity, improving infrastructure, and supporting farmers. Establishing a state-of-the-art laboratory for pesticide and heavy metal residue analysis will ensure the supply of quality pesticides and safeguard crop and livestock health. In dairy farming, efforts should include training farmers, assisting with capital investments for commercial dairy farms, and increasing milk yield through breed improvement programs. Expanding the semen production capacity, including sexed semen, and encouraging the rearing of high-yielding calves are crucial steps. The adoption of silage and the establishment of Dairy Machinery Service Centres will support year-round feed availability. Additionally, financial support, such as equalizing interest rates for dairy farmers with those for agriculture and extending loan recovery periods, will enhance their economic stability.

In veterinary care, setting up mobile veterinary units and additional disease diagnostic laboratories will provide timely and effective animal health services. Mandatory vaccination against diseases like Foot and Mouth Disease and Brucellosis, along with large-scale

vaccination programs, will control outbreaks and improve overall herd health. For milk marketing and processing, modernizing cooperative sector milk plants and establishing a Milk Price Stabilization Fund will reduce processing costs and shield milk producers from price fluctuations. These policy recommendations aim to boost productivity, ensure sustainability, and increase profitability within the livestock sector.

Fake fertilizers

The use of counterfeit pesticides and fertilizers is also very common and destroys crops across Punjab. The ease with which counterfeit products enter the market underscores the urgent need for robust monitoring systems and streamlined bureaucratic processes to protect farmers' interests. To address this, the government should provide farmers with the knowledge needed to differentiate between genuine and fake fertilizers. It should be mandatory for the shopkeepers to issue a bill on purchase of fertlizers. Educational initiatives and accessible resources will be crucial in reducing the spread of counterfeit products. A sustained effort is required to develop a regulatory framework that identifies and addresses the weaknesses in the agricultural sector.

Agroforestry

To effectively promote agroforestry in Punjab, it is essential to focus on targeted development in Kandi areas which include districts like Hoshiarpur, Pathankot, Mohali, Rupnagar, and Sahid Bhagat Singh, are ideal for timber and biomass production. By leveraging these regions for agroforestry, Punjab can address its current deficits in timber, paper, and wood-based products. The state should also support the cultivation of high-yielding, disease-resistant clones of Eucalyptus and Poplars, utilizing tissue culture and cloning techniques to reduce maturity periods and enhance profitability. Aiming to plant 0.4 lakh hectares annually, with a harvest cycle of 5-6 years, could cover approximately 2-2.5 lakh hectares over time.

Additionally, developing modern timber markets across the state is crucial. Establishing 4-5 timber markets with advanced infrastructure for drying, seasoning, and sawmills will improve the processing and marketing of timber and wood products. This infrastructure will benefit farmers and agroforestry groups by facilitating the production of value-added products. Finally, a supportive policy framework is needed to encourage large-scale investments in agroforestry and wood-based industries. Coordinated efforts in producing quality planting material, advancing planting technologies, and supporting wood industry development are essential to fully harness the potential of agroforestry in Punjab.

Initiatives like carbon credit compensation program which aims to disburse a total of Rs 45 crore across 3,686 farmers in the Kandi region, should be promoted. This initiative not only offers farmers additional income through carbon credits and the sale of mature trees but also promotes agroforestry by reducing carbon emissions, minimizing pesticide and water usage, and improving soil quality. It helps address Punjab's low forest cover and encourages crop diversification. (Agnihotri Chaba 2024).

Revival of marketing Institutions

The revival of market institutions like Markfed is crucial due to its ongoing struggle with market competition, technological gaps, operational inefficiencies, and financial constraints. Markfed faces significant challenges in expanding market reach and maintaining product quality amidst stiff competition from private players. Technological gaps further impede its competitiveness, particularly in adopting modern procurement, storage, and customer engagement methods. Operational delays and inefficiencies in inventory management and supply chains exacerbate the situation, particularly during market fluctuations. Financially, Markfed's accumulated debt, reliance on government subsidies, and pricing pressures from private competitors severely limit its financial flexibility and investment capacity. According to its audited financial report for 2022-23, Markfed's cumulative losses as of March 2023 stand at INR 3,085 Crores, including a loss exceeding INR 100 Crores in FY 2022-23. Additionally, its short-term debt of INR 586 Crores is not serviceable with the available cash balance of INR 457 Crores, indicating a continuing trend of financial distress (Markfed 2023).

In conclusion, addressing the key challenges in Punjab's agriculture sector requires a comprehensive strategy that includes combating counterfeit fertilizers, improving farm mechanization, expanding horticultural development, ensuring quality seed supply, and promoting agroforestry. By implementing these measures, Punjab can enhance agricultural productivity, support farmers' livelihoods, and contribute to a more sustainable and resilient agricultural system.

Annexure 1: Punjab's crop calendars

Vegetable Calendar
Punjab

S. #	Crop	C. Name	T. Name	Seed @	Sowing	Transplanting	Harvesting
01	Arum	Arvi	Colocaria esculenta	800-900 g	Feb-Mar	-	Aug-Sep
02	Bitter gourd	Karela	Momordica charantia	3.5 kg	Mar-Apr	-	May- Jun
				-	-	-	Aug-Sep
03	Bottle gourd	Locci	Laginaria siceraria	2-2.5 kg	Feb-Mar	-	Apr-Jun
				-	Jun-Jul	-	Aug-Sep
04	Brinjal	Baingan	Solanum melongena	200-250g	Nov, Feb, Jun	Feb, Apr, Aug	Apr-Jun-Sep
05	Carrot	Gaajar	Daucus carota	8 kg	Sep-Oct	-	Dec-Mar
06	Cauliflower	Phool gobhi	Brassica oleracea	0.5-1 kg	End May-Jun	Jul	Dec-Jan
				-	Jul, Aug, Sep	Aug , Sep, Oct	Feb-Mar
	Cabbage	Band gobhi	Brassica olerace, capitata group	0.5-1 kg	Sep-Oct	Oct-Nov	Nov-May
07	Chillies	Marach	Capsicum indicum	500 g	Oct-Nov	Feb	May-Jul
					May-Jun	Jun-Jul	Sep-Nov
08	Coriander	Dhania	Coriandrum sativum	8 kg	Sep-Oct	-	Nov-Mar
09	Cucumber	Kheera	Cucumis sativus	1-1.5 kg	Feb-Mar	-	Apr-May
					Jul-Aug	-	Sep-Oct
10	Fenugreek	Methi	Trigonella foenumgraecum	3-4 kg	Sep-Oct	-	Nov-Feb
11	Garlic	Lehsan	Allium sativum	350 kg	Oct	-	Apr-May
	Ginger	Adrak	Zingiber officinale				
12	Okra	Bhindi	Abelmoschus esculentus	10 kg	Feb-Mar	-	Apr-Sep
				8 kg	Jun-Jul	-	Sep-Nov
13	Onion	Piyaz	Oleum cepa	5 kg	Jul-Aug	Sep	Dec-Mar
				3 kg	Oct-Nov	Dec-Jan	Apr-May
14	Peas	Matar	Lathyrus belinensis	20 kg	15 Sep-15 Oct	-	Dec-Jan
				12 kg	Nov	-	Feb-Mar
15	Potato	Aalu	Solanum tuberosum	1200-1400 kg	15 Sep-15 Oct	-	1st – 15 Jan
					15 Feb-15 Mar	-	15 Apr-15 May
16	Radish	Mooli	Raphanus sativus	3 kg	Sep-Nov	-	Oct-Mar
				5 kg	Jul-Aug	-	Aug-Oct
17	Spinach	Palak	Spinacia oeracea	15-20 kg	Jun-Nov	-	Aug-Mar
18	Sponge gourd	Toari	Luffa acutangula	1.5 kg	Mar-Apr	-	Jun-Jul
				-	Jun-Jul	-	Aug-Sep
19	Sweet Potato	Shakarkandi	Ipomoea batatus	14000 cuttings	Nov	Feb-Mar	Jul
					Mar	Jun-Jul	Nov
20	Tinda gourd	Tinda	Citrulus vulgaris	1.5-2 kg	Mar-Apr	-	End May-Jun
					Jun-Jul	-	Aug-Sep
21	Tomato	Tamatar	Lycopersicon esculentum	0.125	Oct -Nov	Dec-Feb	Apr-Jun
22	Turmeric	Haldi	Gurouma longa	600-700 g	Mar-Apr	-	Dec-Mar
23	Turnip	Shaljam	Brassica rapa	1 kg	Aug-Nov	-	Oct-Mar

Crop Calendar
Punjab

S. #	Crop	C. Name	T. Name	Seed @	Sowing	Transplanting	Harvesting
01	Barely	Jo	Hordeum vulgare	30-35 kg	15 Oct-Nov	-	15 Mar-Apr
02	Broad Bean	Lobia	Vicia faba			-	
03	Cotton	Kappas	Gossypium hirsutum	8-10 kg	May-Jun	-	15 Sep-15Nov
					-	-	-
04	Gram	Channa	Cicer arietinum	20-25 kg	Oct-Nov	-	End Mar-10 Apr
05	Groundnut	Mong phali	Arachis hypogaea	25-30 kg	15 Feb-Apr	-	
06	Lentil	Masoor	Lens culinaris	8-10 kg	15 Sep-Nov	-	
07	Linseed	Ulsi	Linium ustitatissimum	6-8 kg	15 Oct-15 Nov	-	End Apr
08	Maize	Makaee	Zea mays	10-12 kg	Oct-Dec	-	Apr-May
					End Jul	-	
09	Mash	Mash	Vigna mungo	8-10 kg	15 Jun-End Jul	-	Early Oct
10	Millet	Baajra	Pennisetum glaucum	1.5-2 kg	15 Jul-15 Aug	-	1st Nov-15 Nov
11	Mung	Mung	Vigna radiata	8-10 kg	Jun-Jul	-	Early Nov
					15 Feb-End Mar	-	
12	Mustard & Rapeseed	Sarson	Brassica compestris /junca	1.5-2 kg	15 Sep-Nov	-	Apr-May
					Aug-Sep	-	Dec
13	Potato	Aalu	Solanum tuberosum	1200-1400 kg	15 Sep-15 Oct	-	1st – 15 Jan
					15 Feb-15 Mar	-	15 Apr-15 May
14	Rice	Chaawal	Oryza sativa L.	7-8 kg	15 May-15 Jun	15 Jun-20 Jul	Nov
15	Safflower	Kosamba	Cathamus tinctorius	6-8 kg	End Oct-End Nov	-	End May-Jun
					Feb	-	
16	Sesamum	Till	Sesamum indicum	1-1.5 kg	15 Jun-15 Jul	-	Nov-Dec
17	Sorghum	Jawar	Sorghum bicolor	8-10 kg	Jun-Jul	-	Nov
18	Soyabean	Soyabean	Glycine max	28-32 kg	Jan-15 Feb	-	June
					Jul-Aug	-	Nov
19	Sugarbeet	Chukandar	Beta vulgaris	1.5-2 kg	Sep-15 Oct	-	15 May-15 June
					15 Feb-End Mar	-	
20	Sugarcane	Ganna	Saccharum officinarum	100-120 M	Sep-Mid Oct	-	Feb-Mar
					15 Feb-Mar	-	
21	Sunflower	Sooraj mukhi	Helianthus annus	2.5-3 kg	1 Feb-15 Mar	-	Nov-Dec
					15 Jun-15Aug	-	
22	Wheat	Gandam	Triticum aestivum	50-60 kg	1st Nov-15 Dec	-	15 Apr

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