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Climate smart agriculture practices in India: A case study of district SAS Nagar, Punjab

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Abstract

Climate change presents considerable challenges to global agriculture, necessitating the development of innovative strategies to ensure food security and environmental sustainability. The concept of Climate Smart Agriculture (CSA) arises as a holistic method that incorporates climate adaptation, mitigation, and resilience into agricultural practices. Major components of CSA include crop diversification, improved water and soil management techniques, agroforestry, and use of climate-resilient crop varieties. This paper highlights the principles and practices of CSA in SAS Nagar District, Punjab. 60 farmers from 10 villages were interviewed to assess the changes in cropping pattern in response to climate change. Additionally, the research investigates adoption of water conservation techniques in the era of alarming rates of ground water depletion. The findings offer valuable insights into the effectiveness of CSA techniques adopted by the farmers of the region highlighting its potential to enhance productivity, reduce greenhouse gas emissions, and build adaptive capacity among farming communities.

Keywords: Climate change, climate smart agriculture, food security, SAS Nagar District, Punjab, crop diversification, water management, sustainability

1. Introduction

Agriculture in coming years and decades is sure to face formidable challenges for the simple reason that climate change and its inherent impacts are a reality now. The challenges aggravates multiple times as the whole world would need an increase of around 70% by 2050 in its food production to feed its ever increasing population. So, the world needs to find ways to sustainable agriculture and the answer lies in Climate Smart Agriculture.

Rising temperatures due to global warming have already started eating up the yield of food grains and other agriculture crops. It has been predicted that the temperature will rise 2-5 °C in future climate by 2100 (IPCC, 2014). Each 1 °C rise in the global mean temperature reduces global maize yield by 7.4%, wheat yield by 6%, rice yield by 6.2% and soybean yield by 3.1%. An increase in the average temperature of 2 °C could lead to 20-40% reductions in cereal grain output, notably in Asia and Africa. Majority of the population around the world reside in rural areas and are relatively poor with agriculture being their primary source of income. Climate Change is expected to hit the developing countries the hardest (FAO, 2024). Despite growing awareness of the need to maintain the natural resource base, unsustainable agricultural practices are still the norm, and food security is dependent on just a few key species; 60 percent of all nutritional needs are met by only four crops: rice, wheat, maize, and potato (FAO, 2015).

Current debates among many prominent development actors feature CSA as the solution to the global challenge of achieving food security and economic development under a changing climate. The FAO, member and host of the Global Alliance for Climate-Smart Agriculture, has defined CSA as agricultural production systems that 'sustainably increase productivity, resilience (adaptation), reduce/remove greenhouse gases (mitigation) and enhance achievement of national food security and development goals' (Climate Smart Agriculture, 2015). Climate-smart agriculture (CSA) has grown from a concept into an approach implemented throughout the world, by all types of stakeholders (FAO, 2021).

The Indian agricultural sector is diverse, vivid, and dynamic. Its importance within the economy is highlighted by the fact that around 54.6 percent of India's total workforce is engaged in agriculture and allied activities. The development of the sector, naturally, has been a key priority for the Government of India. Climate change, however, has emerged as a matter of concern to Indian agriculture.

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The agriculture sector in India has witnessed a series of reforms and transformative measures over the last five years with the mandate to double farmers' incomes. Given the

challenges of climate change, the concept of CSA is gaining traction in the Indian context to cope with and address the issues ^[1].

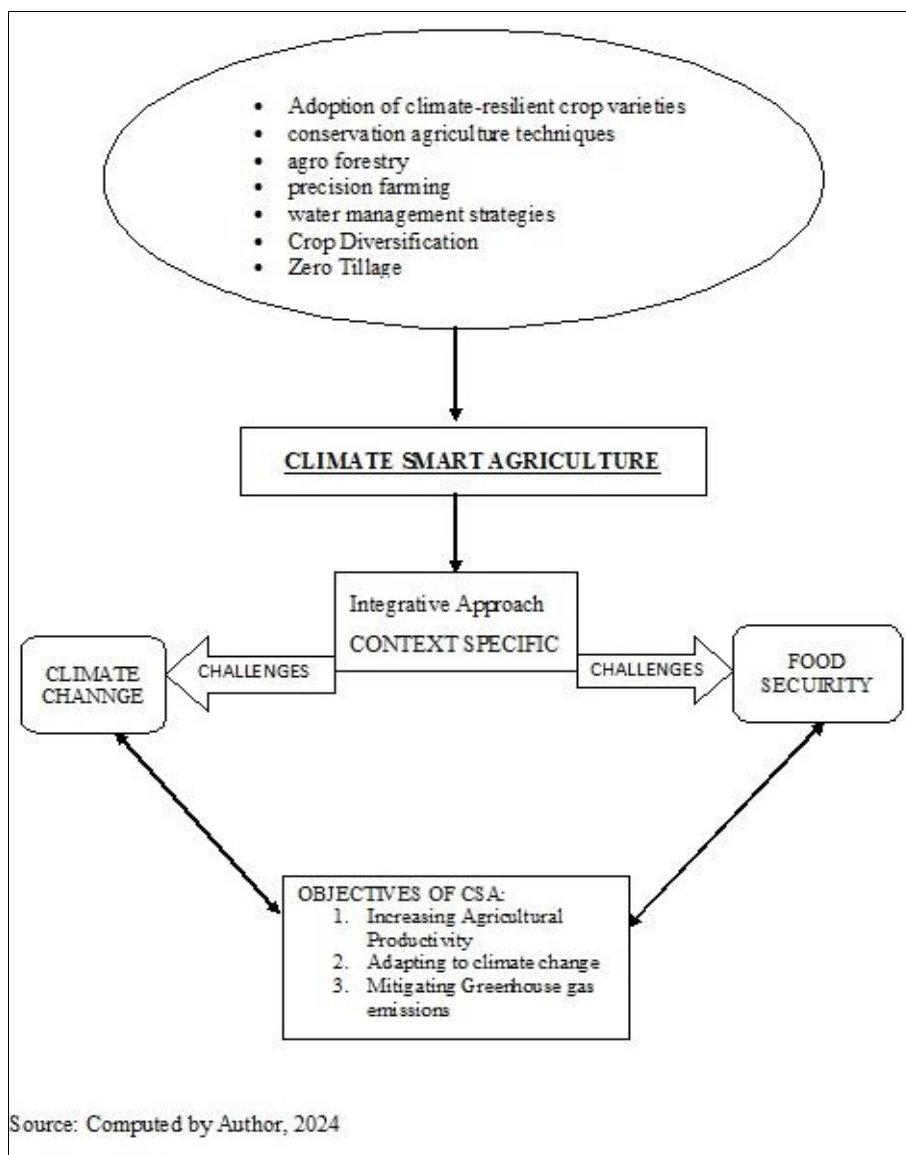


Fig 1: Concept of CSA

The adverse impact of climate change on agriculture production indicates food security threat to the farming community of Punjab. There is increase in mean temperature during growing period of these crops from 0.22 °C (for rabi winter crops) to 0.73 °C (for kharif summer crops) of rise will lead to much higher loss by 2080. For example, the yield loss will increase from 13 to 24 percent for maize, from 11 percent to 24 percent for cotton, and from 1% to 2% for rice, respectively. Decline in overall rainfall by 107 mm during the paddy (rice) growing season (June-September) and by 257mm during maize growing season (May-October) could be the main reason behind over exploitation of ground water resources in Punjab ^[2].

A transformation of the agricultural sector, including crop and livestock production, fisheries and forestry, is urgently needed to respond to climate change and sustainably increase agricultural productivity and incomes. Climate-smart agriculture is rooted in sustainable agriculture and rural development objectives which, if reached, would contribute to achieving the Millennium Development Goals

(MDGs) of reducing hunger and improved environmental management. As part of the Sustainable Development Agenda, CSA is directly linked to SDG1 (No Poverty), SDG2 (Zero Hunger), and SDG13 (Climate Action). At the same time, SDG5 is also relevant to CSA as it addresses gender equality. Women are increasingly being seen as more vulnerable than men to the effects of climate change and therefore need special attention ^[1].

1.1 Objectives

1. To study changes in cropping pattern in response to climate change.
2. To examine groundwater depletion and water management techniques.

1.2 Study area

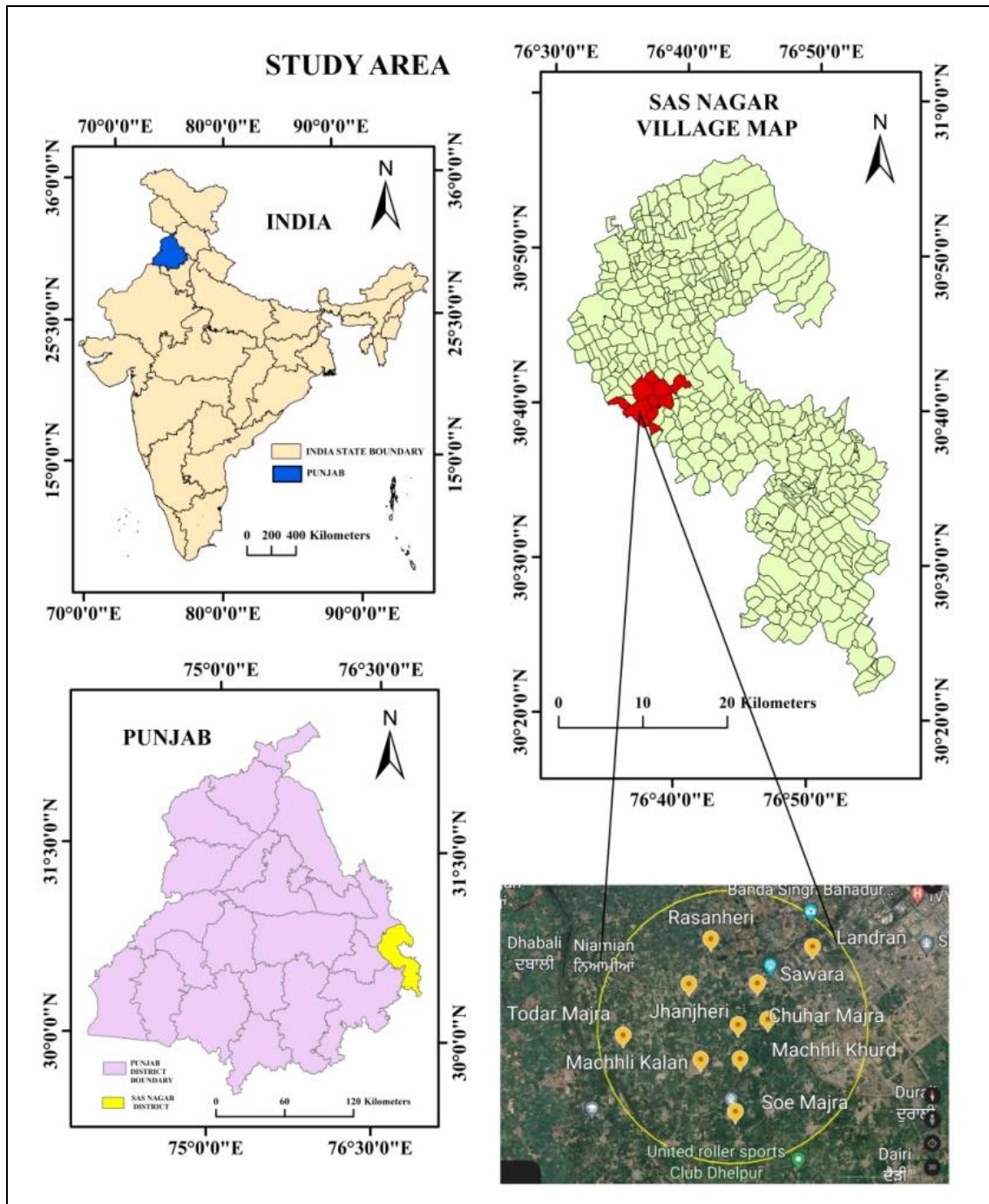
SAS Nagar District in the northwestern region of India is located in the state of Punjab. SAS Nagar is situated in the eastern region of Punjab State and extends from the north latitude 30°21'00" to 30°56'00" and from the east longitude

76°30'00" to 76°55'00" with a geographical area of 1189 sq.km.

The natural drainage of the Derabassi block of the district is formed by the Ghaggar River and its tributaries. The north-eastern part is drained by Siswan Nadi, Jainti Ki Rao and Patiala Ki Rao. These rivers are fed by the Siwalik Hills. Summers are from March to June with temperatures reaching above 40 °C during the day. July to September marks the monsoon season with normal annual rainfall of 1061 mm. Winter in SAS Nagar District is characterized by cool and dry weather. The temperature drops notably, with daytime highs ranging from 12 °C to 20 °C (54°F to 68°F).

Nights can be cold, sometimes falling below 5 °C (41°F). The region often experiences foggy conditions, particularly in the early hours of the day. The district also receives occasional winter rainfall from the west.

Most of the area of the district is plain having loam to silt clay & well drained soils except along the Ghaggar River and choes where some sandy patches are found. Total Geographical area of SAS Nagar District is 121000 hectares out of which 86000 hectares are cultivable area. Agriculture has traditionally been an important economic activity in the district (Micro, Small & Medium Enterprises Development Institute Govt. of India, 2010-11).



Source: Survey of India and Google Earth

Map 1: Location of study area

2. Research methodology and data sources

The study has been conducted for SAS Nagar district, Punjab. A radius of 5km was taken from Chuhar Majra and

60 farmers from 10 villages were selected using convenient sampling method. These villages include Landran, Sawara, Saidpur, Soemajra, Jhanjheri, Chuhar Majra, Machhli

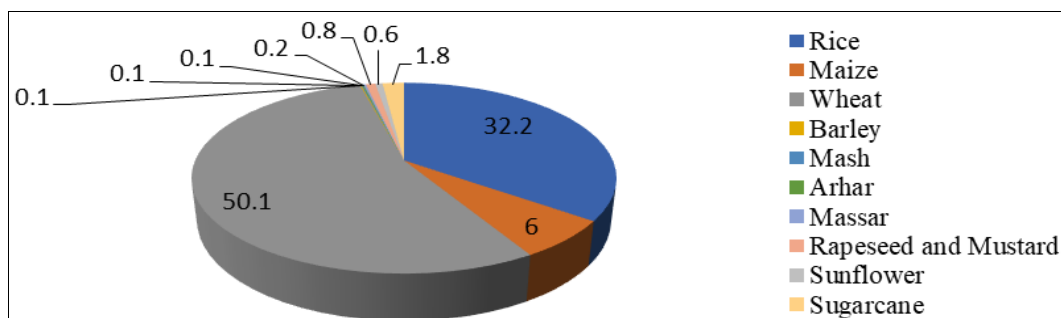
Kalan, Machhli Khurd, Todar Majra and Rasanheri. An interview schedule was prepared for primary data collection. It dealt with statements to know cropping pattern of farmers, changing groundwater level and appropriate water conservation techniques adopted in response to it. Simple statistical tools like frequencies, percentages, bar graphs, pie charts were used in the study. Secondary data was also used from various government reports like Punjab Statistical Abstract 2022, Central Groundwater Control Board 2022 etc. to facilitate the research work.

3. Results and Discussion

3.1 Changes in cropping pattern in response to climate change: Climate change has the potential to exert a

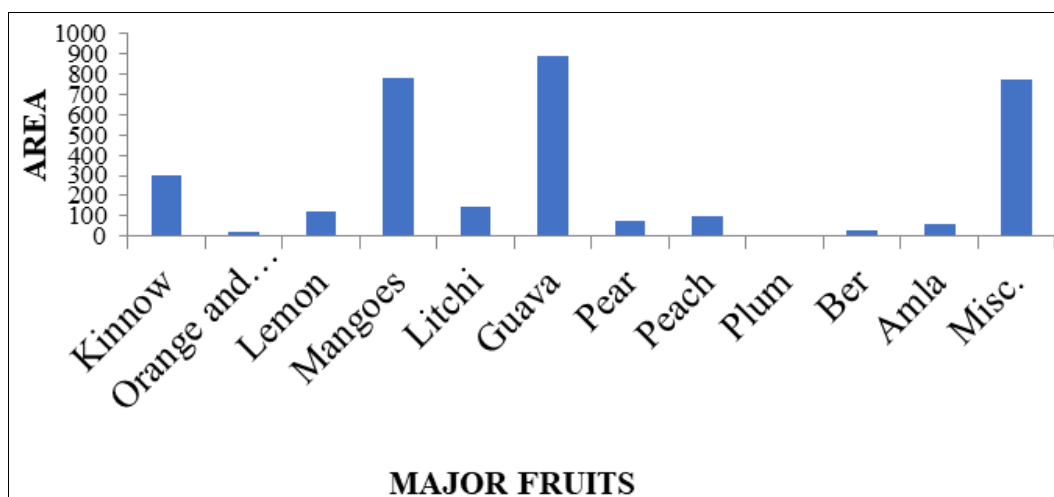
considerable influence on cropping patterns, frequently requiring modifications in agricultural techniques to accommodate changing environmental circumstances. In an effort to mitigate the risks associated with climate variability, farmers may opt to diversify their crop selections.

Majority of farmers interviewed were aware of drought-resistant crops being implemented in agriculture sector, followed by precision agriculture techniques and agroforestry practices. SAS Nagar district is predominantly under rice and wheat cultivation; however, farmers are adopting crop diversification and shifting towards maize, pulses (particularly moong and mash), sugarcane, vegetables and fruit trees.



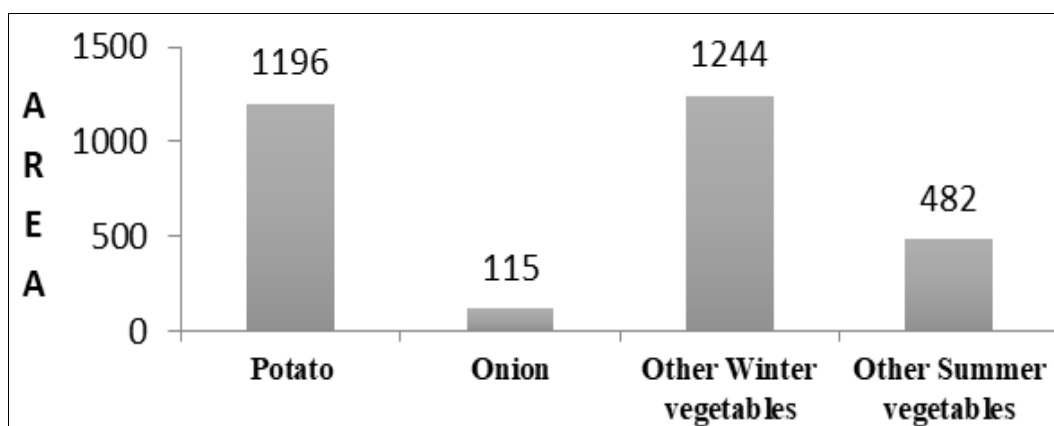
Source: Punjab Statistical Abstract, 2022

Fig 2: Area under major crops in SAS Nagar (thousand hectare)



Source: Punjab Statistical Abstract, 2022

Fig 3: Cumulative area under different fruits in SAS Nagar



Source: Punjab Statistical Abstract, 2022

Fig 4: Area under different vegetables in SAS Nagar (Hectare)

Following trends of crop diversification were observed in the farmers interviewed due to changing climatic conditions such as increasing temperatures, erratic monsoon, and extreme weather events which affect the water availability for irrigation purposes and prompt the farmers to try new crops other than traditional rice-wheat cropping system.

1. **Basmati:** Farmers are cultivating less water-consuming varieties of paddy, including Basmati, to check the fast-depleting water table.
2. **PR-126:** replacement of the long-duration PUSA-44 variety with the water-efficient short-duration paddy variety PR-126. Paddy varieties such as PUSA-44 typically require 5,000 to 6,000 liters of water per kilogram of rice, whereas water-efficient varieties like PR-126 and PR-121 only need 4,000 liters for the same yield. Furthermore, these varieties have an early harvest readiness, reducing input costs and leaving minimal residue post-harvest. Agricultural experts from Ludhiana's Punjab Agricultural University (PAU) recommend transplanting 25-30-day-old nursery of the PR-126 variety between June 25 and July 10, and 30-35-day-old nursery of other rice varieties after June 20.
3. **MOONG:** incorporating a third crop into the system such as summer moong or peas which are leguminous crops that enhance soil health. Moong a 65-day crop, between wheat-paddy cycles sowing is done between March 15-April 20.
4. **Maize:** Farmers are also shifting to kharif season maize as an alternative to paddy as maize sown in February (spring maize) is highly hazardous from Punjab's perspective. When sown in June or July, maize requires 4-5 irrigation cycles in the rainy season.
5. **Mustard:** 11 farmers out of 60 interviewed are also cultivating oilseeds particularly mustard a rabi crop which requires less amount of water for irrigation.
6. **Sugarcane:** farmers in few villages are also shifting towards sugarcane cultivation as alternative to wheat-rice mono cropping system.
7. **Agroforestry:** planting Eucalyptus and Poplar trees in this region capture and sequester carbon dioxide from the atmosphere, aiding in the mitigation of climate change by decreasing concentrations of greenhouse gases.
8. **Vegetables:** Among the 60 farmers surveyed 7 farmers

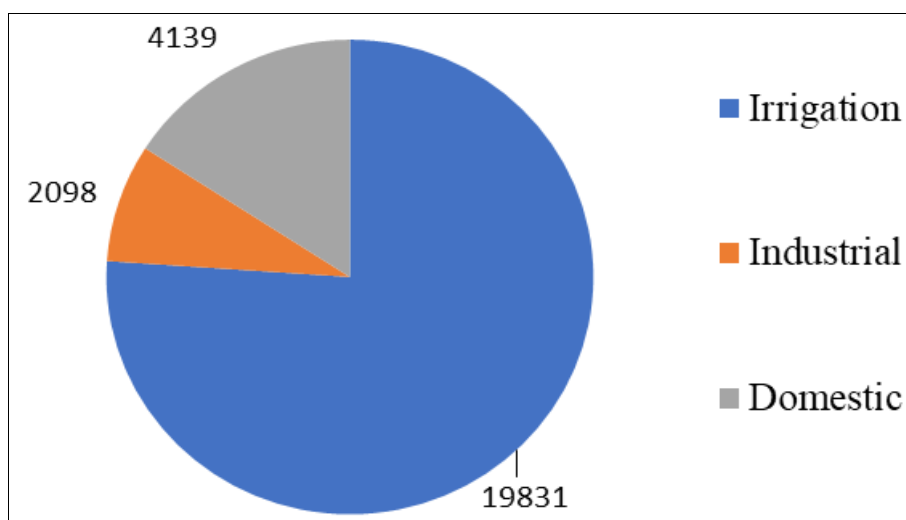
grow vegetables on their farms under protected cultivation practices such as low tunnel technology and mulching for year round production. Due to its short duration, it is easily fit into any crop rotation. Protected vegetable cultivation is a profitable, employment generating practice and it is also source of income in off-season so farmers are so the farmers are exploring these options of crop diversification. The major vegetables grown are capsicum, cucumber cauliflower, peas, potato, onion, chilies, tomato, brinjal, beans, okra, muskmelon, watermelon, strawberries, pumpkin, bottle gourd, bitter gourd, sponge gourd, radish etc.

The farmers who have adopted agronomical practices such as zero tillage, deep plowing and conservation tillage as well as have diversified their crops observed increasing trend of crop productivity (51% of the farmers). Those farmers who were reluctant to incorporate these short duration varieties and stuck to traditional wheat-rice monoculture had either static (27% of the farmers) or decreasing crop productivity (22% of the farmers).

3.2 Groundwater depletion and water management techniques

Green Revolution has made Punjab the breadbasket of nation but it had serious affects on groundwater level of the state. In Punjab, farmers heavily utilized groundwater for irrigation to fulfill the water requirements of these high-yielding varieties. Tube wells and electric pumps became prevalent tools for groundwater extraction, enabling continuous irrigation year-round. Groundwater depletion refers to the decline in the amount of water stored in underground aquifers, which are natural reservoirs of water located beneath the Earth's surface. Changes in precipitation patterns and rising temperatures as a result of climate change have the potential to affect groundwater recharge rates, worsening depletion in certain areas.

SAS Nagar has a well developed irrigation network with almost whole of the cropped area under irrigation. Most of the area under irrigation is under tube wells. According to Punjab Statistical Abstract of 2022-2023, net irrigated area by tube wells and wells is 86000 hectares. This has implications for the availability of groundwater in the district.



Source: Central Ground Water Board Northwestern Region, 2022-2023

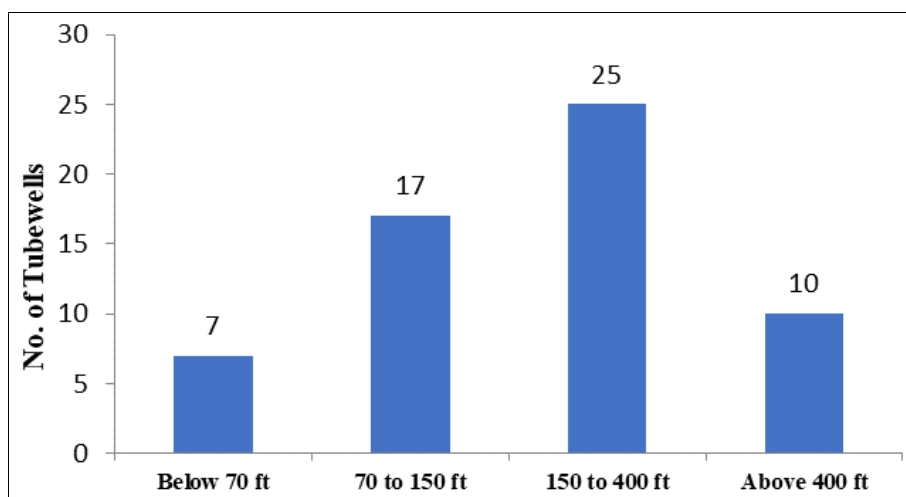
Fig 5: Current annual ground water extraction (Ham) of SAS Nagar

The survey reveals that 54 farmers out of 60 use only tube well for irrigation purposes, while 4 use water from rivulet along with tube well and only 2 farmers irrigate their land from nearby rivulet. Therefore, it can be observed that majority of the farmers (96.7%) have tube well connection. Electric tube wells are the most commonly used by farmers (53 farmers), while diesel (4 farmers) and solar power tube wells (only 1 farmer has solar powered tube well) are among the unpopular ones. The reason for this trend is free electricity for irrigation (for agriculture power connections) that has stimulated agricultural growth and rural economy in Punjab. However, this free and unmetered electricity supply has also led to inefficient use of electricity and groundwater. The survey conducted of 60 farmers discovered that only 2

farmers had metered supply of electricity because they don't have agriculture power connection for their tube wells.

3.2.1 Increasing depth of tube wells

At least 10 farmers revealed that they experienced drastic change in depth of tube well in last 10 years. The water level had plummeted below 300 feet, making it impossible for the monoblock motor to function. One of the farmer revealed that the first tube well he dug at 60 ft, in 2000, hit water at 650 ft, and was dug up to 800 ft--a common practice meant to future-proof the tube well and avoids repeated costs of digging. Farmers have been increasing the depth of the well to double- 60 to 170 ft, 150 to 310 ft and 150 to 750 ft to extract water from the deep aquifer.



Source: Field Survey, 2024

Fig 6: Depth of tubewell

The shallow wells, historically utilized for irrigation, have become depleted, leading to a shift in farming practices. Affluent farmers have transitioned to utilizing deep tube wells for irrigation purposes, while others less fortunate have resorted to cultivating sugarcane, a crop with lower water demands.

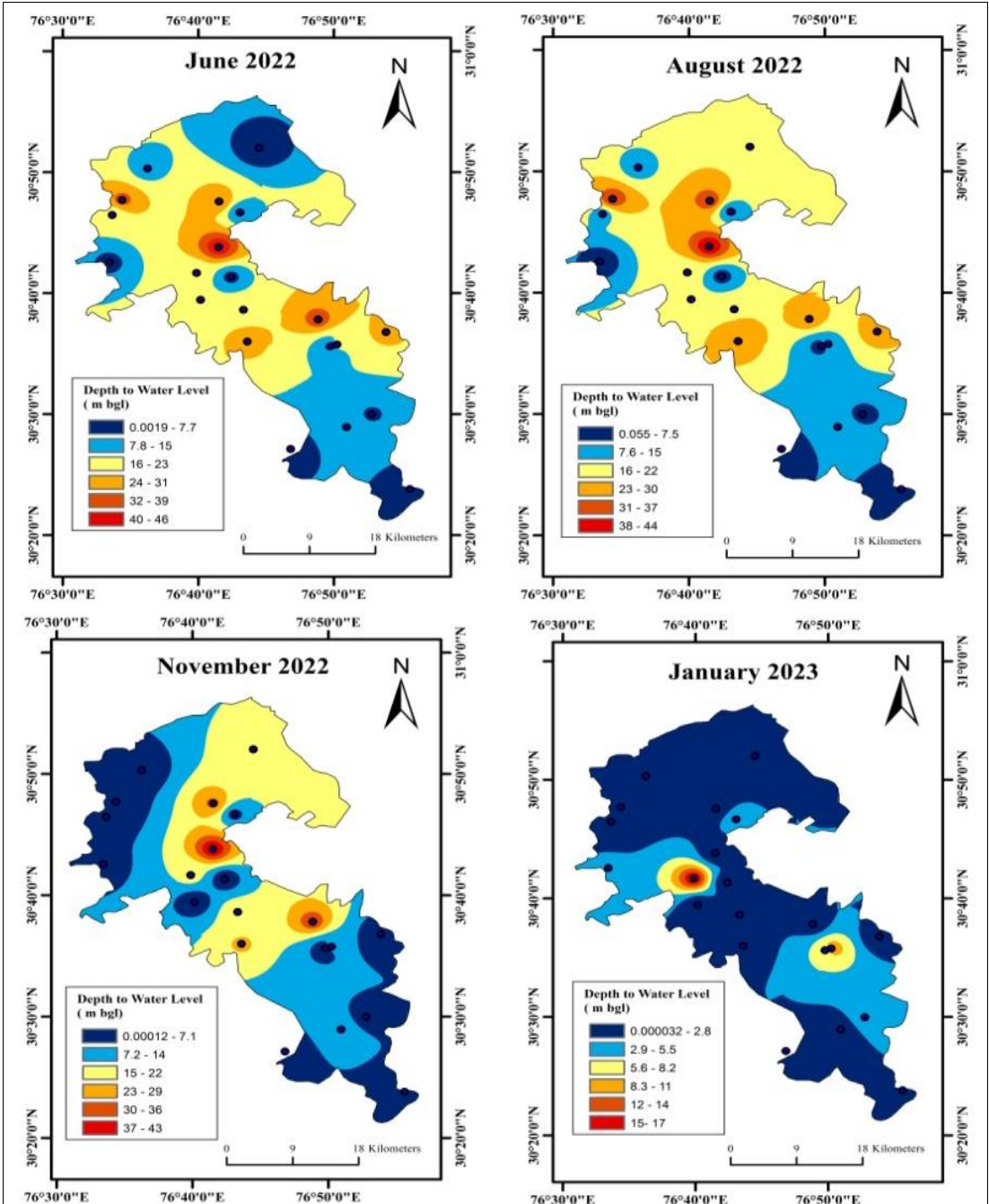
3.2.2 Ground water level fluctuations/trends: The Central

Ground Water Board, North Western Region, has established 488 Ground water observation wells in Punjab State and Union Territory of Chandigarh for monitoring water level. In SAS Nagar district there are 8 dug wells, 10 Piezometer (CGWB) and 29 Piezometer (STATE). In order to assess the quantitative change in ground water resources, water levels were monitored as a routine of four times in a year.

Table 1: Maximum and minimum water levels during all four seasons

Range	June 2022	August 2022	November 2022	January 2023
Minimum	2 mbgl at Sirsini	1.13 mbgl at Sirsini	1.18 mbgl at Sirsini	1.37 mbgl at Sirsini
Maximum	46.39 mbgl at Balongi	44.52 mbgl at Balongi	43.03 mbgl at Balongi	16.54 mbgl at Landran*

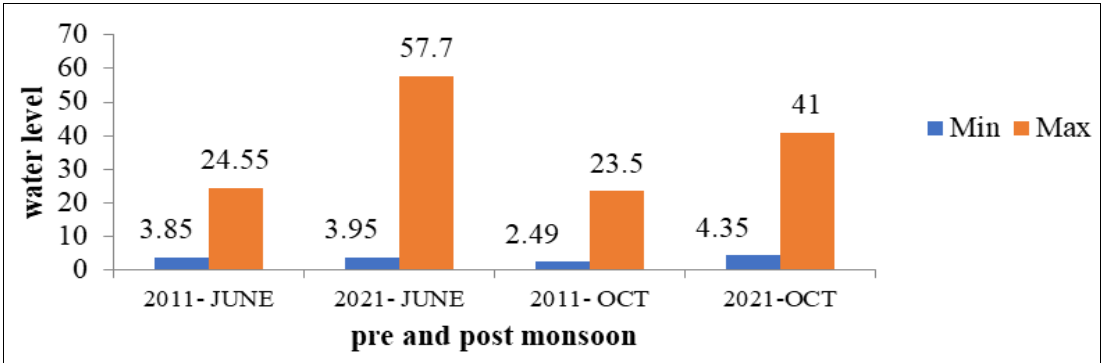
*Data for the month of January 2023 is not completely available for all the ground water observation wells



Source: Computed from Central Ground Water Board Northwestern Region, 2022-2023

Map 2: Depth to wath level of SAS Nagar District

There is a decline in groundwater level from 2011 to 2021 in SAS Nagar district.



Source: Punjab Statistical Abstract, 2022

Fig 7: Pre-monsoon and post-monsoon ground water level in SAS Nagar (in Meters)

3.2.3 Causes of over exploitation of groundwater

Climate changes alter recharge rates of groundwater aquifers. Increasing temperatures and erratic monsoons are

the major climate change drivers that effect availability of groundwater directly.

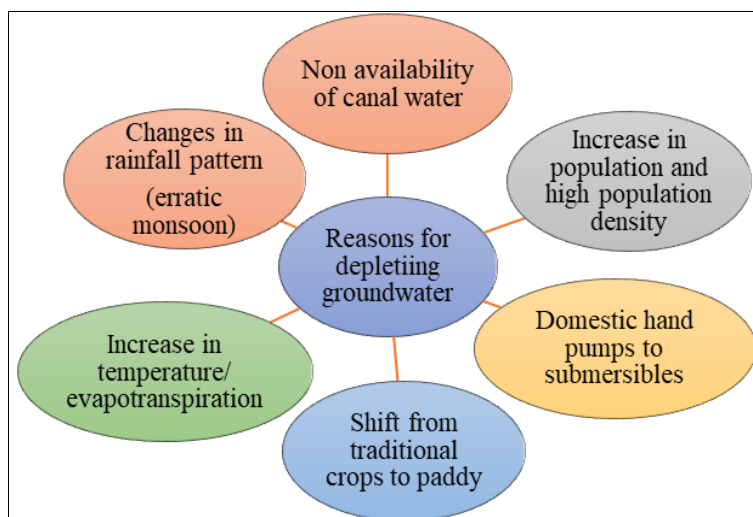
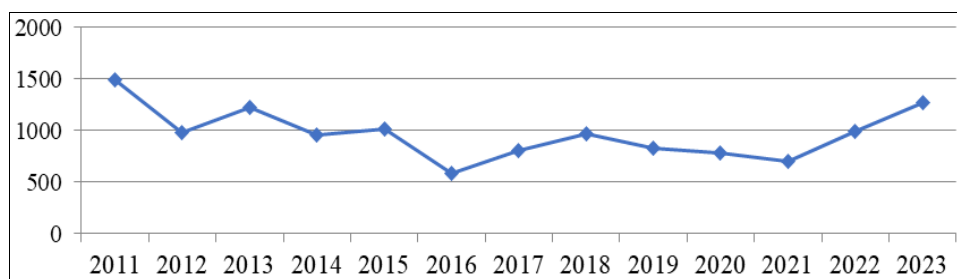


Fig 8: Key Factors Contributing to Groundwater Depletion

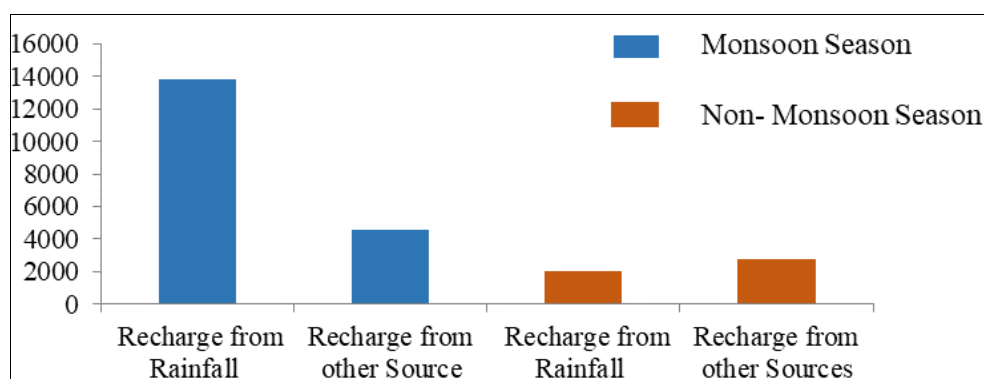


Source: IMD, 2011-2023

Fig 9: Average annual rainfall of SAS Nagar District (mm)

In the monsoon season, which typically occurs from June to September in the region, heavy rainfall contribute significantly to groundwater recharge. Recharge from Rainfall is high during monsoon season as compared to other sources. Recharge from other sources such as canals,

surface water irrigation, ground water irrigation, tanks and ponds, water conservation structures is high in the non monsoon season as compared to recharge from rainfall in non monsoon season.



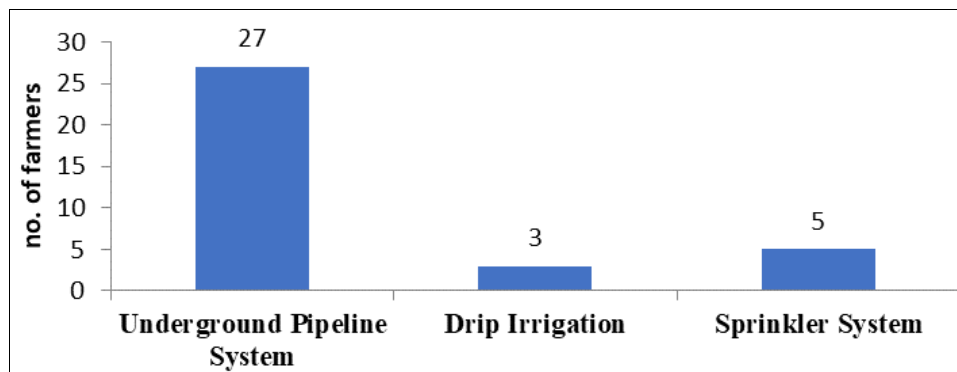
Source: Central Ground Water Board Northwestern Region, 2022-2023

Fig 10: Ground Water Recharge of SAS Nagar (Ham)

3.2.4 Groundwater conservation techniques

One solution to control the fast depleting groundwater level is to promote the micro-irrigation system, comprising sprinkler and drip irrigation that enable precision farming by making water available in a targeted manner. The most popular water conservation technique among the farmers

surveyed is underground pipeline system. A well-designed pipeline system conserves water, reduces energy consumption, and minimizes the land area required for field channels. Underground pipelines can also incorporate drip irrigation or precision irrigation technology, which precisely supplies water to plant root zones in controlled quantities.



Source: Field Survey, 2024

Fig 11: Techniques adopted for water conservation

Some of the feasible interventions and the possible savings of water suggested by Punjab Water Regulation and

Development Authority in its Guidelines for Groundwater Extraction and Conservation, 2020 are listed below:

Table 2: Water saving practices in paddy crop

Water saving practice	Water saving potential
Delaying paddy transplanting to June 25 or later	1,000 to 2,000 m ³ per hectare
Alternate wetting and drying, and maximum 50 mm depth of irrigation water in the paddy field	500-2,500 m ³ per hectare
Delaying paddy transplanting to June 25 or later coupled with growing short duration varieties	1,500-2,500 m ³ per hectare

Table 3: Water saving Practices in wheat crop

Water saving practice	Water saving potential
Use of small irrigation plots (6-8 plots per acre) for wheat crop	Up to 350 m ³ per hectare
Direct sowing of wheat in standing paddy stubble using zero-till drills such as Happy Seeder or Super Seeder	up to 700 m ³ per hectare
Furrow irrigation in bed-planted wheat	750 m ³ per hectare
Irrigation through sub-surface drip system	3,500-4,000 m ³ per hectare

4. Replacing paddy with other less water consuming crops

Groundwater resources can be conserved by diversifying from paddy crop to other water saving crops in the Kharif season as mentioned below:

Table 4: Water Saving Potential of Replacement Crops Compared to Paddy

Replacement crop	Water saving potential
From paddy to Kharif Maize	10,000 m ³ per hectare
From paddy to millets (bajra)	11,000 m ³ per hectare
From paddy to oilseeds (groundnut)	11,000 m ³ per hectare
From paddy to pulses (moong bean)	11,000 m ³ per hectare

Increasing awareness and adoption of water conservation measures among farmers helps save energy and money. The water conservation structures are one time investment and the results improve environmental and ecological condition in the irrigated land. Heavy ground water overdraft is being reduced by these efforts.

5. Conclusion and Recommendations

This study underscores the significance of embracing Climate-Smart Agriculture as a comprehensive approach to tackling the challenges presented by climate change, while also advocating for sustainable and resilient agricultural systems. Through leveraging the interconnections among adaptation, mitigation, and sustainable development objectives, CSA presents a direction towards constructing climate-adaptable food systems that are capable of sustaining both human populations and the environment amidst changing climatic circumstances.

Farmers of SAS Nagar district are cautious about frequent

extreme weather events, shifting precipitation patterns, and temperature fluctuations that pose significant challenges to traditional cropping patterns and necessitate proactive adaptation measures. They are diversifying their crops and are cultivating vegetables, fruit trees, moong, mustard, maize etc. along with short duration varieties of wheat and paddy. The research reveals the alarming rate of groundwater depletion in SAS Nagar district that falls under the overexploited category of groundwater with fluctuations as per monsoon season. Tube wells irrigate almost whole area of the district. Effective water management techniques are paramount to address groundwater depletion and sustainably utilize water resources in SAS Nagar district. Farmers aware about the declining groundwater level are adopting water conservation techniques, underground pipeline system being the most famous followed by drip and sprinkler irrigation. Government Subsidies on these structures provide a positive step towards embracing water management on farms.

6. Following recommendations can help implement climate smart agriculture in the district

- The Canal network in the district is negligible, it should be increased in order to decrease the over dependence on ground water.
- Harnessing solar energy for both new pumpsets and substitution of old and inefficient diesel pumpsets can reduce the burden on government and can be an environment friendly transition.
- Promotion of Laser Land Leveling for efficient distribution of irrigation water
- Attention must be paid to rejuvenating the traditional

water bodies every year in the villages to recharge groundwater for future generations.

- Organic farming needs encouragement and for this vermicompost and green manuring units need to be set up and farmers should be made aware about the benefits of improving soil fertility organically.
- Wood based industries can be set up in the district that can buy poplar wood from farmers who adopt agroforestry practices.
- Food processing units should be set up in the region to promote vegetable and fruit cultivation

Climate Change is not a myth but a reality that need immediate attention. Agriculture being the most effected by extreme weather conditions, Climate Smart Agriculture is the future of famers in this region. For agriculture to sustain in the region farmers must move forward from the initial stage and fully adopt Climate Smart Agriculture practices like crop diversification and groundwater conservation techniques.

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