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CLIMATE CHANGE AND ITS IMPACT ON AGRICULTURE: CHALLENGES AND ADAPTATION STRATEGIES

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Abstract: Climate change, driven by human activities such as fossil fuel combustion, has led to significant global temperature increases and extreme weather events. This phenomenon poses severe challenges to agriculture, particularly in India, where the sector is highly dependent on natural resources. Key impacts include soil degradation, water scarcity, and reduced crop productivity. Soil health is compromised due to changes in temperature, salinity, and organic matter availability, leading to land degradation. Water resources are strained by uneven rainfall distribution and increased temperatures, exacerbating water scarcity and affecting aquatic life. Crop productivity is threatened by altered weather patterns, pests, and diseases, with potential declines in yields by 4.5% to 9% by 2039 and less nutritional quality. Adaptation strategies are crucial, including the use of biochar to restore soil organic carbon, advanced water management practices, development of climate-resilient crop varieties, crop diversification, crop rotation, cover cropping and advanced weather forecasting devices. These measures aim to enhance agricultural resilience, ensuring food security and sustainable development in the face of ongoing climate change.
Keywords: Climate Change, Soil Health, Water management, Climate resilient crops, Crop productivity.

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INTRODUCTION

Climate change refers to a long-term transition in temperature & weather globally. One of the main factors for this transition is the burning of fossil fuels by humans which generates various greenhouse gases *e.g.,* CO_2 & CH_4 which behave like a sheet around the earth, trapping sun's heat & raising temperature. The other consequences of climate change are water scarcity, droughts, forest fires, floods, rising sea levels, declining biodiversity, human health, etc. (United Nations). According to UN Food and Agriculture Organization, nearly 2 billion hectares of global land are affected, including loss of 24 billion tons of fertile soil due to erosion. Degraded land impacting 1.5 billion people causes hunger, unemployment, and forced migration. To achieve land reclamation by 2023, over 10 million hectares around the Sahara need restoration (Food & Agriculture Organization of United Nations). As the agriculture sector is highly dependent on natural resources like soil, land, and water, this poses a significant challenge to people worldwide. India is also vulnerable region to climate change risks. Agriculture is the key determinant of overall economic and social well-being in India. The potentially serious consequences of climate change impacted the ecosystem and people of the Indian sub-continent along with crop failure, increased food and livelihood insecurity, water scarcity, etc. In recent years, India observed increase in temperature, regional variation of monsoon, frequent drought and severe storm incidence in coastal states, and Himalayan glacial recession (Roy et al., 2024).

Different types of effects have also been observed in various states & regions of India. As per the survey conducted at Nuh district (a semi-arid region) in Haryana, 384 farmers shared their perception of climate change. It was observed that they faced a reduction in rainfall, increased intensity of rainfall, and a rise in the minimum temperature, resulting in a significant decline in crop yield, soil erosion, and loss of indigenous crop varieties. This adversely affects the livelihoods of farmers who heavily rely on agriculture (Mehta, 2024). In another study of Uttar Pradesh, farmers believe that climate change poses a significant challenge to agriculture and their livelihoods. To effectively adapt and lessen their vulnerability to the effects of climate change, there is a need to form more partnerships with the Government and non-governmental organizations (NGOs) (Jatav 2024). Extreme forest fires, warmer temperatures and prolonged droughts have been reported in United States also. It is estimated that these changes will reduce crop yields, expansion of pests & diseases, etc. (Smithsonian). Asian countries like China, Japan, etc. are severely impacted by climate change. The threat of heatwaves across Asia, droughts in arid and semiarid regions of West, Central, and South Asia, delays and weakening of the monsoon circulation in South Asia, floods in monsoon regions of South, Southeast, and East Asia, and glacier melting in the Hindu Kush Himalaya region are all increased by rising temperatures (Shaw et al., 2022). This paper gives us an overview of climate change, its implications towards agriculture and some adaptive strategies such as soil organic carbon restoration, water management, climate resilient crops for enhancement in crop productivity that can be put in place for better management of the rapidly changing climate in India.

MAJOR IMPACTS ON AGRICULTURE

Impact on soil: The potential of the soil to keep functioning as an essential system within the constraints of ecosystems and land use is termed soil health. It allows the soil to support biological productivity, preserve the environment's air and water quality, and advance the health of people, animals, and plants. Climate change could affect soil health through variations in temperature, salinity, hydrology, and the availability of organic matter resulting in land degradation. Increased CO_2 concentration, high and low rainfall extremes, temperature rise, and their interactions are all expected to have an impact on several soil physical processes, putting the soils at serious risk of salinization, reduced water availability, altered C and N dynamics, reduced nutrient storage in the soil, and decreased biodiversity. It also alters the important physical, chemical & biological properties of soil like soil texture, soil porosity, bulk density, soil temperature, soil pH, EC, plant available nutrients, sorption & cation exchange capacity, soil organic matter, C:N ratio, soil respiration, soil microbial biomass, etc. (Patil 2018).

Impact on water resources: India has abundant surface water resources, the principal source of these resources is rainfall which is highly unevenly distributed both spatially and temporally, which frequently leads to severe water scarcity in some areas and flood threats in others. As per the report (2023) “National Compilation on Dynamic Ground Water Resources of India” by the Central Ground Water Board (CGWB), the blocks of Haryana, Punjab, and Rajasthan have more than 75% of over-exploitation, critical, semi-critical or saline groundwater as shown in Figure 1 (India Today). According to the Inter-governmental Panel on Climate Change (IPCC), variations in the global climate may make acute and persistent water shortages worse, especially in arid and semi-arid regions of the world. Given that the majority of India is dry or semi-arid, the nation may be extremely vulnerable, especially given that the majority of its water resources come from isolated reservoirs or bore wells. It has been proposed that regions in temperate and tropical Asia, that are more vulnerable to flooding, may see more intense precipitation, especially during the summer monsoon. Additionally, it is suggested that under projected climate change scenarios, surface runoff in arid and semi-arid Asia is expected to drastically decrease and that countries (including India), exceeding the water use by 20% of the total potential water resources

available, are expected to experience severe water stress during drought periods. Higher water temperature is expected to affect the water quality adversely by altering the rate of operation of biogeochemical processes and, most importantly, lowering the dissolved oxygen concentration of water. Water-stressed regions of Sabarmati basin, Krishna basin (particularly the Tunga Bhadra sub-basin), the Cauvery and Pennar basins may be vulnerable to increased temperatures (Mujumdar, 2008).

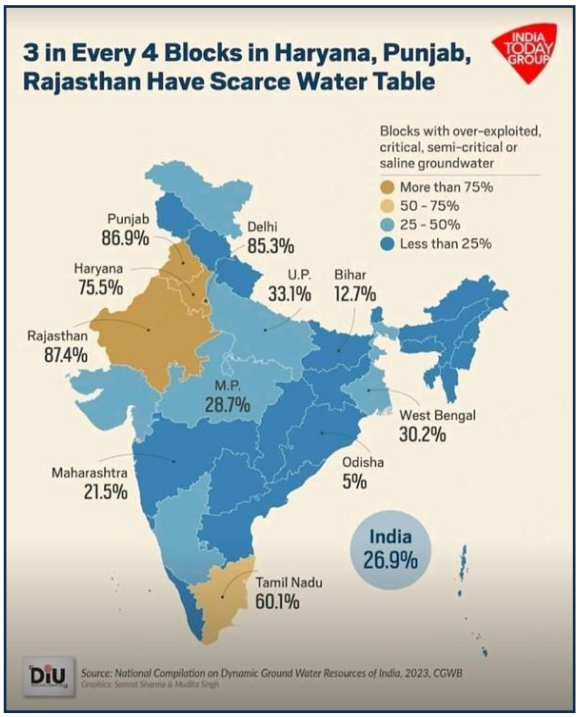

Figure 1: Water Scarcity in few States of India (India Today)

Decrease in crop productivity: Due to great dependence on monsoon rains and large farming population, India's farming sector faces challenges from climate change, which have a disruptive impact on crop yields, water availability, pests and diseases, and overall food security. A dynamic balance of biophysical resources, including soil quality, water availability, sunlight, CO_2, temperature, and pollinator abundance, determines the quantity and nutritional quality of agricultural production. Extreme weather, pests, diseases, and air pollution can reduce production. It is expected to have an impact on agriculture, offering opportunities as well as risks. ICAR report states that crop yields might potentially decline by 4.5% to 9% by 2039 under medium-term climate change scenarios and crop output predictions (Prakash 2024). If adaptation measures fail to be implemented, it is expected that the yields of rainfed rice in India will decrease by 20% in 2050 and 47% in 2080, while the yields of irrigated rice will decrease by 3.5% in 2050 and 5% in 2080 scenarios, respectively. Towards the end of the century with significant spatial and temporal variations, wheat yield is predicted to decrease due to climate change by 19.3% in 2050 and 40% in 2080 scenarios (Press Information Bureau 1909206). As per the global report prediction, a loss of 10 to 40 per cent in crop productivity is estimated for 2100 (Rao et al. 2019). For example, in India, an increase in temperature by 1.5° C and decrease in the precipitation of 2 mm, reduces the rice yield by 3 to 15 percent (Ahluwalia and Malhotra, 2006).

Birthal et al. (2014) examined the variations in India's climate between 1969 and 2005, taking into various factors like temperature and precipitation. Their research aimed to evaluate the effects on crop yields. According to their research, significant changes in temperature and precipitation patterns brought on by climate change might cause rice yields to drop by 15% and wheat yields to drop by 22% (Birthal et al. 2014). As per the study findings by ICAR, quantity as well as the nutritional value of food grains has also been affected. The foodgrains that we eat have lost food value; instead, they are accumulating toxins. High-yielding rice and wheat varieties released over the last 50 years show drastic decline in the concentration of key essential micronutrients like Fe, Zn, Ca, Cu in food grains and severe increase in the accumulation of toxic elements like Ar, Al, Ba, Sr (Centre for Science & Environment).

Reduced crop yields can also lead to some socio-economic implications like- food security and high food prices. Climate changed-induced crop productivity changes leading to a food shortage by 2030 resulting increase in food prices creating food security concerns. It was also predicted that GDP in all South Asian countries to decline as the agricultural sector plays an important role in terms of contribution to GDP and employment generation (Bandara & Cai 2014).

ADAPTATION STRATEGIES

With 85% of Indian farmers lacking financial resilience, climate change and associated problems are major concerns. The consequences of climate change will not go away in the upcoming decades, even if greenhouse gas emissions are significantly reduced as a mitigation strategy. For this reason, adaptation is of critical importance. As the primary practitioners of adaptation strategies to lessen the negative effects on the production system, farmers are in this sense the "front lines of climate change" (Datta & Behera 2022). To increase agricultural resilience to climate change, the Indian Government has developed various programs and initiatives like National Action Plan on Climate Change (NAPCC) and the National Mission for Sustainable Agriculture (NMSA). Indian agriculture is to become more climate-resilient through the evolution and application of techniques (Press Information Bureau 1909206). A few of those agricultural strategies are discussed below:

Restoration of soil organic carbon: Climate change induced increased global warming and changing precipitation has changed the whole dynamics worldwide. Particularly significant losses have resulted from soil erosion; in several locations, up to 1% of topsoil is lost annually. Because soil degradation exacerbates soil losses of carbon (C), nitrogen (N), and phosphorus (P) it poses an additional danger to agriculture's ability to maintain its environmental integrity (Mosier et al, 2021). 85%, 97%, 83%, and 71% of Indian soil is deficient in organic carbon (OC), Nitrogen, Phosphorus & Potassium, respectively (Figure 2) (GS Score). To restore soil carbon & improve fertility, Biochar is gaining attention these days. An ecologically friendly and sustainable replacement for regular fertilizers is biochar. Since it has a stable carbon structure, which can absorb carbon dioxide from the atmosphere over an extended amount of time, it lessens atmospheric carbon dioxide levels and slows down climate change.

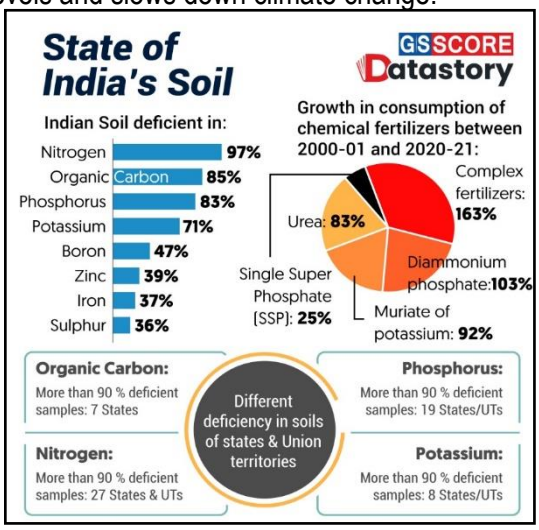

Figure 2: State of India's Soil (GS Score)

This procedure results in enhancement in porosity & stability of the soil, where beneficial soil microbial habitat can survive. By facilitating the breakdown of organic matter, nitrogen cycling, and humus production, this increased microbial activity enriches the soil with organic compounds and advantageous bacteria. Due to its high surface area and negative charge, biochar has a high cation exchange capacity (CEC), which keeps vital nutrients intact and allows them to be exchanged with plant roots to prevent nutrient leaching. By improving soil fertility, this retention mechanism encourages strong plant growth and increased agricultural yield. Additionally, biochar-modified soils show enhanced water-retention qualities, strengthening plants' resistance to drought and providing continuous water availability for robust development (Kundu & Kumar 2024). Restoration of SOC can also be achieved considering following approaches: cover cropping, reduced tillage, organic amendments, agroforestry, crop rotation (Table 1).

Table 1: Different approaches for restoration of SOC

Approach	Description	Benefits	References
Use of Biochar	Biochar is a stable form of carbon produced from organic materials through pyrolysis. It enhances soil structure, water retention, and nutrient availability.	Increased SOC by 10-30% over a few years. 20% increase in SOC in biochar-amended soils.	Lehmann et al.2006

Cover Cropping	Cover crops, such as legumes and grasses, are planted during off-seasons to protect and enrich the soil.	Increase SOC by 0.1-0.5% per year. cover crops increased SOC by 0.3% annually	Blanco-Canqui & Lal 2009
Reduced Tillage	Minimizing soil disturbance helps preserve soil structure and organic matter.	Reduced tillage practices can lead to a 15-30% increase in SOC over 10 years. no-till farming increased SOC by 25% compared to conventional tillage.	Six et al.2000
Organic Amendments	Applying organic materials like compost, manure, and crop residues adds organic matter to the soil	Increased SOC by 5-15% within a few years. 12% increase in SOC with regular compost application.	Mäder et al.2002
Agroforestry	Integrating trees and shrubs into agricultural landscapes enhances carbon sequestration.	116% increase in SOC in agroforestry systems (250.0±5.2 Mg ha^{-1}) in comparison to soil collected from evaluated pastures (116.0±4.6 Mg ha−1), Due to litter produced from leaves of timber tree species	Rodriguez et al. 2023.
Crop Rotation	Diverse crop rotations improve soil structure and organic matter content	Crop rotation can enhance SOC by 0.2 to 0.6% per year. diverse rotations increased SOC by 0.4% annually.	West & Post 2002

Water management: The availability and quality of India's water resources are being seriously impacted by climate change. Scientific approaches and novel approaches are vital to reduce these harmful effects. Advanced irrigation techniques, rainwater harvesting, remote sensing & Geographic Information System can be helpful in such situations. In recognition of these breakthroughs and effective practices on the field, the National Institution for Transforming India (NITI) Aayog compiles a list of water conservation and management techniques every year that can be replicated in other regions also. One of them is Low-cost irrigation in the driest region of Anantpur District, Andhra Pradesh. A unique sub-surface, plant root-zone-measured moisture system called System of Water for Agriculture Rejuvenation (SWAR) was used for irrigation, which uses only one-third of the water, with zero wastage. Similarly, Aquifer-based Groundwater Management, Community-led Springshed Management, Participatory Springshed Management, Bore-well pooling by farmers to address water security, etc. mentioned in the (Compendium of Best Practices in Water Management 2.0) as given in Table 2 (NITI Aayog).

Climate resilient crops for enhancement in crop productivity: Climate resilient crops are the ones that can anticipate, prepare, and respond to disturbances created because of adverse climate. These tolerant varieties play an important role in coping with climate variability as well as enhancing productivity. Biotic & Abiotic stress are there which are involved in limiting productivity. Plants may respond in several ways to heat, cold, or drought. Such responses might include changes to metabolic and molecular processes, signal transduction pathways, gene expression, and source-sink relationships for adaptation. The most common abiotic factors that hamper plant growth and productivity are drought, heat, salinity, cold, and flooding, among others as well. To maintain the production system and fulfill the growing demand for food grains, farmers must have access to enough supplies of high-quality seeds and climate-resilient crop varieties. It is necessary for farmers to have cultivars that yield well under stressful circumstances and can yield a considerable amount when conditions are favorable (Maheswari et al, 2019). Recently, the Government of India released 109 high-yielding (List given in Table 3), climate-resilient & bio-fortified varieties of 61 crops (34 field crops & 27 horticultural crops) majorly developed by ICAR (The Economic Times). State-wise recommendation & specific features of these

high-yielding varieties are also mentioned (Press Information Bureau, 2044754).

Table 2: Groundwater Management Projects/Models (NITI Aayog)

Initiative	District/Region	Funded by	Benefits
Aquifer-based Ground Water Management	Pune	Advanced Centre for Water Resources Development and Management (ACWADAM), Srinivasan Service Trust (SST) and Arghyam Trust	Ban on drilling of borewells, Efficient use of water through the use of drips and sprinklers, Water conservation structures helped enhance the recharging capability of aquifers.
Community-led Springshed Management	Kumaon Region, Uttarakhand	Central Himalayan Rural Action Group (CHIRAG), ACWADAM, Arghyam	Availability of spring water despite low rainfall indicating better revival of springs, creation of Jal Samitis has empowered women and developed a core group of women leaders, with the ability to conduct trainings
Participatory Springshed Management	Thanakkasoga Gram Panchayat, Himachal Pradesh	People's Science Institute, ACWADAM, Arghyam	Equitable water-sharing system amongst the communities, increased availability of water for irrigation, protection of the vadose zone and plantation helped in improving filtration, thereby reducing faecal coliform contamination.
Water Security and Participatory Groundwater Management	Kutch District,	Samerth, Arghyam	Security of drinking water, efficient management of water ensures sufficient availability throughout the year, drudgery of water collection has now been reduced to 3–4 hours per day, giving women sufficient time for other activities.
Springs Wetlands and Groundwater Connect in Nilgiris	Happy Valley	Keystone Foundation	Springs that used to dry up in the summers become perennial, sustained water levels in wells.
Adaptation to Climate Change Through Participatory Springshed Management	11 districts of Nagaland	People's Science Institute (PSI), Dehradun, and Department of Land Resources, Nagaland	Increased spring discharge during the lean season
Bore-Well Pooling by Farmers to Address Water Security	Andhra Pradesh and Telangana	WASSAN (Watershed Support Services and Activities Network), Arghyam	Reduced pumping time, Improved water availability, Increased crop productivity, Rise in groundwater levels, Assured livelihoods and reduced migration

Table 3: List of 109 high-yielding climate-resilient & bio-fortified variety (Press Information Bureau 2044754)

Name of Crop	Characteristics (variety-wise specific characteristics mentioned in (Press Information Bureau 2044754)	Name of the Variety/Hybrid
CEREALS		
Rice	Suitable for coastal saline areas, rainfed shallow low land, irrigated alkaline/saline stress areas, direct seeded aerobic condition in drought prone rainfed as well as water limiting areas, submergence stress conditions	CR Dhan 416 (IET 30201), CR DHAN 810 (IET 30409), CR Dhan 108 (IET29052), CSR 101 (IET-30827), Swarna PurviDhan 5 IET 29036 (RCPR 68-IR83929-B-B-291-2-1-1-2), DRR Dhan 73 (IET 30242), DRR Dhan 74 (IET 30252), DRR Dhan 78 (IET 30240), KKL (R) 4 (IET 30697), (KR 19011)
Wheat	Suitable for restricted irrigated condition, enhance nutritional value, rust resistant	Pusa Gehun Sharbati (HI 1665)
Durum Wheat	Terminal heat tolerant variety	Pusa Gehun Gaurav (HI- 8840)
Barley	-	DWRB-219

Maize	Rich in provitamin-A, lysine and tryptophan, moderately tolerant to water logging	Pusa Popcorn Hybrid – 1 (APCH 2), Pusa Bio fortified Maize Hybrid – 4 (APH4), Pusa HM4 Male Sterile Baby Corn-2 (ABSH4-2), IMH 230 IMHSB 20R-6, IMH 231 IMHSB 20K-10, Pusa Popcorn Hybrid – 2 (APCH 3),
Sorghum	Suitable for rainfed ecology Kharif season	DSH-6 (CSH-49) (SPH-1943)
Pearl Millet	High iron and zinc content	MH 2417 (Pusa- 1801)
Finger Millet	Suitable for rainfed situations	VL Mandua- 402
Proso Millet	Suitable for rainfed Kharif season	CPRMV-1 (DHPM- 60-4/PMV 466)
Barnyard Millet	Suitable for rainfed situations	VL Madira- 254
PULSES		
Chickpea	Suitable for desi timely sown rainfed /irrigated conditions, mechanical harvesting in rainfed	Pant Gram 10 (PG 265), Nandyal Gram 1267 (NBeG 1267)
Pigeon Pea	Suitable for rainfed/irrigated areas	Phule Pallavi (Phule Tur-12-19-2), NAAM-88
Lentil	Suitable for salinity conditions, high seed protein content	Pant Lentil 14 (PL 320), RKL 20-26(D) Kota Masoor 6, PSL-17
Field Pea	Suitable for rainfed/irrigated areas	Pant Pea 484
Faba Bean	-	HFB-3 (HB 14-21)
Mung Bean	Suitable for rice fallows and upland situations	Lam Pesara 610 (LGG 610), PMS-8
OILSEEDS		
Safflower	Suitable for late sown rainfed condition, resistant to *Fusarium* wilt	ISF-123-sel-15, ISF-300
Soybean	Suitable for rainfed Kharif season	NRC 197, NRC 149
Groundnut	Suitable for moderately tolerant to early and late seasons drought, timely sown rainfed/ irrigated Kharif	Girnar 6 (NRCGCS 637), TCGS 1707 (ICAR KONARK) Spanish Bunch
Sesame	Suitable for summer crop with early or late sown condition	Tanjila (CUMS-09A)
FORAGE CROPS		
Forage Pearl Millet	Suitable for rainfed/irrigated areas	JPM 18-7 (Jawahar Pearl Millet 18-7)
Berseem	Suitable for irrigated multi-cut during winter season	Jawahar berseem 08-17 (JB 08-17)
Forage Multicut Oat	Resistant to powdery mildew	Him Palam Forage Oat-1 (PLP-24)
Oat	-	Jawahar Oat 13-513 (JO- 13-513)
Forage Maize	Resistant to Maydis leaf blight MLB	Pusa Forage Maize Hybrid-1 (AFH-7), HQPM 28
Forage Sorghum	Suitable for rainfed Kharif	CSV 57F (SPV 2801) (UTFS 111)
SUGARCANE		
Sugarcane	Tolerant to drought, excellent performance under waterlogged condition	Karan 17 (Co 17018), IKHSU-16 (CoLk 16202), IKHSU-17 (CoLk 16470), CoPb 99 (CoPb 17215)
FIBRE CROPS		
Cotton	Suitable for rainfed condition, brown linted naturally colour cotton suitable for handloom weaving	CICR-H Bt Cotton 65 (ICAR -CICR 18 Bt), CICR- H Bt Cotton 40 (ICAR-CICR- PKV 081 Bt), Shalini (CNH 17395) (CICR-H Cotton 58), CNH-18529 (CICR-H NC Cotton 64), PDKV Dhawal (AKA-2013-8)
White Jute	Suitable for timely sown rainfed/ irrigated condition	JRC 9
POTENTIAL CROPS		
Buckwheat	Suitable for rainfed Kharif hilly areas	Him Tara (EC125940)
Amaranth	Higher Lysine & total protein content	Him Gauri (IC037156)
Grain Amaranth	Suitable for rainfed Kharif ecology, Higher Lysine, oil and total protein content	RMA 120 (Jodhpur Rajgira 2), Gujarat Amaranth 8 (GA 8) SKNA 1407, VL Chua 140
Winged Bean	No disease & pests observed	PWB 17-18 (Phule Shrawani)
Adzuki Bean	Rich in nutrition	Him Jwala (IC341939)
Pillipesara	-	Prathama (OUAT Kalinga Pillipesara-1) (IC 524667)
Kalingada	Suitable for rainfed Kharif season, seeds contain higher amount of oil, protein, iron	SKNK 1407 (Gujarat Kalingada 3)
Perilla	Useful as oriental medicine as an anti-asthmatic, antibacterial, antidote, antimicrobial, antipyretic, antiseptic, antispasmodic, antitussive, aromatic, carminative, diaphoretic, emollient, expectorant, pectoral, restorative, stomachic, and tonic	Poorvottar Perilla-2 IC-615382, Poorvottar Perilla-1 (IC-615369)
HORTICULTURAL CROPS---FRUITS		

Mango	Suitable for growing in subtropical and tropical regions, wider adaptability	Arka Udaya, Ambika, Arunika
Pomegranate	Moderately bacterial blight and drought tolerant	Solapur Anardana
Guava	Suitable for both table and processing purpose, rich in lycopene, wider adaptability is tropical and sub-tropical regions	Lalit, Arka Kiran
Bael	-	Swarna Vasudha
Pummelo	-	Arka Chandra
HORTICULTURAL CROPS---VEGETABLES		
Tomato	Tolerant to high temperatures, rich in Vitamin C, resistant to four diseases including, ToLCD (tomato leaf curl disease, late blight, Fusarium-wilt and bacterialwilt	Pusa Shakti, Pusa Tomato Hybrid 6
Bottle Gourd	Suitable for *kharif, zaid* and off-season production under low tunnel/ protected structure	Kashi Shubhara
Okra	Genic Male sterility based F_1 hybrid resistant to YVMV disease, iodine rich fruits	Arka Nikita
Indian Bean	Bushy in growth habit, tolerant to DYMV and high temperature 35^{o}C, climate resilient, pole type and photo-insensitive variety	Kashi Bouni Sem- 207, Arka Vistar
Muskmelon	Tolerant to high temperature	Thar Mahima
Watermelon	Tolerant to mosaic disease	Thar Tripti
TUBER CROPS		
Potato	Moderate resistance to late blight, high antioxidants in flesh, high tuber dry matter, heat tolerant variety having mite and hopper burn tolerance	Kufri Chipsona-5, Kufri Jamunia, Kufri Bhaskar
SPICES		
Nutmeg	First farmers participatory variety with bold nuts and fully covered mace	Kerala Shree
Small Cardamom	Tolerant to drought	IISR Manushree, IISR Kaveri
Fennel	Resistant to ramularia blight	RF-290
Ajwain	-	Gujarat Ajwain 3
Mango Ginger	-	IISR Amrit
PLANTATION CROPS		
Cocoa	Withstands black pod rot and tea mosquito bug infestation, Tolerant to low moisture stress, Rich in Fe and Zn contents	Vittal Cocoa Hybrid-1, Vittal Cocoa Hybrid-2
Cashew	Suitable for rainfed conditions	Nethra Jumbo-1, Nethra Ganga (H-130)
Coconut	Sweet tender coconut water & good quality copra, Early flowering	Kalpa Suvarna, Kalpa Shatabdi
FLOWER CROPS		
Marigold	-	Pusa Bahar
Tuberose	Tolerant to root-knot nematode	Arka Vaibhav
Crossandra	Moderately resistant to Phytophthora wilt	Arka Shreeya
Gladiolus	Resistant to *Fusarium* wilt disease	Arka Amar, Arka Aayush
MEDICINAL PLANTS		
Velvet Bean	Tolerant to drought	Arka Dhanvantari, Arka Daksha
Ashwagandha	Tolerant to bacterial wilt, late blight diseases and pests viz., Epilachna beetle, mites and aphids	Arka Ashwagandha
Mandukaparni	Good for herbal industries for extraction of triterpenoids, Higher asiaticoside and higher tri-terpenoid content	Arka Prabhavi

CONCLUSION

The impact of climate change on land, water, and crop yield is profound and multifaceted, posing significant threats to Indian as well as global agricultural systems. The evidence underscores the urgency of developing adaptive strategies to mitigate these impacts and to enhance the resilience of agricultural systems, ensuring food security and sustainable development in the face of ongoing climate change. To gain a better knowledge of acceptable solutions to climate change, current research on crop genetics, breeding, and yield gaps in the agricultural farming system must be expanded upon. To mitigate the effect of climate

change, agricultural research should be primarily focused on breeding for stress resistance, such as drought tolerance. To better comprehend and prepare for the temporal and spatial dimensions of climate change, agricultural research on crop-specific products would need to be better integrated with climate and weather forecasting research. To enable cost-effective solutions to climate change at the farm and farmer levels, it is imperative to comprehend and ease the obstacles to adaptation. The only way to boost risk-adjusted returns to farmers from climate change is to establish a smooth collaboration between policymakers, R&D advocates, extension organizations, and farmers. Action must be taken right away to improve the institutional framework for forming and maintaining these kinds of collaborations. Other elements of agricultural production systems, particularly livestock production, which is closely related to crop production, will be impacted directly or indirectly by the effects of climate change on food production.

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