Swadeshi Farming

Battling Climate Change

Research Project for
India Policy Foundation
as part of
Lodha Foundation Fellowship
2021-22

Suman Sharma

॥ प्रदीपयेम जगत् सर्वम् ॥
भारत नीति प्रतिष्ठान
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Suman Sharma

Challenge of Climate Change

The current climate on Earth is outside our historical experience and these extreme conditions will intensify because our activities will cause even more warming before this lessens. Our water systems and ecosystems, agriculture, infrastructure and economic growth are already being adversely impacted by climate change.

The year 2020 will always be remembered as a challenging year, one that brought us face to face with problems that were common to human societies across the globe, but were largely ignored or undermined until climate extremes – uncontrollable forest fires, torrential and unseasonal rains, cyclones, floods, hurricanes, soaring temperatures *et al* – made life increasingly uncomfortable in major cities across the developed world. On the flip side, this huge challenge brings with it an opportunity for the world to work together to find workable solutions that help the earth and its denizens, including the human race.

The climate catastrophes of 2021 that followed make it imperative that we do something to reverse the human disruption of the ecosystem, especially in agriculture. More than ever before, we need to support organic farming and promote consumers to buy organic food from local farmers. We must compost wet waste as much as possible, especially on the farm, save and share native (also called heritage) seeds, and build what environmentalist Vandana Shiva calls "a community seed library".[1] Small and vulnerable communities across the world are increasingly accepting that farming methods that conform to the climate and soil of a region (that is, agro-climatic zones, or ecological agriculture) can help resist and eventually mitigate climate change.

Sharp and unnatural variations of temperature can impact economic growth at country-wide level. Analysing how warming impacts various countries, Marshall Burke and Noah Diffenbaugh (Stanford University) found that warm countries tend to grow slightly less in terms of per capita GDP in warmer years than in cooler years. Aggregated over half a century, the cumulative effects of warming are large: India's per capita GDP is about 30 per cent lower today than it would have been without global warming.[2] Worldwide, global warming is increasing global economic inequality, especially vis-à-vis warmer countries.

Developing resilience is therefore the major focus of policy makers, governments and industries. It was hoped that climate change would be an area where the global community would join hands to overcome the common challenge, but nations are setting their national goals in conformity with their perception of their economic needs and technological abilities, which is not surprising or unexpected. Agriculture reportedly contributes almost one fourth of global greenhouse gas emissions and has emerged as a key area for ameliorative action vis-à-vis the climate.

Globally, the principal greenhouse gases emitted by human activities are carbon dioxide, methane, nitrous oxide, and fluorinated gases. The primary source of carbon dioxide (CO2) in the atmosphere is from burning of fossil fuels as well as from emissions from direct human-induced impacts on forestry and other land use, such as through deforestation, land clearing

[1] Raising Our Hands For A More Ecological 2022, January 3, 2022. https://vandanashivamovie.com/raising-our-hands-for-a-more-ecological-2022/

[2] The Times of India, 'Humans have created an unknown climate —India's per capita GDP is 30% lower due to this', Srijana Mitra Das, December 18, 2021. https://timesofindia.indiatimes.com/humans-have-created-an-unknown-climate-indias-per-capita-gdp-is-30-lower-due-to-this/articleshow/88346680.cms

for agriculture, and degradation of soils. However, land can also remove CO2 from the atmosphere through reforestation, improvement of soils, and other activities.

Methane (CH4) is emitted from agricultural activities, waste management, energy use, and biomass. Nitrous oxide (N2O) derives from agricultural activities, such as the use of fertilizers, as well as fossil fuel combustion. Fluorinated Gases (F-gases) are the byproduct of industrial processes, refrigeration, and the use of a variety of consumer products that include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6).

Gabriel A. Vecchi, teaching geosciences at Princeton University, studies the impact of human actions on the Earth's oceans and winds, and its mild weather days: "The core of my research is to understand how the oceans and atmosphere come together to give us our climate and weather that affects land, like tropical cyclones, the monsoons and phenomena like El Nino. The seasons we currently see are a specific type of climate change, the predictable changes that come from the fact that Earth's orbit is tilted relative to the sun. So, higher latitudes have a distinct cold and warm season with a transition. Tropical places broadly have a rainy season and a dry season.[3]

Scientists are now discovering that global warming has changed the odds of certain climate events. The powerful heat wave in western USA and Canada in 2021 would have been almost impossible without global warming. Temperature records and climate models show that over the past 150 years, the amount of carbon dioxide, methane and other gases in the atmosphere have increased, mainly due to the burning of fossil fuels. When these molecules are in the atmosphere, it makes it more difficult for the planet to cool, and Earth's temperature rises. The temperature especially rises in the oceans which absorb a lot of heat and expand, causing rise in sea levels. As the planet warms, the ice on land also melts and the water from ice caps, glaciers, etc., run off into the oceans, further augmenting sea level rise.

Warming also impacts climate by increasing moisture in the atmosphere, as a warmer atmosphere holds more water vapour. This triggers extreme rain events because there is more rain to squeeze out of the atmosphere. There is some evidence that the wind circulation in the tropics may be slowing down, even as the speed of certain extreme winds, such as cyclones, seem to be increasing, largely due to the warming oceans and higher atmospheric moisture. Vecchi explains that two main ingredients drive extreme rain, namely, the amount of moisture in the air and how rapidly the winds bring that moisture together, which causes rain. Global warming is affecting both these factors, especially in the Tropics.

Climatic changes are also impacting the Tropics by reducing the number of mild days, when the temperature is neither too hot, nor too cold, humidity isn't high and rain is slight or non-existent. Instead, there will be more days that are extremely warm and humid. Global warming could produce more mild days at higher latitudes that tend to be colder, so when the baseline temperature rises there are fewer uncomfortably cold days.

For India, the temperature of the warmest days will continue to rise, as will night temperature. Overall, Gabriel A. Vecchi says, the general baseline is moving up into higher temperatures. The seasons will continue, but tropical parts of India will have the rhythm of the monsoon dictating temperature and rainfall. The El Nino phenomenon in the tropical

[3] The Times of India, 'Studying the weather is critical now - the tropics could have fewer mild days', Times Evoke, December 18, 2021. https://timesofindia.indiatimes.com/studying-the-weather-is-critical-now-the-tropics-could-have-fewer-mild-days/articleshow/88347220.cms

Pacific that involves intermittent warming of the East Pacific every few years impacts the Indian monsoon, and deserves close observation.[4]

Deepti Singh (Washington State University) analysed the wet and dry spells in India and found that the wet spells have become more intense with greater risk of extreme precipitation, even as the dry spells have grown more protracted. Thus, during the monsoon season, precipitation has become more extreme, with flooding of rivers across the country. Human activity has impacted geophysical processes in the atmosphere and these are causing economic changes in many nations.[5]

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IPCC

The Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC), titled, *Climate Change 2021: The Physical Science Basis*, released in August 2021, has warned that climate change will have economy-wide repercussions in India if not mitigated, and could result in the loss of agriculture cover in the country.[6] It stated that the impact of climate crisis, like changing monsoon patterns, rising sea levels, deadlier heat waves, intense storms and flooding, pose an acute risk to the agriculture sector.[7]

The AR6 observes that rising air pollution levels have reduced the intensity and frequency of monsoon rains in India and much of South Asia. The report for the first time ever acknowledges the role of compound extremes and multiple climate change drivers operating in tandem, and triggering disasters in India and elsewhere. The IPCC report also observes that urbanisation has increased intense rainfall in cities across South Asia; it has used a range of scientific evidences generated on Indian cities. India and other South Asian nations need to factor in these findings as they plan post-novel coronavirus disease (COVID-19) economic recovery.[8]

"Rainfall has been on the decline and monsoon deficits on the rise in different regions in South Asia. Agreement among datasets invoke confidence about a decrease in mean rainfall over most parts of the eastern and central north regions of India", the report noted, adding that "concurrently the frequency of heavy precipitation events has increased over India, while the frequency of moderate rain events has decreased since 1950". The dominant cause behind the decrease of south and Southeast Asian monsoon precipitation since the mid-20th century is "anthropogenic aerosol forcing". Anthropogenic aerosol is a suspension of fine solid particles or liquid droplets in the air, created mostly by air pollutants like particulate and smoke emitted from vehicles, industries and other sources. In north India, the problem is compounded by rice stubble burning before sowing the Rabi crops.

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[4] The Times of India, 'Studying the weather is critical now - the tropics could have fewer mild days', Times Evoke, December 18, 2021. https://timesofindia.indiatimes.com/studying-the-weather-is-critical-now-the-tropics-could-have-fewer-mild-days/articleshow/88347220.cms

[5] The Times of India, 'Humans have created an unknown climate —India's per capita GDP is 30% lower due to this', Srijana Mitra Das, December 18, 2021. https://timesofindia.indiatimes.com/humans-have-created-an-unknown-climate-indias-per-capita-gdp-is-30-lower-due-to-this/articleshow/88346680.cms

[6] AR6 Climate Change 2021: The Physical Science Basis, August 2021. https://www.ipcc.ch/report/ar6/wg1/

[7] The Hindustan Times, PM Modi releases climate resilient crop varieties: How will they help India, Amit Chaturvedi, Sep 28, 2021. https://www.hindustantimes.com/india-news/pm-modi-releases-climate-resilient-crop-varieties-how-will-they-help-india-101632817619148.html

[8] Basu, Jayanta, What the new IPCC AR6 report means for Indian cities, August 12, 2021. https://www.downtoearth.org.in/news/climate-change/what-the-new-ipcc-ar6-report-means-for-indian-cities-78425

The level of air pollution, particularly toxic particulate-like particulate matter 2.5, is highest in the Indian sub-continent with Bangladesh, Pakistan and India occupying the top three positions respectively, at global benchmark. Subimal Ghosh of the Indian Institute of Technology (IIT), Mumbai, a lead author of the IPCC report, observed that, "Air pollution has increased over the Indian subcontinent, and so have aerosol levels; it acts as a barrier and reduces the difference of temperature between sea surface and land. This provides a cooling effect and reduces monsoon intensity".

The IPCC report predicted a turnaround in monsoon intensity in India due to rising temperature: "… models projected for the 21st century a significant increase in temperature over South Asia (high confidence with robust evidence) and in projections of increased summer monsoon precipitation (medium confidence)". Krishnan Raghaban, senior scientist, Indian Institute of Tropical Meteorology (IITM) and a coordinating lead author of the IPCC report, observed that while the exact nature of the monsoon in the near future (2020-2040) looked uncertain due to inherent variability, there was some certainty that monsoon rainfall would increase beyond 2040.

Throughout Asia, according to the authors, the "intensity and frequency of hot extremes, such as warm days, warm nights, and heat waves; and decreases in the intensity and frequency of cold extremes, such as cold days and cold nights" is likely. However, India and Pakistan are expected to suffer more: "More intense heat waves of longer durations and occurring at a higher frequency are projected over India and Pakistan".

Subimal Ghosh states that AR6 report predicts with "medium confidence" that major Indian cities would experience more bursts of intense rainfalls, mainly influenced by urbanisation. It notes: "There has been new evidence of the effect of local land use and land cover change on heavy precipitation (with) a growing set of literature linking increases in heavy precipitation in urban centres to urbanisation". This is because "urbanisation intensifies extreme precipitation, especially in the afternoon and early evening, over the urban area and its down-wind region".

The high intensity of heat released in major cities, coupled with locally generated air pollution, triggers aerosol load that contributes in cloud formation. Urban structures often trap the wind and act to bring bursts of intense rainfall in cities like Mumbai, Kolkata, Chennai and others. The temperature of Kolkata during 1950-2018 increased 2.6 degree Celsius, the highest among all cities mentioned in the IPCC regional factsheet. This, Ghosh adds, is because "Aerosol acts in diverse ways – while at a macro scale it imparts a cooling effect and reduces monsoon rain, at a micro scale, especially in urban centres, it contributes to intense bursts of downpour". This pattern has been experienced in many Indian cities in recent years.

Cities in the South Asia region would therefore experience more intense rainfall, and owing to inadequate infrastructure, could face severe waterlogging in coming years. The frequency of major floods in the Ganga basin has increased at least four times compared to earlier decades. Floods are now an all-India phenomenon.

The US National Aeronautics and Space Administration (NASA) has predicted that several Asian cities located on or near the coastline would face significant sea level rise by 2100. Mumbai and Chennai have had 0.58 and 0.57 metres of sea level rise, the highest among

Indian metros, followed by Kolkata (Khidderpur in report) with 0.15 metre rise. The report for the first time acknowledged the role of compounding extremes (several climate change drivers operating together) in maximizing disaster impacts in India and other countries. Roxy Mathew Koll, climate scientist at the IITM, remarked that Cyclone Yaas is "a tell-tale example of compound extremes such as high intensity cyclonic wind, rising sea level, more intense rainfall". Increasing heat and forest fires are a perfect example of compound extremes.

The IPCC AR6 observed: "Rainfall has been on the decline and monsoon deficits on the rise in different regions in South Asia. Agreement among datasets invoke confidence about a decrease in mean rainfall over most parts of the eastern and central north regions of India". It noted that "concurrently the frequency of heavy precipitation events has increased over India, while the frequency of moderate rain events has decreased since 1950".[9]

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IPCC Working Group 2
Maximum window two decades

Accumulating scientific evidence is emphatic that climate change is a threat to human welfare and the health of the planet. The window – a maximum of two decades during which serious mitigation steps should be taken – is closing on a livable planet, according to the report of the IPCC working group II (*Climate Change 2022: Impacts, Adaptation and Vulnerability*), released on February 28, 2022. Even at current levels, human actions in heating the climate are causing dangerous disruption, imperiling vast swathes of the natural world and making parts of the planet unlivable.[10]

Should current trends in greenhouse gas emissions continue and global temperatures rise 1.5 degree C above pre-industrial levels, the adverse effects could be "irreversible". These include the melting of ice caps and glaciers, increasing number of wildfires, mass mortalities in species such as trees and corals, peat-lands drying and thawing of permafrost, thus releasing additional carbon emissions and warming the climate further. These weather extremes are occurring simultaneously and have exposed millions of people to acute food and water insecurity, especially in Africa, Asia, Central and South America, on Small Islands and in the Arctic.[11]

The report asserts that the entire planet is affected and no inhabited region is exempt from the dire impacts of rising temperatures and extreme weather. Nearly half the global population (between 3.3 and 3.6 billion people) lives in areas "highly vulnerable" to climate change. Millions face food and water shortages owing to climate change, even at current levels of heating. We are already witnessing the mass die-offs of species, from trees to corals. Important tipping points include the Greenland Ice Sheet; West Antarctic Ice Sheet; low latitude coral reefs; Barrent sea ice; Amazon rainforest; the monsoons; and Atlantic meridional overturning circulation (AMOC).

[9] Basu, Jayanta, What the new IPCC AR6 report means for Indian cities, August 12, 2021. https://www.downtoearth.org.in/news/climate-change/what-the-new-ipcc-ar6-report-means-for-indian-cities-78425

[10] The Guardian, IPCC issues 'bleakest warning yet' on impacts of climate breakdown, Fiona Harvey, February 28, 2022. https://www.theguardian.com/environment/2022/feb/28/ipcc-issues-bleakest-warning-yet-impacts-climate-breakdown?CMP=twt_gu&utm_source=Twitter&utm_medium=&s=03#Echobox=1646046296

[11] Climate change: a threat to human wellbeing and health of the planet, February 28, 2022. https://www.ipcc.ch/report/ar6/wg2/resources/press/press-release/

The 1.5 degree C above pre-industrial levels is a "critical level" beyond which the impacts of the climate crisis escalate rapidly and some become irreversible. Coastal areas around the globe, and small, low-lying islands, are in danger of inundation. Already, key ecosystems are losing their ability to absorb carbon dioxide, turning them from carbon sinks to carbon sources. While some countries have agreed to conserve 30 per cent of the Earth's land, it may actually be necessary to conserve 50 per cent in order to restore the ability of natural ecosystems to cope with the damage already wreaked on them.

The IPCC-2 assessment report is based on seven years of study of the work of thousands of scientists. It warns that small islands will be among those worst affected. Walton Webson (Antigua and Barbuda), chair of the Alliance of Small Island States, urged the UN to convene a special session to consider action. He lamented, "We are… accelerating towards the cliff edge. We are not seeing the action from the big emitters that is required to get emissions down in this critical decade – this means halving emissions by 2030 at the latest. It is clear that time is slipping away from us."

An important measure to adapt to climate crisis is to build flood defences, help farmers to grow different crops, and build more resilient infrastructure. The climate crisis will certainly exacerbate hunger, ill-health and poverty as it will destroy the foundations of food and water security. This will increase human "displacement" and "involuntary migration" of people. UN secretary general António Guterres called the report "an atlas of human suffering and a damning indictment of failed climate leadership."

Environment Minister Bhupender Yadav said the report of the Working Group II reaffirms India's call for equity, climate justice, and curbing unsustainable consumption, and stresses the urgency of action on adaptation, building resilience and reducing risks and vulnerability to impacts of climate change. He urged developed countries to take the lead in urgent mitigation and provide finance for adaptation, loss and damage. Yadav said "loss and damage due to limits to adaptation are underway and will rise with further warming."[12]

The Working Group II report is the second installment of the IPCC's Sixth Assessment Report (AR6), which will be completed this year. It offers options to adapt to a changing climate, stressing nature's potential not only to reduce climate risks and improve people's lives. Hans-Otto Pörtner, IPCC Working Group II Co-Chair, observed that, "Healthy ecosystems are more resilient to climate change and provide life-critical services such as food and clean water." Hence, restoring degraded ecosystems and effectively and equitably conserving 30 to 50 per cent of Earth's land, freshwater and ocean habitats will enhance nature's capacity to absorb and store carbon, thus promoting sustainable development. However, this calls for adequate finance and political support.

Global trends towards excessive extraction of natural resources, growing urbanization, social inequalities, losses and damages from extreme events require reconsideration from governments, private sector, and civil society. However, cities also provide opportunities for climate action through green buildings, reliable supplies of clean water and renewable energy, and sustainable transport systems that connect urban and rural areas and promote a more inclusive and just society.

[12] https://twitter.com/byadavbjp/status/1498327268477009921

Gautam Hirak Talukdar, scientist at Wildlife Institute of India and a lead author of the report, said, "India is already taking giant strides towards transitioning to a low carbon economy. But during this transition, specially in terms of electrification, there will be trade-offs and challenges which this report will inform and that will be of importance to India."[13] Roxy Mathew Koll, climate scientist, Indian Institute of Tropical Meteorology, said, "We might have to take up the best adaptation measures that work for us to build a climate-resilient, disaster-proof country, but that will require immediate policy and action—since time is short. South Asia and particularly India is already facing increased risks due to rising extreme weather events such as floods, landslides, and droughts, cyclones, heatwaves and cold waves, and a rising sea level. The dense population and low household income in the region will raise the vulnerability and risk that we are facing."

Johan Rockstrom, director, Potsdam Institute for Climate Impact Research, speaking at a webinar titled, "*Protecting The Planet's Future: An Environmental Agenda,*" organised by India International Centre and Public Health Foundation of India, said that many of these tipping points are approaching instability and there are cascading impacts on the climate system when this happens. Information from the Earth Commission suggests that "1.5 degree warming is the real boundary… many elements are approaching tipping points under well below 2 degree C warming and at 1.5 degree warming," which could pose a real danger to climatic systems globally.

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COP-26

For many developing countries, climate change is looming large over their existence. We have to take big steps today to save the world. This is the need of the hour and this will also prove the relevance of this forum. I am confident that the decisions taken in Glasgow will save the future of our future generations, giving them the gift of a secure and prosperous life.
– Prime Minister Narendra Modi at COP26 Summit in Glasgow

Addressing the COP26 Summit in Glasgow, Prime Minister Modi said that despite being 17 per cent of the world's population, India has been responsible for only 5 per cent of its emissions because it has left no stone unturned in fulfilling its duty to save the planet from the scourge of climate change.[14] In India, Modi said, more passengers than the entire world's population travel by Indian Railways annually. The Indian Railways has now decided to be 'Net Zero' by 2030. He put India at the forefront of the fight against climate change by proposing a five-point climate agenda:

- India's non-fossil energy capacity to reach 500 GW by 2030.
- India to meet 50 per cent of its energy requirements with renewable energy by 2030.
- India will reduce its total projected carbon emissions by one billion tonnes from now to 2030.
- By 2030, India will reduce the carbon intensity of its economy to less than 45 per cent.
- By 2070, India will achieve the target of net zero emissions.

[13] Hindustan Times, New IPCC report key for India, say experts, February 10, 2022, https://www.hindustantimes.com/india-news/new-ipcc-report-key-for-india-say-experts-101644431125063.html
[14] Yadav, Bhupendra, COP26 Diary, January 11, 2021. https://bhupenderyadav.in/blog/cop26-diary-01-11-2021

Reminding the developed economies of their responsibilities, he urged, "India expects developed nations to make climate finance of 1 trillion dollars available at the earliest. Today it's important to track climate finance just like we track the progress of climate mitigation." India's collaborative approach towards tackling climate change including mooting the International Solar Alliance and a coalition for disaster resilient infrastructure for climate adaptation to save crores of lives.

Adaptation, not mitigation, in fact, will be the focus of India's development policies. Whether it is sources of drinking water to affordable housing, all must be made resilient against climate change. India's programs such as Tap Water for All, Clean India Mission and Clean Cooking Fuel For All have given adaptation benefits to needy citizens and also improved their quality of life.

The international climate debate, Modi said, has neglected "adaptation" and stressed "mitigation", thereby doing injustice to countries that are extremely vulnerable to climate change. Many traditional communities know how to live in harmony with nature, and their knowledge should be accorded due importance in our adaptation policies. Indeed, to ensure this knowledge reaches the next generation, he suggested that it should be included in the school syllabus.

Climate change is a global cause of concern and the responsibility lies with world citizens to reverse its damage. The developed nations bear a major portion of responsibility to cut greenhouse gas (GHG) emissions. India, along with the developed world, enjoys a shared but contrasting liability as far as global climate change is concerned.

India's has always been committed to mitigating the impact of climate change, both domestically and for the planet, and its self-committed targets at COP 26 (31 October to 13 November 2021) were lauded by the global community. Though currently India ranks as the third largest producer of emissions, historically India accounted for barely five per cent of GHG between 1870 to 2020 vis-à-vis major emitters like China, the United States and the European Union. While setting aggressive targets, India has adopted a prudent mix of changing the energy matrix, and focusing on agrarian reforms.

At COP26, Modi launched the 'One Sun One World One Grid' and 'Infrastructure for Resilient Island States' initiatives with partner countries to accelerate creation of green grids for transfer of renewable power and technical and capacity-building support to Small Island Countries. The aim is to promote infrastructure resilience by ensuring availability of clean energy from a world-wide grid everywhere at all times.[15]

In the run-up to the Glasgow meeting, Arunabha Ghosh, CEO, Council on Energy, Environment and Water (CEEW) noted that India "is a climate leader that delivers".[16] With 38.5 per cent of non-fossil fuel electricity generation capacity already installed, India is well placed to achieve the 40 per cent target it declared in its Nationally Determined Contributions (NDCs). Against its emission intensity of GDP pledge of 33-35 per cent reduction by 2030 against 2005 levels, it has already reduced by 24 per cent. This is no mean achievement.

[15] Bhupender Yadav, keynote address at HT Environment Conclave 2nd Edition, February 23, 2022, on theme, "A new growth paradigm for India: Designing an Environment, Social and Governance model for the post covid-19 Economy."
[16] The Hindustan Times, COP26: Play both the good and bad cop, Arunabha Ghosh, Oct 13, 2021. https://www.hindustantimes.com/opinion/cop26-play-both-the-good-and-bad-cop-101634123259538.html

India has set a target of 450 GW of renewables by 2030 via an Energy Compact submitted to the UN High-Level Dialogue on Energy in September 2021, and hopes to connect almost all households to electricity while shifting rapidly to clean power. The new National Hydrogen Energy Mission, which aims to lower costs of green hydrogen, can help in de-carbonisation of heavy industry and long-distance transport. The National Thermal Power Corporation Ltd. (NTPC) also plans to install more than 50 GW of renewables by 2030. The private sector ITC Ltd. aims to achieve 50 per cent share of renewable energy in its energy mix by 2030. Many cement companies (JK, JSW, Ultratech) have set targets of clean energy share of 30-75 per cent within the decade.

Ghosh asserts that India can consider setting a net-zero target year (not before 2070) but it needs commitments on technological advances and capital availability. We may note that India's cumulative emissions (1900-2100) would be lower than that of China, the United States or the European Union. Indeed, since 2008, rich countries have emitted nine years' worth of India's emissions over and above what they had committed to, even as the $100 billion mitigation fund remains a pie in the sky. Today, experts evaluate the finance needed at $1 trillion to enable developing countries to install clean energy infrastructure by 2030. Keeping its focus on its domestic vulnerability, India aims to build resilience against climate shocks. The Coalition for Disaster Resilient Infrastructure proposes enhancing local capacity to save lives and protect livelihoods from increasing climate risks.[17]

More impressively, India has taken the lead by proposing the International Solar Alliance (ISA), which is a revolutionary step in renewable energy. India has set 2030 as its deadline for making itself 'Net Zero' in its vast railway network, which will eventually lead to a reduction of 60 million tonnes of emissions annually. India's huge LED bulb campaign has been successful in reducing emissions by 40 million tonnes annually.

Prime Minister Modi has proposed that people make lifestyle changes and create a movement that can revolutionise core and diverse sectors of the economy, including agriculture. He also stressed the need for the developed world to release its promised climate finance of $1 trillion and low cost climate technologies.

While delivering the keynote address at the UN High-Level Dialogue on Desertification, Land Degradation and Drought in June 2021, Prime Minister Modi said that India is on track to achieve its national commitment to land degradation neutrality. He emphasized that India is working towards restoring 26 million ha of degraded land by 2030. This would contribute to India's commitment to achieving an additional carbon sink of 2.5 to 3 billion tonnes of carbon dioxide equivalent.[18]

The Union Minister for Environment, Forest & Climate Change, Bhupender Yadav, asserts that India is an attractive destination for global clean energy investments. US Secretary for Climate Change, John Kerry, who has visited India twice in this connection, termed the clean energy partnership as a major opportunity for India and the US. The India-US Climate and Clean Energy Agenda 2030 Partnership was launched at the Leaders' Summit on Climate in April 2021 by Prime Minister Narendra Modi and US President Joe Biden.

[17] The Hindustan Times, COP26: Play both the good and bad cop, Arunabha Ghosh, Oct 13, 2021. https://www.hindustantimes.com/opinion/cop26-play-both-the-good-and-bad-cop-101634123259538.html

[18] Indian Express, Missing the wood for the trees, Bhupender Yadav, February 11, 2022. https://indianexpress.com/article/opinion/columns/how-to-expand-indias-forest-cover-7766778/#:~:text=The%20provisions%20in%20draft%20NFP,outside%20forests%20in%20partnership%20with

Yadav said that at Glasgow (COP26), had called for Lifestyle for the Environment (LIFE), by "mindful and deliberate utilisation as opposed to mindless and destructive consumption". The Prime Minister emphasized the Indian ethos rooted in harmony with the environment. The Budget 2022 accordingly mooted energy transition and climate action as one of the pillars of the development and growth agenda of Amrit Kaal, the 25-year period from the 75th anniversary to the centenary of independent India.[19] To achieve this goal, the Government of India has prioritised allocation of significant domestic financial resources towards developing indigenous capacities for energy transition and climate action. Given the critical role of solar power, the Budget has hiked the production-linked incentive for domestic integrated solar manufacturing facilities from Rs 4,500 crore (2021) to Rs 19,500 crore. The goal is to achieve 280 GW of solar power by 2030. Simultaneously, energy storage systems, including grid-scale battery systems are being given infrastructure status.

India believes that forests play a major role in climate mitigation and especially in carbon sequestration. The India State of Forest Report (ISFR) 2021 shows the total forest and tree cover at 80.9 million hectares (ha.) or 24.62 per cent of the country's geographical area. India added 2,261 sq. km. of forest and tree cover between 2019 and 2021. Bhupender Yadav explains that India's definition of forest cover conforms to the Kyoto Protocol, wherein a "forest" has a minimum area of 0.05 to 1 ha (India has 1.0 ha minimum), with the tree crown cover percentage being more than 10 to 30 per cent (India has 10 per cent) and with trees having the potential to reach a minimum height of 2 to 5 m at maturity *in situ* (in India, it's 2 m). India thus assesses forests as "all lands, more than 1 hectare in area, with a tree canopy density of more than 10 per cent irrespective of ownership and legal status. Such lands may not necessarily be a recorded forest area. It also includes orchards, bamboo, palm etc."[20]

Forest cover is assessed on the basis of satellite data, which identifies umbrella-shaped canopies from the sky. The accuracy of classification for forest and non-forest is 95.79 per cent and the accuracy of classification in different density classes is as high as 92.99 per cent. Yadav further states that forest cover is also estimated from field inventory data, which corroborates the figures obtained from satellite-based interpretation. The interpreted maps of the Forest Survey of India (FSI can be accessed by everyone.

Then, plantations are important. Cashew plantations, which mainly grow along the coast, offer the first line of defence against cyclones, which are coming with increasing frequency and ferocity. Mixed plantations, especially of native species, meet all the ecological functions of natural forests as there is also a lot of wildlife here. Certainly, natural forests cannot be equated with plantations, but the latter too have vital ecological functions.

India has aligned its afforestation efforts with its wildlife conservation efforts. Project Tiger, launched in 1973 with nine tiger reserves, now encompasses 51 tiger reserves. These preserve natural ecosystems that support ecological processes that provide various goods and services essential for human well-being. Tiger habitats also create a huge carbon sink. At the same time, efforts are being made to conserve that habitat of lions, elephants and other animals whose existence is threatened by poaching or shrinking habitats.

[19] The Times of India, Green bonds will fund reduction of carbon intensity, Bhupender Yadav, February 10, 2022. https://timesofindia.indiatimes.com/blogs/voices/green-bonds-will-fund-reduction-of-carbon-intensity-union-environment-minister-argues-budget-creates-a-foundation-for-sustainable-growth/

[20] Indian Express, Missing the wood for the trees, Bhupender Yadav, February 11, 2022. https://indianexpress.com/article/opinion/columns/how-to-expand-indias-forest-cover-7766778/#:~:text=The%20provisions%20in%20draft%20NFP,outside%20forests%20in%20partnership%20with

India is still far from the goal of 33 per cent area under forest and tree cover as set in the National Forest Policy, 1988. The government hopes that the deficit of 9 per cent is achieved with plantations /afforestation outside forests, trees outside forest (TOF), and restocking degraded and scrub forests. According to the ISFR 2021, the TOF area comprises 36.18 per cent of the total forest and tree cover and is now a focus area of draft NFP 2021.

The draft NFP 2021 aims to improve tree cover outside forests by promoting agro-forestry and farm forestry; managing and expanding green spaces in urban and peri-urban areas; plantation of trees outside forests in partnership with local communities, land-owning agencies, and private enterprises; creation of urban forests (woodlands, gardens, avenue plantations, herbal gardens, etc.) as an integral component of urban habitat planning and development; afforestation/reforestation in public-private partnership (PPP) mode; promotion of urban forests, which include woodlands, wetlands, parks, tree groves, tree garden, plantations in institutional areas, on avenues and around water bodies, and so on. This is a holistic approach that can help to restore the ecological balance.

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Mangroves

Mangrove forests offer the best solution to climate mitigation, especially carbon sequestration, and have a vital role to play in the ecosystem of the planet. Mangroves are the habitat of several species of flora and fauna, materials, and medicines.[21] They occupy barely 1 per cent of the world's forested land, but contribute as much as 14 per cent of carbon sequestration by the oceans. However, their rapid denudation due to aquaculture, urban development, agriculture, and industrial development has had deleterious effects worldwide. Upsetting these "blue carbon ecosystems" can disrupt the world atmospheric gas system and leave huge amounts of carbon dioxide in the atmosphere. In India, the States of Kerala and Odisha are focusing on the development of mangroves to mitigate the impact of cyclones and other adverse weather events.

A mangrove (rhizophoraceae) includes various plant species (trees, shrubs) that are tolerant to salty waters and grow in the intertidal zones tropical and subtropical sheltered coastlines. The area covered by mangroves is called the *mangal*. Mangroves grow mainly in brackish and salty water wetlands, but can also grow in fresh water wetlands. They have salt-coping mechanisms that enable them to filter out more than 90 per cent of the salt in seawater. They hoard water in thick succulent leaves; some mangrove species have a waxy coating to seal in water and reduce evaporation. Some species have tiny hairs to deflect wind and sunlight and openings on the underside of their leaves, away from the sunlight. They breathe with snorkel-like parts. Their dense root system enables them to stand upright in soft, waterlogged coastal sediment.

Mangrove forests grow within 30° north and 30° south of the equator, and cover around 18.1 million ha the world over, and include 54 to 75 species. South and Southeast Asia host 7.52 million ha of mangrove forest, 41.5 per cent of the global mangroves. Healthy mangroves are critical to marine ecology. The detritus from fallen leaves and branches from mangroves

[21] Nyanga, Charles, The Role of Mangroves Forests in Decarbonizing the Atmosphere, Intechopen, August 2020.

supports several sea creatures. Mangroves are the habitat of several species of plants and animals. They provide breeding grounds for birds, reptiles, crustaceans, fish, and insects.

Mangrove forests can store three to four times more carbon than forests on land. Mangroves can store carbon from the atmosphere during their growing period from 50 metric tons to as much as 220 metric tons per acre. In the planet as a whole, mangroves sequester more than 24 million metric tons of carbon per year. Studies suggest that if fully restored, mangroves forests can sequester 69,000,000 tonnes of CO2 from the atmosphere and save 296,000,000 tonnes of soil carbon stock in avoided emissions.

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India's Agricultural Dilemma

Nearly 58 per cent of the Indian population earns its livelihood from agriculture, farming, forestry, animal husbandry and dairy. Of these, approximately 10 per cent are affected by Climate Change directly, and the rest indirectly.

India's farming challenges go back to the days of the Green Revolution in the late 1960s when the Central Government supported US technologies that were capital-intensive, to boost agricultural production. These high yielding dwarf varieties of rice and wheat, to which agricultural scientists added further varieties, eventually led to the depletion of the ground water table and affected water quality as indiscriminate use of fertilisers and pesticides leached into the ground water. In many "green revolution" districts in Punjab, water is no longer potable. More seriously, chemical agriculture seriously eroded soil fertility. This created the vicious cycle of farmers using more and more fertilisers and pesticides to achieve the desired yields. However, farm yields declined inevitably even as input costs rose, and farmers fell into a debt cycle that resulted in an alarming number of farmer suicides.

In the past two decades, Genetically Modified Cotton, after showing promising yields, underwent the same cycle of declining yields and excessive fertilizers, and diminishing soil fertility. After being discouraged by Government owing to its failure to prove pest-resistant, GM Cotton continues to be grown illegally in several regions despite several warnings by the Centre. Chemical agriculture has thus contributed in no small measure to the crisis in Indian agriculture. It is noteworthy that even large Indian farms lack the size of American farms; the modest farm sizes of the majority of farmers could not support the kind of costly inputs required by green revolution technology.

What India needs is to marry its conventional (organic) agriculture with the best of scientific technology, a path she has recently adopted, in order to achieve sustainable agriculture. Natural, organic farming is rooted in our traditions, and has been defined in Vrikshayurveda, the ancient Indian Science of plant life. So far, over 6.5 lakh hectares of agricultural land across eleven States are following organic farming. Andhra Pradesh leads the way with 2.15 lakh ha under natural farming, followed by Gujarat (1.17 lakh ha) and Madhya Pradesh (99,000 ha), according to Dr. Neelam Patel, senior adviser, NITI Aayog.[22] The presence of earthworms and other micro-organisms in the soil contribute to soil fertility immensely. As the use of chemical fertilisers rose from 12.4 kg/ha in 1969 to 175 kg/ha in 2018, there was a proportional loss of organic carbon in soil.

[22] Indian Express, Natural farming rooted in ancient Indian science: NITI Aayog adviser, Avinash Nair, December 14, 2021. https://indianexpress.com/article/india/natural-farming-rooted-in-ancient-indian-science-niti-aayog-adviser-7673221/

The green revolution legacy, meanwhile, continues in other aspects as well. While agriculture has become largely machine-driven in major States, rich farmers of States like Punjab use machines for almost every step in farming. This 100 per cent usage of electricity contributes to emissions, while poor farmers everywhere also try save time by converting labour intensive work into machine-driven work-share. Low interest bank loans help facilitate in purchase of high-end machinery, which adds to emissions, while cutting time and labour force.

Machine-driven agriculture has had its advantages, but the flipside has been of stubble burning which has caught the attention of the western media in recent times. North India has come under heavy criticism for adding to environment pollution by stubble burning, for which the excuse given by farmers is that the stubble cannot be extracted through machines.

The south-west monsoon is where the maximum impact of climate change is felt, on which 90 per cent of India's farmers are dependent. Delayed rainfall, low rainfall, drought or floods, contraction in farmlands due to increasing urbanization and corporatization, prime lands being cropped for infrastructure projects, large tracts of land being converted into special economic zones (SEZs), agricultural and forest lands being acquired by state governments forcefully in some places, to aid certain schemes of the Central Government, are some of the challenges augmenting the climate menace. In the process, farmers feel threatened and endangered.[23]

Global warming could lead to an increase in insect pest population which are inimical to yields of staple crops like soybean, paddy, wheat, and corn. While warmer temperatures prolong the harvest seasons, they also increase the number of breeding cycles of insects along with their metabolism.

Planned intervention by the Government to sustain a minimum and constant level of food security in the country is imperative as India's challenges rise in terms of arable land, diminishing levels of aquifers, unpredictable monsoons, increasing food demands, decay in crop yields, and increasing greenhouse gas (GHG).[24]

Enhanced water recycling, raised levels of micro-irrigation and restraining sugarcane cultivation, channeled by domestic and industrial sectors can help meet the nation's food requirements, despite the sporadic and uneven availability of natural resources.[25]

A shift in food habits witnessed mostly in urban India has brought about lifestyle changes resulting in increased usage of coarse whole grains in place of regular white rice and wheat, thereby reducing dependence on rice, which is water intensive. Paddy cultivation is responsible for the maximum groundwater exploitation crop diversification helps to mitigate the climate crisis, but much more needs to be done.[26] Implementing these minor shifts in food consumption can help to reduce the annual demand for electricity for irrigation from 65 per cent to 60 per cent, reduce water consumption for irrigation by 18 per cent to 24 per cent, and the agriculture sector's total GHG emissions by 17 per cent to 25 per cent, by 2050.

[23] Chaudhary, Krishan Bir, Development Misplaced, Partridge Publishing, 2014, p. 4.
[24] Environmental Research Letters, Sustainable alternative futures for agriculture in India-the energy, emissions, and resource implications, Kaveri Ashok et al, May 18, 2021, p. 1. https://iopscience.iop.org/article/10.1088/1748-9326/abf0cd
[25] Environmental Research Letters, Sustainable alternative futures for agriculture in India, ibid., p. 6.
[26] Environmental Research Letters, Sustainable alternative futures for agriculture in India, ibid., p. 7.

Government figures show that the total groundwater demand for rice, wheat, coarse whole grains, and pulses in 2019 was 250, 108, 35, and 6 BCM, respectively, and the corresponding surface water demand was 140, 60, 20, and 4 BCM, respectively.

Rise in temperature and availability of water will have adverse effects on crop yields and could cause a significant gap in food grain supply, by 2050. As production declines, more cultivable land would be required to meet the increasing demand for food, but there are natural limits on available arable land. A United Nations report, of August 2021, emphasizes that with the increase in the effects of global warming, agricultural produce will shrink and poverty levels will rise.

The Indian Council of Agricultural Research has studied the impact of climate change over many years. In the early 2010s, it used crop simulation models to show that climate change could reduce timely sown irrigated wheat production by about 6 per cent by 2020. In the case of late sown wheat, the projected losses could be as high as 18 per cent. It projected a 4 per cent fall in yields of irrigated rice crop and 6 per cent fall in rain-fed rice by 2020 due to climate changes. The warming trend in India over the past 100 years is estimated at 0.60°C. The projected impacts on yield fluctuations could impact food security, and call for serious attention to adaptation and mitigation strategies. The problem is aggravated by persistent land degradation, land fragmentation, labour problem, overexploitation of natural resources, et al. The urgent need to adopt improved land and water management systems, eco-friendly technologies and good agricultural practices across different agro-ecosystems was emphasized.[27]

Vandana Shiva points out that the reduction in snowfall is a danger signal as this means less snow in glaciers, and less stream-flow. The shorter period of snowfall inhibits the formation of hard ice crystals; hence, more of the glacier is liable to melt every summer. In the past two decades, rainfall has been witnessed instead of snow, even at higher altitudes. This, in turn, has accelerated the melting of glaciers. At the same time, heavy rainfall,, which was unknown in high altitude deserts, has become more frequent, causing flash floods and washing away homes and fields, trees and livestock. Climate refugees are already evident in Himalayan villages such as Rongjuk.[28]

India is the world's second largest producer of textiles, and this is a sector that could be severely damaged by climate change. The net vale in textile exports of India is estimated to be approximately $14 billion. Garment manufacturing concentrated in pockets in certain States, such as Delhi, Ludhiana, Bangalore, Tirupur and Jaipur, provides employment to hundreds of Indian youths. Since most of the garment sewing pockets are in north India, where summer temperatures can soar up to 45 to 47 degree Celsius, or even higher, it has been observed that an increase in temperature by one degree in summer months decreases production by approximately four percent, as the labour force are daily wagers and do not turn up for work in hot, humid and often poorly ventilated working areas.

The Economic Survey of 2017-18 focussed on severe drought conditions caused by extreme weather conditions, where farmer incomes are reduced by at least 14 per cent as a result of a 40 per cent reduction in rainfall. Some farmer friendly schemes like MNREGA (rural job

[27] Manzoor, Haris, Climate change-agriculture nexus: Indian scenario, GE-International Journal of Engineering Research, Vol. 2, Issue 4, June 2014, pp. 34-46.
https://www.academia.edu/40393054/CLIMATE_CHANGE_AGRICULTURE_NEXUS_INDIAN_SCENARIO
[28] Shiva, Vandana, Making Peace With The Earth: Beyond Resource, Land and Food Wars, Women Unlimited, 2012, p. 106.

guarantee scheme), Sinchai Yojana (irrigation scheme) and the Pradhan Mantri Fasal Bima Yojana (agricultural crop insurance scheme), are viewed as mitigating factors on climate change.

Climate change affects agricultural productivity in two ways: directly, due to changes in temperature, precipitation and/or carbon dioxide (CO2) levels and indirectly, through changes in soil, distribution and frequency of infestation by pests, insects, diseases or weeds. Acute water shortage combined with thermal stress can adversely affect wheat and rice productivity despite the positive effects of elevated CO2. The mean temperature in India is projected to increase by 0.40 C to 2.00 C in kharif and 1.10 C to 4.50 C in rabi by 2070 (IPCC, 1996). Mean rainfall may increase by 10 per cent during rabi by 2070.[29]

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National Mission for Sustainable Agriculture (NMSA)

Soil and water sustain agricultural growth and need to be conserved through appropriate location-specific measures. Nearly 60% of India's net sown area is rainfed, and contributes 40% of the total food production. Hence, the development of rainfed agriculture is critical to meeting the growing demands for food grains.

The NMSA is part of the Sustainable Agriculture Mission that is one of the eight Missions under the National Action Plan on Climate Change (NAPCC). It focuses on promoting sustainable agriculture through adaptation measures based on ten key dimensions of Indian agriculture, viz., Improved crop seeds, livestock and fish cultures, Water Use Efficiency, Pest Management, Improved Farm Practices, Nutrient Management, Agricultural insurance, Credit support, Markets, Access to Information and Livelihood diversification. These measures were embedded in ongoing and proposed programs of the Dept. of Agriculture & Cooperation (DAC&FW) during the XII Five Year Plan.[30]

On Farm Water Management (OFWM) is a key component of NMSA and aims at enhancing water use efficiency through technological interventions like drip & sprinkler technologies, efficient water application & distribution system, secondary storage etc. In 2015-16, these activities were subsumed under the 'Per Drop More Crop (PDMC)' component of the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY).[31] The PMKSY-PDMC focuses on water use efficiency at farm level through precision/ Micro Irrigation (Drip and Sprinkler Irrigation) to optimize the use of available water resources; it supports micro level water storage or water conservation /management activities to supplement source creation. Since, 2015-16 an area of 30.69 lakh ha has been brought under micro irrigation.

Rainfed Area Development Programme covers an area of an area of 3.42 lakh ha and focuses on Integrated Farming System for enhancing productivity and minimizing risks associated with climatic variability. The system integrates crops with horticulture, livestock, fishery, vermi-organic compost, green manuring, apiculture etc. to help farmers maximise returns for sustained livelihood and mitigate the impacts of drought, flood or other extreme weather events.

[29] Yadav, Neeru, Effect of Climate Change on Indian Agriculture, 2018 IJSRST, Volume 4, Issue 2.
[30] https://nmsa.dac.gov.in/
[31] PIB, National Mission for Sustainable Agriculture, December 18, 2018. https://pib.gov.in/PressReleasePage.aspx?PRID=1556469

Soil Health Management (SHM) aims to promote Integrated Nutrient Management (INM) through judicious use of chemical fertilizers including secondary and micro nutrients in conjunction with organic manures and bio fertilizers to enhance soil health and productivity, strengthen soil and fertilizer testing facilities to improve soil fertility. Farmers are trained on the balanced use of fertilizers. The Soil Health Card (February, 2015) gives farmers information on soil nutrients status of their soil and recommendation on appropriate dosage of nutrients to be applied for improving soil health and its fertility.

***Karnataka*:** The Government of Karnataka adopted Rainfed Area Development (RAD) to help farmers to maximize farm output besides mitigating the adverse impact of drought, flood, or other extreme weather events. It emphasised multi-cropping, rotational cropping, inter-cropping, mixed-cropping practices along with allied activities like horticulture, livestock, fishery, agroforestry, apiculture, conservation/promotion of NTFPs etc.[32]

Table 1: Rainfed Agriculture in Karnataka

No.	Farming System	Unit	Subsidy (in Rs.)
A. Integrated Farming System			
1	Horticulture Based Farming System	Ha	25000
2	Livestock Based System	No's	40000
3	Silvi-pastoral system/ NTFP	Ha	15000
4	Tree based cropping systems: Cereal/Pulses/Oil Seed with peripheral plantation like drumstick, papaya, citrus species, low density tress/shrubs of economic value etc	Ha	15000
B. Value addition and Resource Conservation			
1	Apiculture	Colony	800
2	Silage Unit (Silage pits)	No.'s	125000
3	Community Tank (Community/govt. Land)	No.'s	2000000
4	Water application & distribution (pipe/pre cast distribution system)	Ha	10000
5	Water lifting devices	No.'s	15000
6	In situ moisture con.	Ha	4000
7	Vermi compost (permanent) (Coverage with MNREGA)	No.'s	50000
8	Training on IFS/resource conservation	No.'s	10000

The NMSA hopes to make Indian agriculture more climate resilient through suitable adaptation and mitigation measures in both crops and animal husbandry. While the primary focus is on conservation and sustainable use of natural resources for food and livelihood security, it will expand its coverage primarily to rainfed areas by integrating farming systems with livestock and fisheries, so that agricultural production continues to grow in a sustainable manner.

[32] National Mission For Sustainable Agriculture – RAD, June 5, 2020. https://watershed.karnataka.gov.in/info-2/NMSA+-+RAD/en

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Food nutrition

India has taken the lead to address the challenges of climate change in agricultural production along with the larger issue of malnutrition in society by developing nutritious crop varieties with special traits for climate resilience and higher nutrient-content. Releasing 35 crop varieties with special traits, developed by the Indian Council of Agricultural Research (ICAR) on September 28, 2021 (by video conference), Prime Minister Narendra Modi asserted, "Climate change is a big challenge for entire ecosystem; new pests/diseases impacting crops, animals and human beings".[33] He was inaugurating the National Institute of Biotic Stress Management; all ICAR institutes, State and Central agricultural universities, and Krishi Vigyan Kendras attended the conference. Modi said that climate change is a big challenge for agriculture and the entire ecosystem, and called for stepping up efforts to fight it.[34]

The Prime Minister said that over the past 6-7 years, science and technology are being used on a priority basis to solve the challenges facing agriculture, such as nutritious seeds adapted to new conditions, especially changing climate. He recalled that India had managed to tackle the massive locust attack in several states in 2020, amidst the Corona pandemic, and helped farmers from suffering too much damage.[35] He added that to provide farmers with a safety net, the government had issued 11 crore Soil Health Cards to protect the land; helped to complete nearly 100 pending irrigation projects to provide water security to farmers; provided new varieties of seeds to protect crops from diseases and ensure higher yields. Loans are being facilitated through Kisan Credit Cards.

Modi warned climate change is leading to new types of pests, new diseases, and, above all, epidemics that pose a huge threat to the health of humans, livestock and crops. An alliance of farmers and scientists can face these new challenges. The development of millets and other grains could show the way ahead; the UN has already declared 2022 as the Year of the Millet.

The Prime Minister's Office (PMO) said the new crop varieties have special traits and will promote awareness about the adoption of climate resilient technologies. The new varieties include a drought tolerant variety of chickpea, wilt and sterility mosaic resistant pigeonpea, early maturing variety of soybean, disease resistant varieties of rice and biofortified varieties of wheat, pearl millet, maize and chickpea, quinoa, buckwheat, winged bean and faba bean (broad bean). These varieties also include those that address the anti-nutritional factors found in some crops that adversely affect human and animal health.[36]

The National Library of Medicine states that anti-nutritional factors are those substances generated in natural food substances by the normal metabolism of species and by different mechanisms, which exert effects contrary to optimum nutrition. The PMO revealed that crop varieties like Pusa Double Zero Mustard 33, first Canola quality hybrid RCH 1 with <2%

[33] Press Trust of India (@PTI_News), Sep 28, 2021. https://twitter.com/PTI_News/status/1442746358591410177?s=03
[34] The Hindustan Times, PM Modi releases climate resilient crop varieties: How will they help India, Amit Chaturvedi, Sep 28, 2021. https://www.hindustantimes.com/india-news/pm-modi-releases-climate-resilient-crop-varieties-how-will-they-help-india-101632817619148.html
[35] PM dedicates to the Nation 35 crop varieties with special traits. https://pib.gov.in/PressReleasePage.aspx?PRID=1758974
[36] PTI, PM Modi launches 35 crop varieties with special traits to address climate change, malnutrition, September 28, 2021. https://www.thehindu.com/news/national/pm-modi-launches-35-crop-varieties-with-special-traits-to-address-climate-change-malnutrition/article36707465.ece

erucic acid and <30 ppm glucosinolates, and a soybean variety free from two anti-nutritional factors namely Kunitz trypsin inhibitor and lipoxygenase have been developed. Other varieties with special traits have been developed in soybean, sorghum, and baby corn, and so on.

The need for climate resilient crops was felt as ongoing studies by the ICAR showed that farming activities currently consume up to 30 per cent more water due to "high evaporative demand and crop duration due to forced maturity" in states such as Andhra Pradesh, Punjab and Rajasthan. Experts have warned about the adverse effects of climate change for years. India set up the National Innovations in Climate Resilient Agriculture (NICRA) under ICAR in 2011. The ICAR project also covers livestock, fisheries and natural resource management.

The challenge is to ensure that agriculture survives extreme weather events so that citizens have food to eat, because it's not rocket science to know that natural disasters disrupt food supply. In the past decade, India and neighbouring countries like Bangladesh and Nepal have suffered abnormal floods. Farms have to recover from such catastrophic weather events and maintain the nation's food supply. Our best hope lies in native, hardy, climate adapted seeds as these have the best chance of surviving weather disasters as opposed to hybrid seeds or genetically modified seeds.[37]

According to current estimates, climate change could reduce agricultural yields by 4.5 to 9 per cent. Hence India decided to focus on developing climate resilient crops, rather than merely higher yield varieties. The emphasis shifted to varieties that are tolerant to diseases, insect pests, drought, salinity, flooding, early maturing and amenable to mechanical harvesting.

Potentially, the most promising are the Indian Agricultural Research Institute's (IARI) first-ever non-GM (genetically modified) herbicide-tolerant rice varieties that can be directly seeded, save significant amounts of water and labour when compared with conventional transplanting. The Pusa Basmati 1979 and Pusa Basmati 1985 contain a mutated acetolactate synthase (ALS) gene that enables farmers to spray Imazethapyr, a broad-spectrum herbicide, to control weeds. This eliminates the need to prepare nurseries where paddy seeds are first raised into young plants, before being uprooted and replanted 25-35 days later in the main field.[38]

Paddy transplantation is both labour- and water-intensive as the fields where the seedlings are transplanted have to be "puddled" (tilled) in standing water. For at least three weeks thereafter, the plants have to be watered almost daily to maintain a water level of 4-5 cm. Even after this, farmers continue watering the plants every two-three days for the next four-five weeks till the crop is in tillering (stem development) stage. A.K. Singh, director, IARI, explained that "Water is a natural herbicide that takes care of weeds in the paddy crop's early-growth period".

The new varieties replace water with Imazethapyr and dispense with the need for nursery, puddling, transplanting and flooding of fields. Paddy transplantation requires nearly 30 irrigations, each consuming some 5 hectare-cm of water (one hectare-cm equals 100,000

[37] How Food Survives Extreme Weather Events, May 19, 2021. https://vandanashivamovie.com/how-food-survives-extreme-weather-events/
[38] Indian Express, India gets first herbicide-tolerant & non-GM rice varieties; launch today, Harish Damodaran, September 28, 2021. https://indianexpress.com/article/india/india-gets-first-herbicide-tolerant-launch-today-7538299/

litres). Puddling takes an additional 15 hectare-cm. DSR requires nearly 30 per cent less water, saves Rs 3,000 per acre in labour for transplantation, and 10-15 days' time due to no nursery preparation.

This is an important development as Imazethapyr, effective against a range of broadleaf, grassy and sedge weeds cannot be used on normal paddy as the chemical does not distinguish between the crop and invasive plants. Moreover, the herbicide if sprayed on normal rice plants binds itself to the ALS enzymes, inhibiting their production of amino acids needed for crop growth and development. The new basmati varieties contain an ALS gene whose DNA sequence has been altered using ethyl methanesulfonate, a chemical mutant. Hence, the ALS enzymes no longer have binding sites for Imazethapyr and amino acid synthesis isn't inhibited. The plants can also "tolerate" application of the herbicide; hence it kills only the weeds.

Pusa Basmati 1979 and 1985 have been bred by crossing existing popular varieties (Pusa 1121 and Pusa 1509) with 'Robin', a mutant line derived from Nagina 22, an upland drought-tolerant rice variety. The mutant was identified for Imazethapyr-tolerance by S. Robin, a rice breeder from Tamil Nadu Agricultural University in Coimbatore. Farmers in Punjab and Haryana have already adopted direct seeding of rice (DSR) to overcome labour shortages and depleting water tables. In 2021, nearly 6 lakh of the total 44.3 lakh hectares under paddy in these two states came under DSR, relying mainly on two herbicides, Pendimethalin (applied within 72 hours of sowing) and Bispyribac-sodium (after 18-20 days). But these are costlier than Imazethapyr (Rs 1,500 versus Rs 300/acre) which has a wider weed-control range and is safer.

Union Agriculture Minister Narendra Singh Tomar said 86 per cent of Indian farmers are small farmers; hence the government's emphasis is to enhance the income of these farmers. This is the rationale behind schemes like PM-KISAN, Pradhan Mantri Fasal BimaYojna, PM Kisan Samman Nidhi, formation of 10,000 Farmer Producer Organisations, Agriculture Infrastructure Fund for post-harvest management infrastructure and community farm assets in villages; MSP that is at least 50% over cost of production, transportation through Kisan Rail and eNAM for marketing.[39]

The Prime Minister also inaugurated the new campus for the National Institute of Biotic Stress Tolerance, Raipur. Chhattisgarh Chief Minister Bhupesh Baghel said, "Climate change is a cause of concern across the world. We are seeing its impact in our area. There are two reasons — one is natural and the other one is reduction in carbon in soil". He called for extensive studies to ascertain the impact of climate change in the country.

The three major greenhouse gases are carbon dioxide (CO2), nitrogen oxide (N2O) and methane (CH4). The Intergovernmental Panel on Climate change (IPCC) revealed that in the year 2005, the atmospheric concentration of carbon dioxide (CO2) increased from a pre–industrial concentration of about 280 parts per million to 379 parts per million; methane (CH4) rose from pre–industrial concentration of 715 parts per billion to 1774 parts per billion; and nitrogen oxide (N2O) rose from about 270 parts per billion to 319 parts per billion mainly on account of chemical fertilizers in agriculture.[40]

[39] PM dedicates to the Nation 35 crop varieties with special traits. https://pib.gov.in/PressReleasePage.aspx?PRID=1758974
[40] Shiva, Vandana, Climate Change And Agriculture, February 23, 2011. https://www.countercurrents.org/shiva230211.htm

Modern or industrial agriculture is more vulnerable to climate change which is intensifying droughts and floods. The emphasis on single crops leads to crop failure when rain either does not come in time, or is too much or too little. Chemically fertilized soils cannot withstand a drought. Vandana Shiva says that farmers have raised crops resistant to climate extremes over generations. The solution therefore is the promote and preserve India's biodiversity and organic farming methods, which in turn will reduce climate change impact and alleviate poverty. Organic systems produce food with higher nutrition, reduce water use and decrease the risks of crop failure. After the Orissa Super Cyclone of 1998, and the Tsunami of 2004, her organisation, Navdanya, distributed seeds of saline resistant rice varieties to rejuvenate agriculture in lands rendered saline by the sea.[41]

Farm animals have been an intrinsic part of Indian farming. They contribute to soil fertility by feeding soil organisms by recycling organic matter, thus reducing greenhouse gas emissions. Biodiverse systems can resist droughts and floods because they have higher water holding capacity and hence contribute to adaption to climate change. Organic farming increases carbon absorption by up to 55% and water holding capacity by 10%, thus contributing to both mitigation and adaptation to climate change.

Realisation is dawning all over the world that eco-systems without animals create ecological imbalances. Healthy food begins in healthy soil. When denied a symbiotic relationship with ruminants, grass dies and then soil dies, because ecosystems need both fauna and flora to thrive. When the cycle is disrupted, the climate-disrupting carbon discharges into the atmosphere.

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Heirloom rice for infants

India's indigenous rice varieties are a rich source of fatty acids vital for undernourished infants. According to a study published in *Current Science*, traditional rice varieties are cheaper and more nutritious than industrially-fortified, high-yielding varieties, but are in danger of extinction as farmers prefer high-yielding varieties.[42] Debal Deb, lead author of the study and researcher at the Centre for Interdisciplinary Studies, Kolkata, aasserts that traditional rice varieties or landraces contain essential fatty acids that promote normal brain development in infants.

The study found that 12 out of 94 folk rice varieties examined, could naturally provide important fatty acids, such as arachidonic acid and docosahexaenoic acid, for undernourished mothers. "Vanishing rice varieties contain important long chain polyunsaturated fatty acids that are found in mother's milk and essential for the infant's cognitive development. They are not found in baby food formulae. We suggest that these rice varieties are a good substitute for mother's milk in case the mother is absent or not producing enough milk for the baby," Deb proposed. The late pioneer in Indian rice research, H.R. Richharia, had estimated that about 150,000 indigenous varieties of rice existed in India until 1970. This has since shrunk to about 110,000, and only about 6,000 folk rice varieties remain.

[41] Shiva, Vandana, Climate Change And Agriculture, February 23, 2011. https://www.countercurrents.org/shiva230211.htm

[42] Scidev.net, India's heirloom rice can supplement infant nutrition, K.S. Harikrishnan, September 27, 2021. https://www.scidev.net/asia-pacific/news/indias-heirloom-rice-can-supplement-infant-nutrition/

The Global Hunger Index, which factors in child stunting, wasting and child mortality, placed India 94th of 107 countries in 2020. H.S. Jat, principal scientist, Central Soil Salinity Research Institute, Karnal, urged scientists to start working on nutritional security by including traditional rice varieties in the crop breeding programme or fortification of widely grown high-yielding varieties of rice to reduce child malnutrition. "Conservation of these neglected and vanishing landraces can help address the problem of under-nutrition in infants. It is imperative to design a constructive roadmap for regional nutrition security by cultivating the nutritionally rich folk rice landraces," he said.

K.T. Chandra Mohan, professor and head of the botany department at Brennen College, Thalassery, Kerala, endorsed the nutritional richness of folk rice. "As monoculture of paddy took root, hundreds of folk varieties disappeared and along with it the associated traditional knowledge," he lamented. Farmer Praseed Kumar Thayyil blamed the 'green revolution' of the 1960s for the loss of heirloom varieties. Worse, over the decades, there has been accumulation of toxic contaminants in the paddy fields, decimation of agro-biodiversity, loss of dietary diversity loss and micronutrient malnutrition.

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Other Adaptation and Mitigation Strategies

The large population dependent on agriculture in India makes the country far more vulnerable to climate change than other nations. Agriculture represented 35 per cent of India's Gross National Product (GNP, 2014). Climate change impacts crop yields as also the types of crops that can be grown in certain areas due to availability of water for irrigation, sunshine, and prevalence of pests.[43]

India needs long term investments in strategic research and new policy initiatives that put adaptation at the centre of development planning. We must first document all indigenous practices by farmers; quantify the adaptation and mitigation potential of existing best practices for different crops and livestock in different agro-ecological zones; and evolve new tools and techniques including crop varieties and management practices that foster adaptation.

Crop based strategies envisage growing crops and varieties suited to the changed rainfall and seasons, development of varieties that adapt to heat stress, drought and floods; evolving varieties give high yields under high CO2. Varieties can be developed that can tolerate coastal salinity and sea water inundation. ***Intercropping:*** if one crop fails due to floods or droughts, the second crop gives some minimum assured returns for livelihood security. The germplasm of wild relatives and local land races could provide a valuable source of climate ready traits. We must use germplasm with tolerance to heat and cold stress but neglected due to low yield potential.

Rainfed agriculture includes soil conservation and drought proofing by rainwater harvesting and recycling, efficient use of irrigation water, energy efficiency in agriculture and use of poor quality water. ***Watershed management*** helps in the development of rainfed agriculture, and includes soil and water conservation works, farm ponds, check dams to moderate runoff

[43] Manzoor, Haris, Climate change-agriculture nexus: Indian scenario, ibid., p. 34.

and minimize floods during high intensity rainfall. The plantation of multi-purpose trees in degraded lands helps in carbon sequestration.

Soil carbon sequestration is an important strategy that can help sequester reasonable quantities of carbon in some cropping systems, especially in high rainfall regions. Cropping systems can be divided into soil carbon sequestration and sequestration in vegetation. Tree-based systems can sequester substantial quantities of carbon into biomass in a short period. Carbon sequestration has been found effective groundnut, finger millet, sorghum, and soybean cultivation.

Zero tillage (ZT) in irrigated areas reduces demand for water in rice-wheat cropping system in the Indo-Gangetic plains. ZT helps to enhance soil carbon, reduce energy inputs and improve water and nutrient use efficiency. However, it needs long term study.

Livestock are an integral part of Indian farms. Crop residue of cereals, pulses and oilseeds serve as fodder, while that of cotton, maize, pigeonpea, castor, sunflower and sugarcane are used as low calorie fuel or burnt to ashes or left to decompose over time. Residue mixed in the soil enhances its physical properties and water holding capacity. However, increased cost of labour and transport has led to disinterest in utilizing biomass.

Biomass based biogas production: Anaerobic digestion processes can convert cattle dung and other agro-industrial wastes into clean renewable energy and organic fertilizer.

Biochar is a carbon rich, fine-grained, porous substance that vastly improves soil fertility and improves soil carbon sequestration.

Agro-forestry systems such as agri-silvi-culture, silvipasture and agri-horticulture are ideal for adaptation and mitigation as they protect farmers from climate variability and reduce greenhouse gases. Agro-forestry can sequester carbon and produce a range of economic, environmental and socio-economic benefits; sequestration can be up to 10 T per hectare per year in short rotation Eucalyptus, leucaena plantations.

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Coping with natural disasters

As natural disasters increase on account of climate change, the National Institute of Disaster Management (NIDM) and the German development agency GIZ, have prepared a report, *Mapping Climatic and Biological Disasters in India*, on what to expect in every district with the objective of mitigating the human and economic costs. Detailing the intensity and locations of disasters over a 25-year period, it offers valuable data for planners and policymakers.[44]

From 1995 to 2020, India suffered 1,058 natural disasters, including floods (33 per cent), heatwaves (24 per cent), droughts (22 per cent), cold waves (16 per cent and cyclones (5 per cent). Bihar suffered the highest number of floods, followed by West Bengal, Assam, Manipur and Tripura.

[44] The Third Pole, India's policymakers get detailed data to help manage disasters, Joydeep Gupta, January 31, 2022. https://www.thethirdpole.net/en/climate/indias-policymakers-get-detailed-climate-disasters-data/

In this 25 year period, droughts affected 33 of India's 36 States and Union Territories. Andhra Pradesh, Telangana and Rajasthan suffered droughts more than 15 times during this period, while Karnataka, Bihar, Chhattisgarh and Odisha faced droughts more than 10 times. Heatwaves affected 27 States and Union Territories; Odisha was the worst affected, followed by Maharashtra, West Bengal and Rajasthan.

Eleven states were hit by cyclones during these years. Andhra Pradesh was worst hit, followed by Tamil Nadu, Odisha and West Bengal. The South 24 Parganas district that includes the Sundarbans, the world's largest mangrove forest, suffered the highest number of cyclones in India.

Around the same time, the India Meteorological Department (IMD) published a detailed Hazard Atlas of India based on comprehensive disaster data from 1967 to 2019. The Atlas examined climate hazards and climate vulnerability in all 748 districts according to the parameters of heat wave, drought, extreme rainfall, flood, cyclone, dust storm, lightning, thunderstorm, cold wave, fog, snowfall, hailstorm and wind hazard.

The NIDM-GIZ report examined the human impacts of floods, droughts, cyclones, heatwaves, all aggravated by climate change, between 1995 and 2020. The findings showed that deaths due to floods were highest in Uttar Pradesh, followed by West Bengal and Bihar. But flood-related deaths per 100,000 people were highest in Arunachal Pradesh, followed by Himachal Pradesh, Sikkim and Andhra Pradesh.

In the case of drought, death due to drought is never medically certified. However, agrarian crisis, increasing debt, migration and farmer suicides are a fallout of drought. Between 1995 and 2020, severe droughts occurred in 2002, 2009 and 2015. Nearly 25 per cent districts in India were drought-hit in 2001, 2004, 2012, 2014, 2016 and 2018. In fact, in 2015-16, India faced one of its most severe droughts in 150 years. India suffered a rainfall deficit of 14.5 per cent in average rainfall, while the Indo-Gangetic plain had a rainfall deficit of 25.8 per cent. The dry spell impacted the winter crops over an area of 29.89 million hectares. The drought lasted for 41 months, till 2018, and affected around 330 million people. The impact on agriculture and the rural population was harsh.

Heatwaves are a direct consequence of climate change in India, and are rising in frequency and intensity. Heatwaves have taken a toll in Andhra Pradesh, Uttar Pradesh, Bihar, Maharashtra, Telangana and Jharkhand. In fact, they are second only to cyclones in terms of climate-related fatalities between 1995 and 2020. Cyclones accounted for 48 per cent of lives lost, heatwaves (26 per cent), floods (18 per cent) and cold waves (8 per cent). Together, they took a toll of 104,311 deaths from 1995-2020.

The report makes important recommendations for enhanced disaster management, including:

• The need for sovereign risk assessments, considering the impacts of climate change, to design and promote suitable financing instruments for the sharing and transfer of risks within and across different geographical areas of India. This recommendation underscores the need to know the economic cost of each disaster.

• The need to create databases on the frequency and intensity of various climatic disasters at the basin and watershed scale, where climate change's impacts on hydrological regimes are

best assessed. This enables planners to design basin and watershed-scale risk prevention and mitigation actions that can be jointly implemented by districts and states. All information is currently collected according to administrative boundaries – this often fails to match physical boundaries, and the information goes awry.

• Sharing experiences and support between states, especially as states that previously were not vulnerable become at risk. For example, Odisha has experience in dealing with cyclones and has effectively reduced mortality, which can be used to enhance the capacity of Maharashtra, which is more likely to be exposed to cyclones in the future.

• Collaboration between ministries so that schemes such as the Mahatma Gandhi National Rural Employment Guarantee programme can be used to improve resilience to climate-induced disasters in India.

• Systematic collection of data on disaster impact – especially on and including economic impacts – by India's Central Statistical Organisation, so that there is better understanding of scale and types of impacts in a changing climate.

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Oilseeds

Indian agriculture is lagging behind in the production of oilseeds, pulses and coarse cereals, all of which have a vital role in food nutrition. Vegetable oils contain essential nutrients that are critical for growth and metabolism, protecting brain cells, reducing risk of heart disease, etc. Since the 1990s, India has become one of the largest importers of edible oils in the world. This is despite the fact that India produces around 10 per cent of the world oilseeds, 6-7 per cent of global production of vegetable oil, and nearly 7 per cent of protein meal. Oilseed crops cover approximately 26.5 million ha. of farmland. The Oilseeds sector thus has major potential to augment farm incomes and improve national self-sufficiency in edible oils, besides sharply slashing the import bill. In 2020-21, edible oil imports rose 63 per cent and cost Rs. 1.17 lakh crore.[45]

The various oilseed crops in different agro-climatic regions include groundnut, soybean, rapeseed-mustard, coconut, sesamum, sunflower and safflower, rice bran, niger seed, castor, and linseed (primary source), cottonseed, solvent extracted oil, tree and forest origin oil.

Prime Minister Narendra Modi moved to harness the potential of the oilseed sector by launching the National Edible Oil Mission-Oil Palm (NMEO-OP) on August 9, 2021.[46] India annually consumes 22 million tonnes of edible oils, and imports nearly 15 million tons (68 per cent) to meet the demand. Of this, palm oil accounts for 9 million tonnes (60 per cent) of total import of edible oils.

To achieve the goal of self-sufficiency in oilseeds production, the Union Ministry of Agriculture and Farmers Welfare distributed free high yielding varieties of seeds to farmers for kharif season 2021 in the form of mini-kits. It hoped that the special kharif program will

[45] ET, Edible oils import up 63 pc to Rs 1.17 lakh crore in 2020-21, November 16, 2021. https://economictimes.indiatimes.com/news/economy/foreign-trade/indias-vegetable-oil-imports-cost-a-record-15-7-billion/articleshow/87734197.cms?from=mdr

[46] The Times of India, Achieving self-sufficiency in edible oils, Dr. Prashant Prabhakar Deshpande, September 22, 2021. https://timesofindia.indiatimes.com/blogs/truth-lies-and-politics/achieving-self-sufficiency-in-edible-oils/

bring an additional 6.37 lakh hectares under oilseeds and yield 120.26 lakh quintals of oilseeds and edible oil amounting to 24.36 lakh quintals (the data is not yet available).[47]

The Centre aims to triple the domestic production of palm oil, up to 11 lakh million tons by 2025-26, by increasing the area under oil palm cultivation to 10 lakh hectares by 2025-26, and 16.7 lakh hectares by 2029-30. The focus will be on India's north-eastern states and the Andaman and Nicobar Islands as their weather is conducive to the crop.

The latest data available data suggests that each Indian consumed 19.5 kg of edible oil every year on an average during 2015-16, whereas it was 15.8 kg in 2012-13. This indicates an aggregate demand of around 26 million tons of edible oils per year. In 2018-19, India cultivated oilseeds on 25 million hectares, producing 32 million tons of oilseeds (mainly soybean, rapeseed and mustard, and groundnut). This would yield around 8.4 million tons of edible oil (30 per cent of domestic demand), on a country-wide average of 28 per cent oil recovery.[48]

In 2019, India imported around 15 million tons of edible oils (mainly palm oil), which accounted for 40 per cent of the agricultural imports bill. Palm oil alone amounted to 62 per cent of total imports, followed by soya oil (21 per cent) and sunflower oil (16 per cent). Palm oil is mainly imported from Indonesia and Malaysia, soya oil from Argentina and Brazil, and sunflower oil from Ukraine and Argentina. Besides draining the exchequer, dependence on the international market causes price volatility and impacts both consumers and producers. Thus, labour shortage in palm oil plantations of Indonesia and Malaysia, drought in Argentina affecting soybean production, decreased production of sunflower crops in Ukraine and heavy buying of edible oils by China affected the price of edible oils in domestic and international markets in 2020. The government reduced the import tariff on palm oil by 10 per cent in November 2020 to calm the domestic market.

However, India has the potential to increase domestic production of oilseeds. In 2018-19, the Technology Mission on Oilseeds and other initiatives helped to increase the area under oilseeds to 32 million tons. This could not satisfy the domestic demand, but was a sharp rise from 9 million tons in 1986. The government also launched schemes such as Oil Palm Area Expansion under Rastriya Krishi Vikas Yojana; increased minimum support prices of oilseed crops; created buffer stock for oilseeds; cluster demonstration of oilseed crops, etc., to boost domestic output.[49]

With improved quality seeds, optimum use of agro-chemicals and better management, around 3.6 million tons of additional oils can be produced, assuming 1.5 tons per ha is realizable yield. Improved varieties like Pusa 12, JS 20-34 of soybean, pusa double zero 30 and 31 of mustard (low erucic acid and high yielding), newer, location specific improved varieties like Kadiri-6, Chattisghar Mungfali 1 (CGM 1) have been released for cultivation. The government needs to spread awareness about these new varieties and promoted extension work in this area. It would take at least one decade to gauge the progress made under the new initiatives.

[47] The Hindu, Why India is not self-sufficient in oilseed production, Radheshyam Jadhav, September 12, 2021. https://www.thehindubusinessline.com/data-stories/deep-dive/why-india-is-not-self-sufficient-in-oilseed-production/article36418723.ece

[48] Down to Earth, How India can be 'atmanirbhar' for edible oil production, Girish Kumar Jha, Renjini V.R., Aditya K.S., February 12, 2021. https://www.downtoearth.org.in/blog/agriculture/how-india-can-be-atmanirbhar-for-edible-oil-production-75517

[49] Down to Earth, How India can be 'atmanirbhar' for edible oil production, ibid.

Use of fallow land can increase the area under oilseed crops. India has 11.7 mha of rice fallow, which can be used for safflower and mustard crops that don't need much water.[50] Rice bran oil, a byproduct of the paddy crop, has gained acceptance among urban consumers as it is known to reduce the risk of heart diseases and type 2 diabetes. Rice bran comprises around 8.5 per cent of the total production of rice and has around 15 per cent content. It can yield around 2 million tons of edible oil.

Oil palms yield 4 to 5 tons of edible oil per ha, compared to around 1 ton/ha of traditional oil seeds. Studies show that India has the potential to increase the area under oil palm by 1.9 million hectares, which can produce around 7.6 million tons of additional edible oil (Ministry of Agriculture, 2018). However, palm oil has a long gestation period, harvesting the crop is challenging, and it is a water guzzling crop.

Girish Kumar Jha et al point out that frequent change in tariff to manage the demand-supply situation and domestic prices is a poor strategy and that India will gain by having a stable export-import policy. This will encourage farmers to increase domestic production of edible oilseeds.

Data for crop-wise coverage of irrigated area (2016-17) shows that oil seeds coverage of the irrigated area is 27.8 per cent. Oil seed production has risen slowly, and the average per hectare yield of major oilseeds is over 50 per cent lower than average world yields in several crops.[51] The Solvent Extractors Association of India (SEA) is demanding higher Minimum Support Price (MSP) for oilseeds, so that more farmers take to oilseed cultivation. Industry members point out that India's domestic oilseed production must rise by 54 MT by 2025 to reduce edible oil imports by 10 MT annually.

The Ministry of Consumer Affairs, Food, and Public Distribution estimates the total domestic demand of edible oils at around 250 lakh metric tonnes per year, of which 60 per cent is met by imports, mainly palm oil from Indonesia and Malaysia. "As the country has to depend heavily on imports to meet the gap between demand and supply, the international prices have an impact on domestic prices of edible oils," the Ministry stated in June 2021.[52]

The import bill for agricultural commodities in 2019-20 was $19.91 billion, of which the vegetable oils bill was 48 per cent. In May 2021, the Central government called all stakeholders to discuss the stability of edible oil prices. The government admitted that dependency of almost 60 per cent on imports inhibits the growth of the edible oil industry and contributes to food inflation.

Deepak Chavan, an agriculture market expert, observed that, "As of now, there is no comprehensive strategy when it comes to the production of oil seeds. Farmers cultivate as per the trends in the market rate. But when there is bumper production, the government imports oils and other products which results in a fall in prices." He said government must prepare a plan regarding cultivation, marketing and import-export, as the current ad-hoc strategy hurts farmers.

[50] Down to Earth, How India can be 'atmanirbhar' for edible oil production, ibid.
[51] The Hindu, Why India is not self-sufficient in oilseed production, op. cit.
[52] The Hindu, Why India is not self-sufficient in oilseed production, ibid.

S.B. Wankhede, advisor, Seed Industry Association of Maharashtra, concurred that, "Policy is the major problem when it comes to increasing seed oil production. For years, farmers produced groundnuts and sunflower but with unseasonal rains and pests, they have turned to soya. Thus, we must have a micro-level plan with technological support."

It is significant that until 2007-08, India's edible oil production exceeded its imports, due to the Oilseeds Mission in the 1980s and 1990s. However, low import duty led to palmolein flooding the market and discouraged farmers from growing oilseeds. Oilseed cultivation must be made remunerative for farmers by checking cheap imports and giving fair prices to oilseed producers. This will also provide poor consumers access to healthy edible oil through public distribution system (PDS).

Experts point out that on at least 2 million hectares of paddy land in India, which remains fallow after the monsoon season of paddy cultivation, relay cropping of mustard using residual moisture could yield an additional 3.5 to 4 million tonnes of rapeseed-mustard. This has been tried in non-conventional mustard-growing areas.[53] Further, large scale adoption of System of Crop Intensification (SCI) will increase productivity and reduce water consumption and cultivation costs. The System of Mustard Intensification is yielding results in Bihar and Madhya Pradesh

Recommendations

Natural farming so far covers over 6.5 lakh hectares of agricultural land in 11 states, of which Andhra Pradesh takes the lead with 2.15 lakh hectares, followed by Gujarat (1.17 lakh hectares) and Madhya Pradesh (99,000 hectares). But this is clearly not enough and India needs to vastly scale up natural farming across the country.

Natural farming can be supplemented by organic farming. There is very little difference between natural farming and organic farming, as the purpose of organic farming is to quickly transition to natural farming that does not need any external inputs outside the farmstead (also called zero budget farming). Currently, however, organic farming makes use of externally purchased inputs such as bio-fertilisers and vermi-compost. Such farmers can transition to natural farming methods with training and support from agriculture extension workers and/or NGOs. Hence, organic farming can help scale up the transition to non-chemical farming.

Natural farming is scientific. It is now widely acknowledged that the presence of earthworms and other micro-organisms in soil contribute to soil fertility in ways that cannot be quantified. India has to spend Rs 1.25 lakh crore annually to subsidize urea because chemical fertilisers kill the soil micro-organisms that increase organic carbon in soil. This can be seen from the fact that the use of fertilisers in India rose from 12.4 kilogram per hectare in 1969 to 175 kilogram per hectare in 2018. The depletion of organic carbon in soil has been commensurate; its impact on food nutrition has not been adequately quantified, but in increasingly concerning nutritionists and health workers.

India should therefore

[53] Kuruganti, Kavitha, Improving India's oilseeds production, August 23, 2016. https://www.downtoearth.org.in/blog/agriculture/improving-india-s-oilseeds-production-55366

– Promote natural/organic farming across the country via the Paramparagat Krishi Vikas Yojana and National Project on Organic Farming, on a war footing.

- Begin with natural farming in rainfed areas as farmers in rainfed regions use only a third of fertilisers per hectare compared to irrigated areas. This will facilitate the transition to chemical-free farming. Farmers in tribal communities that depend wholly on rainfed agriculture have a high degree of interest in natural farming.

- Help farmers transitioning to chemical-free farming to enroll in the government's crop insurance scheme, India Fasal Bima Yojana (PMFBY). Changes in farming practices, including crop diversification, increase the farmer's risk and should be covered.

- Promote microenterprises that produce inputs for chemical-free agriculture, as the non-availability of natural inputs impedes the movement towards chemical-free agriculture. Government must note that every farmer does not have the knowledge or labour or time to develop his own inputs. Setting up village-level input preparation and shops in every village could provide livelihood to thousands of youth.

- The Council on Energy, Environment and Water (CEEW) estimates that nearly five million farmers are already engaged in natural or sustainable farming across the country. They are being supported by hundreds of NGOs. Both these farmers and NGOs should be encouraged to teach others through on-field demonstrations in order to increase chemical-free agriculture.

- Agricultural universities must evolve curriculum for natural farming and sustainable practices, and enhance the skills of the agriculture extension workers in this regard.

- Community institutions must be utilised to spread awareness in this regard. In fact, an ecosystem should be developed so that farmers can learn from and support each other.

- There should be support monitoring and impact studies on all methods of sustainable agriculture.

- The Government's ambitious plans for millet promotion must be embedded with the goal of sustainable agriculture.

Ultimately, India must achieve the goal of an entirely chemical-free food system.

END

CASE STUDY ONE: Sustainable farming in India

The term "organic farming" entered popular consciousness with Rachael Carson's *Silent Spring* (1962). Through the 1960s and 1970s, awareness grew of the importance of organic food for human and environmental health, and promoted the growth of an organic industry along with organised marketing and certification agents for quality assurance.[54] In India, the first national meeting of promoters and practitioners of organic farming was held at Gandhi's Sevagram in 1984. The *Organic Farming Source Book* (Other India Press) discusses India's organic farming movement that resulted in the creation of the Organic Farmers Association of India (OFAI).[55]

The term "sustainable agriculture" gained currency in the United States in the 1980s after it was mentioned in US legislation in 1985. It led to a programme on Low Input Sustainable Agriculture (LISA). In 1990, the US Congress formally defined 'sustainable agriculture' under the law. In India, the central government launched the National Mission for Sustainable Agriculture (NMSA) in 2014-15, wherein sustainable agriculture was defined in ten dimensions.[56]

"Regenerative agriculture" has acquired acceptance in the past decade in the context of concerns about climate change. It encompasses ecological restoration, soil conservation, carbon sequestration in the topsoil, and improving biodiversity. It is claimed that sustainable agriculture merely sustains the status quo, while regenerative agriculture aims to restore our fast degrading ecological systems. The terms sustainable agriculture or agroecology are preferred by governments and intergovernmental organisations whereas civil society bodies use regenerative agriculture.

The origins of natural farming origins can be traced to Mokichi Okada who mooted the concept of "nature farming" in 1935 and was the first to introduce farming without fertilizers and pesticides.[57] Masanobu Fukouka popularised the term *shizen noho* (natural farming in English), but it is undeniable that natural farming techniques have always been followed in different parts of the world.

Agronomist Basil Bensin contributed the term "agroecology" at the turn of the twentieth century to indicate ecological methods used in agriculture.[58] Later, Tischler published *Agrarökologie* (agroecology) that combined ecology and agronomy for integrated agricultural management. After the concept of "agroecosystems" was introduced by the U.S. biologist, Eugene Odum, agroecology expanded to include whole agroecosystems. In the 2000s agroecology further expanded to include entire food systems, economic and social

[54] Kuepper, P. 2010. "A Brief Overview of the History and Philosophy of Organic Agriculture. Kerr Center for Sustainable Agriculture. http://kerrcenter.com/wp-content/uploads/2014/08/organic-philosophy-report.pdf.

[55] Council on Energy, Environment and Water (CEEW), Sustainable Agriculture in India 2021: What We Know and How to Scale Up, Niti Gupta, Shanal Pradhan, Abhishek Jain, and Nayha Patel, April 2021.

[56] Department of Agriculture & Co-operation. 2014. "National Mission for Sustainable Agriculture Operational Guidelines." New Delhi. https://nmsa.dac.gov.in/pdfdoc/NMSA_Guidelines_English.pdf.

[57] 3. Miyake, Y., and Kohsaka, R. 2020. "History, ethnicity, and policy analysis of organic farming in Japan: When nature was detached from organic". In Journal of Ethnic Foods (Vol. 7, Issue 1, p. 20). BioMed Central Ltd. https://doi.org/10.1186/s42779-020-00052-6

[58] Wezel, A., & Soldat, V. 2009. "A quantitative and qualitative historical analysis of the scientific discipline of agroecology". International Journal of Agricultural Sustainability, 7(1), 3–18. https://doi.org/10.3763/ijas.2009.0400.

dimensions.[59] Civil society groups promoted agroecological movements like *La Via Campesina* (the peasants' way), and Rede Ecovida (Ecovida network) in Southern Brazil.

Green Revolution-led agriculture in a climate changing world

The Green Revolution dominated Indian agriculture in the twentieth century. An input-intensive and technology-focused approach helped India avert potential famines and meet its food security needs by reducing food imports. While the Green Revolution ensured India's self-sufficiency for our cereal needs and touched most Indian farmers, its long-term impacts are now visibly evident.

The chemical inputs (fertilizer, pesticides) led to the degrading of topsoil, declining groundwater levels, contaminating water bodies, and reducing biodiversity. Crop yields could not sustain themselves without increased fertiliser use. Fragmented land holdings and associated low farm incomes pushed many smallholders towards non-farm economic activities. There is now growing realisation that input-intensive agriculture is both a contributor and a victim of climate change.

As more and more extreme climate events (acute and frequent droughts, floods, desert locust attacks) are reported, ground reports hint at the solution via sustainable agriculture. In Andhra Pradesh, during the Pethai and Titli cyclones of 2018, crops cultivated through natural farming showed greater resilience to heavy winds than conventional crops.

Sustainable agriculture is a dynamic concept with a range of meanings and practices. Of these, agroecology covers all three dimensions of sustainability—economic, environmental, and social. It involves less resource-intensive farming solutions, more diversity in crops and livestock, and allows farmers to adapt to local circumstances.

This study found that sustainable agriculture is not the norm in India. Barring a few exceptions, most Sustainable Agriculture Practices (**SAPSs**) have less than five million (or four per cent) farmers practising them. Many SAPs are followed by less than one per cent of total Indian farmers.

Crop rotation is one of the most popular SAPS across the country and covers nearly 30 million hectares and 15 million farmers. Larger farmers follow agroforestry and rainwater harvesting. There is, however, little information regarding mulching (covering the top soil with straw, dead leaves, or cover crops like clover) that prevent evaporation of water, though one stakeholder claimed that it covers an area of about 20 million ha.

Around nine million ha of land is under precision farming, mostly micro-irrigation, under the auspices of the National Mission on Micro Irrigation. Only five million ha is covered under Integrated Pest Management though the program has been promoted for decades. Intercropping is more common in the southern and western regions and covers nearly one million ha; this does not include intercropping areas in horticultural crops.

Despite government policy support, organic farming currently covers only two per cent of the country's total net sown area (140 million ha). India has about two million certified organic

[59] Wezel, A., Bellon, S., Doré, T., Francis, C., Vallod, D., & David, C.2009. "Agroecology as a science, a movement and a practice. A review". Sustainable Agriculture, 2(December), 1–991. https://doi.org/10.1007/978-94-007-0394-0.

producers, but reliable information about uncertified organic farmers is not available. Biodynamic agriculture, a variant of organic farming, has an estimated coverage of 0.1 million ha (where biodynamic inputs are explicitly used along with organic farming practices). Natural farming has witnessed a faster rate of adoption in the last two to three years. Close to one million farmers practice natural farming, mostly in Andhra Pradesh, Karnataka, Maharashtra, and Himachal Pradesh. The associated area is about 0.7 million ha as it has been mainly popular among small and marginal farmers so far. The popularity of the system of rice intensification (SRI) has also rapidly increased in the last five years, with an estimated area of around 3 million ha across the country. The area under partial conservation agriculture (CA) is estimated to be around 2 million ha, mostly in a few states in the Indo-Gangetic Plains (IGPs).

Impact literature on India's sustainable agriculture

From the systematic review of literature, we find that agroforestry, CA, and SRI are the most popular among researchers assessing the impact of SAPSs on various outcomes. In contrast, the impact evidence around permaculture and floating farming in the Indian context is almost non-existent. The impact evidence of biodynamic agriculture is also very limited currently. Regarding different areas of outcomes, most of the SAPSs have many publications focusing on environmental indicators followed by economic and social ones. However, organic farming, natural farming, and integrated farming systems have many publications focused on economic outcomes.

• The literature critically lacks long-term impact assessments of SAPSs across all three sustainability dimensions. Short-term (0.5 – 3 years long) assessments mainly dominate the literature. These are not helpful to understand the long-term impacts of transitioning to SAPSs. Few practices, such as CA, have long-term impact studies, primarily focused on environmental outcomes in Indo-Gangetic plains'.

• Impact studies are mostly limited to plot-level trials, while assessments at a landscape /regional /agroecological-zone level are mostly missing, except for agroforestry. We find that the cost of long-term and larger studies is the biggest reason for these research gaps.

• Most publications evaluate a SAPSs impact on only a single dimension of interest (such as water, soil, gender, or yields).

• Yields, income, soil health, and water find the most interest as a subject area among researchers across all the three sustainability dimensions. Impacts of SAPSs on biodiversity, ecosystem services, health, and gender are least researched.

• Conventional approaches to measuring farm productivity are often not adequate for SAPSs. For yields, the studies tend to compare a single crop yield between sustainable and conventional practices. Crop-diversification through inter-cropping or multi-cropping is common under various SAPSs, and the productivity discussions in literature often ignore outcomes across other crops. Similarly, various SAPSs commonly promote livestock integration, but the evidence capturing total farm productivity, including livestock output, is limited.

Sustainable agriculture's impact evidence in India

• Income: The evidence around SAPSs' impact on farmers' incomes remains insufficient, both in terms of geographical coverage as well as the number of long-term assessments. Notwithstanding this critical limitation, the literature indicates the potential of a few SAPSs to enhance income through a reduction in production costs (CA, natural farming), diversification of agricultural production (IFS, intercropping), and premium prices (organic produce).

• Yields: Notwithstanding the conceptual limitations to adequately estimate farm productivity, we find some emerging patterns for yields under a few SAPSs. For organic farming, at least in the short-term (2-3 years), yields are lower than conventional farming. Beyond this period, some studies show equal and even higher yields for some crops, particularly once the soil form and structure evolve after a few years of applying biological inputs. The short-duration studies of natural farming indicate no statistically significant changes in yields for most crops. For SRI, yield impacts are well documented, showing a statistically significant increase in various paddy varieties. Resource-conserving practices, such as vermicomposting, agroforestry, and crop diversification, have positively impacted yields. However, the lack of studies documenting the long-term impacts of SAPSs on yields makes it difficult to generalise results.

• Water-use: Several studies in literature capture the impact of various SAPSs on water-use efficiency. In particular, SRI, CA, precision farming, rainwater harvesting, contour farming, cover crops, mulching, crop rotation, and agroforestry have positively impacted water conservation. Rainwater harvesting and SRI appeal to smallholder farmers because of their ease of adoption. Pre-monsoon dry sowing in natural farming is considered a breakthrough in the drought-prone regions of Andhra Pradesh, warranting further assessments.

• GHG emissions: Among SAPSs, agroforestry, SRI, and CA have the most evidence for climate mitigation. Evidence associated with agroforestry's carbon-sequestering abilities (above and below ground) is well established. A growing body of evidence suggests that the SRI promotes aerobic soil conditions reducing methane emissions. However, intermittent irrigation, an intrinsic component of SRI, can increase nitrous oxide emissions. Overall, long-term carbon sequestration impacts of the SAPSs need evaluation in India.

• Biodiversity: Several SAPSs like agroforestry, IFS, permaculture, natural farming, organic farming, conservation agriculture, and crop diversification strategies (rotation, intercropping, mixed) tend to increase the spatial, vertical, and temporal diversity of species at a farm (and landscape) level. While research articles mention the impact on biodiversity, studies offering substantive empirical evidence are missing.

• Health: We only find anecdotal evidence mentioning positive health impacts of various SAPSs, mainly through dietary diversity and less exposure to harmful chemicals such as pesticides. Empirical studies comparing SAPSs with conventional agriculture for health outcomes are missing.

• Gender: Women contribute more than 70 per cent of the labour force in Indian agriculture. However, research studies focusing on gender outcomes of SAPSs are minimal. A few practices like vermicomposting, organic farming, IFS, and rainwater harvesting define women's roles, but the evidence on women's impact is missing. We need further research to

understand the impact of various SAPSs on women's workloads, income, empowerment, and employment.

Policy ecosystem for sustainable agriculture in India

Since 2014-15, India has had a National Mission for Sustainable Agriculture (NMSA) to promote sustainable agriculture. It consists of several programmes focusing on agroforestry, rainfed areas, water and soil health management, climate impacts, and adaptation. Beyond NMSA, the Pradhan Mantri Krishi Sinchai Yojana promotes the adoption of precision farming techniques such as micro-irrigation, and the Integrated Watershed Management Programme supports rainwater harvesting.

However, merely 0.8 per cent of the Ministry of Agriculture and Farmers Welfare (MoAFW) budget is allocated to NMSA. Beyond the INR 142,000 crore (USD 20 billion) budget of MoAFW the Central government also spends about INR 71,309 crore (USD 10 billion) annually on fertiliser subsidies.1 So, while the Indian government recognises the importance of promoting sustainable agriculture, the focus remains heavily skewed towards green revolution-led farming.

Among SAPSs, eight of the 30 practices receive some budgetary support under various Central government programmes. These include organic farming, integrated farming system, rainwater harvesting, contour farming (terraces), vermicomposting, mulching, precision farming, and IPM. Among these, organic farming has received the most policy attention as the Indian states have also formulated exclusive organic farming policies.

Civil society action on sustainable agriculture in India

Similar to the policy side, organic farming gets the most interest among CSOs. Whereas very few CSOs deal with precision farming, integrated farming systems, and biodynamic agriculture.

Across States, Maharashtra is the most popular among the CSOs. Rajasthan, Madhya Pradesh, and Odisha are the next in order. We find very few CSOs active in states like Punjab and Haryana.

These CSOs provide various support to promote SAPSs, including training, capacity building and awareness generation of farmers, support for inputs preparation and seed management, field demonstration activities. A few are also involved in technology transfer.

Key emerging themes in India's sustainable agriculture

This section discusses the key cross-cutting themes that emerged during our research and are central to the discussion on sustainable agriculture in India.

• The role of knowledge: Most SAPSs are knowledge-intensive and need knowledge exchange and capacity building among farmers to enable their successful adoption.

• The reliance on farm-labour: Given the practices are niche, the mechanisation for various input preparations, weed removal, or even harvesting in a mixed cropping field is not mainstream yet – increasing the reliance on labour for various on-field activities. Labour

intensiveness may pose a barrier to the adoption of some of the SAPSs among medium to large farmers.

• Motivation to adopt SAPSs: First, conventional agriculture's long-term negative impacts are pushing farmers to look for alternatives. Second, where farmers are in a resource constrained environment, such as rain-fed areas, and not using significant external inputs, anyway, and hence are willing to make the incremental shift to adopt SAPSs.

• SAPSs' role in food and nutrition security: Most SAPSs promote crop and food diversity through intercropping, mixed cropping, crop rotation, agroforestry, or IFS. One, it improves the farmer's food security by diversifying their food and income sources. Secondly, by improving the diversity of available nutrition, it enhances the nutrition security for agriculture families which could possibly solve the country's underlying malnutrition problems. However, both these aspects are hardly studied in the available literature and thus warrant future research.

Way forward to scale-up sustainable agriculture in India

Based on the gathered insights, we propose the following next steps towards an evidence-backed scale-up of sustainable agriculture in India.

- Focus on knowledge exchange and capacity building among farmers and agriculture extension workers on SAPSs. Leveraging and building on the extensive prevailing on-ground CSO capacity would be a great first step.
- Restructure the government support to farmers. Instead of encouraging resource intensive cultivation through inputs-based subsidies, align incentives towards resource conservation while rewarding outcomes (such as total farm productivity, enhanced ecosystem services) and not merely outputs such as yields. It will allow a multitude of farming approaches, including SAPSs, to flourish.
- Support rigorous evidence generation through long-term comparative assessment (between resource-intensive and sustainable agriculture) in view of changing-climate to inform long-term resilient approaches to nutrition security. It would help enable an evidence-backed and context-relevant scale up of SAPSs.
- Broaden perspectives of stakeholders across the agriculture ecosystem to consider alternative approaches, as they are only exposed to resource-intensive agriculture for the last six decades. A suite of strategies spanning evidence-driven narratives to on-ground field visits would help.
- Adopt transition support plans to extend short-term transitionary support to those who would get adversely impacted by a large-scale transition to sustainable agriculture.
- Make sustainable agriculture visible by integrating data and information collection on SAPs in the prevailing agriculture data systems at the national and state level. In the absence of reliable data, it is difficult to ascertain the scale and extent of sustainable agriculture in India.

Conclusion

While states like Sikkim and Andhra Pradesh are leading the way on sustainable agriculture in India, the adoption remains on the margins at an all-India level. Likewise, the impact evidence about its outcomes on the economic, social and environmental front is limited. At one end, we must generate more long-term evidence. Alongside, we should leverage existing

evidence to scale-up context-specific SAPSs. The scale-up could start with rainfed areas, as they are already practising low-resource agriculture, have low productivities, and primarily stand to gain from the transition. As the positive results at scale would emerge, farmers in irrigated areas will follow suit.

At the budgetary level, significantly increase allocation to sustainable agriculture enabling its evidence-backed scale-up across the country. At the tactical level, focus on region- and practice-wise priorities, which span a wide variety: from technological innovation to help mechanise labour-intensive processes to farmers' capacity building in knowledge-intensive practices.

Finally, broaden the national policy focus from food security to nutrition security and yield to total farm productivity. It would help recognise the critical role that sustainable agriculture could play to ensure India's nutrition security in a climate-constrained world.

[Council on Energy, Environment and Water (CEEW), Sustainable Agriculture in India 2021: What We Know and How to Scale Up, Niti Gupta, Shanal Pradhan, Abhishek Jain, and Nayha Patel, April 2021]

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CASE STUDY TWO: ICAR on Climate Change and Indian Agriculture

Climate and agriculture are globally interconnected and even a minute change in climate adversely impacts agricultural production. Currently, the world is experiencing extreme climate changes with increase in average atmospheric temperature. In 1972, the Club of Rome Report officially confirmed that global warming is an international issue; the World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP) declared Carbon dioxide (CO2) the main contributor to global warming and climate change.

Climate Change: Global Status

The global climatic system is experiencing several long-term changes. The direct solar radiations striking the earth's surface are being trapped by Green House Gases (GHGs) like carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), etc., and causing global temperatures to rise. The CO2 levels have reached up to 410 ppm and are causing a warming effect.

Climate change causes rising sea levels, more frequent extreme weather conditions, changes in precipitation and expansion of deserts. By 2100, the mean global sea levels are projected to rise from 18 cm to 140 cm (IPCC, 2007). In 2019, several parts of Europe registered highest temperatures over the past 100 years. South Asian countries have faced devastating floods, cyclones, droughts, storms, heat waves, melting of glaciers, changes in pattern and rate of precipitation, decline in agricultural productivity, shortage of fresh water, damage to ecosystem and environment, etc.

To combat/reverse these impacts, the Marshall Island pledged to minimize the Carbon (C) emission rates by 32 percent by 2025 with net total of zero emissions by 2050 (Saddington and David, 2016). The Bangladesh government has reported that around 68,51,147 people were affected due to tidal wave of heavy storm of about 150 km/hr with a 20 feet height (Islam and Nazrul, 2008).
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The United Nations Office for Disaster Risk Reduction (UNISDR) (2018) stated that during 1998-2017, disaster-hit countries experienced direct economic losses to the tune of US$ 2908 billion, of which 77 percent were due to climate related disasters. Climate change impacts are more pronounced in the agriculture sector; the Government of India's economic survey (2018) estimated that the annual loss of US$ 9-10 billion was due to the adverse effects of climate change.

Climate Change Impacts in South Asia and India

Floods: In 2008, millions of people were displaced by floods in Bihar. About 20 million people were similarly affected in Mumbai in 2005. In Delhi and Haryana, property worth millions was destroyed when the Yamuna river rose above the danger mark in 2008. Kerala experienced its worst floods in 2018 due to unusually high rainfall. Computer Science Engineering (CSE): FACT 17 predicted that the western semi-arid zones of India would receive higher maximum rainfall than normal, while central India would suffer rainfall reduction of 10 to 20 per cent during winter by 2050s. some years ago, Chennai city was flooded, but in 2019, it underwent a severe drinking water crisis that caused large scale migrations.

The Maldives islands are threatened by climate change. Future sea levels may rise by 10-100 cm by 2100 and submerge the entire Maldives island chain.

Droughts: Arid regions in South Asia, including dry regions of Rajasthan in India and some regions of Pakistan, are facing severe drought. Western Rajasthan, parts of Haryana, Uttar Pradesh, Maharashtra, Southern Bihar, Madhya Pradesh, Southern Gujarat, Northern parts of Andhra Pradesh, and Karnataka frequently face dryness and are highly vulnerable to drought (Bhadwal et al., 2007). The arid and semi-arid zones are vulnerable to the losses of economic activities and livelihoods due to the changes in rate of precipitation.

Extreme Events (Cyclones and storms): South Asian countries are badly afflicted by storms, cyclones, landslides, etc. nearly nine million people in the world were severely affected by fierce cyclones, per (UN assessment. The super cyclone that hit Odisha in 1999 took over a million lives and cause extensive damage to properties in the coastal areas (Ahluwalia and Malhotra, 2006). Andhra Pradesh was similarly affected by Hud-Hud cyclone in 2014.

Heatwaves: The frequency and intensity of heat waves are affecting allied sectors of agriculture, namely, dairy, poultry, fishery, etc. Low water availability is causing a drinking water crisis for humans and livestock, and damaging horticulture orchards. India and its neighbouring countries experienced a severe and prolonged heatwave from mid-May to mid-June in 2019. Chiru in Rajasthan experienced record temperatures up to 50.8° C (123.4° F). As of 12 June 2019, the second largest heatwave period (32 days) ever was documented.

Melting of glaciers: South Asia may also be affected by melting of glaciers and snow in the Himalayan regions. This will impact the fresh water stock and survival (Bajracharya, et.al. 2007). Satellite data shows that the rate of retreat of the 30 km long Gangotri Glacier in the last 30 years has been more than threefold the rate of the past 200 years (Rao, 2007).

Sectoral Impacts of Climate Change

Agriculture is livelihood for 50 percent of India's population. Agriculture and allied sectors contribute 15.4 per cent of Indian GDP (OECD, 2017). As crops are selected on the basis of soil, climate, and resource availability, production is critically dependent on weather (Srinivasarao et al., 2016a; Bal and Minhas, 2017). Changes in temperature, precipitation and solar radiation impact the agriculture ecosystem, including livestock, arable land and hydrology, affecting small and marginal farmers.

Sector-wise Effects of Climate Change in Agriculture

Field crops: by the mid-21st century, an average of 30 per cent decrease in crop yields is likely in South Asian countries. North Indian states and Bangladesh are vulnerable due to erratic changes in rainfall and temperature (World Bank, 2008). In India, an increase in temperature by 1.5° C and decrease in precipitation of 2 mm, reduces rice yields by 3 to 15 percent (Ahluwalia and Malhotra, 2006). Green House Gases (GHGs) also affect yields and productivity of crops. Drastic changes in climate affect the growth of pathogens that help the growth and yields of crops and can increase pest and insect population which disrupt overall productivity.

Horticulture: Vegetable crops when exposed to extreme high temperatures suffer very high transpiration losses; fruit setting in citrus fruits is affected. High temperature causes burning or scorching of blossoms, especially on young trees. High temperature induces moisture stress causing sunburn and cracking symptoms in fruit trees like apricot, cherries and apples. Temperature rise at ripening stage causes fruit burning and cracking in litchi plantation (Kumar and Kumar, 2007). Most vegetable crops are affected by flooding, particularly tomato. Crops are also damaged by accumulation of endogenous ethylene (Drew, 1979). If the ozone concentration reaches to >50 ppb/day, vegetable crop yields are reduced by 5 to 15 percent (Raj, 2009).

Livestock, Poultry and Fishery sectors: Global climate changes affect animal health, adaptability and reproduction. Higher temperatures abruptly change the animal's body physiology (Pereira et al., 2008) such as rise in respiration rates (> 70-80/minute), blood flow and body temperature (>102.5º F). In Bangladesh, decrease in livestock production due to diseases, lack of forage, heat stress and breeding strategies caused huge economic losses (Chowdhury and Monzur, 2016). Erratic changes in weather conditions directly impact the production level of animals by 58 per cent and reproduction by 63.3 per cent (Singh et al., 2012). Dairy breeds are more vulnerable to heat stress than meat breeds. An increase in metabolic heat production in higher milk producing breeds leads to higher susceptibility to heat stress; while the low milk producing animals are resistant (Dash et al., 2016). Increase in temperature and temperature-humidity index value beyond the critical threshold level reduces the dry matter intake and milk yield.

Poultries are extremely sensitive to temperature-related issues, especially heat stress. Endocrinological changes caused by prolonged heat stress in broiler chickens enhance lipid accumulation, reduced lipolysis, and induced amino acid catabolism (Geraert et al. 1996). Due to heat stress, feed intake of poultries will be reduced (Deng et al., 2012), which leads to less body weight, egg production and quality of meat, and also reduces the thickness of eggshell and increases egg breakage (Lin et al., 2004). Heat stress has negative effect on strength, weight, ash content and thickness of the eggshell (Miller and Sunde, 1975).

Rising environmental temperature may cause seasonal improvement in growth and development of fishes, but increases the risks to the populations living beyond the thermal tolerance zone (Morgan et al., 2001). The rise in temperature of 1°C will affect the mortality of fish and its geographical distribution (Vivekanandan et al., 2009). The temperature rises of 0.37° C to 0.67° C alter the pattern of monsoon seasonal variations, eventually shifting the breeding period of Indian main carps from June to March in West Bengal and Orissa's fish hatcheries (DARE/ICAR Annual Report, 2008-09).

Adaptation Strategies Combating Climate Change

The most important driver to climate change adaptation is technology. Awareness and capacity building is critical among all the stakeholders from farmers to policy makers for overall climate change adaptation. Community-driven programmes and village institutions' involvement are critical to adapt to climate change. There is a strong need to convergence of multi-ministries' programmes at village or mandal level for deriving benefits of national or state-level climate adaptation programmes.

Adaptation strategies with improved farming techniques/practices can potentially decrease the vulnerability of adverse impacts of climate change. Most adaptation technologies have

co-benefits of mitigation by removing, reducing or displacing the emissions of atmospheric carbon dioxide, methane and nitrous oxide with some co-benefits (FAO, 2012). Water management is the critical factor for overall climate change adaptation in India and elsewhere. Half of the Indian agriculture is rain dependent and therefore, rain water conservation (in-situ as well as ex-situ in terms of farm or community ponds) is the highly prioritised adaptation strategy. This enables the provision of drinking water for livestock sector.

Water Resource Conservation Techniques	
In-situ Soil Moisture Conservation	**Water Saving Techniques**
Subsoiling- Enhances soil moisture and nutrient availability	SRI method of paddy cultivation- Utilizes less water, less seed, less chemical fertilizers and pesticides
Conservation furrows- Percolated rain water is conserved in plant root zone	Direct seeding of paddy with drum seeder- Conserves seed, moisture, labour and produces more tillers
Trench-cum-bunding- Allow percolation of rain water and retain moisture at the root zone for longer period	Broadcasting of paddy- Labor saving and low cost of cultivation
Broad bed furrows- Improves drainage and conserve soil moisture	Drip irrigation- High water use efficiency
Ridges and furrows- Retains soil moisture and maintains proper drainage	
Zero-tillage- Utilizes residual soil moisture, adds organic matter and reduces cost of cultivation	
Plastic mulching- Controls weeds, conserves soil moisture, reduces soil erosion, improves soil structure and enhances soil organic matter content	
Crop intensification with conserved soil moisture- sunhemp seed production in rice fallows- Conservation and effective utilization of residual soil moisture	
Compartmental bunding- Moisture conservation	
Pusa hydrogel- Absorption and retention of soil moisture; slow release for longer period	
Pani pipe technology- Reduces the number of irrigations and recharges the ground water	

Figure: Different resource conservation technologies for climate change adaptation in Indian agriculture

Efficient rice, wheat and sugarcane production systems are most important for conserving water resources. Several land treatments for in-situ rain water conservations, location-specific designs of farm ponds for harvesting of runoff under high intensity rains were made available by the Indian Council of Agricultural Research (ICAR).

Livestock is critical for the stability of livelihoods of small farmers. Three-tier strategy such as better breed, feed and shelter management is recommended by the ICAR for sustainable livestock production. Combination of these strategies could not only contribute to climate change adaptation but also reduce GHG's emissions particularly methane. These include modifying feeding by improving forage quality, using specific dietary additives and usage of fodder grasses that increase the digestive process and eventually reduce emission from enteric fermentation. Usage of dry straw as a feed to the cattle liberates huge amount of CH4 (around 6 ml/100 mg of digested substrate as against the least amount of <2 ml/100 mg in case of fresh tree leaves followed by cereal grains (Bhatta et al., 2015). Combination of different feed additives might have a synergetic reducing effect in controlling of methane emission. Selection of location-suitable aquatic species, enhancing feeding efficiency, adoption of herbivorous and omnivorous aquaculture will possibly reduce GHG emission from input use besides productivity of fisheries.

United Nations Framework Convention on Climate Change (UNFCCC) and Agriculture sector-based Climate Change Negotiation Process

The UNFCCC came out of the Rio Convention in 1994, and aims to prevent all hazardous human activities that interfere with the global climate. The Indian Council of Agricultural Research (ICAR) under the Ministry of Agriculture and Farmers Welfare, Govt. of India, took up the task of institutionalizing the climate adaptation process in the agriculture sector. In 2004, ICAR launched a National Network Project on ''Impacts, Adaptation and Vulnerability of Indian Agriculture to Climate Change'' to focus on comprehensive understanding of climate change impacts on agriculture sectors like cereal crops, horticulture crops, plantation crops, livestock, fish, soil, water, agroforestry, market and policy collaborating with 15 industries during the X plan (A case study of ICAR). A mega project named "National Initiatives for Climate Resilient Agriculture (NICRA) functioned with multi-stakeholder participation in order to bring the stability of food production through climate adaptation and mitigation strategies. Large-scale infrastructure was established across the country for climate change research and technology development. India was proactive in developing district agriculture contingency plans for all rural districts towards preparedness and real time response to climate change impacts.

India also helped the SAARC partners to develop such initiatives. These initiatives and experiences were amply shared among participating countries of UNFCCC process during in-session workshops (Koronivia Joint Work on Agriculture (KJWA) and negotiation process during 2013-2019. ICAR also contributed to multi-ministerial demonstration of climate change mitigation initiatives at UNFCCC through global climate change negotiations in Subsidiary Body for Scientific and Technological Advice (SBSTA) and Conference of Parties (COP). ICAR has also been contributing to refinements in measuring climate change through its participation of Intergovernmental Panel on Climate Change (IPCC.

Koronivia Joint Work on Agriculture (KJWA)

The Koronivia Joint Work on Agriculture (KJWA) is a decision arrived at the 23rd Conference of the Parties to the UNFCCC (COP-23) in November 2017, officially acknowledging the significance of the agriculture and allied sectors in adapting to and mitigating climate change. In partnership with other actors at the international and national level, FAO is working to support the development and implementation of the KJWA. At the (COP-23), the Koronivia Joint Work on Agriculture (decision 4/CP.23) was adopted – a

landmark agreement for the agriculture negotiations under the climate convention which emphasizes the key role of agriculture and food security in the international climate change agenda. The agenda item on issues related to agriculture under the Subsidiary Body for Scientific and Technological Advice (SBSTA) was first formalized in 2011 (decision 2/CP.17), followed by five in-session workshops on the status of scientific knowledge concerning agriculture and climate change. Rich exchanges among countries paved the way towards the KJWA, which calls for collaboration between SBSTA and the Subsidiary Body of Implementation (SBI) on specific elements, including through workshops and expert meetings and thus, widening the scope of the conversation from a scientific and technical focus to implementation. The KJWA decision provides a list of specific elements on which Parties are initially invited to exchange their views. Under this decision, FAO supports countries providing technical support to adapt to and mitigate climate change, working in close collaboration with UNFCCC and other partners.

So far, seven in-session workshops and reports on work related to agriculture were undertaken by the Conference of the Parties (COP and its subsidiary bodies like SBSTA and SBI) (Source: https://unfccc.int/fr/node/192864).

The topics of workshops organized are presented below along with details of location

1) Current state of scientific knowledge on how to enhance the adaptation of agriculture to climate change impacts while promoting rural development, sustainable development and productivity of agricultural systems and food security in all countries, particularly in developing countries (2013 in SBSTA 39 at Warsaw, Poland).

2) Development of early warning systems and contingency plans in relation to extreme weather events and its effects such as desertification, drought, floods, landslides, storm surge, soil erosion, and saline water intrusion (2015 at SBSTA 42 Bonn, Germany).

3) Assessment of risk and vulnerability of agricultural systems to different climate change scenarios at local, regional, and national levels, including but not limited to pests and diseases (2015 at SBSTA 42 Bonn, Germany).

4) Identification of adaptation measures, taking into account the diversity of the agricultural systems, indigenous knowledge systems, and the differences in scale as well as possible co-benefits and sharing experiences in research and development and on the ground activities, including socio-economic, environmental and gender aspects (2016 at SBSTA 44, Bonn, Germany). Identification and assessment of agricultural practices and technologies to enhance productivity in a sustainable manner, food security and resilience, considering the differences in agro-ecological zones and farming systems such as different grassland and cropland practices and systems (2016 at SBSTA 44, Bonn, Germany).

5) Modalities for implementation of the outcomes of the five in-session workshops on issues related to agriculture and other future topics that may arise from this work (2018 at COP-24 at Katowice, Poland).

6) Methods and approaches for assessing adaptation, adaptation co-benefits and resilience (2019 at SBSTA 50, Bonn, Germany)

7) Improved soil carbon, soil health and soil fertility under grassland and cropland as well as integrated systems, including water management (2019 at SBSTA 50 at Bonn, Germany).

Regional Climate Policies at Asian Pacific Network (APN) and SAARC Level

Besides UNFCCC, regional climate policies play a significant role towards climate adaptation and mitigation co-benefits. Various climate adaptation strategies, programmes and policies of Agriculture sector of SAARC countries (India, Sri lanka, Nepal, Bhutan, Maldives, Bangladesh and Pakistan) were discussed at the National Academy of Agricultural Research Management (ICAR-NAARM), Hyderabad during April, 2018 in order to share the knowledge and implement programmes of Climate Change Adaptation in the respective countries (source: ICAR website).

This consultation workshop was organized for SAARC Country representatives under South Asian Association for Regional Cooperation (SAARC) and Asia Pacific Network for Global Change Research (APN). SAARC countries are highly vulnerable due to its tropical climate, long sea coast or island ecosystem etc. Key strategies and way forward in the form of key messages originated from these workshops are:
a) Promoting, training and capacity building among regional countries;
b) Contingency plan implementation process;
c) Agro-advisories;
d) Soil health and carbon sequestration;
e) Livestock feed management;
f) Minimizing coastal vulnerability and
g) Innovative village institutions.

Government of India Initiatives for Climate Change Adaptation

Govt. of India took several initiatives for formulating most efficient missions aiming to combat global warming and for climate change adaptation. All these missions implemented package of several technologies developed by the ICAR. Some important initiatives are presented below with key objectives.

National Mission on Sustainable Agriculture (NMSA):
This Mission was structured under the National Action Plan on Climate Change (NAPCC) and made operational during 2014-15. It aimed to synergize resource conservation, enhancing or restoring soil fertility, thereby improving productivity with focus on soil health management, Integrated Farming System (IFS), integrated animal component and Water Use Efficiency (WUE) specifically in drylands or rainfed agriculture areas.

National Adaptation Fund for Climate Change (NAFCC):
This Scheme was implemented during 2015-16 mainly for supporting concrete adaptation activities dealing with mitigating the adverse effects of global climate change in sectors such as agriculture, water, forestry, animal husbandry, tourism, etc.

Pradhan Mantri Krishi Sinchayee Yojna (PMSKY):
This Scheme was planned and formulated to give more priority on water conservation and its management in agriculture with the vision to extend the area under irrigation from 1st July 2015. The main motto of this Scheme is ‘Har Khet Ko Paani’ to improve water use

efficiency, 'More crop per drop' to provide end-to-end solutions in water source creation, distribution channels and its management.

Pradhan Mantri Fasal Bima Yojna (PMFBY):
This Scheme was introduced on 14th January, 2016 in order to reduce the agricultural distress and farmer's welfare without affecting substantial hikes in the Minimum Support Prices (MSP) on agricultural produces during monsoon fluctuations or any other natural calamity by providing full insured amount on crop losses.

Soil Health Card (SHC):
This Scheme was launched in February, 2015 to issue soil health cards (SHC) to farmers providing detailed information on test based soil nutrient status of their own land along with recommended dose of fertilizers for improving productivity through judicious use of inputs. The Govt. of India targeted to issue 10.48 crores of SHCs since inception of the Scheme.

Green India Mission (GIM):
This Mission was started in February 2014 and outlined under NAPCC. The main objective of this Mission was to protect, restore and enhance the diminishing forest cover in India, and to fight climate change with adaptation and mitigation measures.

National Water Mission (NWM):
A Mission was mounted to ensure Integrated Water Resource Management (IWRM) for conserving the water sources and minimizing its wastage, and also to optimize Water Use Efficiency (WUE) by 20 per cent including agriculture sector.

Paramparagat Krishi Vikas Yojna (PKVY):
It is an extended component of Soil Health Management (SHM) launched in 2015 under NMSA with the objective of supporting and promoting organic farming through adoption of organic village by cluster approach, which in turn result in improvement of soil health.

National Action Plan on Climate Change (NAPCC) and State Action Plan on Climate Change (SAPCC):
The NAPCC was released on 30th June 2008 in order to create awareness among public, Govt. agencies, industries, scientists and society on the risks posed by global climate changes, and steps to encounter the same. It pulls all the existing Government's national plans on energy efficiency agriculture, renewable energy, water, and others. The SAPCC have enlisted climate adaptation and mitigation strategies aligned with eight national missions under NAPCC.

Agricultural Contingency Plans and National Innovations on Climate Resilient Agriculture (NICRA):
Agricultural Contingency Plans are technical documents comprising integrated information on field crops, livestock, horticulture, poultry and fishery and technological solutions for all weather-related problems for the respective farming activities. These are useful to plan earlier towards sustainable agriculture system during weather aberrations and extreme climatic conditions. NICRA is a Network Project of the Indian Council of Agricultural Research (ICAR) started in February 2011 with the objective of enhancing resilience of Indian agriculture to adverse climate changes by adopting innovative technologies. The Project consists of research, technology demonstration, capacity building and sponsored grants (Srinivasarao et al., 2017 & 2019).

Sub-mission on Agro-forestry:
This Mission was launched during 2016-17 with the objective of planting trees on farm bunds. Agroforestry has the potential to bring sustainability in agriculture and also achieving the optimum productivity by mitigating the impact of climate change.

National Livestock Mission:
This Mission was initiated by the Ministry of Agriculture and Farmers' Welfare and got commenced from 2014-15 focussing mainly on livestock development through sustainable approach ultimately protecting the natural environment, ensuring bio-security, conserving animal bio-diversity and farmers' livelihood.

Innovative Poultry Productivity Project:
The National Livestock Mission launched this Project on pilot basis during 2017-18 in 15 recognized poultry potential states to provide nutritional support to the poor farmers and also give supplementary income.

Blue Revolution (Neel Kranti Mission):
The main objective of this Mission is to improve the fishery production, and enhancing the productivity of both marine and inland aquaculture and fishery resources. The objectives of Neel Kranti Mission are to enhance the overall fish production through sustainability, usage of new technologies to modernize the fishery, ensuring food and nutritional security, to generate the employment opportunities and empowerment of fishers and aquaculture farmers.

Fodder Development Scheme:
This Scheme was implemented by the Department of Animal Husbandry in 2005-06 to establish fodder block making units, grassland development, fodder seed production and distribution, and biotechnology research.

National Biogas and Manure Management Programme (NBMMP):
The Ministry of New and Renewable Energy installed this programme in 2014 for the development of rural and semi-urban households by setting up the family type biogas plants.

National Mission on Himalayan Studies:
The Ministry of Environment, Forest & Climate Change (MoEFCC) launched this Mission to support innovative studies and related interventions on sustenance and development of the natural, ecological, cultural, and socio-economic capital values and assets of the Indian Himalayan Region.

Agro-Advisory Services:
The weather information-based service came into existence to contribute to crop or livestock management strategies by providing real time location and crop specific agro-met services. A website 'Crop Weather Outlook' provides all kinds of services related to crop management.

Neem Coated Urea:
It is a form of urea fertilizer coated with neem extracted material, which acts as a slow releaser of nitrogen reducing the pest and disease infestation ultimately minimizing the usage of chemicals in farming by achieving the overall increase in crop yield.

National Adaptation Fund:

The National Adaptation Fund for Climate Change (NAFCC) is a Central Sector Scheme which was set up during 2015-16. The overall aim of NAFCC is to support concrete adaptation activities which mitigate the adverse effects of climate change. The activities under this Scheme are implemented in a project mode. The projects related to adaptation in sectors such as agriculture, animal husbandry, water, forestry, tourism, etc., are eligible for funding under NAFCC. The National Bank for Agriculture and Rural Development (NABARD) is the National Implementing Entity (NIE). Technologies generated by ICAR and State Government Universities are being implemented in coherent package to developing resilient capacity of vulnerable regions in India.

National Action Programme to Combat Desertification:

This programme was initiated and sponsored by UNCCD and MoEFCC to mitigate the effects of drought in dryland regions through community-based approach of drought management which can lead to the empowerment of local communities. The objectives were set up to combat desertification viz. prevention of land degradation, recovery of partly degraded land and reclamation of desertified land.

Conclusions

Global climate change, its causes and impacts are one of the most emerging issues in science and technology domain. India, a tropical country, is facing its impacts through droughts, floods, cyclones, heat waves, hailstorms, and coastal salinity which have become threats to sustainable development. About 70 per cent of the Indian population is directly or indirectly associated with agriculture and sub-sectors, and major Sustainability Development Goals (SDGs) are expected to be met from this sector. Increasing global temperature due to the emission of enormous amount of green-house gases from various sources is the cause of climate change and impacts. Extreme temperature and its erratic events disrupt the activities of all the existing lives on the planet by means of severe damage or loss. Assessment of the impacts and a comprehensive understanding of the benefits of adaptation options over combating the uncommon incidents of climate change is pivotal in the current scenario to sustain life. So far in the journey of Indian agriculture sector, climate adaptation strategies have shown positive impacts.

[ICAR Policy Paper Climate Change and Indian Agriculture: Impacts, Coping Strategies, Programmes and Policy, Ch. Srinivasa Rao, Ravi Shankar Prasad and Trilochan Mohapatra (2019)]

Annex I: Trait specific field crop varieties dedicated to the Nation

1) Quinoa (Him Shakti) with high protein content (15.64%) and oil (8.91%)

2) Buckwheat (Him Phaphra) with high protein (13.1%), methionine and iron (6.6 mg/100g) content

3) Winged bean (PBW 11-2) with high pod yield and protein content

4) Faba bean (HFB 2) with high seed yield and protein content (24.13%)

5) Soybean (NRC 138) with early maturing amenable to mechanical harvesting

6) Soybean (KBVS 1, Karune), first variety of soybean having green pod suitable for consumption

7) Soybean (NRC 142), first double null variety free from anti-nutritional factor Kunitz trypsin inhibitor (KTI) and lipoxygenase-2 (principal contributor to off-flavour)

8) Mustard (PusaDuble Zero Mustard 31), high yielding (26.4 q/ha) variety with Canola quality (erucic acid <2% and glucosinolates<30ppm)

9) Mustard (RCH 1), high yielding (26.7 q/ha) hybrid variety with Canola quality (erucic acid <2% and glucosinolates<30ppm)

10) Pigeonpea (IPH 15-3), early maturing (<150 day), resistant to wilt, sterility and mosaic disease

11) Pigeonpea (IPH 09-5), early maturing (<150 day), resistant to wilt, sterility and mosaic disease

12) Chickpea (Pusa Chickpea 4005), a drought tolerant high yielding variety of chickpea developed through marker assisted selection

13) Chickpea (IPCMB 19-3, Samriddhi), a Fusarium wilt resistant high protein (22.9%) variety developed through marker assisted selection

14) Pearl millet (PB 1877), summer pearl millet variety rich in iron (42 ppm) and zinc (32 ppm)

15) Pearl millet (HHB 67 Improved 2), pearl millet hybrid rich in iron (42 ppm) and zinc (32 ppm) and resistant to downy mildew

16) Sorghum (JaicarRaseela-CSV 49SS SPV 2600), sweet sorghum suitable for 1G biofuel and silage making

17) Sorghum (CSH 47 SPG 1798), high biomass variety suitable for 2G biofuel and silage making

18) Forage sorghum (JaicarUrja-CSV 48 SPV 2402), high biomass variety suitable for 2G biofuel and silage making

19) Rice (Pusa Basmati 1979), herbicide tolerance in the background of PusaBasmati 1121. Suitable for direct seeding also

20) Rice (Pusa Basmati 1985) herbicide tolerance in the background of PusaBasmati 1509. Suitable for direct seeding also

21) Rice (Pusa Basmati 1886), bacterial blight and blast resistance in the background of Pusa Basmati 6.

22) Rice (Pusa Basmati 1847), bacterial blight and blast resistance in the background of Pusa Basmati 1509

23) Rice (Pusa Basmati 1885) bacterial blight and blast resistance in the background of Pusa Basmati 1121

24) Rice (DRR Dhan 58), resistant to bacterial blight (Xa21, xa13, xa5) and seedling stage salinity tolerance (Saltol QTL) in the background of Samba Masuri

25) Rice (DRR Dhan 59), resistant to bacterial blight (Xa33) in the background of Akshyadhan

26) Rice (DRR Dhan 60), resistant to bacterial blight (Xa21, xa13, xa5) and low soil phosphorus tolerance (Pup1) in the background of Samba Masuari

27) Maize (Pusa HQPM-1 Improved (APQH-1), high 7.02 µg/g of provitamin, lysine (4.59%) and tryptophan (0.85%); widely adapted hybrid suitable for all zones

28) Maize (PusaBiofortified Maize Hybrid-1 (APH-1), rich in provitamin-A (6.6 µg/g), lysine (3.37%) and tryptophan (0.72%); hybrid suitable for northern hill and north eastern plain zone

29) Maize (Pusa HM4 Male Sterile Baby Corn (Shishu) (ABSH4-1), first male sterile baby corn hybrid of the country; saves Rs. 8,000-10,000/- per ha as no manual detasseling is required

30) Wheat (DBW 332), high yielding wheat variety with 78.3 q/ha grain yield with high protein content (12.2%) and zinc (40.6 ppm)

31) Wheat (DBW 327), high yielding wheat variety with high Zinc content (44.4 ppm) in its grains

32) Wheat (HI 1636), high yielding biofortified variety with high zinc content (44.4 ppm) and excellent chapati quality (8.24/10)

33) Wheat (HUW 838), high yielding wheat variety with high Zinc content (41.8 ppm) in its grains

34) Wheat (MP (JW) 1358), high yielding wheat variety rich in protein (12.1%) and iron (40.6 ppm)

35) Wheat (HI 8123), high yielding durum wheat variety with high zinc content (40.1 ppm) and protein content (12.1%) with good pasta acceptability (5.9)

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