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**Report Highlights:**

India's agricultural sector is highly vulnerable to the effects of climate change and extreme weather events. With a rapidly growing population and limited natural resource base, India's grain and livestock sectors contribute to significant global greenhouse gas emissions, yet the country's diverse agricultural systems offer significant ecological benefits that can improve resiliency to climate change impacts. India's climate policies have been consistent over the years and continue to emphasize climate change adaptation and mitigation efforts through domestic growth and economic development. As the growth center for energy demand the next two decades, India maintains its goal to install 450 gigawatts of renewable energy by 2030, while prioritizing climate adaption policies and supporting rural, agricultural livelihoods.

## Introduction

India is highly vulnerable to climate change due to its considerable and growing population and growing economy, both closely tied to a limited natural resource base. More than half of the 1.3 billion population directly depend on climate sensitive sectors (agriculture, forestry, fisheries) and natural resources (water, biodiversity and coastlands) for subsistence and livelihood. As India strives to develop its economy, rising industrialization, urbanization, agricultural commercialization, and expansion of power generation capacity based predominately on non-renewable fuels will rapidly increase green-house gas (GHG) emissions. Indian agriculture is particularly vulnerable due to:

- Predominantly unirrigated (rain-fed) agriculture<sup>1</sup> largely contingent on monsoon rains,
- Himalayan glacier-fed, river based irrigation in the north and east,<sup>2</sup>
- Massive livestock population, specifically cattle and water buffalo,<sup>3</sup>
- Densely populated, low lying 7,500 kilometer coastline, and;
- Large number of resource-poor farmers and other producers with limited ability to adopt sustainable resource technologies.

A recent report<sup>4</sup> by the Government of India Ministry of Earth Sciences notes that since the middle of the twentieth century, India has experienced a rise in average temperatures, a decrease in monsoon precipitation, a rise in extreme temperature, rainfall and drought events, an increase in intensity of severe cyclones and other changes in the monsoon system. Scientific evidence suggests that these climate change distresses are expected to continue during the twenty-first century.

Factors including excessive temperatures, acute monsoon system transformations, fragile glacial fed river systems, extreme weather events, and inundation of coastlines due to rising sea levels all will impact India's existing water-based ecosystems. Agriculture is the most vulnerable sector to climate change, owing to its sensitivity to precise weather parameters and likely economic impacts. The changes in climatic events such as temperature, rainfall and atmospheric carbon dioxide (CO<sub>2</sub>) can significantly affect crop yields. These factors affect the livestock, fisheries, plantation, and forestry sectors. Consequently, the livelihoods of a vast population, where more than half of the country relies on agriculture, forestry, wetlands and fisheries as a primary source of income will be affected by the looming climate change scenario.

## India's Growing Economy Raising Global Green House Gas Emissions

India is among the fastest growing economies in the 21<sup>st</sup> century and is currently the world's third largest emitter of GHG followed by China and the United States. Despite the recent setbacks due to the COVID-19 pandemic, the Narendra Modi Administration is hopeful that India can achieve its affirmed \$5 trillion economic target by 2024/25, a significant increase from the GDP of \$2.9 trillion in March 2021. However, meeting this ambitious goal will place additional stress on India's natural resources and require substantial additional energy consumption, further contributing to higher GHG emissions from increased infrastructure, industrialization and

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<sup>1</sup> Of the 140 million hectares of India's cultivated land, about 80 million hectares are unirrigated (rain-fed) contributing about 40 percent of food grain production and supporting two-thirds of the livestock population (Source: Central Research Institute for Dry Land Agriculture).

<sup>2</sup> The Ganga, Brahmaputra and Indus river basins are estimated at 1.4 million square kilometers, accounting for about 56 percent of the total river basin catchment area of the country (Source: National Commission for Integrated Water Resources Development Plan).

<sup>3</sup> India's livestock population in 2019 was estimated at 535.8 million – 192.5 million cattle, 109.98 million buffaloes, 74.3 million sheep, 148.9 million goats, 9.1 million pigs, with the rest horses, mules, donkeys, camels, yaks, etc. (Source: Ministry of Fisheries, Animal Husbandry and Dairying).

<sup>4</sup> See: [Assessment of Climate Change Over the Indian Region, June 2020.](#)

urbanization stemming from a growing middle class. India's GHG emissions expanded from 1.48 billion tons of CO<sub>2</sub> in 2000, to 2.84 billion tons in 2016,<sup>5</sup> and were projected to have crossed 3.0 billion tons in 2020. Growing by approximately three percent annually from 2020, CO<sub>2</sub> emissions are estimated to reach 3.7 billion tons by 2030.<sup>6</sup>

India is largely dependent on fossil fuels for its commercial energy consumption and power generation. India's commercial energy mix (excluding biomass) in 2017/18 included: coal/lignite (45.8 percent), petroleum (34.3 percent), natural gas (6.6 percent), and electricity from nuclear/hydro/renewable sources (13.2 percent). In addition, large sections of the population depend on biomass resources like wood, crop residues and livestock dung for energy. In the agriculture sector, India's large ruminant population and rice fields are significant contributors to GHG emissions in addition to the burning of crop and animal waste.

### **GHG Emissions Caused by the Agriculture Sector**

India is a leading GHG emitter from its food and agricultural systems after China, Indonesia, the United States, Brazil, and the European Union (EU). Indian rice fields and its substantial livestock population are the primary causes of methane release, and fertilizer application to low-carbon soils leads to nitrous oxide emissions. Within agriculture, 54.6 percent of GHG emissions were due to enteric fermentation (livestock), followed by 19.1 percent from agricultural fertilizers, 17.5 percent from rice cultivation, 6.7 percent from poor manure management, and 2.2 percent from burning crop residue.<sup>7</sup>

- *Paddy Rice*: India is the world's largest rice producer by area, estimated at about 44.0 million hectares. Rice farmers primarily transplant paddy rice during the wet monsoon or in irrigated systems by flooding and puddling fields, causing significant methane and nitrous oxide emissions from fertilization.
- *Livestock*: India has the largest population of bovine animals (cattle and buffalo) and among the top three globally for small ruminants (goat and sheep), which also are also a meaningful source of GHG emissions. Emissions from livestock have two components – methane emission from enteric fermentation and manure management and nitrous oxide from traditional animal waste management that favors anaerobic decomposition over improved aerobic composting methods.

### **Climate Change Impacts on India's Agriculture and Related Sectors**

#### *Grains and Pulses*

The number of extreme climatic events (e.g. floods, droughts, cyclones) tripled between 1950 and 2015.<sup>8</sup> Studies suggest that a two degree Celsius warming may lead to annual extreme heatwaves that India last experienced in 2015.<sup>9</sup> While major cereal crop sensitivities to temperature changes, moisture, and CO<sub>2</sub> concentration under various climatic scenarios have been studied in the Indian subcontinent, there are no conclusive reports on the overall impact these factors will have. Studies on rice and wheat, India's two leading food grains, suggest that wheat is sensitive to rising maximum temperature and augmented heatwaves, and rice

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<sup>5</sup> [Third biennial update report \(BUR-III\)](#), submitted to the United Nations Framework Convention on Climate Change (UNFCCC) submitted on February 2021.

<sup>6</sup> Karstensen, Jonas, et al. "[Key Drivers of Indian Greenhouse Gas Emissions](#)." *Econ. Polit. Weekly* 55 (2020): 46-53.

<sup>7</sup> India – [Third Biennial Update Report to the United Nations Framework Convention on Climate Change](#), 2021. Ministry of Environment, Forest and Climate Change, Government of India.

<sup>8</sup> Roxy MK, et. al., 2017. [A threefold rise in widespread extreme rain events over central India](#). *Nature Communications*.

<sup>9</sup> A Degree of Concern: Why Global Temperatures Matter, June 19, 2019; NASA.

is vulnerable to increased minimum temperatures in the region. However, productivity declines due to increased temperatures may be partially offset by elevated CO<sub>2</sub> levels, but projected water shortages and extreme thermal stresses could adversely impact yield. Historically, India's rice yields experience larger declines during extreme weather conditions, including drought.

Climate change impacts on horticultural and other field crops vary based on rising temperatures or regional CO<sub>2</sub> concentration, but India's agriculture may be more vulnerable to the expected higher incidences of extreme weather (e.g. rainfall duration and intensity, drought/flood), pests, and disease. Some of the shorter duration water stress tolerant crops like coarse grains and pulses may perform better than the other higher yielding input intensive crops under varying climate change conditions. For instance, one 2019 study<sup>10</sup> suggests that millet, sorghum, and maize are more resilient to extreme weather with less year-to-year yield changes from climatic fluctuations.

Fall harvested *kharif* crops are most affected by rainfall variance, while winter planted *rabi* crops face challenges in higher minimum temperatures.<sup>11</sup> Winter planted *rabi* crops will also be impacted by seasonal irrigation water availability from residual surface water and reduced aquifer recharge from annual monsoon rains, in addition to depressed water supply from receding glaciers in the Himalayas. Reduced runoff from the Himalayas would impact 19 major rivers in India, such as the Indus, and Ganges—major sources of irrigated water in India.

Significant climate change impacts are suggested in the medium-term (2010-2039),<sup>12</sup> which is predicted to reduce yields between 4.5 to 9 percent of certain crops. Studies conducted by the National Innovations in Climate Resilient Agriculture (NICRA) suggest unirrigated rice yields are projected to decline marginally (less than 2.5 percent) in both 2050 and 2080, and irrigated rice yields may be reduced seven percent and ten percent in 2050 and 2080, respectively.<sup>13</sup> Additionally, wheat yields are estimated to be reduced between 6-25 percent by 2100; and maize yields by 18-23 percent. Yet, extreme climate change benefits crops like chickpeas and other pulses with increased productivity (23-54 percent). Further studies<sup>14</sup> suggest crops that utilize C3 carbon fixation pathways like potato, soybean, and mustard may have a neutral or positive impact in India, but increased photorespiration through stress conditions like drought would result in oxygen fixation and lead to CO<sub>2</sub> release.<sup>15</sup>

### *Livestock*

Climate change could increase water, shelter and energy requirements for raising livestock in India. Heat stress adversely impacts reproductive performance and productivity of dairy animals, and increases the possibility of heat stroke in livestock populations, even local breeds adapted to tropical environments. For instance, research on India's dairy population indicates that rising maximum temperatures result in decreased total dry matter intake and milk yield in cows from the northern state of Haryana.<sup>16</sup> Further increases in natural disasters, including droughts, tropical storms, hurricanes, cyclones, and floods would result in livestock displacement and consequent increased mortality. Additionally, extreme weather conditions (heavy rainfall and floods) could

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<sup>10</sup> Data Science Institute at Columbia. "[How climate change affects crops in India](#)." Science Daily. 17 June 2019.

<sup>11</sup> The *kharif* season starts typically subcontinent's monsoon; crops include maize, rice, and sorghum. Winter *rabi* crops require significant irrigation; typical crops cultivated include pulses, wheat, and certain oilseeds.

<sup>12</sup> See: [National Innovations on Climate Resilient Agriculture \(NICRA\)](#).

<sup>13</sup> [Effect of Climate Change on Agriculture](#), Ministry of Agriculture and Farmers Welfare, February 9, 2021.

<sup>14</sup> See: [Down to Earth](#); May, 2017.

<sup>15</sup> Hirst, Kris, K. (2019). [Adaptations to Climate Change in C3, C4, and CAM Plants](#). ThoughtCo.

<sup>16</sup> Lal SN, Verma DN, Husain KQ (1987). Effect of air temperature and humidity on the feed consumption, cardio respiratory response and milk production in Haryana cows. *Indian Vet J* 64(2):115–121.

result in water contamination through poor manure management, which in turn could lead to the spread of water and foodborne diseases. Greater drought frequency would likely lead to reduced livestock nutrition.

#### *Agroecology, Forest and Fishery Environments*

India is rich in biodiversity where forests (71.2 million hectares) and tree cover (9.5 million hectares) account for approximately 21.7 percent and 2.9 percent of total geographical area, respectively.<sup>17</sup> With nearly 200,000 villages classified as forest villages, rural India largely depends on forest resources to sustain its rural communities, including tea, coffee, and fruit production. High temperatures and moisture stress, coupled with extreme weather conditions could lead to reduced forest productivity and higher forest degradation.

Deforestation caused by human activity has been a significant challenge resulting in the loss of primary forests. Despite these challenges, research suggests that India's northern forests are resilient to droughts and rainfall declines caused by climate change, whereas drier regions including the Deccan Plateau in western/southern India are less resilient to rainfall decline.<sup>18</sup>

Densely populated and intensively cultivated low-lying coastal lands are vulnerable to erosion and land loss, inundation, salinization, sea flooding and upstream movement of sea water into fresh water tributaries that affect coastal agriculture, fisheries and aquaculture. Rice cultivation, commercial fishing and prawn farming practiced in coastal regions could be severely affected with the loss of fresh water availability. Floods and water-logged soils in the coastal region, and subsequent problems of salinity in adjoining tributaries may also adversely affect inland agriculture and fresh water fisheries.

### **India's Policy on Climate Change**

India is active in international climate change negotiations, having signed the UN Framework Convention on Climate Change in 1992 and acceding to the Kyoto Protocol in August 2002. India has also been an active participant in U.S.-led major economies fora, including the G7 and G20. While agreeing on the need to address the climate change threat, India has maintained that its economic development and poverty alleviation goals cannot be compromised to reduce GHG emissions. India has also argued that its per capita GHG emission levels are much below the levels of developed countries. Given the Indian population's dependence on climate-sensitive sectors like agriculture, forests, fisheries and other natural resources for subsistence and livelihoods, the Indian government's priorities remain fixed on reducing the vulnerability of its natural and socioeconomic systems to climatic shocks. Nevertheless, India has focused on some GHG mitigation strategies that target the energy, transportation, industrial, and agricultural sectors by promoting energy conservation, alternative fuels from renewable technologies, water conservation, afforestation, and land and waste management.

India's climate change policies have been communicated through two key documents: the 2008 National Action Plan on Climate Change (NAPCC), and 2015 India's Intended Nationally Determined Commitment (INDC) to the United Nations Framework Convention on Climate Change (UNFCCC). India's National Action Plan on Climate Change (NAPCC) incorporates its vision of ecologically sustainable development through eight priority National Missions – (i) National Solar Mission, (ii) National Mission for Enhanced Energy Efficiency, (iii) National Mission on Sustainable Habitat, (iv) National Water Mission, (v) National Mission for Sustaining the Himalayan Ecosystem, (vi) National Mission for Green India, (vii) National Mission for Sustainable Agriculture, and (viii) National Mission on Strategic Knowledge for Climate Change. Adaptation measures are prominently featured in India's framework for climate change action, which incorporates aspects of traditional

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<sup>17</sup> [State of Forest Report 2019](#).

<sup>18</sup> Das, Pulakesh and Behera, Mukund (2019). Can the forest cover in India withstand large climate alterations? *Biodiversity and Conservation*. 28. 1-17.

Indian lifestyles and cultures. India's heritage has historical precedents that embrace nature, and environmental consciousness is deeply rooted in many traditions. Additionally, most of India's 29 states and seven union territories have submitted their own State Action Plans on Climate Change, which complement the NAPCC.

India's INDC is a statement of intent on climate change action with a major focus on climate change adaptation but committed to three significant mitigation targets for 2030: (i) reducing emission intensity of gross domestic product (GDP) by 33-35 percent from 2005 levels, (ii) increasing the share of non-fossil fuel based electricity to 40 percent of cumulative electric power installed capacity, and (iii) enhancing carbon sink (forests) of 2.5 to three billion metric tons of CO<sub>2</sub> equivalent through additional forest and tree cover. As a party to the Paris Agreement, India must submit its first Biennial Transparency Report to the UNFCCC by 2024, including its GHG inventory.

In December 2020, the Government of India organized an [inter-ministerial Apex Committee for Implementation of Paris Agreement \(AIPA\)](#) to generate a coordinated whole-of-government response from various ministries involved in policy making, regulation, and research and development on climate change matters with the goal of supporting meeting India's obligations under the Paris Agreement. The concerned ministries and agencies of the AIPA include:

- [Ministry of Environment, Forest and Climate Change](#): A nodal ministry responsible for all environmental related activities and coordinating the government's climate change policies and activities.
- [Ministry of Science and Technology](#) and [Ministry of Earth Sciences](#): coordinates research on climate change and its impact.
- [Ministry of Power](#): Conducts research on GHG emissions from the power sector, including coal-based thermal power stations; research and policy initiatives on improving energy efficiency and conservation in the power sector, pollution control, etc.
- [Ministry of New and Renewable Energy](#): Research and policy support for the adoption of new, renewable energy sources and clean technologies.
- [Ministry of Agriculture and Farmers Welfare](#): Research on climate change issues related to agriculture, impact assessment for various crops and agricultural systems.
- [Ministry of Rural Development](#): Wasteland development, supports infrastructure development in rural areas, including, such as the Integrated Watershed Management Programme scheme.
- [Ministry of Jal Shakti](#) (Water Resources): Impact assessment on climate change effects on water resources and developing appropriate strategies.
- [Ministry of Housing and Urban Affairs](#): Provide a roadmap for cities to combat climate change, including investments for planning and implementing actions (e.g. Climate Smart Cities).
- [Ministry of Health and Family Welfare](#): Research and activities on the impact of climate change on human health.
- [Ministry of Finance](#): Policy support for implementing mitigation and adaptation strategies to address climate change, including fiscal support for research and developmental efforts, fiscal incentives for adoption of clean technologies, etc.
- [Ministry of Commerce and Industry](#): Develops policies (including trade) for promoting climate smart industries and use of clean technologies.
- [Ministry of External Affairs](#): Conducts international negotiations on climate change.
- [NITI Aayog \(public policy think tank\)](#): Promotes research and innovation, and provides strategic policy vision for the government and various ministries on contingent issues related to climate change.

The Ministry of Petroleum and Natural Gas and Ministry of Coal are both involved in implementing policy to improve energy efficiency and reducing pollution in transportation, power generation and other sectors using fossil fuels. Additionally, state governments, national and state level research and development institutions, non-governmental organizations, industry associations, and international organizations are also involved in climate change issues in India.

## **Climate Ambition**

### *Renewable Electrification*

India has set large-scale 2030 targets for climate action and clean energy. As part of its Paris Agreement climate mitigation efforts, India has reiterated its previous commitments to install 450 gigawatts of renewable energy by 2030, having reportedly achieved its goal of 175 gigawatts by 2022. However, India has not announced any new GHG reduction obligations, but instead has remained focused on several policy initiatives in electrification, including solar grids and electric vehicles. For example, India's Faster Adoption and Manufacturing of Electric Vehicles (FAME-II) scheme, which includes \$1.4 billion to implement battery manufacturing, improve air quality, and increase India's electric vehicle fleet.<sup>19</sup> Further, the Ministry of Petroleum and Natural Gas has expressed interest in making India's petroleum use cleaner and looks to increase ethanol use in gasoline.<sup>20</sup> The Government of India is also interested in technology that converts agricultural stubble into biogas or other energy products.

### *Afforestation*

The Government of India has conducted various programs in afforestation<sup>21</sup> to combat desertification and lessen the impacts of climate change. The Ministry of Environment and Forests implements three flagship programs to develop and sustain forested areas. The National Afforestation Programme, initiated in 2000, targets persons living in forested areas through community-based activities including agroforestry, improved soil conversation, income generation, and ecological restoration of degraded forests. The Green India Mission, launched in 2014, has attempted to protect, restore and enhance India's diminishing forest cover and respond to climate change by a combination of adaptation and mitigation measures. Forest fire management is part of India's long-term goal of sustainable forest management, and the Forest Fire Prevention and Management Scheme provides resources to prevent and combat forest fires.<sup>22</sup> However, many of these programs are underfunded, with insufficient research to determine the efficacy of the programs.<sup>23</sup>

## **Bilateral and International Coordination**

India has participated in various international coalitions and provided development assistance to other countries in climate change mitigation. Recent initiatives include the International Solar Alliance (ISA), which provides a dedicated platform for cooperation among governments, multilateral organizations, industry, and other stakeholders to help achieve a common goal to increase the use and quality of solar energy to meet energy needs. India committed \$1.7 billion in credit toward solar projects in various countries.

At the 2019 Climate Summit, India launched the Coalition for Disaster Resilient Infrastructure (CDRI) with the goal to improve disaster resilient infrastructure. Twenty countries - including G20 members and four international organizations are presently members. Prime Minister Modi proposed the initiative during the 2016

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<sup>19</sup> March 7, 2019 [Press Information Bureau](#), Government of India.

<sup>20</sup> For more information on India's renewable fuel sector, see [USDA GAIN India Biofuels Annual 2020](#).

<sup>21</sup> *Afforestation* is the establishment of forests or tree stands in a place where no previous tree cover existed.

<sup>22</sup> See [additional information](#) on India's afforestation measures.

<sup>23</sup> Parliament of India, Rajya Sabha, 2019. [Status of Forests in India](#).

Asian Ministerial Conference on Disaster Risk Reduction, and since then, the Government of India has pledged \$70 million to support the CDRI.

Initiated in 2017, the India-UN Development Partnership Fund supports developing countries toward meeting the 2030 Sustainable Development Goals (SDG).<sup>24</sup> This fund has supported Pacific Island, African, and Caribbean countries through activities such as Climate Early Warning Systems, solar electrification, and projects to repair damage from climatic events such as hurricanes. The Government of India pledged \$150 million that has supported SDG projects in 48 countries.

#### *United States*

India and the United States look to maintain the Strategic Energy Dialogue, with proposed new work streams that emphasize climate finance and technology. In April 2021, the United States and India launched the “U.S.-India Climate and Clean Energy Agenda 2030 Partnership.”<sup>25</sup> According to the joint statement, the Partnership will aim to mobilize finance and speed clean energy deployment; demonstrate and scale innovative clean technologies needed to decarbonize sectors including industry, transportation, power, and buildings; and build capacity to measure, manage, and adapt to the risks of climate-related impacts. The framework creates a Climate Action and Finance Mobilization Dialogue, and upgrades the existing energy partnership into the Strategic Clean Energy Partnership.

#### *European Union*

As the third largest emitter of GHG globally, the EU has engaged with India (fourth largest GHG emitter) on issues such as clean and renewable energy, water, and urban development. The EU has supported private and public sector Indian projects on climate action and sustainability.<sup>26</sup> On April 29, 2021, the EU Parliament adopted a measure emphasizing the need to strengthen its bilateral trade relationship and jointly fighting climate change. Additionally, India and the EU agreed to strengthen cooperation under the 2016 EU-India Clean Energy and Climate Partnership to improve renewable energy usage and collaborate on smart grid and other green technologies.

### **Climate Change Agenda for Agriculture Also Focuses on Adaptation**

Four of the eight missions in the NAPCC focus on adaptation efforts, including a) sustainable habitats, b) optimizing water use efficiency, c) creating ecologically sustainable climate resilient agricultural production systems, and, d) safeguarding the Himalayan glaciers and mountain ecosystems. These missions include various initiatives in water usage, disaster management, biodiversity conservation, and ecosystem protection—all which have serious implications in the agriculture sector and on rural livelihoods. In addition, India is implementing specific schemes that promote organic farming, efficient irrigation systems, watershed management, and improving soil health and climate resilient agroecological systems.

Mitigations efforts to reduce GHG emissions from agriculture are largely through initiatives such as horticulture land extension, increased rice intensification systems, direct-seed rice cultivation, solar pumps, micro-irrigation, neem coated urea scheme,<sup>27</sup> bio-fertilizers, balanced feedstock and bypass protein<sup>28</sup> for livestock. A recent

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<sup>24</sup> *Climate Action* is SDG number 13 within the Agenda 2030.

<sup>25</sup> See: April 2021 [U.S.-India Joint Statement](#).

<sup>26</sup> See: [European Parliament Think Tank](#), November 2020.

<sup>27</sup> The Government of India Neem Coated Urea (NCU) scheme is intended to regulate use of urea, enhance availability of nitrogen to the crop and reduce fertilizer application costs. NCU slows down the release of fertilizer and makes it available to the crop more effectively.

<sup>28</sup> *Dairy Bypass Protein* is an animal or plant-based protein source that resists degradation in the cow's rumen in order to pass into the lower gastrointestinal tract and provide essential amino acids to the animal.

study<sup>29</sup> suggests that less than four percent of Indian farmers have adopted sustainable agricultural practices and systems. Scaling up sustainable agriculture is critical to farm incomes and bolster India's nutrition security in a climate-constrained future.

### **Climate Change Agriculture Research**

In February 2011, the Indian Council of Agricultural Research (ICAR) launched the National Innovations in Climate Resilient Agriculture (NICRA) project to enhance the resilience of Indian agriculture to climatic variability and climate change through strategic research and technology demonstration in crops, livestock and fisheries. The project has been conducted at leading research institutions covering field crops, horticulture, livestock, natural resource management and fisheries. The project focuses on major crops like wheat, rice, maize, pigeon pea, groundnut, tomato, mango and banana; cattle, buffalo and small ruminants, and marine and freshwater fish species of economic importance. Major research themes include vulnerability assessment of major production zones, assessing the impacts and evolving varieties tolerant to climatic stresses (e.g. drought, heat, flooding) in major grain and horticulture crops, evolving adaptation and mitigation strategies through enhancing water and nutrient use efficiency and conservation agriculture, studying changes in pest dynamics, pest/pathogen-crop relationships, and emergence of new pests and pathogens under climate change. Under NICRA, various ICAR institutions, state agriculture universities and affiliated research institutions are working on a network mode to share data and simultaneously conduct research. For more information, refer to the NICRA website and publication.

Besides NICRA, various national and international institutions are involved in research on climate change which include impact assessments and vulnerability of various agroecological systems. Some of the institutions include, but are not limited to, the M.S. Swaminathan Foundation for Sustainable Agriculture, The Energy Research Institute (TERI), International Center for Research in Semi-Arid Tropics (ICRISAT), and the Space Application Center/Indian Space Research Organization.

Ongoing agro-climatic research includes the development of drought and heat tolerant genotypes in chickpea, pigeon pea and mung bean, and the development of drought tolerant onions and other horticultural crops. India's research institutions have also developed improved flood/drought tolerant rice varieties and early maturing wheat varieties for late-sown areas to avoid terminal heat stress (at the time of maturity). Additionally, several climate resilient varieties developed by ICAR/state agricultural universities for several crops have been evaluated for adaptation under vulnerable agroecological systems.

### **Attachments:**

No Attachments.

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<sup>29</sup> [Sustainable Agriculture in India 2021](#) (April 2021), Council on Energy, Environment and Water and Food and Land Use Coalition.