# Climate Change in Bangladesh

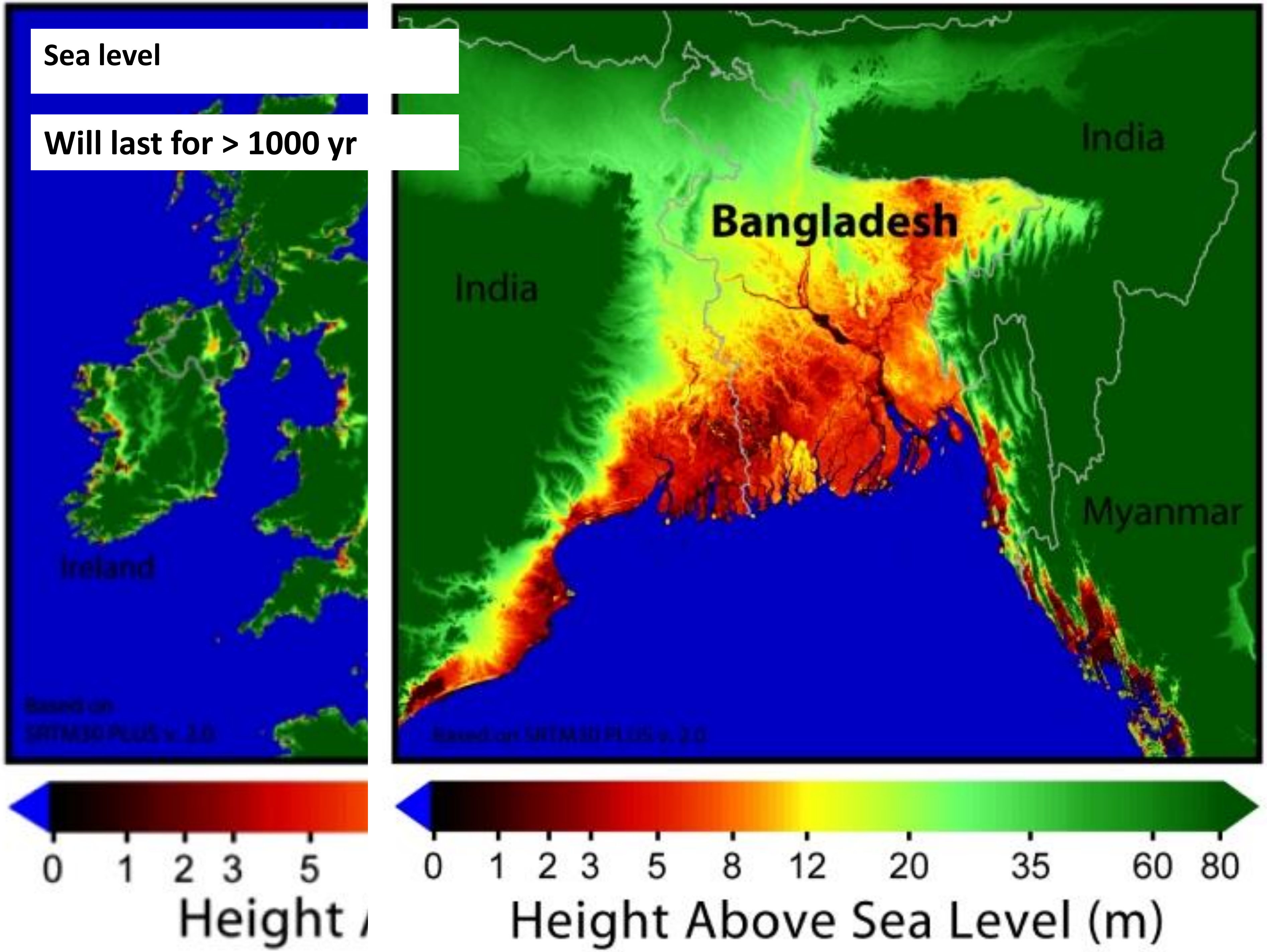

*About 115 times smaller than Russia*

# Climate Change Effects

# Bangladesh the worst sufferer

Bangladesh-most vulnerable countries of the world.

Negligible gas emissions - worst victim.


Sea level
Will last for > 1000 yr
Bangladesh
India
India
Myanmar
Ireland
0 1 2 3 5
Height
0 1 2 3 5 8 12 20 35 60 80
Height Above Sea Level (m)


Drought


Cyclone


Storm surge, salinity

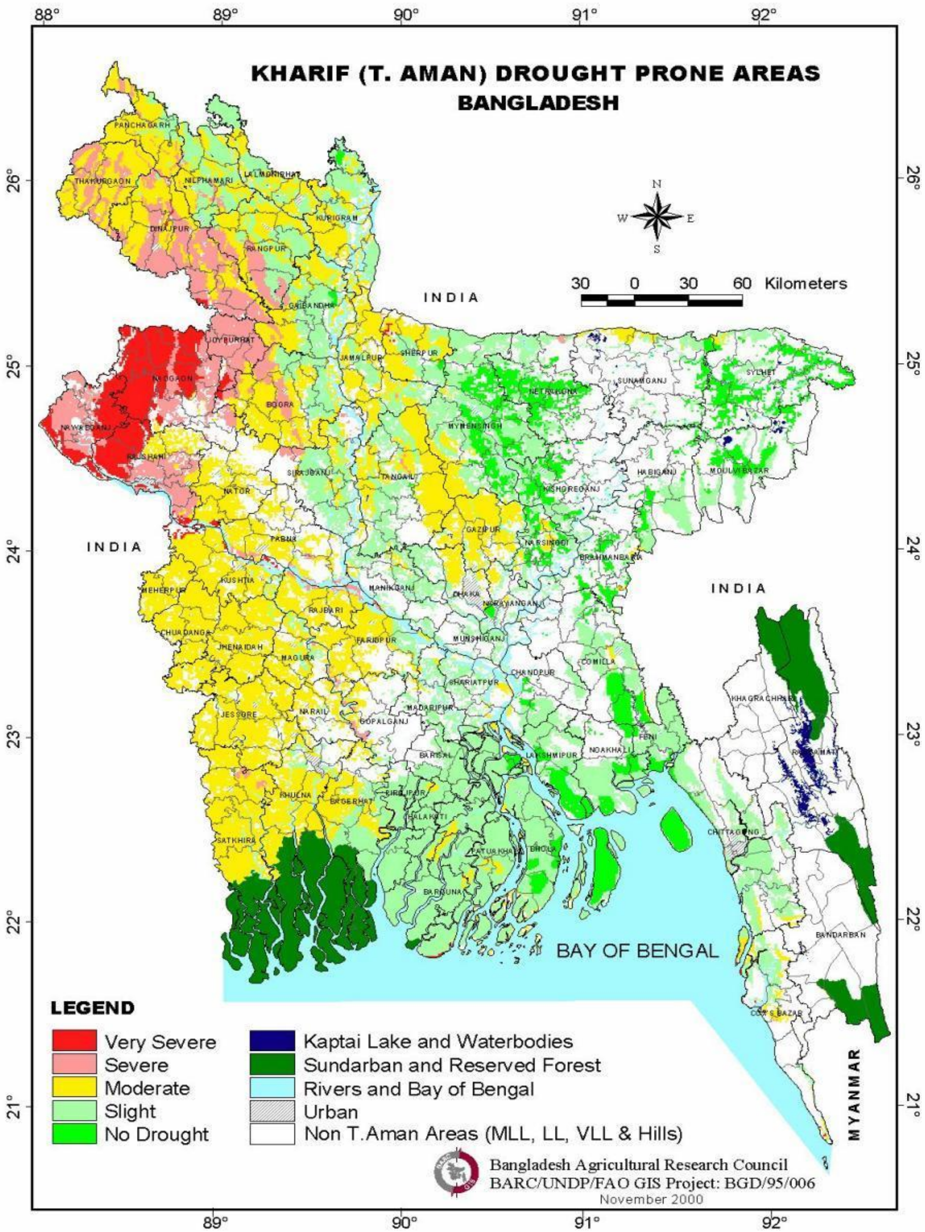
# Hazards Bangladesh faces

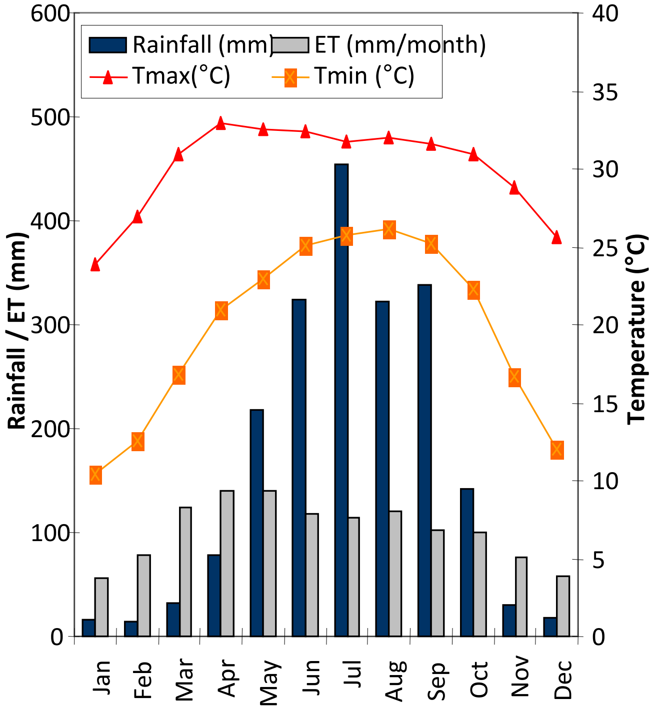

Flood


Water logging


Bank Erosion

# Drought Prone Areas in Bangladesh



# Recent Experiences

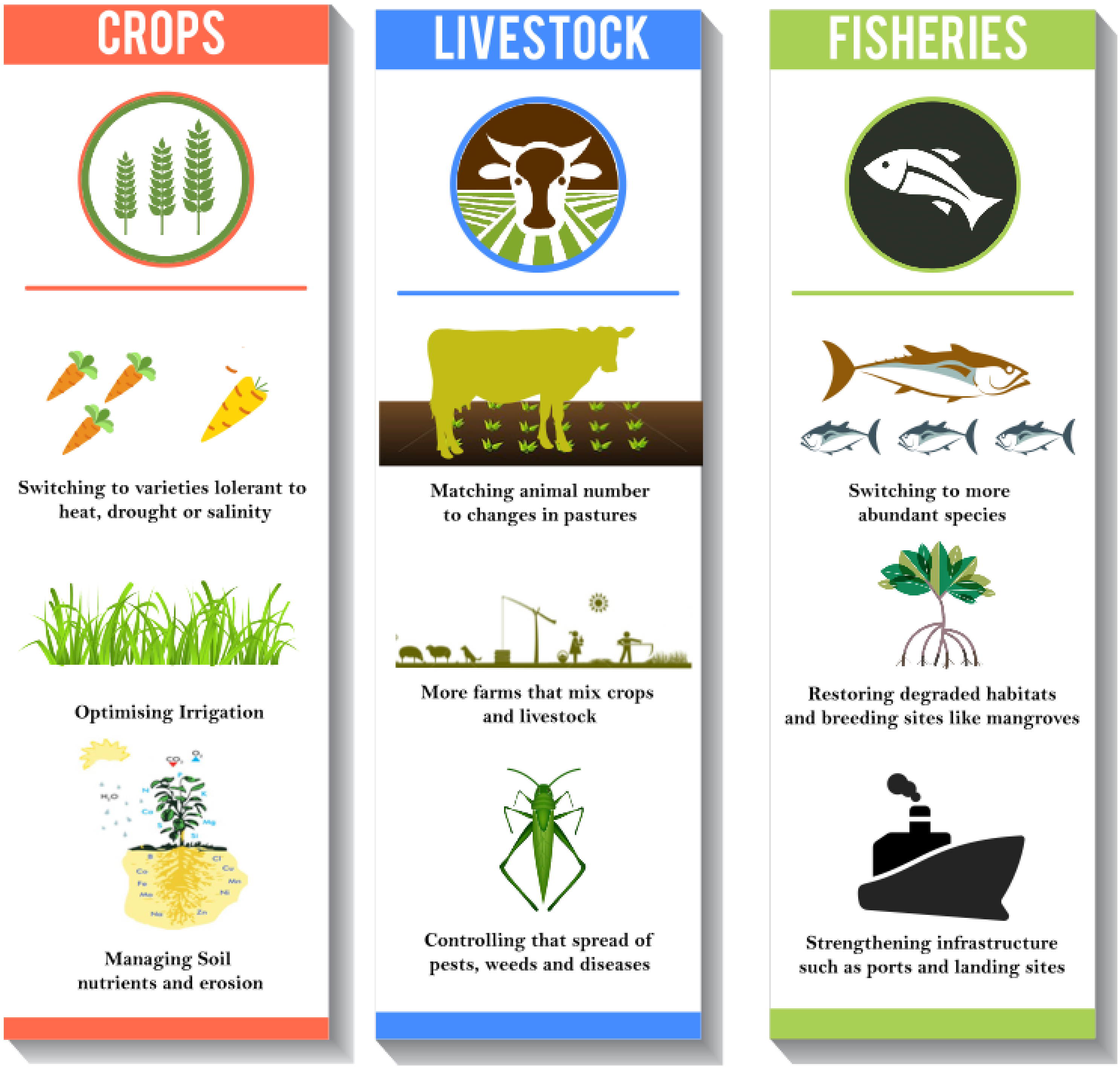
- **Cyclone –SIDR’2007**
- **Cyclone – AILA’2009**
- **Recurring Floods**
- **Desertification of North, North-west and South-west of Bangladesh**
- **Intrusion of saline water**

# Havoc in the Sunderban

# Health, Nutritional & Agricultural Challenges

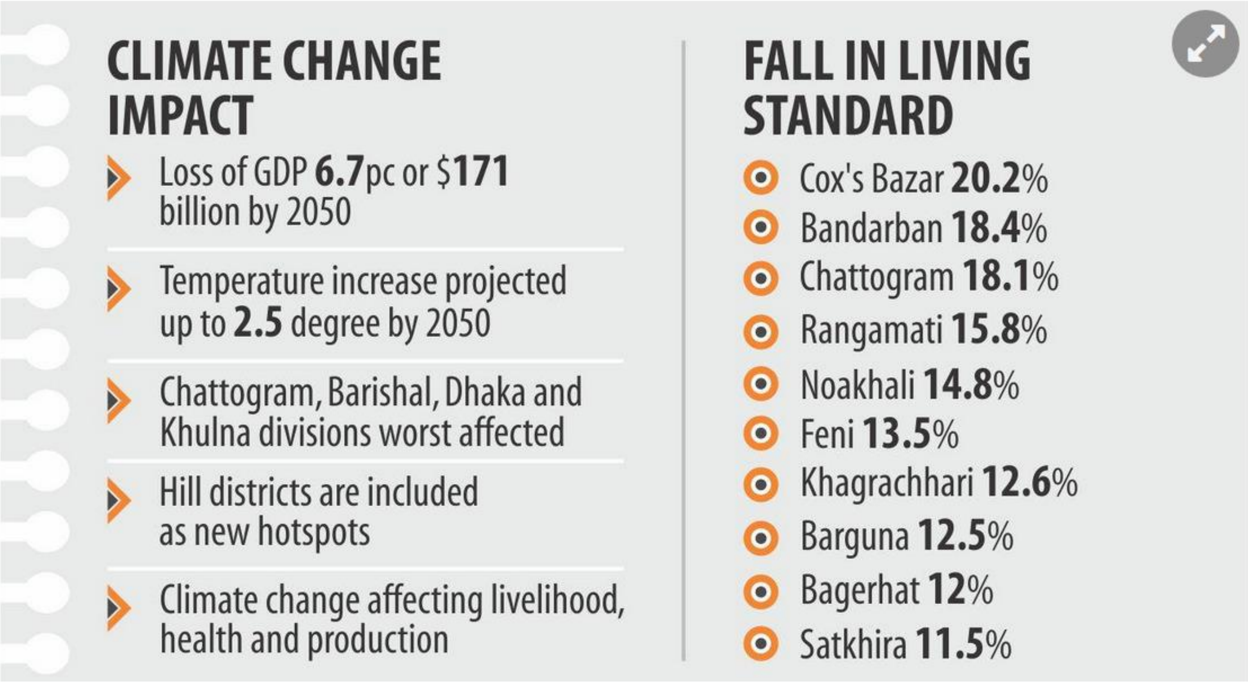
- Arsenic contamination poses major threat to health;
- Increased malnutrition among the poor contribute to the spread of communicable and non-communicable diseases

- Increased incidence of different degenerative diseases due to salinity intrusion;
- Country is now largely food secure – but limits of rice cultivation has been reached in dry period with ground water irrigation;


CROPS
Switching to varieties lolerant to heat, drought or salinity
Optimising Irrigation
Managing Soil nutrients and erosion
LIVESTOCK
Matching animal number to changes in pastures
More farms that mix crops and livestock
Controlling that spread of pests, weeds and diseases
FISHERIES
Switching to more abundant species
Restoring degraded habitats and breeding sites like mangroves
Strengthening infrastructure such as ports and landing sites

# Climate Change Fallout: 13.4cr people to be hit hard

***WB report depicts grim picture***







**TOP NEWS**

- **Shakib falls after valiant 66**
- **'June was hottest month ever record on Earth'**
- **Reconsider gas tariff hike: 14-party govt**
- **PM places proposal for making any Pacific initiative a success**
- **Don't cheat people in name of hajj business: President**
- **14 Russian sailors killed in sub fire:**

# BANGLADESH'S SCORE

## ON GLOBAL CLIMATE RISK INDEX (CRI) FOR 2019

| INDICATORS ANALYSED | FATALITIES IN 2019 | FATALITIES PER 1,00,000 INHABITANTS | LOSSES IN PURCHASING POWER PARITY (MILLION USD) | LOSSES PER UNIT GDP IN % |
|---|---|---|---|---|
| Bangladesh's rank out of **180** countries | 7 | 29 | 20 | 28 |

# The cost of climate change is high

- Average tropical cyclones cost Bangladesh about $1 billion annually.
- By 2050, one-third of agricultural GDP may be lost due to climate variability and extreme events – a devastating figure as the agriculture sector represents around half of employment in the country.
- 13.3 million people may become internal migrants in next 30 years due to climate impacts on agriculture, water scarcity, and rising sea levels, with higher impacts on women.
- In case of a severe flooding, GDP could fall by as much as 9 percent.
- The costs of environmental degradation and natural disasters are predicted to rise over time, compounded by higher heat, humidity, and health impacts.

# We have a fragile policy

Not well-connected or coordinated!

# Why Bangladesh is vulnerable?

Bangladesh is one of the most vulnerable countries because of its

- geographic location;
- flat and low-lying topography;
- high population density;
- reliance of many livelihoods on climate sensitive sectors, particularly agriculture and fisheries;
- corruption?

# Recent Success

- Bangladesh has already developed salinity tolerant, flood tolerant and shorter maturity varieties of rice. This will help in the short run.

- Extensive agricultural extension services are needed to make these varieties available to the farmers.

- But this is only the beginning: more varieties and appropriate ecosystem-based agricultural system need to be developed and popularized;

- There is no country that is not experiencing the drastic effects of climate change. Greenhouse gas emissions are more than 50 percent higher than in 1990.
- The annual average economic losses from climate-related disasters are in the hundreds of billions of dollars.
- This is not to mention the human impact of geo-physical disasters, which are 91 percent climate-related, and which between 1998 and 2017 killed 1.3 million people, and left 4.4 billion injured.
- The goal aims to mobilize US$100 billion annually by 2020 to address the needs of developing countries to both adapt to climate change and invest in low-carbon development.

# Facts and Figures

## +1°C

As of 2017 humans are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels.

## +20cm

Sea levels have risen by about 20 cm (8 inches) since 1880 and are projected to rise another 30–122 cm (1 to 4 feet) by 2100.

## 2050

To limit warming to 1.5C, global net $CO_2$ emissions must drop by 45% between 2010 and 2030, and reach net zero around 2050.

## 1/3

Climate pledges under The Paris Agreement cover only one third of the emissions reductions needed to keep the world below 2°C.

## $26 trillion

Bold climate action could trigger at least US$26 trillion in economic benefits by 2030.

## 18 million

The energy sector alone will create around 18 million more jobs by 2030, focused specifically on sustainable energy.

# Typology of adaptation options



1. Agronomic management
2. Water harvesting and exploitation
3. Water Use efficiency
4. Crop intensification
5. Alternative crop enterprises
6. Post harvest practices



## Policy Response at National Level

- Bangladesh Climate Change Strategy and Action Plan (BCCSAP), 2009
- National Adaptation Programme of Action, 2005, updated in 2009
- Bangladesh Climate Change Trust Act, 2010
- Nationally Determined Contributions (NDC), 2015, Enhanced & Updated in 2021
- NDC Implementation Road Map, 2018
- Bangladesh Delta Plan, 2100
- Mujib Climate Prosperity Plan 2030 (Draft)
- National Disaster Management Policy, 2015
- Standing Orders on Disaster 2019
- Plan of Action to Implement Sendai Framework for Disaster Risk Reduction 2015-2030
- National Strategy on Internal Displacement Management 2021
- National Plan for Disaster Management 2021-2025
- Bangladesh Energy Efficiency and Conservation Master Plan up to 2030
- Renewable Energy Policy of Bangladesh, 2008
- Bangladesh National Action Plan for Reducing SLCPs, 2012, Updated in 2018

## National Determined Contributions (NDC)

- Bangladesh revised and submitted Updated NDC on 26 August 2021, enhancing both unconditional and
- conditional contribution with ambitious quantifiable mitigation targets.
- Our updated, enhanced NDC has expanded its emission reduction coverage from only the energy sector
- to the whole economy of the country.

| | |
|---|---|
| **Unconditional Contribution** (using own resources) | Bangladesh will reduce its GHG emissions by 27.56 $MtCO_2e$ or 6.73% below BAU in 2030. |
| **Conditional Contribution** (with international support) | Bangladesh will reduce additional emissions by 61.9 $MtCO_2e$ or 15.12% below BAU in 2030. |
| **Combined Total Contribution** | Bangladesh will reduce its GHG emissions by 89.47 $MtCO_2e$ or 21.85% below BAU in 2030. |

# Bangladesh Delta Plan 2100

- The Government has recently adopted the Bangladesh Delta Plan 2100, a comprehensive 100-year strategic plan aimed at gradual sustainable development through adaptive delta management process.
- The plan targets to achieve a safe, climate-resilient and prosperous delta with a mission to ensure long term water and food security, economic growth and environmental sustainability, effectively reducing vulnerability to natural disasters and building resilience to climate change.

# BAGLADESH DELTA PLAN-2100

## FIRST PHASE

**80** projects in progress

Worth **Tk 2,97,600**cr

Additional **Tk 34,72** crore invested

To be completed by **2030**

DELTAPLAN
2100 BANGLADESH

## COMPONENTS

- Delta Governance Council
- Delta Wing
- Delta Knowledge Bank
- Digital Data Store
- Delta Fund

# DELTA PLAN FALLS BEHIND TARGET

| Targets for 2020 | Present situation |
| --- | --- |
| Bringing down the number of flood vulnerable people to **60 million** | **80 million** people are currently at risk |
| Reducing the maximum extent of severe flooding to **35%** of total area | Around half the area goes under water in such cases |
| Bringing down cyclone-prone areas to **4%** | **10%** of total area is currently at risk of cyclone |
| Reducing the extent of saline water intrusion to **35%** of coastal area | Salinity intrusion currently taking place in **40%** of coastal area |
| Reducing number of people vulnerable to natural disasters to **67.9 million** | **97.9 million** people currently at risk |

# Adaptation Measures in Agriculture

- Government of Bangladesh has undertaken research on development of drought, cold, waterlog, diseases, pest and salt tolerant crop varieties to cope with the changing climate.
- **Early harvest short duration rice varieties:** BRRI dhan 62 (100 days), 66, 71 (113 days); BINA dhan 7, 11, 16, 17, 19-22 (100-120 days); traditional varieties require 140-150 days.
- **Drought tolerant early varieties:** BRRI dhan 42, 43 (100 days), 57 (100-105 days), 66 and 71 (also short duration); BINA dhan-17, 19, 21.
- **Salt tolerant rice varieties:** BRRI dhan 23, 40, 41, 55, 67, 73 (8 ds/m); BRRI dhan 53, 54, 61, (6 ds/m); BRRI dhan 47 (8-12 ds/m), 97(8-14 ds/m), 99 (8-10 ds/m); BINA dhan 8, 10, 23.
- **Flooding tolerant varieties:** BRRI dhan51, BRRI dhan52, BRRI dhan79; BINA dhan 11, 12, 23.
- **Stress tolerant other crop varieties:** BARI Gom 22 , 23, 24 (heat tolerant); BARI Gom 25, 26, 30, 31 (early maturing heat tolerant); BINA Gom 1 & BARI Hybrid Maize 16 (salt tolerant); BINA mung-8, 9, 10, BINA masur 8, 10 and BARI Hybrid Maize 12, 13 (drought tolerant).

## Role at International Level

- **Kyoto Protocol:** Bangladesh is among the first 4 countries accepting the 2nd commitment period of the Kyoto Protocol on 13 November 2013.
- **Paris Agreement:** Bangladesh signed the Paris Agreement on the first day of opening for signature on 22 April 2016 and ratified on 21 September 2016.
- **Membership in UNFCCC Bodies:**

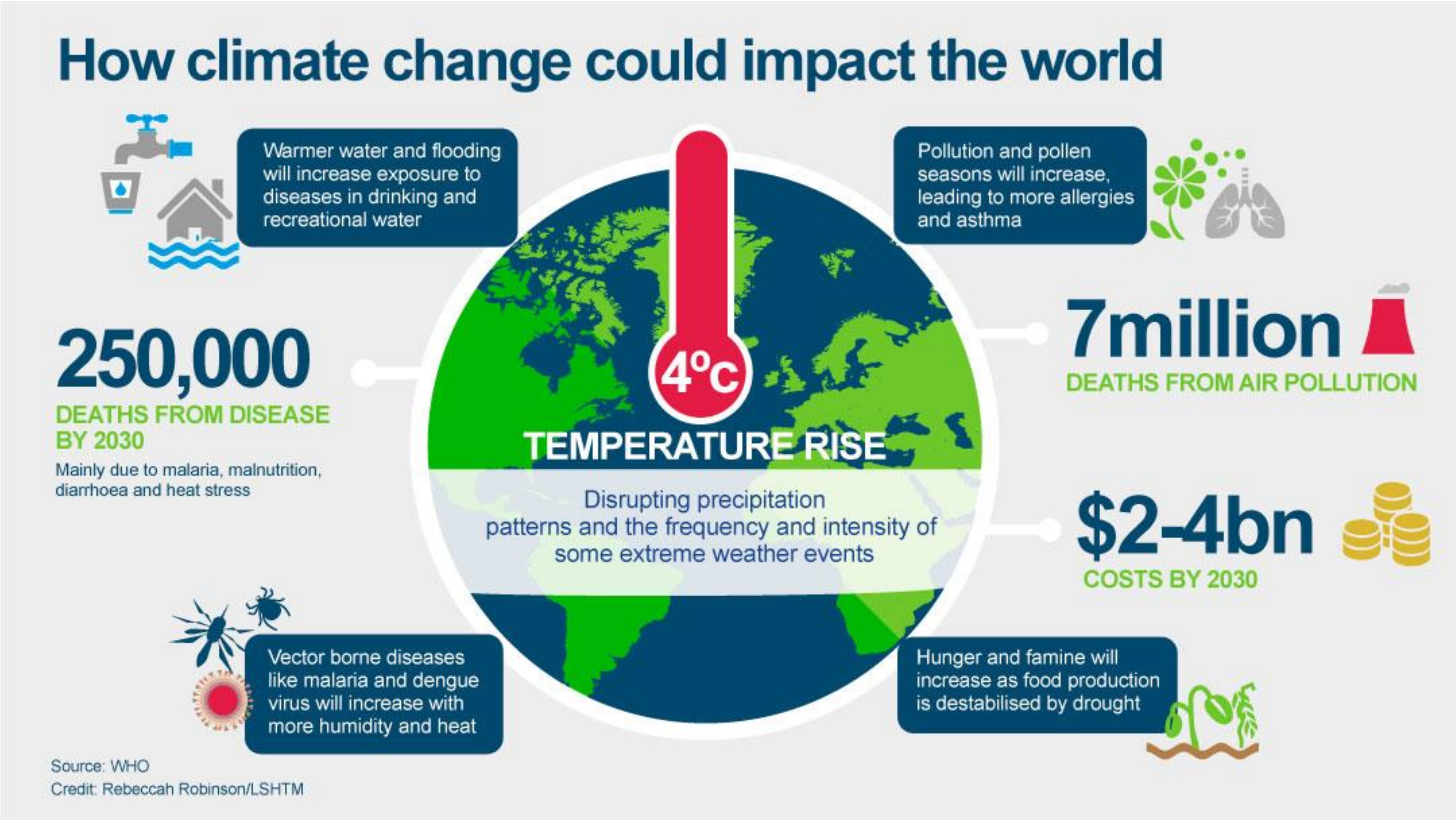
❖ Member of Technology Executive Committee

❖ Alternate Member of CDM Executive Board

❖ Alternate Member of Joint Implementation Supervisory Committee (JISC)

❖ Member of Compliance Committee referred to Article 15.2 of Paris Agreement - PAICC.

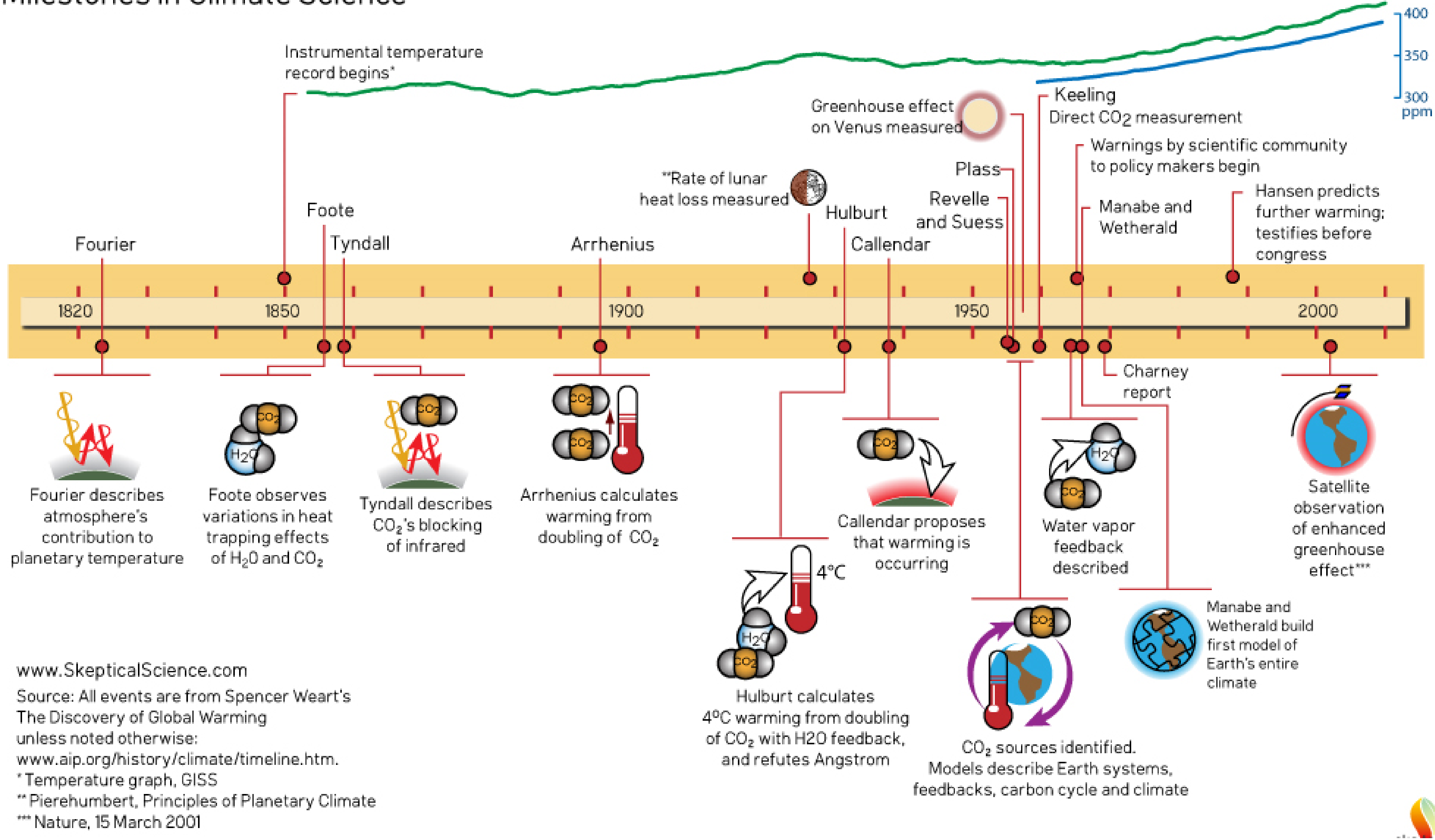
# Climate Change and Global Issues


How climate change could impact the world
Warmer water and flooding will increase exposure to diseases in drinking and recreational water
Pollution and pollen seasons will increase, leading to more allergies and asthma
250,000
DEATHS FROM DISEASE BY 2030
Mainly due to malaria, malnutrition, diarrhoea and heat stress
4°c
TEMPERATURE RISE
Disrupting precipitation patterns and the frequency and intensity of some extreme weather events
7million
DEATHS FROM AIR POLLUTION
$2-4bn
COSTS BY 2030
Vector borne diseases like malaria and dengue virus will increase with more humidity and heat
Hunger and famine will increase as food production is destabilised by drought
Source: WHO
Credit: Rebeccah Robinson/LSHTM

# History of climate change

- Scientists study changes in Earth's climate by analysing rock formations, ice cores, and plant growth over millions of years.
- The first weather records began in the $18^{th}$ century, and methods of measuring atmospheric changes have only been developed in the last 150 years.
- This timeline tracks the events that have severely impacted Earth's climate, and the techniques used to study them.

# Milestones in Climate Science



# Hotter temperatures

- As greenhouse gas concentrations rise, so does the global surface temperature. The last decade, 2011-2020, is the warmest on record.
- Since the 1980s, each decade has been warmer than the previous one.
- Nearly all land areas are seeing more hot days and heat waves. Higher temperatures increase heat-related illnesses and make working outdoors more difficult.
- Wildfires start more easily and spread more rapidly when conditions are hotter. Temperatures in the Arctic have warmed at least twice as fast as the global average.

# More severe storms

- Destructive storms have become more intense and more frequent in many regions.
- As temperatures rise, more moisture evaporates, which exacerbates extreme rainfall and flooding, causing more destructive storms.
- The frequency and extent of tropical storms is also affected by the warming ocean.
- Cyclones, hurricanes, and typhoons feed on warm waters at the ocean surface. Such storms often destroy homes and communities, causing deaths and huge economic losses.

# Increased drought

- Climate change is changing water availability, making it scarcer in more regions.
- Global warming exacerbates water shortages in already water-stressed regions and is leading to an increased risk of agricultural droughts affecting crops, and ecological droughts increasing the vulnerability of ecosystems.
- Droughts can also stir destructive sand and dust storms that can move billions of tons of sand across continents.
- Deserts are expanding, reducing land for growing food. Many people now face the threat of not having enough water on a regular basis.

# A warming, rising ocean

- The ocean soaks up most of the heat from global warming. The rate at which the ocean is warming strongly increased over the past two decades, across all depths of the ocean.
- As the ocean warms, its volume increases since water expands as it gets warmer.
- Melting ice sheets also cause sea levels to rise, threatening coastal and island communities.
- In addition, the ocean absorbs carbon dioxide, keeping it from the atmosphere. But more carbon dioxide makes the ocean more acidic, which endangers marine life and coral reefs.

# Loss of species

- Climate change poses risks to the survival of species on land and in the ocean.
- These risks increase as temperatures climb. Exacerbated by climate change, the world is losing species at a rate 1,000 times greater than at any other time in recorded human history.
- One million species are at risk of becoming extinct within the next few decades.
- Forest fires, extreme weather, and invasive pests and diseases are among many threats related to climate change.
- Some species will be able to relocate and survive, but others will not.

# Not enough food

- Changes in the climate and increases in extreme weather events are among the reasons behind a global rise in hunger and poor nutrition.
- Fisheries, crops, and livestock may be destroyed or become less productive.
- With the ocean becoming more acidic, marine resources that feed billions of people are at risk.
- Changes in snow and ice cover in many Arctic regions have disrupted food supplies from herding, hunting, and fishing.
- Heat stress can diminish water and grasslands for grazing, causing declining crop yields and affecting livestock.

# More health risks

- Climate change is the single biggest health threat facing humanity.
- Climate impacts are already harming health, through air pollution, disease, extreme weather events, forced displacement, pressures on mental health, and increased hunger and poor nutrition in places where people cannot grow or find sufficient food.
- Every year, environmental factors take the lives of around 13 million people.
- Changing weather patterns are expanding diseases, and extreme weather events increase deaths and make it difficult for health care systems to keep up.

# Poverty and displacement

- Climate change increases the factors that put and keep people in poverty.
- Floods may sweep away urban slums, destroying homes and livelihoods.
- Heat can make it difficult to work in outdoor jobs. Water scarcity may affect crops.
- Over the past decade (2010–2019), weather-related events displaced an estimated 23.1 million people on average each year, leaving many more vulnerable to poverty.
- Most refugees come from countries that are most vulnerable and least ready to adapt to the impacts of climate change.

**According to a study, conserving 30% of land will safeguard 70% of terrestrial plant and vertebrate animal species, while 68% of all clean water will be made available.**

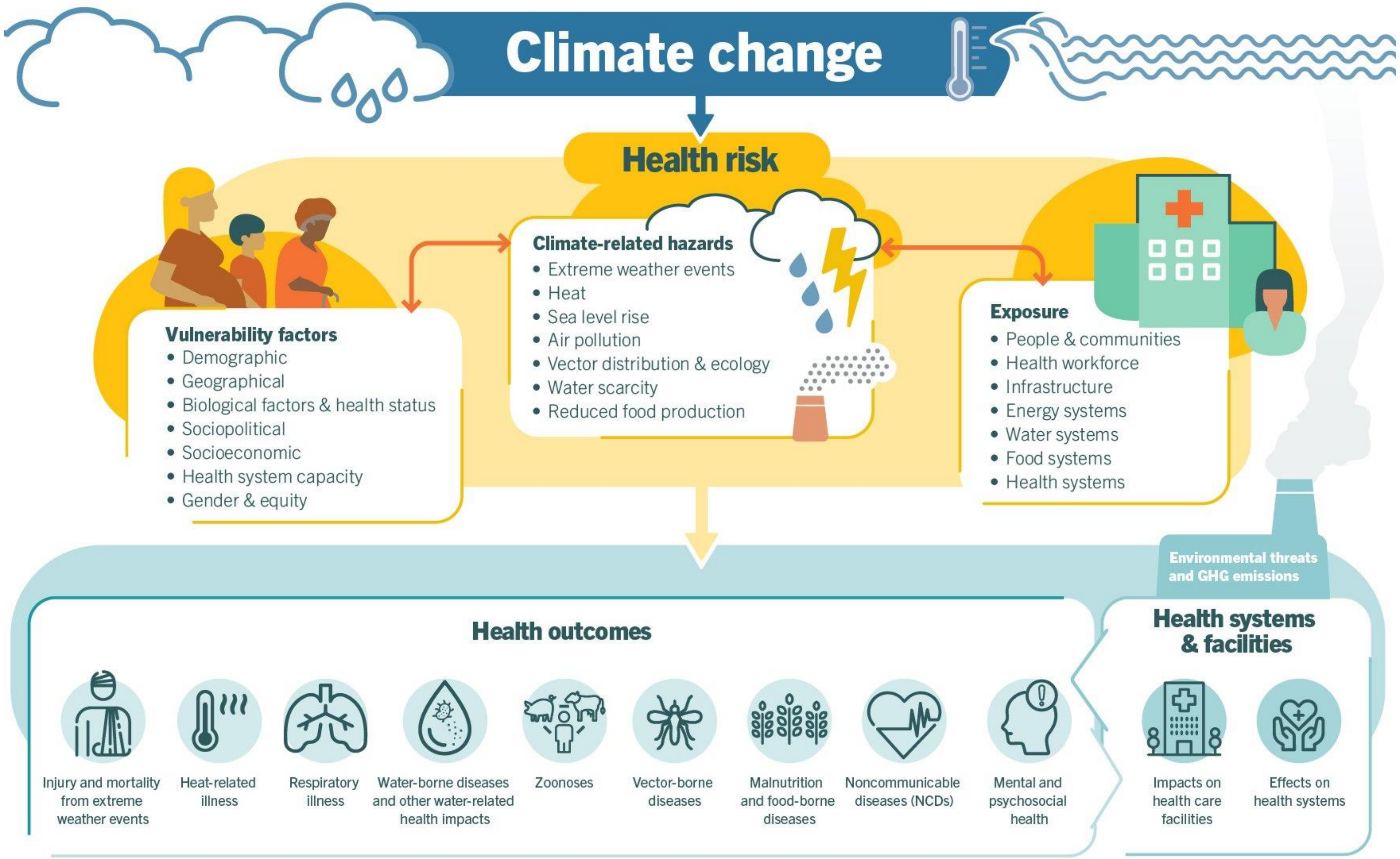
# Climate change impacts on health

The Intergovernmental Panel on Climate Change's (IPCC) Sixth Assessment Report (AR6) concluded that climate risks are appearing faster and will become more severe sooner than previously expected, and it will be harder to adapt with increased global heating.

- It further reveals that 3.6 billion people already live in areas highly susceptible to climate change.
- Despite contributing minimally to global emissions, low-income countries and small island developing states (SIDS) endure the harshest health impacts.
- In vulnerable regions, the death rate from extreme weather events in the last decade was 15 times higher than in less vulnerable ones.

- Climate change is impacting health in a myriad of ways, including by leading to death and illness from increasingly frequent extreme weather events, such as heatwaves, storms and floods, the disruption of food systems, increases in zoonoses and food-, water- and vector-borne diseases, and mental health issues.
- Furthermore, climate change is undermining many of the social determinants for good health, such as livelihoods, equality and access to health care and social support structures.
- These climate-sensitive health risks are disproportionately felt by the most vulnerable and disadvantaged, including women, children, ethnic minorities, poor communities, migrants or displaced persons, older populations, and those with underlying health conditions.

*An overview of climate-sensitive health risks, their exposure pathways and vulnerability factors. Climate change impacts health both directly and indirectly, and is strongly mediated by environmental, social and public health determinants.*



- Although it is unequivocal that climate change affects human health, it remains challenging to accurately estimate the scale and impact of many climate-sensitive health risks.
- However, scientific advances progressively allow us to attribute an increase in morbidity and mortality to global warming, and more accurately determine the risks and scale of these health threats.

- WHO data indicates 2 billion people lack safe drinking water and 600 million suffer from foodborne illnesses annually, with children under 5 bearing 30% of foodborne fatalities.
- Climate stressors heighten waterborne and foodborne disease risks. In 2020, 770 million faced hunger, predominantly in Africa and Asia.
- Climate change affects food availability, quality and diversity, exacerbating food and nutrition crises.

- Temperature and precipitation changes enhance the spread of vector-borne diseases.
- Without preventive actions, deaths from such diseases, currently over 700 000 annually, may rise.
- Climate change induces both immediate mental health issues, like anxiety and post-traumatic stress, and long-term disorders due to factors like displacement and disrupted social cohesion.

- Recent research attributes 37% of heat-related deaths to human-induced climate change.
- Heat-related deaths among those over 65 have risen by 70% in two decades.
- In 2020, 98 million more experienced food insecurity compared to the 1981–2010 average.
- The WHO conservatively projects 250 000 additional yearly deaths by the 2030s due to climate change impacts on diseases like malaria and coastal flooding.
- However, modelling challenges persist, especially around capturing risks like drought and migration pressures.

- The climate crisis threatens to undo the last 50 years of progress in development, global health and poverty reduction, and to further widen existing health inequalities between and within populations.
- It severely jeopardizes the realization of UHC in various ways, including by compounding the existing burden of disease and by exacerbating existing barriers to accessing health services, often at the times when they are most needed.
- Over 930 million people – around 12% of the world's population – spend at least 10% of their household budget to pay for health care.
- With the poorest people largely uninsured, health shocks and stresses already currently push around 100 million people into poverty every year, with the impacts of climate change worsening this trend.

# Climate change and equity

- In the short- to medium-term, the health impacts of climate change will be determined mainly by the vulnerability of populations, their resilience to the current rate of climate change and the extent and pace of adaptation.
- In the longer-term, the effects will increasingly depend on the extent to which transformational action is taken now to reduce emissions and avoid the breaching of dangerous temperature thresholds and potential irreversible tipping points.

While no one is safe from these risks, the people whose health is being harmed first and worst by the climate crisis are the people who contribute least to its causes, and who are least able to protect themselves and their families against it: people in low-income and disadvantaged countries and communities.

Addressing climate change's health burden underscores the equity imperative: those most responsible for emissions should bear the highest mitigation and adaptation costs, emphasizing health equity and vulnerable group prioritization.

# Climate change on global transportation

- Transport is responsible for about one-quarter of all greenhouse gas emissions. The sector’s emissions are set to double by 2050.
- But humanity can reduce that tally by up to **4.7 Gt** by embracing electric vehicles, both privately and in public transit systems, and by creating safe spaces where people can walk, cycle and use other forms of non-motorized transport.
- Doing those things would have other benefits, as well. For instance, without action to cut vehicle emissions, deaths from exposure to exhaust fumes in urban areas are set to increase by over 50 per cent by 2030.

- The lowest income countries produce one-tenth of emissions, but are the most heavily impacted by climate change.

  Vulnerable populations in these countries suffer damaging outcomes in terms of health, food and water, education and more.

  Developing countries have a window of opportunity to put mitigating policies in place.

# Climate change and airline takeoff

Hotter temperatures at ground level therefore make it more difficult for airplanes to gain enough lift to take flight. Hotter temperatures can cause weight restrictions for flight take-off — meaning fewer passengers and reduced capacity for luggage, cargo, and fuel.

# Actions are required at every level: government, private sector and the public

- Switch fleets to electric vehicles
- Incentivize a transition to zero-emission transportation, including for cars, taxis, buses, trucks and trains
- Invest in and remove barriers to non-motorized mobility infrastructure, like protected bicycle lanes or paths for pedestrians Promote the significant public health benefits of low-carbon policies, including increased public transportation and non-motorized mobility

# Climate change and poverty

- The effects of climate change are hitting many of the world's poorest people first, and hardest. And they're making poverty worse.
- Extreme weather patterns, natural hazards and food and water shortages are threatening the lives of people living in poverty and, the poorer people are, the harder it is to recover from failed harvests, destroyed homes, and health crises.
- It has been estimated that, by 2030, **climate change could push more than 120 million more people into poverty**.
- That's why ActionAid is working with communities around the world to help build resilience, adapt to the effects of climate change, respond to disasters and support the specific needs of women and girls.

# The relationship between climate change and poverty

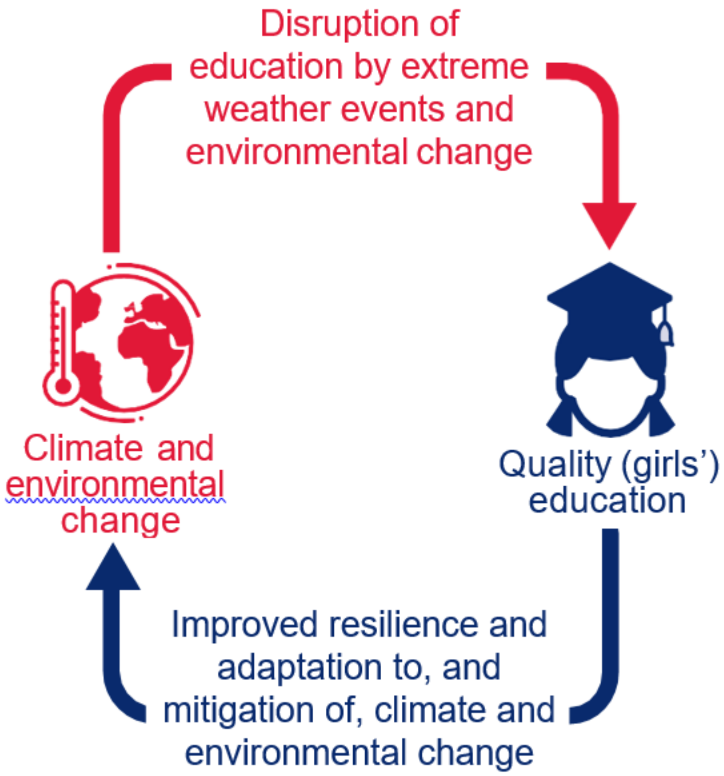
- Despite historically being the least likely to contribute to rising $CO_2$ emissions, **people living in poverty are often the worst affected**.
- Meanwhile, many of the world’s richest and highest-polluting countries are feeling the impact of climate change the least.
- Richer countries tend to have the resources and networks to adapt to the changing climate, and more resilient infrastructure (such as water systems and housing) to cope with erratic weather events and disasters.
- While poorer countries almost always have **fewer resources and weaker infrastructure, making them more vulnerable to the effects of climate change**.

# Water scarcity

- Access to water is becoming threatened by climate change. Frequent droughts, increased evaporation and changes in rainfall patterns and run-off particularly impact water availability in areas like the sub-tropics, which already experience water scarcity.
- By 2025, there will be 5 billion people on the planet, up from the current 1.7 billion who will be affected by water scarcity.

# Education

Many families will survive economic downturns brought on by decimated crops through counter-productive means such as pulling their children out of school to save on fees and/or putting them to work to make up for lost income.



# Creating refugees

- Climate change is a powerful driver of internal migration because of its impacts on people’s livelihoods and loss of liveability in highly exposed locations.
- By 2050, 216 million climate refugees will have been displaced in six world regions, with the top three being in sub-Saharan Africa (86 million), East Asia and the Pacific (49 million), South Asia (40 million).

# Work-related hazards

- Excessive heat during work creates occupational health risks; it restricts a worker's physical functions and capabilities, work capacity and productivity.
- Heat stress is projected to reduce total working hours worldwide by 2.2% and global GDP by $2.4 billion in 2030.

# Climate Change Organizations

- Adaptation Fund: Finances projects and programs that help vulnerable communities in developing countries adapt to climate change.
- BIS - Climate Change and Green Finance: Gathers the various strands of work produced by the BIS, its committees and hosted associations, as well as its stakeholders on topics relating to climate change, green finance and sustainability.
- C40 Cities: C40 is a network of the world's megacities committed to addressing climate change.

- CDP: CDP is a not-for-profit charity that runs the global disclosure system for investors, companies, cities, states and regions to manage their environmental impacts.
- Carbon Tracker: Independent financial think tank that carries out in-depth analysis on the impact of the energy transition on capital markets and the potential investment in high-cost, carbon-intensive fossil fuels.
- Center for Climate and Energy Solutions: Independent, nonpartisan, nonprofit organization working to forge practical solutions to climate change
- Climate Bonds Initiative: An international organization working to mobilize global capital for climate action. Developer of the Climate Bonds Standard and Certification Scheme.

- Climate Investment Coalition: Works to accelerate climate action and a green recovery to help meet the goals of the Paris Agreement and the net-zero transition by mobilising investments for clean energy and climate by 2030.
- Climate Investment Funds: Accelerates climate action by empowering transformations in clean technology, energy access, climate resilience, and sustainable forests in developing and middle income countries.
- Coalition for Rainforest Nations: International organization of over 50 rainforest nations. Created the global rainforest conservation mechanism REDD+ which now protects 90% of the world’s tropical rainforests.
- Environmental Defense Fund: Nonprofit environmental advocacy group.
- FAO - Climate Change: Supports countries to both mitigate and adapt to the effects of climate change through a wide range of research based and practical programs and projects.

- Glasgow Financial Alliance for Net Zero (GFANZ): GFANZ, chaired by Mark Carney, UN Special Envoy on Climate Action and Finance, unites over 160 firms (together responsible for assets in excess of US$70 trillion) from the leading net zero initiatives across the financial system to accelerate the transition to net zero emissions by 2050 at the latest.
- Green Climate Fund: World's largest climate fund, mandated to support developing countries raise and realize their Nationally Determined Contributions (NDC) ambitions towards low-emissions, climate-resilient pathways.
- IEA: The IEA is committed to shaping a secure and sustainable energy future for all
- Inside Climate News: Pulitzer Prize-winning, nonprofit, nonpartisan news organization that provides essential reporting and analysis on climate change, energy and the environment, for the public and for decision makers.

- IPCC: The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body for assessing the science related to climate change.
- NDC Partnership: The NDC Partnership brings together more than 200 members, including more than 115 countries, developed and developing, and more than 80 institutions to create and deliver on ambitious climate action that helps achieve the Paris Agreement and the Sustainable Development Goals (SDGs).
- NGFS: The Central Banks and Supervisors Network for Greening the Financial System (NGFS) is a group of Central Banks and Supervisors willing, on a voluntary basis, to exchange experiences, share best practices, contribute to the development of environment and climate risk management in the financial sector, and to mobilize mainstream finance to support the transition toward a sustainable economy.
- OMFIF Sustainable Policy Institute: A community designed to meet the policy, regulatory and investment challenges posed by ESG factors

- REDES: The Network of Regulators for Sustainable Development (REDES) aims to promote sustainable regulation and supervision among Latin American and the Caribbean countries and consolidate a regional forum to identify common challenges and facilitate the coordination of policies and initiatives in the face of the global agenda.
- TCFD: The Financial Stability Board created the Task Force on Climate-related Financial Disclosures (TCFD) to improve and increase reporting of climate-related financial information.
- TNFD: Taskforce on Nature-related Financial Disclosures (TNFD) will deliver a framework for organisations to report and act on evolving nature-related risks, to support a shift in global financial flows away from nature-negative outcomes and toward nature-positive outcomes.

- UNDP Climate Promise: Tackling the climate crisis requires that all countries make bold pledges under the Paris Agreement to reduce emissions of the greenhouse gases (GHG) that cause global warming. The Climate Promise is our commitment to ensure that any country wishing to increase the ambition of their national climate pledge is able to do so.
- United Nations Environment Programme (UNEP): Leading global environmental authority
- World Climate Foundation: An impact-oriented organisation that works with inspiring leaders from government, business, financial institutions and civil society organisations to build resilience, and enabling the necessary transformation that addresses both the climate change and biodiversity crises.

- World Meteorological Organization (WMO): Specialized agency of the United Nations responsible for promoting international cooperation on atmospheric science, climatology, hydrology and geophysics.

# Global Climate Change Policies

## 1988 Intergovernmental Panel on Climate Change (IPCC) established

World Meteorological Organization (WMO) and UN Environment Programme (UNEP) establish the Intergovernmental Panel on Climate Change (IPCC). Membership is open to all members of the WMO and UN with thousands of scientists and other experts contributing to the understanding of human-induced climate change, its potential impacts and options for adaptation and mitigation. The IPCC provides an internationally accepted authority on climate change, producing reports that have the agreement of leading climate scientists and consensus from participating government.

## 1990 - IPCC's First Assessment Report (AR1)

The report concludes that emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases, resulting on average in an additional warming of the Earth's surface and calls for a global treaty on climate change.

## 1990 UN General Assembly Negotiations on a Framework Convention begin

The UN General Assembly establish the Intergovernmental Negotiating Committee (INC) for a Framework Convention on Climate Change around binding commitments, targets and timetables for emissions reductions, financial mechanisms, technology transfer, and 'common but differentiated' responsibilities of developed and developing countries.

## 1992 United Nations Framework Convention on Climate Change

The text of the United Nations Framework Convention on Climate Change is adopted at the United Nations Headquarters in New York. The objective of the treaty is to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system” and provides a framework for negotiating specific international treaties (called "protocols") that may set binding limits on greenhouse gases.

## 1992 Rio Earth Summit

The UNFCCC opens for signature at the Earth Summit in Rio, bringing the world together to curb greenhouse gas emissions and adapt to climate change.

## 1994 UNFCCC Enters into Force

The UNFCCC enters into force. Countries that sign the treaty are known as 'Parties' who meet annually at the Conference of the Parties (COP) to negotiate multilateral responses to climate change.

## 1995 Conference of Parties 1, Berlin

Delegates agreed that commitments in the Convention were 'inadequate' and established a process to negotiate strengthened commitments for developed countries, thus laying the groundwork for the Kyoto Protocol.

### 1997 Kyoto Protocol Adopted

The third Conference of the Parties achieves an historical milestone with adoption of the Kyoto Protocol, the world's first greenhouse gas emissions reduction treaty. The Protocol operationalises the UNFCCC by committing developed countries to limit and reduce greenhouse gases (GHG) emissions in accordance with agreed individual targets and places a heavier burden on them under the principle of “common but differentiated responsibility and respective capabilities”.

### 2011 COP 17, Durban

At the seventeenth Conference of the Parties, governments commit to a new universal climate change agreement by 2015 for the period beyond 2020, leading to the launch of the Ad Hoc Working Group on the Durban Platform for Enhanced Action.

### 2012 COP 18, Doha

At the eighteenth Conference of the Parties, governments agree to speedily work toward a universal climate change agreement by 2015 and to find ways to scale up efforts before 2020 beyond existing pledges to curb emissions. They also adopt the Doha Amendment, launching a second commitment period of the Kyoto Protocol.

## 2014 - IPCC's Fifth Assessment Report (AR5)

"Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level"

## 2015 The 2030 Agenda for Sustainable Development

The 17 interconnecting Sustainable Development Goals (SDGs) are a “call to action to end poverty, protect the planet and improve the lives and prospects of everyone everywhere” setting out a plan to achieve the goals. No. 13 addresses Climate Action with an objective to; take urgent action to combat climate change and its impacts by regulating emissions and promoting developments in renewable energy.

## 2015 COP 21 – Paris Agreement

## 2018 IPCC Confirms Importance of 1.5C Goal

A special Global Warming of 1.5C report by the IPCC makes clear that climate change is already happening, upgraded its risk warning from previous reports, and warned that every fraction of additional warming would worsen the impact. According to the report, global warming will likely rise to 1.5 °C above pre-industrial levels between 2030 and 2052 if warming continues to increase at the current rate. Limiting warming below or close to 1.5 °C would require a decrease in net emissions of around 45% by 2030 and reach net zero by 2050.

## 2018 Katowice Climate Package

At COP 24 in Poland, governments adopt a robust set of guidelines for implementing the landmark 2015 Paris Climate Change Agreement. The agreed 'Katowice Climate Package' operationalizes the climate change regime contained in the Paris Agreement, promotes international cooperation and encourages greater ambition.

# Conference of the Parties (COP)

| Location | Session | Conference |
|---|---|---|
| Baku, Azerbaijan | COP 29 | UN Climate Change Conference Baku – November 2024 |
| Dubai, UAE | COP 28 | UN Climate Change Conference – December 2023 |
| Sharm el-Sheikh, Egypt | COP 27 | Sharm el-Sheikh Climate Change Conference - November 2022 |
| Glasgow, United Kingdom | COP 26 | Glasgow Climate Change Conference – October-November 2021 |
| Madrid, Spain | COP 25 | UN Climate Change Conference - December 2019 |
| Katowice, Poland | COP 24 | Katowice Climate Change Conference – December 2018 |
| Bonn, Germany | COP 23 | UN Climate Change Conference - November 2017 |
| Marrakech, Morocco | COP 22 | Marrakech Climate Change Conference - November 2016 |
| Paris, France | COP 21 | Paris Climate Change Conference - November 2015 |
| Lima, Peru | COP 20 | Lima Climate Change Conference - December 2014 |
| Warsaw, Poland | COP 19 | Warsaw Climate Change Conference - November 2013 |
| Doha, Qatar | COP 18 | Doha Climate Change Conference - November 2012 |
| Durban, South Africa | COP 17 | Durban Climate Change Conference - November 2011 |

| Location | Session | Conference |
| --- | --- | --- |
| Cancun, Mexico | COP 16 | Cancún Climate Change Conference - November 2010 |
| Copenhagen, Denmark | COP 15 | Copenhagen Climate Change Conference - December 2009 |
| Poznan, Poland | COP 14 | Poznan Climate Change Conference - December 2008 |
| Bali, Indonesia | COP 13 | Bali Climate Change Conference - December 2007 |
| Nairobi, Kenya | COP 12 | Nairobi Climate Change Conference - November 2006 |
| Montreal, Canada | COP 11 | Montreal Climate Change Conference - December 2005 |
| Buenos Aires, Argentina | COP 10 | Buenos Aires Climate Change Conference - December 2004 |
| Milan, Italy | COP 9 | Milan Climate Change Conference - December 2003 |
| New Delhi, India | COP 8 | New Delhi Climate Change Conference - October 2002 |
| Marrakech, Morocco | COP 7 | Marrakech Climate Change Conference - October 2001 |
| Bonn, Germany | COP 6-2 | Bonn Climate Change Conference - July 2001 |
| The Hague, Netherlands | COP 6 | The Hague Climate Change Conference - November 2000 |
| Bonn, Germany | COP 5 | Bonn Climate Change Conference - October 1999 |
| Buenos Aires, Argentina | COP 4 | Buenos Aires Climate Change Conference - November 1998 |
| Kyoto, Japan | COP 3 | Kyoto Climate Change Conference - December 1997 |

# Rice and Climate change

- Climate change is affecting rice production in Asia and Africa, where the crop is a staple food for millions. Climatic extremes such as droughts, floods, extreme temperatures, and rising sea levels – which causes salinization of inlands – in Asia alone already affect production for about 30% of the 700 million poor who live in rainfed rice-growing areas.

# Climate change

**Fifth IPCC Report (2013):**

- Attributes Climate Change to human interventions
- Concludes Temp would be larger in tropics & subtropics
    - ➢ Rainfall heavier, more floods
    - ➢ Dry seasons drier, more drought and desertification
    - ➢ Sea level rise, inundation and salinity intrusion

| Temperature rise | Change in precipitation | Extreme weather | Sea level changes | Glacial Retreat |
|---|---|---|---|---|

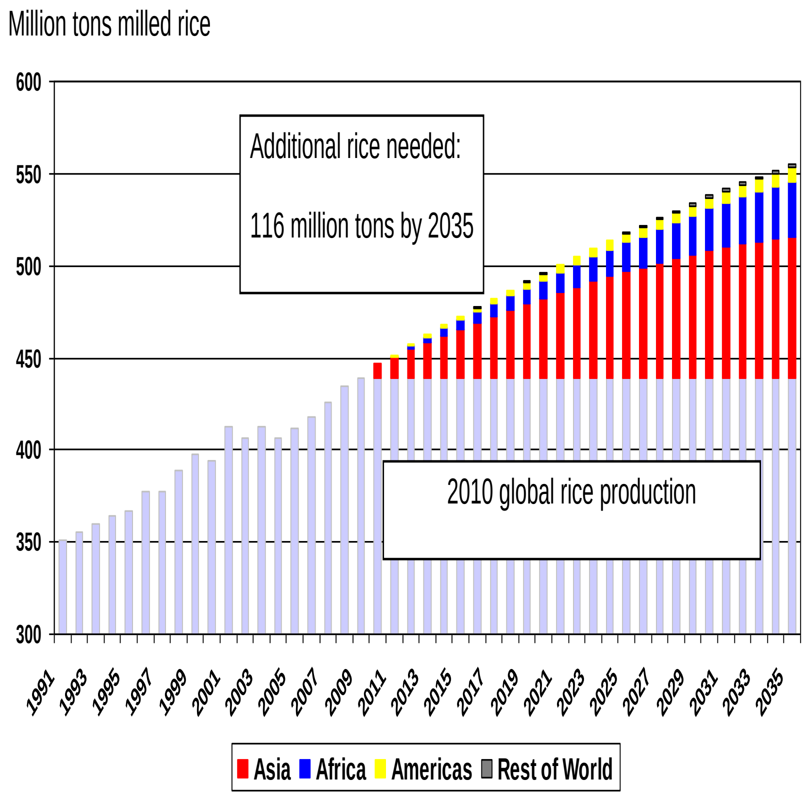

# Impact of climate change:

Climate change:

• Translates to crop agricultural risks beyond adaptive capacity, and consequently higher poverty

• Asia, overwhelmingly dependent on rice as staple, a decline in production will affect:

- ➢ human nutrition
- ➢ economic development
- ➢ poverty alleviation
- ➢ political stability



# Impact of climate change:

Rice production will both affect and be affected by climate change:

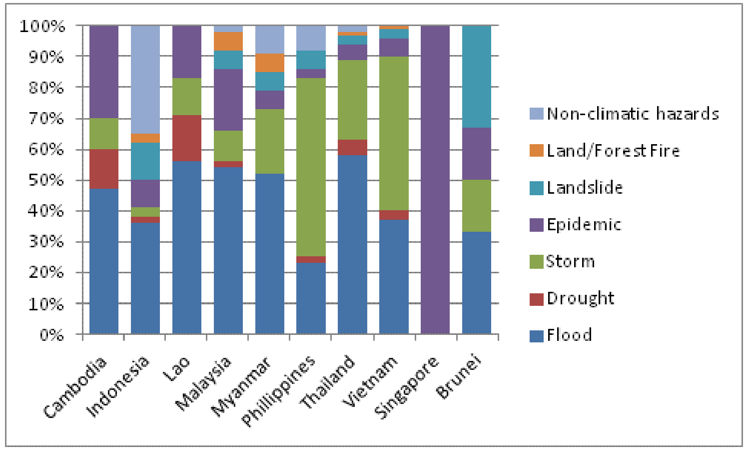
➢ Effect on climate from emissions of GHG from rice fields
➢ Climate Change places stress on the rice plants. These emanate from two factors:

- Abiotic factors
- Biotic factors

# Impact of CC on rice:

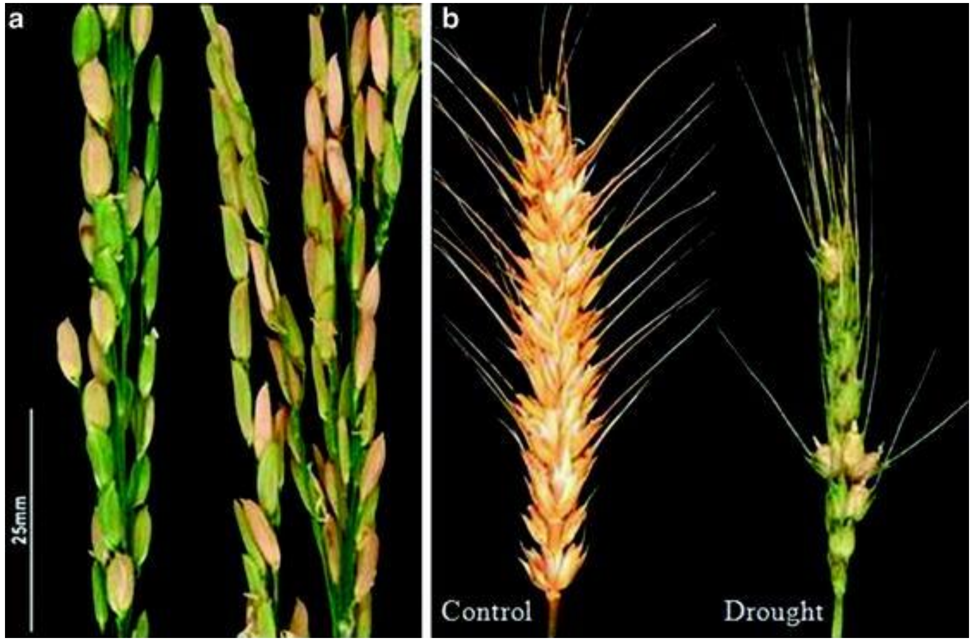
***Abiotic stress:***

- **Drought** – 20% rice area in Asia (23 mil ha) drought prone.
- **Flooding** – Affects 10-15 mil ha annually with production losses of between 1 – 12%.
- **Temperature** – Higher temperatures can cause spikelet sterility , and heat stress at night also affects production.
- **Salinity and sea level rise** – Affects 10 mil ha of coastal and inland areas in Asia; mega-deltas produce half of Asia's rice



# Reproductive development and seed formation

- Drought directly affects the reproduction process of plants. Early reproductive stages, micro- and megasporogensis are the most sensitive among the sub-phases.
- Pollen viability, germination, pollen tube growth, stigma viability and receptivity, anthesis, pollination, fertilization, and embryo development are severely vulnerable to drought stress.
- Lacking of any of these processes causes embryo abortion that ultimately affects the yield.
- Drought stress after fertilization decreases seed size rather than seed number.



Photos Courtesy: Prof. Tim Wheeler

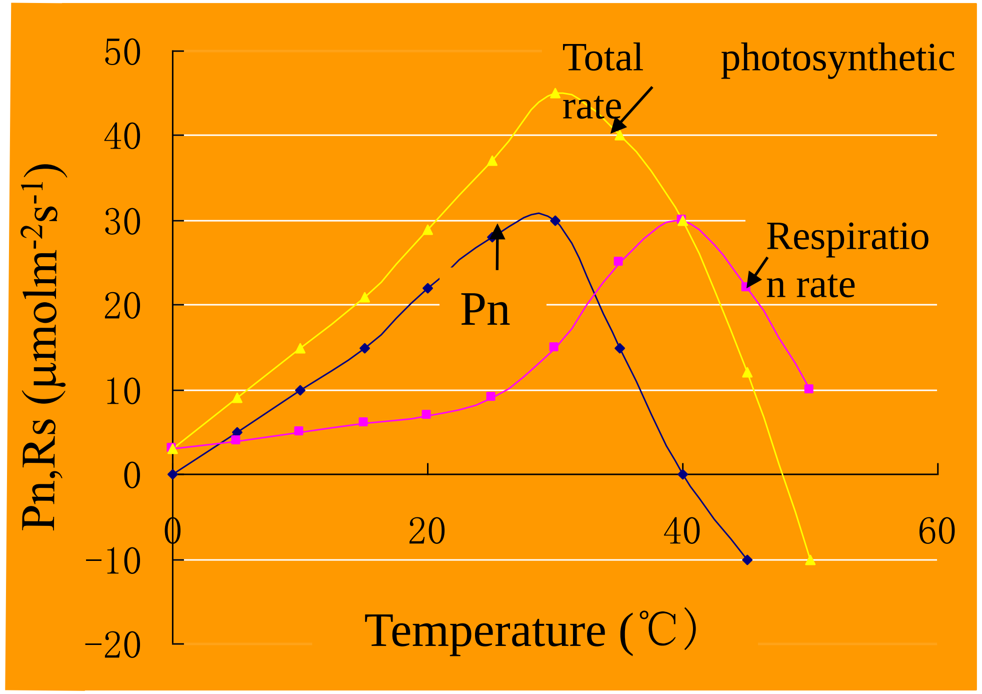
- Rice plants exposed to 6 h of heat stress (38°C) at flowering.
- Spikelets that flowered during the stress exposure were sterile (green) while those that flowered the next day under optimum conditions set seed (brown).

# Yield

- As HT negatively affects plant establishment, growth, DM partitioning, reproductive growth and photosynthesis, it ultimately poses serious consequence on crop yield.
- Several lines of studies indicated the reduction of crop yield under HT which greatly varies with the degree and duration of temperature as well as genotypes of the crop.

## Low temperature

- Low temperatures may disturb the key organs of photosynthesis, including chloroplast and thylakoid membranes, causes swelling of plastids and thylakoid lamellae, vesiculation of thylakoid, accumulation of lipid drops and ultimately disorganization of entire plastid.
- Low temperature also disrupts the systems including electron transport, carbon cycle metabolism and stomatal conductance.
- Among the photosynthetic apparatus PSII is the primary target of damage under LT stress.
- Moreover, LT reduces the activity of stromal and carbon assimilation enzymes like Calvin cycle enzyme, ATP synthase, and restricts ribulosebisphosphate regeneration and limits the photophosphorylation.



# Low Temperature

- During the development of male gametophyte LT causes disruption of meiosis, tapetal hypertrophy, stunted development of pollen grain, anther protein degradation, pollen sterility, pollen tube deformation.
- In female gametophyte development its effects are characterized by reduced style and ovary length, disruption of meiosis, reduced stigma receptivity, callose deposition in style, damage to embryo sac components, and arrest of the fertilization process.
- At flowering LT may cause delayed flowering, bud abscission, sterile or distorted flowers, while at grain filling the source-sink relation is altered, kernel filling rate is reduced and ultimately reduced sized, unfilled or aborted seeds are produced.

**A** **B**

**Damage to spikelets and panical exsertion in rice due to cold stress**

Source: Hasanuzzaman et al. (2013)

## Yield components and yield

- Reproductive phase products are the key components of economic yield and hence LT stress during the reproductive phase has significant economic and social consequences.
- All the adverse effect of cold stress ultimately lowers the yield of crop.

# Impact of CC on rice:

**$CO_2$ fertilization**

• Yields increase with $CO_2$ levels up to 750 ppm, in mid and high latitudes

• Low latitudes, slight temp increases can reverse gains from $CO_2$ fertilization

***Biotic stress:***

**Pests and disease**

• Animal pests, diseases, weeds ca. 40 % yield loss Asia (high estimate?)

• With higher temperatures, pests and diseases are likely to extend their range

• Conclusion – with abiotic stress, cumulative damage high

# Modelling

Overall effects of Climate Change – dependent on climate model used and $CO_2$ fertilization.

**IMPACT Model** for developing countries, by 2050:

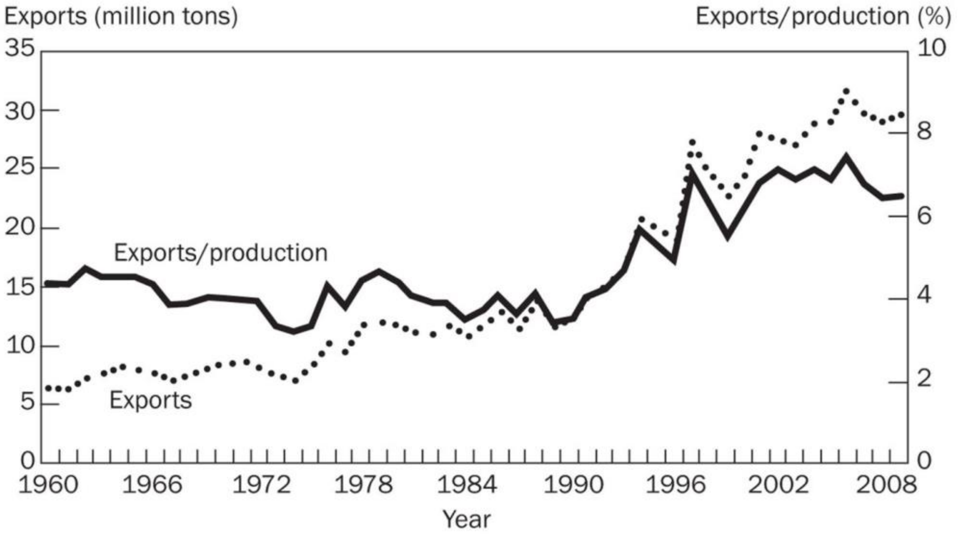
- Irrigated rice – yield loss -14%
- Rain-fed rice -1.4%
- $CO_2$ fertilization – loss of 0.5% to gain of 6.5%
- East Asia, less drastic, decline -10%
- Resulting world price increase by 32-37%

## Economic and demographic drivers on rice:

- Rural-urban migration
- HIV/AIDS
- Labor availability declining, wages increasing
- Urban expansion

➡ These economic and demographic drivers will lower rice production.

- Climate change, as an overarching factor, will generally aggravate the many non-climate factors in forcing down agricultural production




## Impact on trade:

- International rice trade increased 4x since the 1960s
- Rice trade in Asia extensive distortions
- 2050 – trade in cereals to face strong adjustments
- Climate change – reduction in agricultural GDP; fragile already, to deteriorate further with CC

# Impact of rice on climate change:

- While rice fields sequester $CO_2$, they emit nitrous oxide and methane:
    - SEA – 43 % of global nitrous oxide emissions
    - E. Asia – emits 68% of global methane
    - S. Asia – 20% global $CO_2$ annually

- Rice monocultures release methane:
    - Organic inputs stimulate methane emissions
    - Rice fields worldwide emit 31-112 Tg of methane annually

# Adaptation - Breeding:

Varietal improvement most important means of adaptation in rice systems:

- Modern High Yielding Variety – pre-adapted
- Drought tolerant rice varieties
- Drought and flood tolerance combined
- Salinity tolerance
- Floret sterility at higher temperature
- Genetic sequencing technology – submergence tolerance
- C3 to C4 rice plant

# Adaptation – Breeding

**Green super rice** is the goal of breeding work – varieties that combine traits for lower chemical fertilizer and pesticides, tolerance for drought, salinity and floods, and resistance to pests and diseases

## Adaptation – Farming systems:

- Aerobic rice varieties
- Shift to rice-wheat production systems
- Water saving technologies
- Resource conserving technologies – no tillage, slow-release fertilizer, site-specific nutrient management
- Climate smart agriculture
- Direct seeding – rain-fed areas
- Post harvest sector losses
- Climate induced migration

## Mitigation of emissions from rice sector:

- Mitigation technologies are:
  - improving rice plants through breeding – saves land conversion, reduced deforestation/avoided emissions
  - changing farming systems – with enhancing productivity, marginal lands left not encroached
  - changing to more diverse farming systems such as aerobic rice, rice-wheat systems, mid-season drainage, rain fed systems
  - utilizing crop residues for renewable energy and carbon sequestration

## III Governance and Green Economy:

- Incorporating CC into **national green growth policies** for sustainable development - e.g. renewable energy, low-carbon transport, energy- and water-efficient buildings, and sustainable agriculture...
- In agriculture, **adaptation measures mainstreamed into national development plans**
- **Trade** – more countries would be reliant on food imports – need for a more open global trading regime
- **Financial arrangements** – for adopting mitigation technologies
- Market based approaches for managing **environmental services**

## III Governance and Green Economy:

- Innovative cross-sectoral policies include:
  - changing investment allocation within and across sectors
  - eliminating existing detrimental policies that will exacerbate climate change impacts
  - price signals, market mechanisms, insurance, microfinance, research etc.
  - supporting approaches which reduce GHG emissions, that include measures for fertilizer management, crop carbon sequestration, open field burning, deforestation and forest degradation (REDD)…

## III Governance and Green Economy:

- National Adaptation Program for Action (**NAPA**) - framework to address climate concerns in agriculture, to access international funding for NAPA projects

- Nationally Appropriate Mitigation Actions (**NAMA**) – a guide for national planning for GHG mitigation in agriculture

## IV Key Findings and Recommendations:

Key findings:

- Global CC – mainly due to human activities
- Extent of change uncertain, net effects on rice production indeterminate; precautionary and no-regrets steps must be taken
- If $CO_2$ levels stabilize, and temperature increase is not excessive, net effect on rice production minimal
- Global warming causing extension of range of pests and diseases to higher latitudes, with higher crop loss
- Adaptation and mitigation measures are works in progress

## IV Key Findings and Recommendations:

Key findings:

- Impacts from CC stated has not taken into account the accelerating research and development in varietal breeding taking place
- Possible that climate-resilient varieties of rice and farming systems that lower emissions will be developed in time to cope with the incremental climate change
- Improvements made to rice-based farming systems, post-harvest technology, and marketing cumulatively would act act as adaptations or help abate emissions

## IV Key Findings and Recommendations:

Key findings:

- Climate-adapted/resilient varieties and cropping systems have to reach millions of farmers in Asia
- NAPA – framework for action, and funding for LDCs
- Shared resources (e.g. water) require inter-sectoral and inter-governmental cooperation
- Fair and open trading needed to minimize price volatility
- Intensive irrigation farming provides most of rice crop – mitigation and adaptation actions must mainly take place within the capacity of the agro-ecosystem

# IV Key Findings and Recommendations:

Key Recommendations:

- FAO should advise member governments that rice research and development must continue to be supported so future demands can be met, and prices kept affordable for poor

- FAO, with its privileged position, should help and encourage governments to incorporate the latest research and development results into its rice sector strategy, that are in line with green growth principles

# IV Key Findings and Recommendations:

Key Recommendations:

- FAO should also encourage and facilitate communication between regions, national governments, ministries, etc. This is needed not only on a technical level, but also on policy level

- The findings of this report should be incorporated in FAO’s Framework Programme on Climate Change Adaptation as a base for determining cross sectoral policies to help countries avert land-use-changes that affect vital agricultural or other natural resources

- CGIAR scientists from the International Rice Research Insititute (IRRI) and AfricaRice, together with national research and agricultural extension system partners, have long tackled the problem through breeding to develop new, climate-smart varieties of rice. Their drought-, flood- and salttolerant rice varieties are designed to adapt to rapidly changing climatic conditions.

- Adoption of CGIAR's climate–smart varieties of rice, together with adjusted management practices, has led to significant increases in yield and sustenance of production in climate change stress-affected areas, including those inhabited by the most impoverished farming communities.

- Conventional and marker-assisted breeding is used to incorporate specific desirable traits into rice plants, resulting in improved varieties that are more resilient to stresses and can survive unfavorable conditions made more intense and frequent by climate change. The breeding lines are then tested in several different locations and countries, including direct trials in farmers' fields. The selected lines – those shown to survive under stress and retain desirable grain qualities – are finally either released directly, or bred into widely grown and popular local varieties.

- Drought is the most widespread and damaging of all environmental stresses, affecting 23 million hectares of rainfed rice in South and Southeast Asia as well as large areas in Africa, where 70-80% of ricelands are rainfed. About 30 drought-tolerant varieties have been released by CGIAR and partners in several countries, including the Sahbhagi Dhan variety in India, Sahod Ulan in the Philippines, and Sookha or Sukkha Dhan in Nepal. The average yield advantage of these drought-tolerant varieties is 0.8-1.2 tons per hectare over drought-susceptible ones.

- Floods cause farmers in Bangladesh and India to lose up to 4 million tons of rice per year. CGIAR-released varieties carrying the SUB1 gene – which makes rice plants better able to withstand complete submergence in water – have shown an average yield advantage of 1-3 tons over original varieties, after floods lasting 10-18 days. Some examples include the Swarna-Sub1 variety in India, Samba Mahsuri-Sub1 in Bangladesh, IR64-Sub1 in the Philippines, and Ciherang-Sub1 in Indonesia and Nepal, and FARO 66 and 67 in Nigeria.

- Saltwater encroachment due to rising sea levels and lower rainfall threatens rice crops in coastal farming areas. In Bangladesh, salinity affects about one million hectares of arable land. CGIAR researchers at IRRI and AfricaRice have developed and released more than 20 salt-tolerant varieties, and have incorporated salt tolerance into popular rice varieties such as BRRI Dhan11, 28, and 29 in Bangladesh, as well as various varieties in India and West Africa. These salt-tolerant varieties have resulted in considerable increase and stability of productivity in salt-affected areas and, in some cases, led to expansion into areas previously abandoned because of high salinity.

- Adoption of CGIAR's climate–smart varieties of rice, together with adjusted management practices, has led to significant increases in yield and sustenance of production in climate change stress-affected areas, including those inhabited by the most impoverished farming communities. The varieties are now being planted by millions of farmers in South and Southeast Asia, and in Africa.

2014), which is conducive to the flexible formulation of climate protection strategies for rice production.

## Adverse Impact on Rice Production

According to the IPCC Fifth Assessment Report, adverse effects of climate change and extreme climate events on crop yields are common (Pachauri and Meyer, 2014). If the temperature increases by 1–3°C in the future, the probability of shortening the rice growth period in China is 100% (Tao et al., 2008). When the temperature increases 1.5 and 2.0°C, the growth period of DCR in China will be shortened by 4–8% and 6–10%, respectively, and the growth period of SCR will be shortened by approximately 2% (Chen et al., 2018). A study combining grid crop models, single point crop models, statistical models and observational experiments showed that a temperature increase of 1% could lead to an average 3.2% decrease in global rice yield (Zhao et al., 2017b). By the end of the twenty-first century, sustained temperature increases are expected to reduce global rice yields by 3.4–10.9% The range of rice yield in China due to future climate change is −40.2 to 6.2%, with an average yield reduction of 10.6%, and the spatial difference is obvious ( . If the impact of increased $CO_2$ concentration on yield is considered, it has a certain compensation effect on the production reduction caused by climate change . However, such compensation cannot offset the adverse effects of high temperature increases in some scenarios and regions or reduce interannual variability in rice yield (Tao et al., 2008; Xiong et al., 2009). In addition, the increase in precipitation and temperature variability may lead to an increase in frequency and reduction in low-yield years (Yao et al., 2007; Xiong et al., 2009).

The areas with the most obvious decrease in rice yield and increase in rice instability are the Sichuan Basin (SB), YRB, and Huang-Huai-Hai Plain (HHHP), which may become highly sensitive areas for rice due to future climate change (Xiong et al., 2009). Studies have also shown that the adverse effects of climate change on rice yield can be effectively mitigated if appropriate coping strategies are adopted In the future, there will be a need to conduct research on the measures to cope with climate change in rice production from the aspects of cultivating varieties with strong stress resistance and high utilization of $CO_2$ concentration, optimization of cultivation management and anti-stress cultivation techniques, and adaptation to strengthen sowing date and planting area. In particular, a growing number of impact assessments have focused on changes in extreme weather events and their potential impact on rice production (Zhang et al., 2017, Zhang et al., 2018; Chen et al., 2018; Huang et al., 2018). From the 2000s to the 2050s, the area affected by extreme high-temperature stress in the global reproductive growing season of rice will increase from 8 to 27% (Alexandratos and Bruinsma, 2012; Gourdji et al., 2013). The probability, intensity and area of rice production subjected to high temperature stress in China will also increase, which may offset the positive effect of increased heat resources and reduced damage caused by low temperature (Tao et al., 2013; Wang et al., 2014; Zhang et al., 2016). When temperature rises by 1.5 and 2.0°C, rice yield in China may decrease by 2 and 5% under heat stress, respectively (Chen et al., 2018). The Sichuan Basin and the middle and lower

# EFFECTS OF FUTURE CLIMATE CHANGE ON RICE PRODUCTION

## Positive Impact on Rice Production

In the 1930s, 1950s, and 1970s, the daily average temperature of the rice growing season in China was 0.8–2.7°C, 1.7–3.4°C, and 2.3–4.1°C, respectively, higher than that in the first decade of the twenty-first century (Lv et al., 2018). The potential boundary between double and triple harvests in China will continue to move northward (Ju et al., 2013a; Tian et al., 2014), and the potential share of the triple-growing system in the total area of the planting system will increase by the end of the twenty-first century, reaching a maximum of 75.0% (Yang et al., 2015). The potential planting boundary of single- and double-cropping rice will continue to move northward in the future. Compared with 1961–1990, the expandable planting area of single- and double-cropping rice in China in the 2080s will be approximately 5.0 × 105 $hm^2$ and 6.2 × 106 $hm^2$, respectively (Xiong et al., 2009). The increase in heat resources extends the potential growing season of crops and significantly increases the growing season elasticity of rice (Ohta and Kimura, 2007; Tian et al., reaches of the YR may become areas of high temperature heat damage, while Northeast China, the Yunnan-Guizhou Plateau YGP and East China are more at risk of severe low temperature damage than other regions (Wang et al., 2014; Zhang et al., 2017). In the future, increased precipitation variability may lead to an increased frequency of seasonal drought and heavy rain (Cai et al., 2018). In the eastern province of Jiangsu and other regions, extreme precipitation events may have a more significant impact on rice yield than extreme temperature events (Huang et al., 2018). In addition, rising temperatures will lead to an overall increase in evapotranspiration from reference crops, and southwestern China will experience an aridification process with a significant decrease in the wetness index (Tian et al., 2014).

## PROBLEMS AND PROSPECTS

In recent years, a large number of studies have been carried out on the comprehensive impact of climate warming on crop production and its countermeasures. The trend of climate warming and the response characteristics of the crop growth period and productivity have been clarified, and some adaptive planting technologies and coping strategies have been developed. However, there are still great uncertainties in understanding the response and adaptation of specific regions and crops to future climate warming in their growing seasons, and there is still a lack of holistic coping techniques in adaptive production and coping strategies. Therefore, systematic theoretical research and innovation of key technologies and models of regional adaptation are urgently needed.

### Strengthen Research on Climate Change Impact Mechanisms and Their Application in Impact Assessment

First, in theoretical research on crop response and adaptation to climate warming, the integration of field empirical research and regional model analysis should be further improved upon in the future. Existing studies mostly focus on model analysis and historical data mining, and few empirical studies in the field mainly focus on the single factor of temperature change. However, climate warming is not a single mean temperature change but also includes extreme weather and precipitation changes, as well as the accompanying changes in atmospheric composition, especially in atmospheric $CO_2$ and near-surface $O_3$. Therefore, the impact of climate warming on crop production is a combination of multiple factors, and comprehensive field demonstration and multifactor model mining are needed to clarify the comprehensive impact of climate warming and even climate change on crop production and reduce the uncertainty of future understanding.

### Reducing Uncertainty in Climate Change Impact Assessments

Second, there is an urgent need for innovation in research content, methods and means. Existing studies mostly focus on crop growth period and productivity, but research on crop product quality and safety, which is increasingly a concern of society, is still very unclear, and the research content and objective cannot meet the new requirements of improving the quality and efficiency and green development of China's agriculture. In terms of research objectives, existing studies mostly focus on major food crops and mostly on a few varieties. However, the impact of warming on non-food crops is also significant, and there are significant differences between varieties of the same crop type. Studies on limited crop types and single varieties can hardly meet the innovative needs of adaptive technologies and coping strategies. With regard to research methods and means, especially field empirical research, most of the studies consider a single factor, and some involve two factors. It is urgent to establish multifactor comprehensive field facilities and corresponding comprehensive models to improve research methods that simulate the real climate system.

### Improving Methods and Techniques for Climate Change Impact Assessment

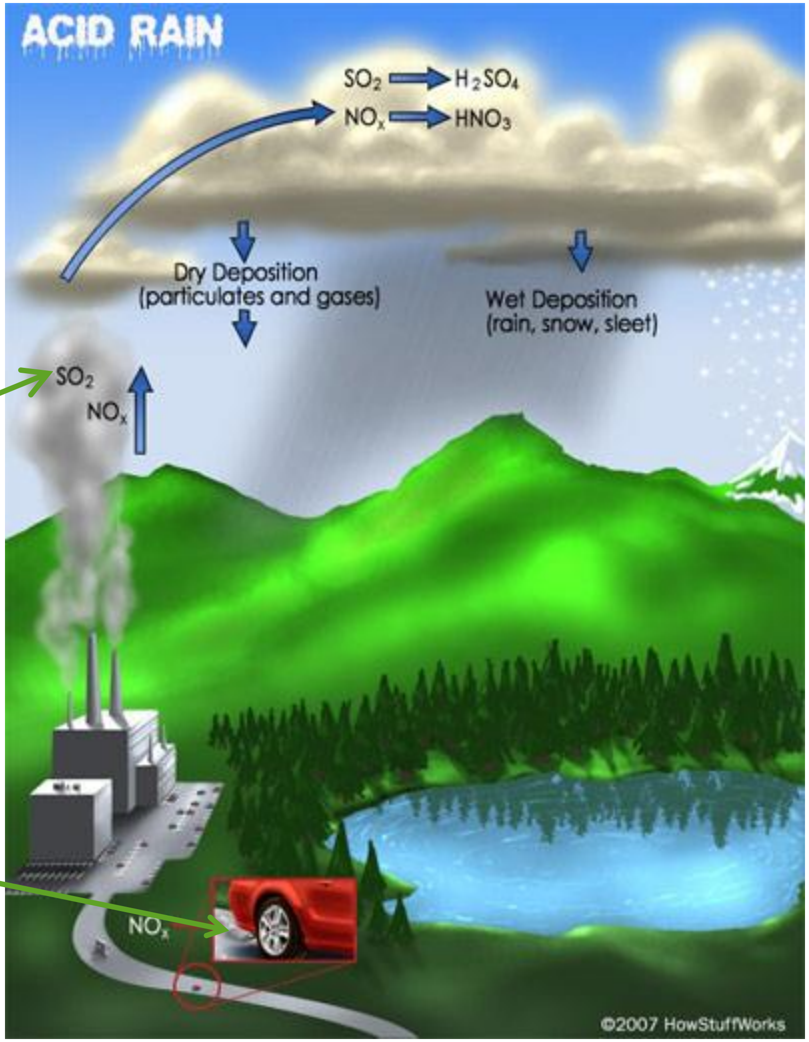
Finally, in terms of rice production technologies and models to cope with climate warming, we still focus on strategies with insufficient system integration of key technologies and inadequate adaptability and practicability of coping technologies. To reduce the impact of climate warming on rice supply and food security, rice production should consider multiple aspects, including how to improve the adaptive capacity of rice production systems. At the same time, it should also include how to promote coordination between soil organic carbon sequestration and greenhouse gas (GHG) emissions reduction in paddy fields, especially $CH_4$ emission reduction, to contribute to mitigating climate warming and creating climate-smart agriculture (FAO, 2019).

# What is the pH of rain?

- Pure water has a **pH of 7** – neutral (neither an acid nor a base)
- Normal **<u>precipitation</u>** is slightly ***<u>acidic</u>*** (pH =5.6) because carbon dioxide (**$CO_2$**)n the air mixes with rain water to form a weak acid called **<u>carbonic acid.</u>**
- **$H_2O + CO_2 \rightarrow H_2CO_3$**

# How does acid rain form?

- Factories that burn fossil fuels release sulfur dioxide($SO_2$) and nitrous oxides($NO_x$ )
- Cars that burn fossil fuels release nitrous oxides. ($NO_x$ )



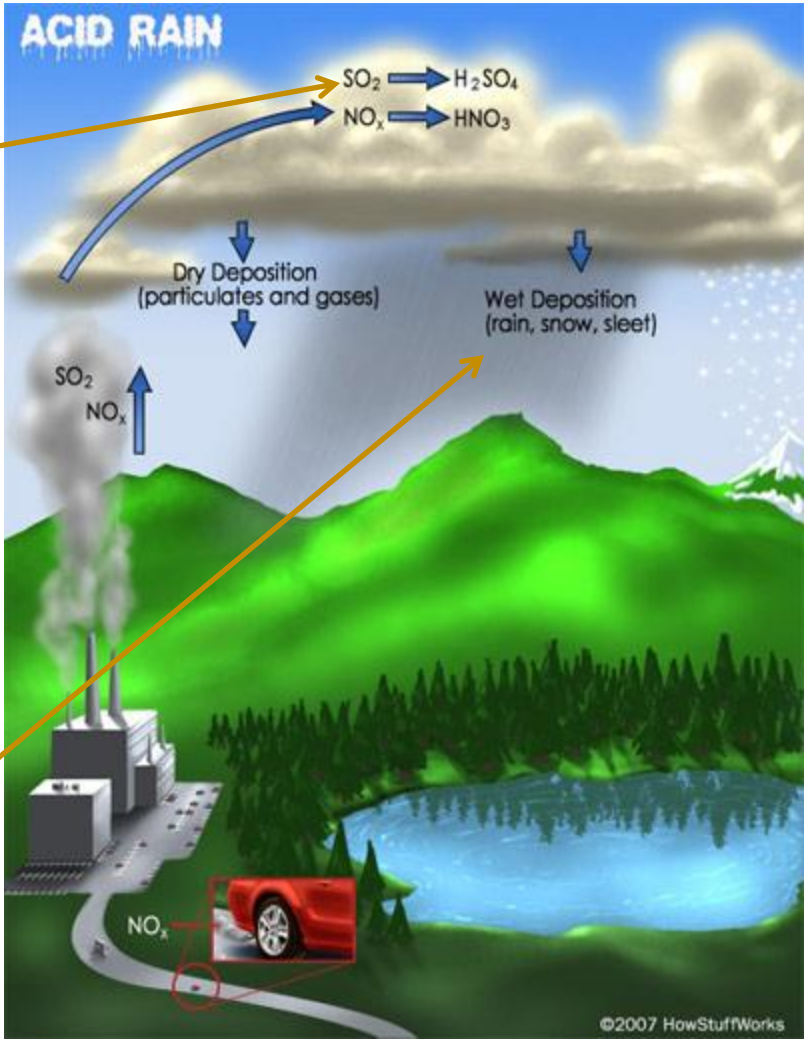
# How does acid precipitation form?

- Sulfur and nitrous oxides combine with water in the atmosphere to form sulfuric acid and nitric acid

**$H_2O + SO_2 \rightarrow H_2SO_4$**

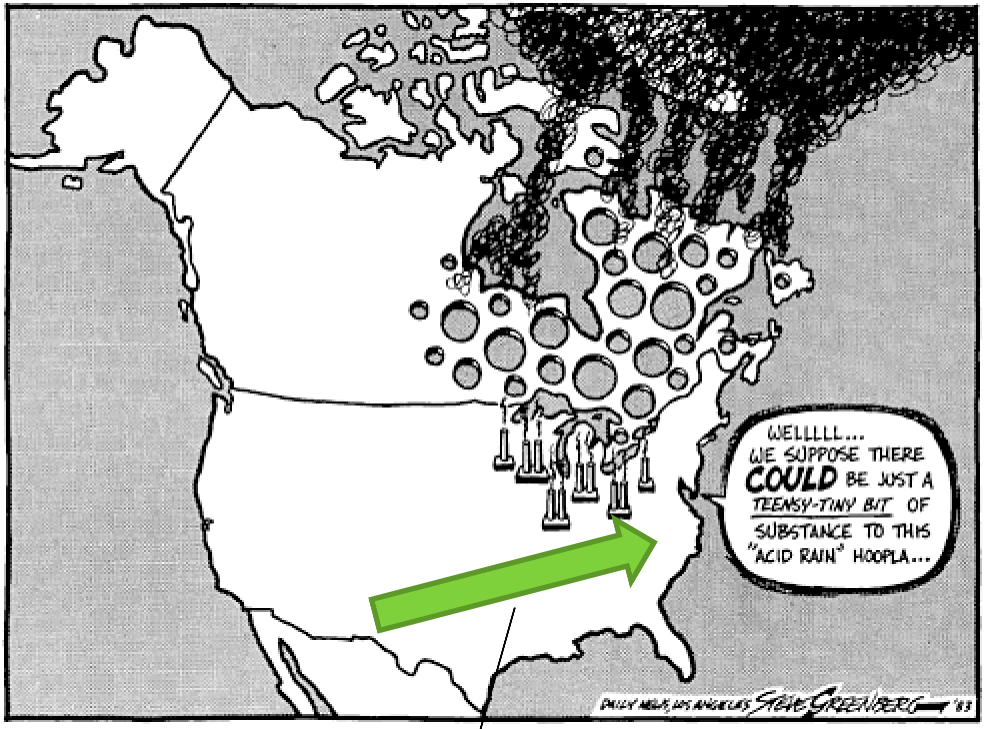
**$H_2O + N_2O_x \rightarrow HNO_3$**

- These <u>strong acids</u> lower the pH of rain more than $H_2CO_3$

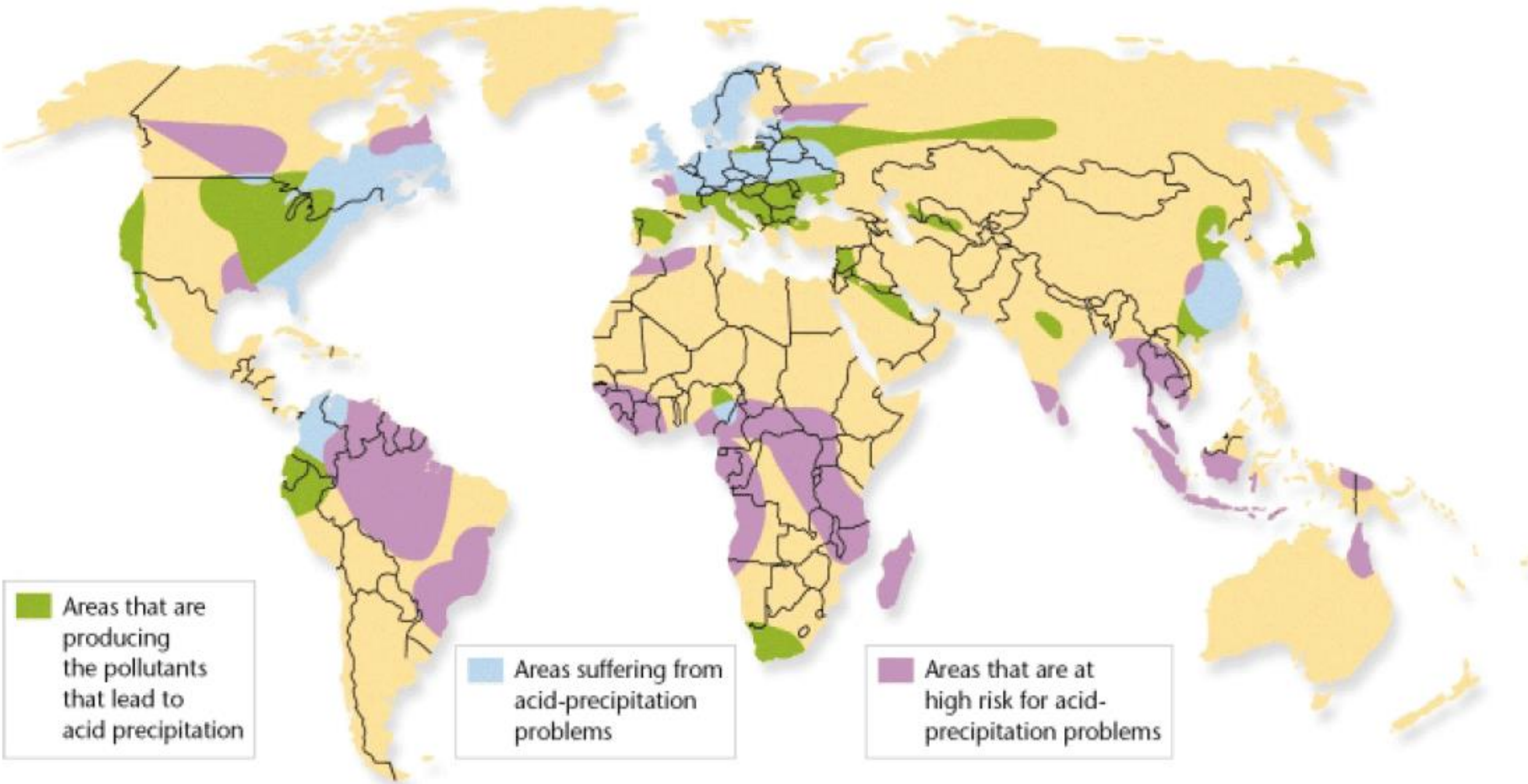


# So where does it come from and where is it going?

- Acid rain follows the winds.
- It starts in places where there are a lot of coal-fired power plants and factories and ends up wherever the wind blows it
- <u>**Point  or Non-point**</u> **Source Pollution ??**




Prevailing Winds in N. America


Areas that are producing the pollutants that lead to acid precipitation
Areas suffering from acid-precipitation problems
Areas that are at high risk for acid-precipitation problems

# What happens to the soil and water around us?

**Acidification** of soils & water

- Acid rain can cause a drop in the pH of soil and water - called acidification.

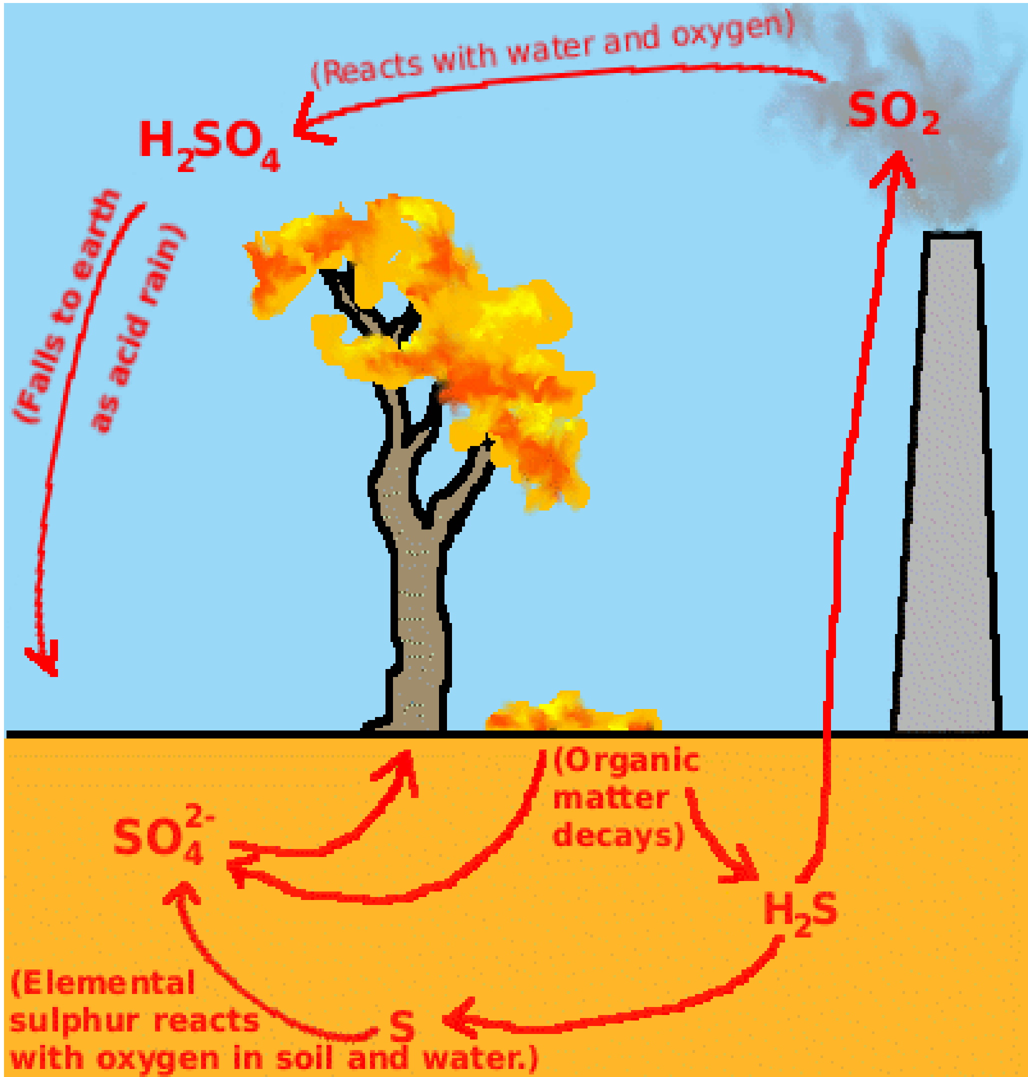
# What is the Effect of Acid Rain on Plants?

When the soil becomes acidic, nutrients that plants need are washed away by rainwater.

Acid Rain causes toxic metals to be released into the soil-causing root damage.

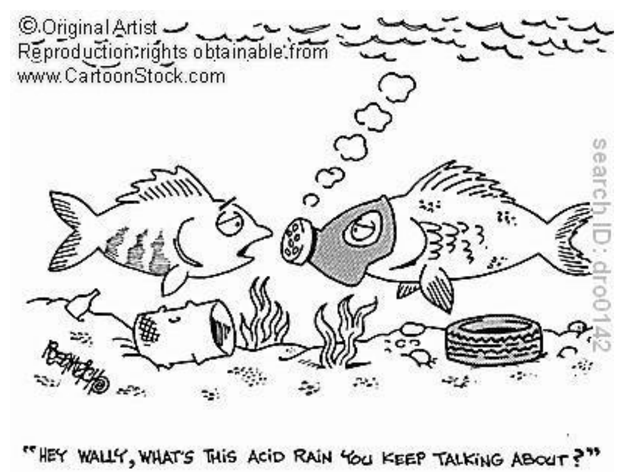
Sulfur dioxide clogs the openings on the surfaces of plants- *no photosynthesis*

# So what does acid rain damage in plants look like?

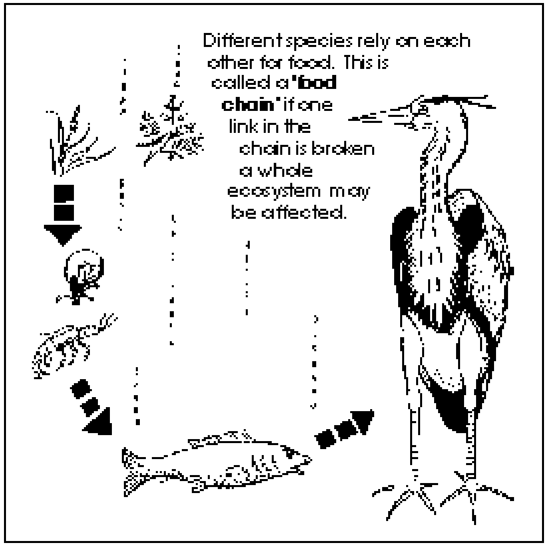


# Acid Precipitation and Aquatic Ecosystems

- Acid precipitation can causes aluminum to leach out of the soil surrounding a lake.
- The aluminum accumulates in the gills of fish and interferes with oxygen and salt exchange.
- As a result, fish are slowly suffocated
- If acid precipitation falls on a lake and changes the water's pH, it can kill aquatic plants and animals.



# What does acid rain damage in these ecosystems look like?



# What is "acid shock"?

**Acid shock**

- **the sudden runoff of large amounts of highly acidic water into lakes, streams, and rivers** when snow melts in the spring or when heavy rains follow a drought

**Effects of Acid Shock**

- **large numbers of fish die**
- affects the reproduction of fish and amphibians that remain. They produce fewer eggs, and those eggs often do not hatch.
- The offspring that do survive often have birth defects and cannot reproduce

# Acid Precipitation and Humans

1) Toxic metals (aluminum and mercury) can be released into the environment.
   - These toxic metals get into crops, water, and fish.
   - The toxins then poison the humans who eat the crops, water and fish.

# Acid Precipitation and Humans

*2)* Research has indicated that there may be a connection between large amounts of acid precipitation and an increase in respiratory problems in a community's children

# Acid Precipitation and Humans

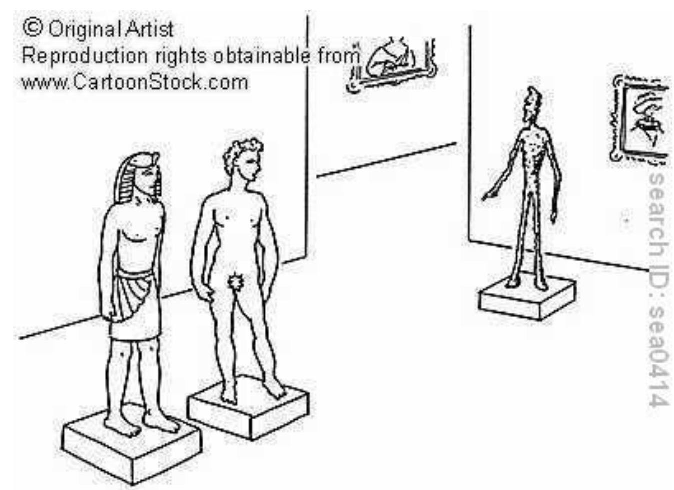
*3)* Fisherman can’t fish because the number of fish is decreased because by acidification of lakes

The Forestry industry is also affected because trees are damaged by acid precipitation.

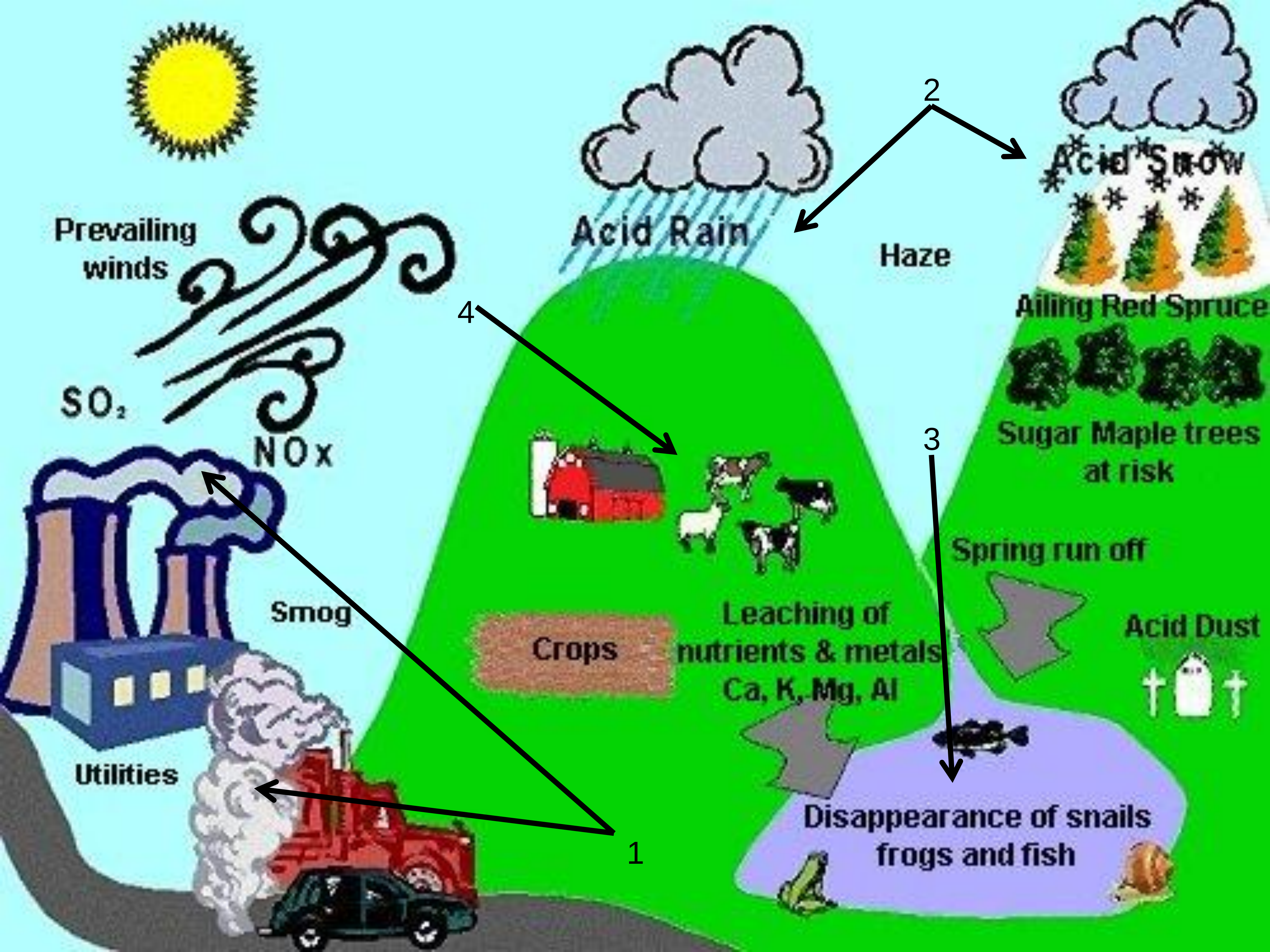
# Acid Precipitation and Humans

*4)* Acid precipitation can dissolve the calcium carbonate in common building materials, such as concrete.

As a result, some of the worlds most important and historic monuments, including those made of marble are being affected.




"Poor thing. He got left out in the acid rain."


Prevailing winds
SO₂
NOx
Utilities
Smog
Acid Rain
Haze
Acid Snow
Ailing Red Spruce
Sugar Maple trees at risk
Crops
Leaching of nutrients & metals Ca, K, Mg, Al
Spring run off
Acid Dust
Disappearance of snails frogs and fish
1
2
3
4

# Acid Rain Effects

1. What are the effects of acid rain on:

a) Plants

b) Humans

2. How is **acid rain** related to **point/ non-point sources of pollution**?

3. How is **acid rain** connected to **biomagnification** and **bioaccumulation**?

# Acid Rain Lab

- Part 1- “Dragon’s Breath”
  - BtB: a pH indicator (blue → yellow pH =<6)
  - Observe pH changes as you add $CO_2$ through a straw (blowing bubbles)
- Part 2- How does acid rain affect limestone?
  - Chalk will represent our limestone
  - 4 solutions to test- 1 full piece of chalk/solution
    - Distilled water (control)
    - 50/50 water and vinegar (NOT 10/90 solution as stated in pkt.)
    - 100% vinegar

# AGRONOMY AS AN OPTION FOR CLIMATE CHANGE MITIGATION

**Introduction**

Climate change is occurring since the time immemorial but the accelerated rate of change mainly due to anthropogenic activity is one of the greatest challenges facing the world today, and it is already having a significant impact on agriculture (IPCC, 2014; FAO, 2021). Rising temperatures, changes in rainfall patterns, and extreme weather events are all affecting crop yields and soil health, which in turn threatens food security and livelihoods for millions of people. Agronomy, the science of crop production and soil management, has an important role to play in mitigating the effects of climate change on agriculture (Seppelt et al., 2022). By adopting practices that promote soil health, conserve water, and reduce greenhouse gas emissions, farmers can help to build resilience to climate change and contribute to global efforts to reduce emissions.

## CLIMATE CHANGE IMPACTS ON AGRICULTURE

Climate change is a global phenomenon that is having significant impacts on agriculture. Rising temperatures, changes in rainfall patterns, and extreme weather events are affecting crop yields, soil health, and water availability. These impacts are threatening food security and livelihoods for millions of people around the world. Higher temperatures can lead to heat stress, reduced photosynthesis, and lower yields. Changes in rainfall patterns can also affect crop yields, with droughts and floods having significant impacts on crop growth and development (USDA, 2021). Pests and diseases are also becoming more widespread and damaging as a result of climate change.

Changes in temperature and rainfall patterns can alter soil moisture, which can affect nutrient availability and soil structure. Soil erosion is also becoming more common as a result of extreme weather events, which can lead to nutrient loss and reduced soil fertility. Additionally, changes in soil temperature and moisture can affect soil microbial communities, which play a critical role in nutrient cycling and plant growth (Wu et al., 2022). Changes in precipitation patterns and increased evaporation rates are affecting water availability and quality. Droughts and heat waves are becoming more frequent and severe, leading to water scarcity and reduced crop yields (Table. 1). Flooding is also becoming more common, which can lead to soil erosion and nutrient loss. Additionally, changes in water temperature and nutrient levels can affect aquatic ecosystems and the quality of water for human consumption.

### Agronomy practices for climate change mitigation

Agronomic management practices have a significant role in mitigating the impacts of climate change. Agriculture is one of the major contributors to greenhouse gas emissions, but it also has the potential to sequester carbon and reduce emissions.

***Conservation agriculture***: It involves reducing or eliminating tillage to conserve soil moisture, reduce soil erosion, and increase soil organic matter. By reducing the need for tillage, conservation agriculture can also reduce the use of fossil fuels and the emissions associated with soil disturbance (Jat et al., 2019a). In addition, conservation agriculture can increase the amount of carbon stored in the soil, helping to mitigate greenhouse gas emissions.

***Crop diversification***: It is the phenomena of bringing out desirable changes in the existing cropping pattern towards a more imperative and sustainable one. Planting a variety of crops to reduce pest and disease pressure, improve soil health, and provide a more diverse range of food and income sources (Jat et al., 2019b). By increasing the diversity of crops grown in a particular area, it can also help to reduce the risk of crop failure due to extreme weather events, such as droughts or floods.

***Precision agriculture***: It is the new generation technology to optimize the use of inputs, such as fertilizer and water by utilising GIS, GPS and remote sensing technology and to minimize the environmental impacts of agriculture. By using precision agriculture practices, farmers can reduce the use of inputs, increase crop yields, and minimize the emissions associated with agricultural practices (Padhan et al., 2021a).

**Table. 1. Effect of climate change on agriculture**

| **Effect of Climate Change** | **Remarks** |
|---|---|
| Reduced crop yields | Global crop yields are projected to decline by 1.8% per decade due to climate change. (IPCC, 2014) |
| Shifting planting and harvest seasons | In the United States, planting and harvest seasons for crops such as corn and soybeans have shifted earlier by 5-10 days over the past 30 years due to climate change. (USGCRP, 2018) |
| Increased frequency and severity of extreme weather events | Extreme weather events such as floods, droughts, and heatwaves have caused significant crop losses, particularly in developing countries. (FAO, 2021) |
| Decreased soil fertility and health | Climate change has led to increased soil erosion, salinization, and acidification, negatively impacting soil health and fertility. (IPCC, 2014) |
| Changes in pest and disease pressure | Rising temperatures and changing precipitation patterns have altered pest and disease pressure, affecting crop yields and quality. (USDA, 2021) |
| Reduced water availability and quality | Climate change has led to decreased water availability in some regions, particularly in arid and semi-arid regions, as well as changes in water quality due to increased runoff and erosion. (FAO, 2021) |

***Agroforestry***: Integration of trees into agricultural landscapes to improve soil health, provide shade for crops, and sequester carbon along with providing a range of ecosystem services, such as improving soil fertility, reducing erosion, and providing habitat for wildlife. By sequestering carbon in woody biomass and soil organic matter, agroforestry can help to mitigate greenhouse gas emissions.

***Cover cropping:*** It involves planting a crop that is grown primarily for its ability to improve soil health and protect soil from erosion vis-à-vis increasing the soil organic matter, improving soil structure, and reduce the need for tillage. By improving soil health and reducing erosion, cover cropping can help to mitigate the impacts of climate change.

***Policy measures:*** Governments can provide support for sustainable agriculture practices, such as subsidies for conservation agriculture, agroforestry, and crop diversification. Policies that promote the use of renewable energy, such as solar or wind power, can also help to reduce greenhouse gas emissions and mitigate the impacts of climate change on agriculture.

There are also other strategies that can help to mitigate the impacts of climate change on agriculture. For example, research and development can help to develop new crop varieties that are more resilient to climate change, and that can produce higher yields with less water and fertilizer. Climate-smart agriculture approaches can also help to increase agricultural productivity while reducing greenhouse gas emissions. Furthermore, the benefits of agronomy practices for climate change mitigation are not limited to agriculture. By sequestering carbon and reducing greenhouse gas emissions, these practices can also have broader benefits for the environment and society as a whole. For example, agroforestry can provide habitat for wildlife and improve air and water quality, while cover cropping and conservation agriculture can reduce erosion and improve soil fertility. Overall, agronomy practices have the potential to play a significant role in mitigating the impacts of climate change on agriculture by adopting sustainable practices such as conservation agriculture, agroforestry, cover cropping, crop diversification, and precision agriculture, farmers can reduce their environmental footprint while also improving soil health, increasing yields, and contributing to climate change mitigation efforts.

**Climate smart agronomy (CSA)**

Climate smart agronomy (CSA) refers to a set of practices and technologies that enable farmers to adapt to the changing climate while enhancing productivity and reducing greenhouse gas emissions. The concept of CSA is based on three key principles (Figure 1): productivity, adaptation, and mitigation (Barasa et al., 2021).

***Benefits of CSA***

The adoption of CSA practices has numerous benefits for sustainable agriculture. These benefits include:

- Improved productivity and food security
- Enhanced resilience to climate change effects
- Reduced greenhouse gas emissions
- Improved soil health and fertility
- Reduced soil erosion and water pollution
- Diversification of income sources

**Agronomic practices: producer as well as mitigator**

Agronomic activities such as land use change, tillage, and fertilizer application can release greenhouse gases (GHGs) such as carbon dioxide, nitrous oxide, and methane into the atmosphere. However, agronomic practices can also be used to sequester carbon in the soil and reduce GHG emissions from agricultural activities (Figure 2). Agriculture is a significant contributor to GHG emissions, accounting for approximately 10-12% of global anthropogenic emissions. The primary sources of emissions from agricultural activities are livestock and soil management practices. Livestock is responsible for the majority of methane emissions, while soil management practices such as tillage and fertilizer application are responsible for nitrous oxide emissions. Agriculture also contributes to deforestation, which releases carbon dioxide into the atmosphere.

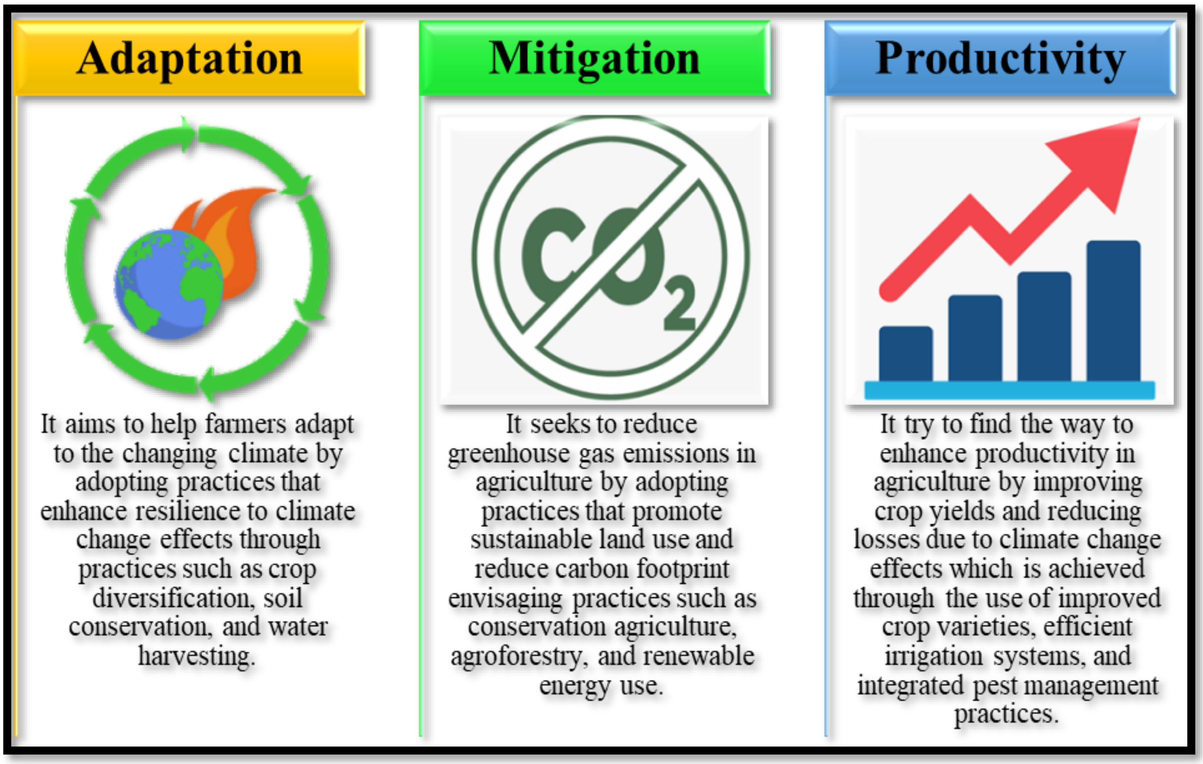



**Figure 1. Three pillars of climate smart agronomy**

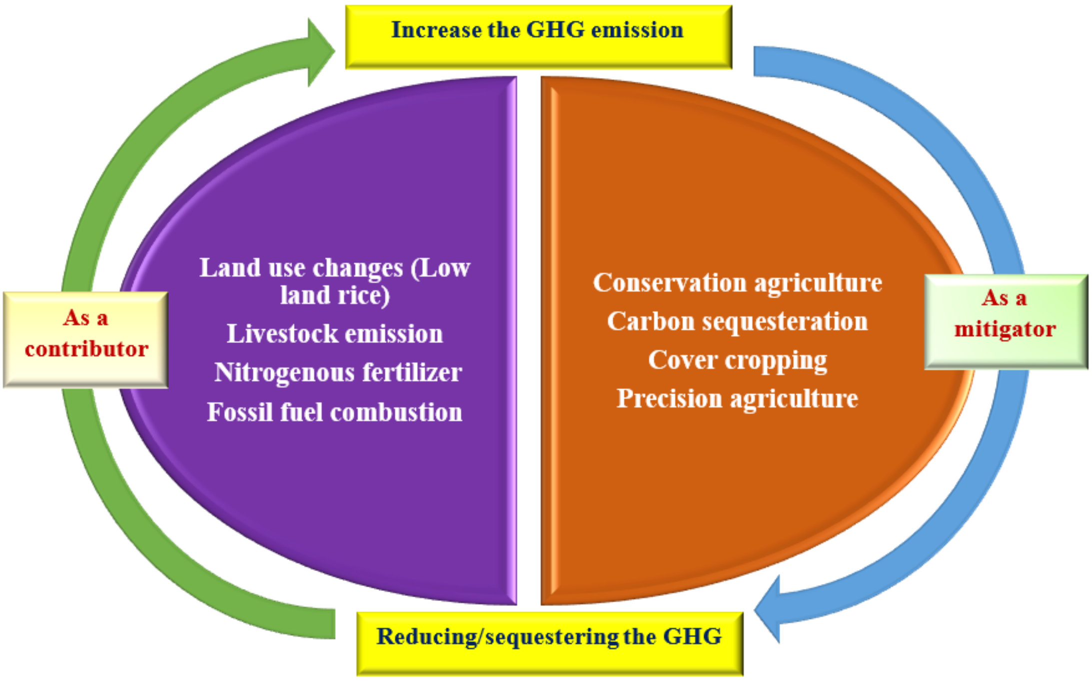



**Figure 2. Agronomic practices as a contributor and mitigator to climate change**

Agronomy practices can help mitigate climate change by reducing emissions and sequestering carbon in the soil. Conservation tillage, for example, reduces soil disturbance, increases soil organic matter, and sequesters carbon in the soil. Cover crops also increase soil organic matter and fix atmospheric nitrogen in the soil, reducing the need for synthetic fertilizers and reducing GHG emissions. Nutrient management practices, such as using organic fertilizers and precision farming techniques, can also reduce GHG emissions by reducing fertilizer use and improving fertilizer efficiency (Padhan et al., 2021b). Crop rotation can also reduce GHG emissions by improving soil health and reducing the need for synthetic fertilizers and pesticides. Agroforestry, the integration of trees into agricultural systems, can sequester carbon in the soil and reduce soil erosion. Integrated pest management, using a combination of cultural, biological, and chemical methods to manage pests and diseases, can reduce the need for synthetic pesticides and improve soil health. Precision agriculture, using technology such as GPS and sensors to optimize inputs (Shyam et al., 2021), can reduce waste and improve efficiency, resulting in reduced GHG emissions. Therefore, agronomic practices are the contributor as well as mitigator of climate change.

**Conclusion**

Agronomic practises are essential for reducing the impact of climate change on agriculture. By enhancing soil carbon sequestration, lowering nitrous oxide emissions, and lowering methane emissions from livestock production, greenhouse gas emissions from agriculture can be lowered. Due to a lack of resources and knowledge, smallholder farmers may have trouble implementing sustainable agronomy practises. Governments, extension agencies, and other stakeholders can offer assistance, money, and support to farmers so they can successfully implement these practises. Stakeholders can create a more sustainable and resilient agriculture sector that can address the challenges of climate change while ensuring food security and enhancing livelihoods by giving priority to climate wise agronomy practises.

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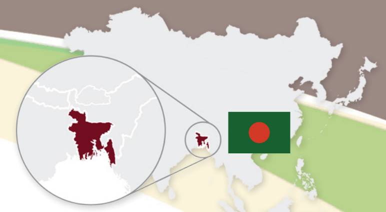

# Climate-Smart Agriculture in Bangladesh

## Climate-smart agriculture (CSA) considerations

- P The agricultural sector in Bangladesh has grown steadily in recent years, driven by an increase in productivity and efficiency achieved through investments in improved technology and mechanization supported by conducive public policies. This has led to considerable improvements in food security as well as rural poverty reduction. 90% of this reduction in the past five years can be attributed to increased farm income.

- P A $ I Agriculture in the country is characterized by subsistence production systems largely dominated by small and marginal farmers, yet a significant shift towards commercial farming with high value crops, fisheries and animal products has been evident in recent years. This is expected to contribute to further poverty reduction through improvements in health, nutrition and education outcomes in Bangladesh.

- P M Given its abundant water resources, rice paddy production under irrigated conditions is the top contributor to agricultural GHG emissions in Bangladesh. In an effort to reduce these emissions and other environmental impacts, farmers are increasingly applying alternative wetting and drying (AWD) methods of irrigation, using deep placed briquetted urea fertilizer, moving to non-rice crops and incorporating straw stubbles in to rice paddies as an alternative to burning crop residues—the latter contributing to soil organic matter replenishment.

- A P Climate-smart agricultural strategies that address saline intrusion (up to 8 km by 2030) resulting from sea level rise and tropical storm swells are especially critical in Bangladesh where many smallholders occupy low-lying, flood prone deltas. CSA interventions can draw on traditional practices like the Sorjan system (tall beds for vegetable and crop production alternating with furrows suitable for submergence tolerant crops and fish production) as well as new practices like vertical gardens. Floating bed cultivation of vegetables in the low lying southern districts, homestead production and roof top gardening of fruits and vegetables are also spreading rapidly.

- M A The lack of accessible and reliable climate information among farmers represents a considerable challenge to the scaling out of CSA practices. Strengthening climate information services and making them easily accessible to farmers would greatly improve their capacity to adapt farming practices. For instance, salt intrusion into irrigation canals prevents their use for commercial or household gardening in the southern regions of Bangladesh. Knowing where and when intrusion will occur through the use of simple salinity meters would allow farmers to make crop choices and also plan for appropriate response and mitigation strategies.

- A M P I $ Limited financial capital for CSA investments and related activities remains a constraint for many farmers in Bangladesh. Climate index insurance models, for example, have not proven successful at scale. Microcredit has been insufficient in boosting agricultural sector growth as many CSA activities require more macro-credit (e.g. conservation machinery). However, several low risk interventions like pond excavation and ghers (paddy and aquaculture ponds with tall dikes for vegetable production) are more likely to be eligible for commercial funding. Improvements in agro-meteorological services are essential for increased private sector investment in agriculture. More information on the long-term impacts of such investments on natural landscapes is needed in order to ensure sustainability.

- I $ New forms of CSA as well as innovative production systems finance need to be explored, including the allocation of domestic funding for priority CSA interventions and strengthening cooperation with development partners to access funds for CSA activities. At the same time, private sector engagement in impact investment initiatives holds considerable potential for advancing the CSA agenda. Creating an enabling environment for private capital will require improved coordination between the ministries involved in climate change planning in Bangladesh.

A Adaptation M Mitigation P Productivity I Institutions $ Finance

The climate-smart agriculture (CSA) concept reflects an ambition to improve the integration of agriculture development and climate responsiveness. It aims to achieve food security and broader development goals under a changing climate and increasing food demand. CSA initiatives sustainably increase productivity, enhance resilience, and reduce/remove greenhouse gases (GHGs), and require planning to address tradeoffs and synergies between these three pillars: productivity, adaptation, and mitigation [1]. The priorities of different countries and stakeholders are reflected to achieve more efficient, effective, and equitable food systems that address challenges in environmental, social, and economic dimensions across productive landscapes. While the concept is new, and still evolving, many of the practices that make up CSA already exist worldwide and are used by farmers to cope with various production risks [2]. Mainstreaming CSA requires critical stocktaking of ongoing and promising practices for the future, and of institutional and financial enablers for CSA adoption. This country profile provides a snapshot of a developing baseline created to initiate discussion, both within countries and globally, about entry points for investing in CSA at scale.

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# National context

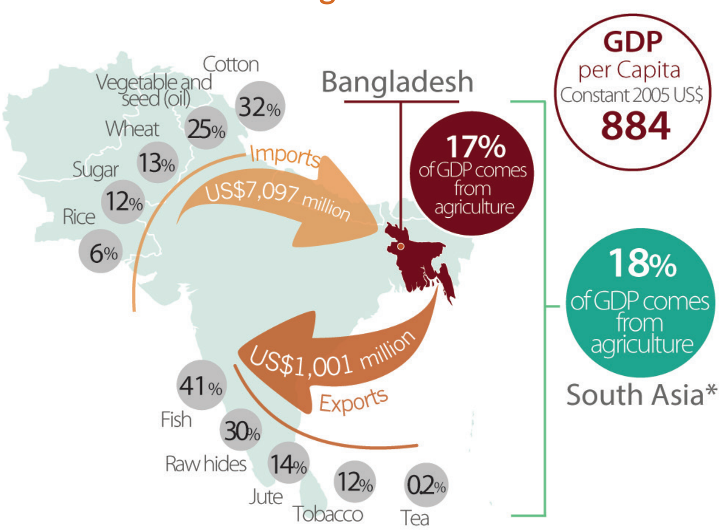
## Economic relevance of agriculture

Agriculture is a mainstay of the Bangladesh economy, contributing to 16.5% of the country's Gross Domestic Product (GDP) and serving as the largest employment sector in the country. Approximately 87% of rural inhabitants derive at least a portion of their income from agricultural activities [3]. The population of Bangladesh has almost doubled since the 1980s, reaching approximately 161 million people in 2016. This increase, coupled with high population density (over 1,000 per square km) and growing urbanization and infrastructure build-up for industrialization, has put considerable pressure on arable land, which decreased from 0.11 ha/capita in 1980 to 0.05 ha/capita in 2014 [4]. Ninety-nine percent of farms in Bangladesh are small-scale and fragmented, with an average area of less than one hectare [5].

Sustained policy support for increased food grain production to meet national demand has contributed to improved self-reliance (especially for rice and maize production) in Bangladesh, yet the country still depends heavily on imports for other crops and agricultural products such as wheat, vegetable oil, and cotton[1] [6]. Increases in farm income have contributed substantially to poverty reduction in the past decade[2], yet almost a third of the population still lives below the national poverty line, mostly in rural areas [3, 4]. The country is especially challenged by a lack of economic opportunity [7] and faces moderate inequality in income distribution, ranking 3rd out of eight countries in South Asia on the Gini Index (a score of 0.31 out of 100) [3]. Nearly 40% of the population lacks access to electricity, while another 15% has no access to improved water supplies [4]. Still the economy of Bangladesh has grown steadily over the past decade, consistently achieving GDP growth between 6% and 7% annually.

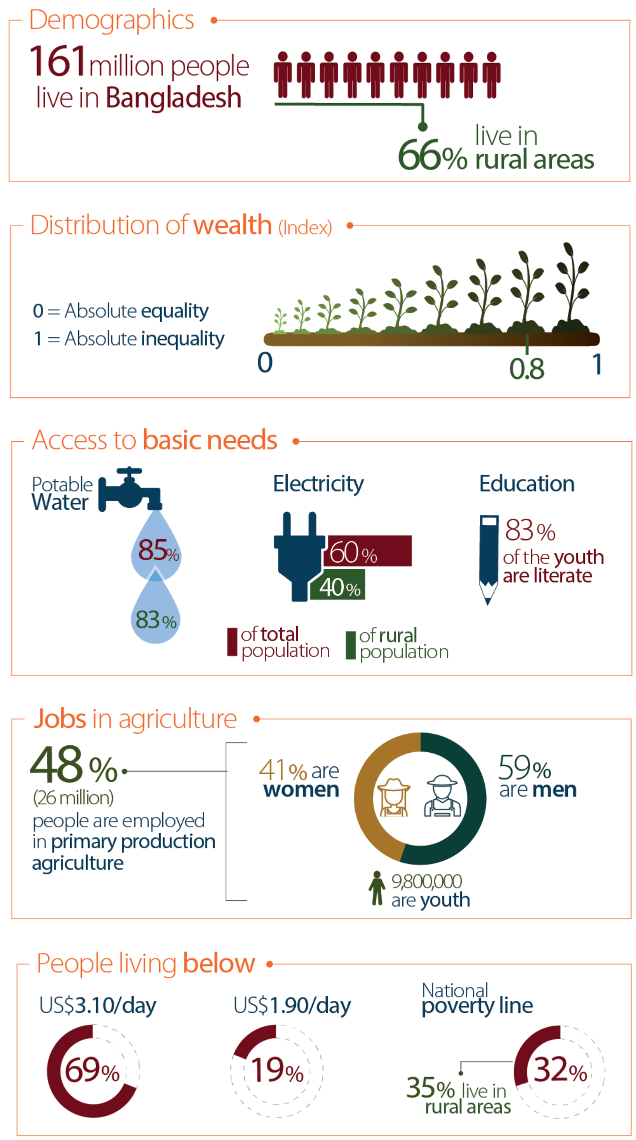
In 2016, Bangladesh received middle-income country status. However, according to the Social Progress Index (SPI), which measures a country's performance in relation to three key societal dimensions[3] (basic human needs, wellbeing and opportunities), Bangladesh scores among the countries with the lowest SPI scores in the world (52.7). Women's empowerment in particular, remains constrained by limited decision-making power and unsatisfactory control over productive resources and income in Bangladesh [8].

### Economic relevance of agriculture in Bangladesh[3, 5]




*South Asia: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka

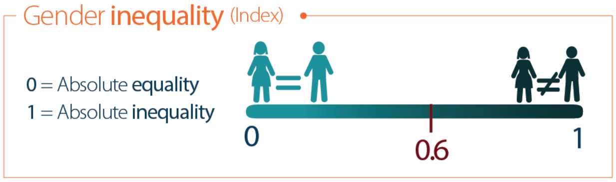
### People, agriculture and livelihoods in Bangladesh [3, 5]

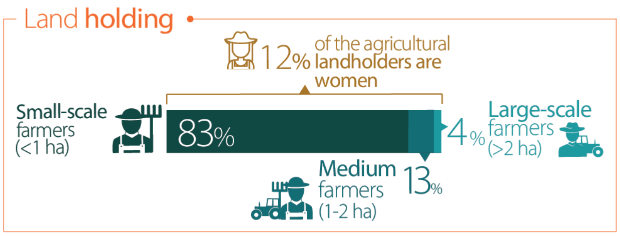


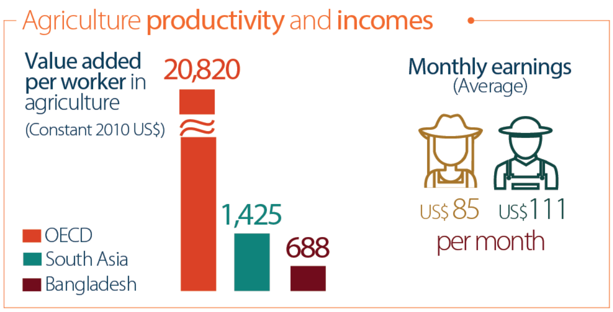

1 Cotton is mainly imported for use in the garment industry, which explains the unfavourable (negative) trade gap of 7:1.

2 Between 2005 and 2010, 90% of the decline in poverty in Bangladesh was associated with increased farm income [3].

3 The SPI indicators relate to: nutrition, water, shelter and personal safety (basic human needs dimension); access to knowledge and information, health, environmental quality (wellbeing dimension); and personal rights, freedom and choice, tolerance and inclusion, access to advanced education (opportunities dimension).



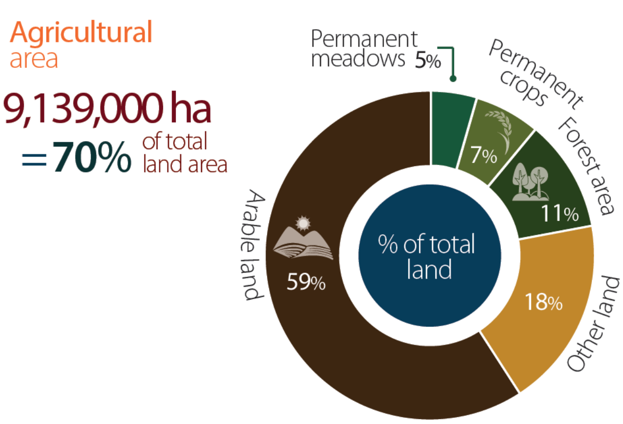




## Land use

Agricultural land in Bangladesh covers roughly 9.1 million hectares[4], which is 70% of the country's land area. Around 59.2% of the agricultural area is considered arable, 6.5% is occupied by permanent crops, while meadows and pastures account for 4.6% (area which is expected to decrease). Forested area represents approximately 11% of total land area in Bangladesh [6]. Due to increased pressure on land from urban and peri-urban expansion, overall cropland area in Bangladesh has diminished in recent years. Meanwhile, intensification has increased significantly and land is double cropped in most areas, with an average cropping intensity of 192% throughout the entire country [9, 10]. In some areas, land can be cultivated with up to three and four crops, especially at higher elevations where high yielding varieties of rice, wheat, potato, sunflower, and mungbean are grown [5].

### Land use in Bangladesh [5, 6]




## Agricultural production systems

Despite its relatively small size (147,570 km$^2$), Bangladesh is a very diverse country in terms of topography, soils and climate. Water resources are plentiful in the rainy season—although many areas face scarcity in dry months—and the country's nutrient-rich alluvial soils are highly fertile, allowing for the cultivation of a variety of food and cash crops throughout the year. Agriculture in Bangladesh has in the past traditionally been subsistence-oriented. However, it is transforming rapidly into more commercial production of high value crops, livestock and aquaculture. Most farms grow field crops and vegetables (including home gardens), raise trees for fuel, fruits and timber, and rear livestock such as cattle and poultry. Many farmers in Bangladesh also participate in pond aquaculture production [11] and commercial shrimp culture in saline-prone areas of southern districts.

The country has been classified into 30 Agroecological Zones (AEZs) based on topography, flooding, and soil type (a map of AEZs is found in Annex 1). These AEZs are further subdivided in 88 agroecological sub-regions and 535 agroecological units. This CSA Profile focuses on two major regions in the country: the northern region—key for agricultural production—and the southern region where high exposure to extreme climate events (e.g. cyclones, tropical storms) and changes in climate and socio-economic vulnerability significantly challenge the region's agricultural productivity [9]. All major crops discussed in this profile are cultivated both in the northern and southern regions of Bangladesh, although crop suitability varies between regions.

Rice is the country's dominant crop (77–80 percent of cultivated land devoted to paddy) and a key component of the population's diet. Bangladeshis are the world's second largest per capita consumers of rice at 200 kg/year. Three main paddy rice systems are farmed in the country: *aman* (dependent on the tropical monsoon rains, which usually occur between June and October); *boro* (in winter); and *aus* (in spring). *Aman* monsoon summer rice occupies 70% of all cultivable land in Bangladesh [6]. Boro, meanwhile, is dry-season, irrigated rice system predominantly using high yielding varieties (HYVs) grown between December and May. It occupies approximately 60% of the cultivable area. *Boro* is often considered "risk-free" since it is mostly grown before the spring storms or cyclones. As such, it has the highest rice yields (reaching eight tons/ha), almost double that of monsoon rice. The third paddy type, *aus*, is a direct-seeded and rainfed variety occupying only 20% of the *Aman* rice area. *Aus* rice yields are usually the lowest in Bangladesh, due to the prevalence of traditional varieties and greater storm and cyclone risk during this season. In 2014, of the total rice production in the country, *aus*, *aman* and *boro* rice accounted for 7%, 38% and 55%, respectively [12]. Improved agricultural production over the past years has been largely associated with increased rice yields from HYVs and hybrids rather than expansion of cultivated area.

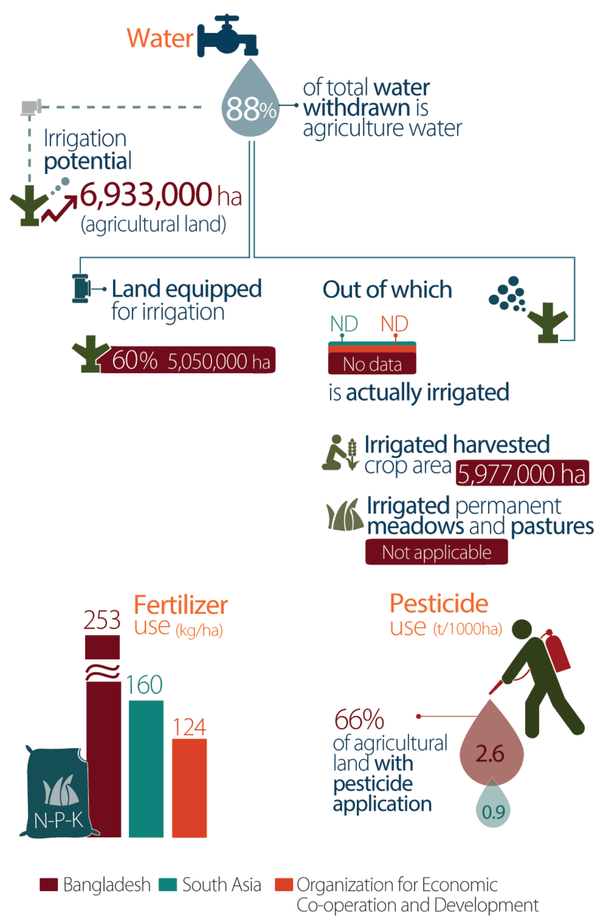
4 While FAO states the area to be 9.1 million hectares, the Bangladesh Ministry of Agriculture claims the area to be 7.9 million hectares in size.

Jute, an important fibrous commercial crop, has also been cultivated in Bangladesh for centuries. According to the Indian Jute Mill Association, Bangladesh accounts for 48% of the global jute production, a figure that is expected to rise despite increased risks from monsoon flooding. The crop is preferred for its resistance to floods during the monsoon season and is sometimes planted as a substitute for monsoon rice. Jute is effective in rotation and relay cropped with other crops given its deep root system and abundant vegetation, both contributing to improved soil fertility. The country has invested in considerable jute crop research and was the first to map the genomes of two local jute species. With the recent approval of genetically modified organisms (GMOs) for cultivation by the Government of Bangladesh (GoB)—currently limited to eggplant and blight resistant potatoes—there is potential to expand jute production through further research and the adoption of modified varieties. Retention of rainwater by in excavated canals for jute retting has further opened up opportunities for jute cultivation.

Other key crops in Bangladesh include wheat, mustard, and maize, often sown after the Aman rice crop in winter (October-March). Maize is especially productive in Bangladesh given the widespread adoption of hybrid varieties and irrigation, explaining the country's high yield performance relative to the surrounding region. The country has also seen increased demand for mungbean in recent years, leading to a swift expansion in the production area of that crop [5]. Mungbean is a short-duration crop, especially well-suited for cultivation between spring, summer, or fall cropping seasons. Finally, vegetable production has also increased in Bangladesh during recent years, given the availability of improved seeds, changes in consumption patterns and the profitability of vegetables in local markets.

Bangladesh ranks third and fourth in the world for fisheries and aquaculture production. Fisheries and aquaculture play a major role in employment: about 17 million people (11% of the total population) are associated with the fisheries sector, with 5 million people involved in marine fisheries. Bangladesh's fisheries sector subdivides into aquaculture (52.5% of total production) and capture fisheries, of which inland capture accounts for 29%, and marine and coastal capture for 18.5% of production. In 2014-15, the total sector value was estimated at US$ 3.6 billion. Fish provides 56% of animal protein consumption in Bangladesh [13]. Pond and seasonal floodplain aquaculture supply about 42% of total yearly fish production in the country [10] and are highly profitable relative to many field and commercial crops [6]. Fish feed, fingerlings and other inputs have become more readily available in the country, fostering both homestead and commercial fish production. Livestock production, meanwhile, contributes to only 13% of agricultural GDP and 2.5 % of total GDP in Bangladesh [14]. Even though livestock represents 13% of agriculture GDP, it employs about 20% of the labor force full-time and 50% part-time. Over 70% of rural households are engaged in livestock production, and income from livestock contributes a large share of the smallholder and landless farmers' livelihoods [15]. Three commodity groups dominate the livestock production systems in Bangladesh: cattle and buffalo milk, large and small ruminant meat, and poultry meat and eggs. Dairy production in particular is an important economic activity in Bangladesh, providing 3.6 million households with supplementary income. Poultry production, however, plays an outsized role in the subsector, contributing to almost 40% of all meat production and representing the fastest growing segment of the livestock industry [16]. Bovine (cattle and buffalo) and small ruminant (goat) production has also grown in recent years, much of it owing to cattle export bans from India to Bangladesh. This has led to an increase, although nascent, in rural calve-fattening operations. Milk production also remains small-scale given the lack of dairy cooperatives and fodder for dairy cattle. The use and importance of cattle and buffalo as draft power for field preparation and transport is decreasing because of the rapid expansion of three-wheel tractors' use in Bangladesh. In 2014, more than 550,000 power tillers were used to prepare more than 80% of Bangladesh's crop land [17].

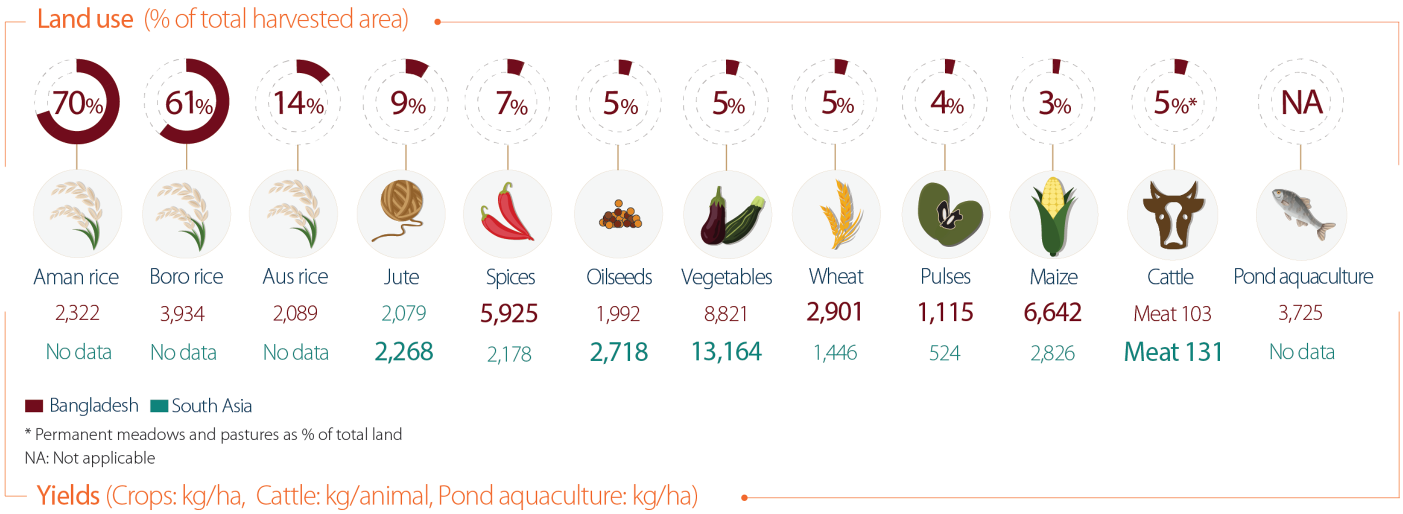
## Agriculture input use in Bangladesh[4, 6, 48]




5 Almost all global jute is produced in the Ganges River Basin (India and Bangladesh).

The following infographic shows a selection of agriculture production systems central to food security and sector performance in Bangladesh. The importance of each system is determined based on its contribution to economic growth, productivity, and nutrition quality indicators in the country. For more information on the methodology regarding production system selection, see Annex 2.

### Production systems key for food security in Bangladesh[5, 6]



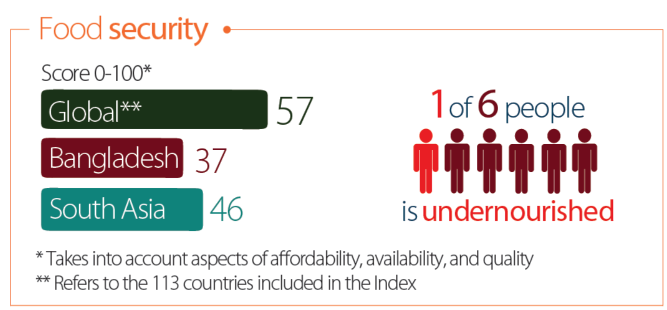

## Food security and nutrition

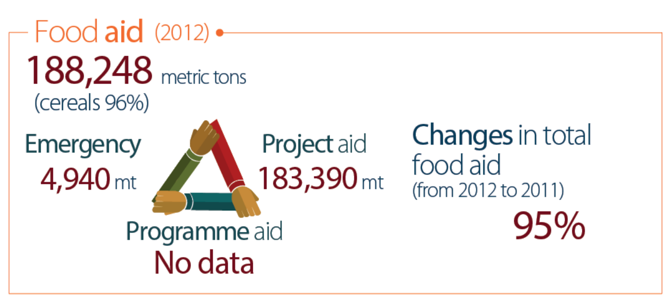
A major accomplishment for Bangladesh has been achieving food security – despite frequent natural disasters and population growth over the past 40 years, food grain production has tripled between 1972 and 2014, from 9.774 to 35.731 million tons [18].

Bangladesh made significant progress in ensuring the nutrition and health of its population and in meeting the Millennium Development Goals (MDG) targets of halving hunger by 2015. Rice self-sufficiency has been achieved (with inter-year fluctuations) and calories from fish, meat and vegetables have been rising sharply for the past five years as the country experiences significant economic growth. Per capita calorie intake was estimated at 2,318 kilocalories (kcal) per day in 2010, above the minimum requirement of 2,122 kcal/day. However, the country's Food Security Index and the Global Hunger Index scores remain among the lowest in South Asia [19].

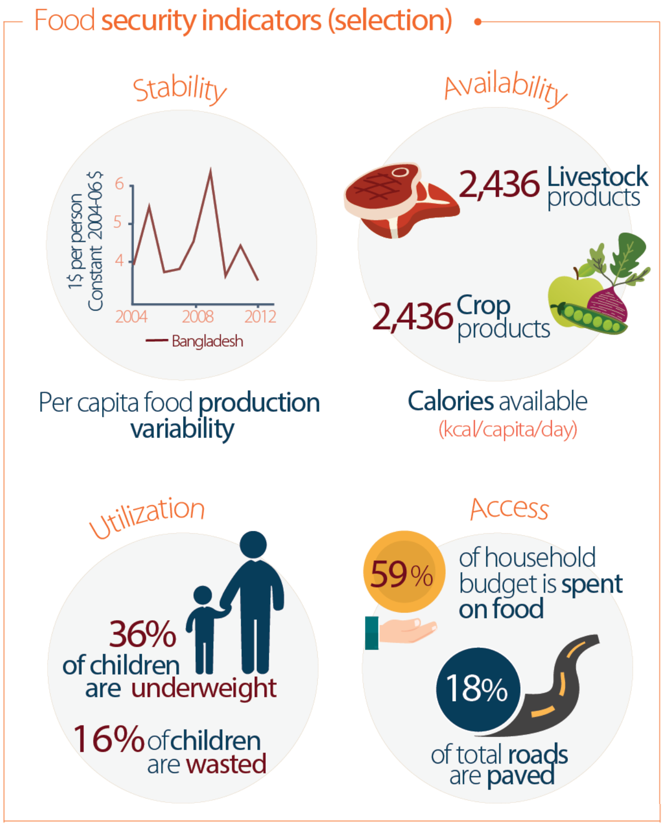
Approximately 17% of the population is classified as undernourished, with child underweight and wasting rates at 36% and 16% respectively. The areas most prone to stunting are in the northeast and the southeast. Although these rates have been declining over the years[6], they indicate that food and nutrition insecurity in Bangladesh remains a problem that stems not only from limited availability of food for some vulnerable sections of people, but also a lack of access to high quality foods. Limited market access, price volatility and climate impacts (e.g. rainfall variability, drought, floods, and cyclones) each contribute to food insecurity in the country [20].

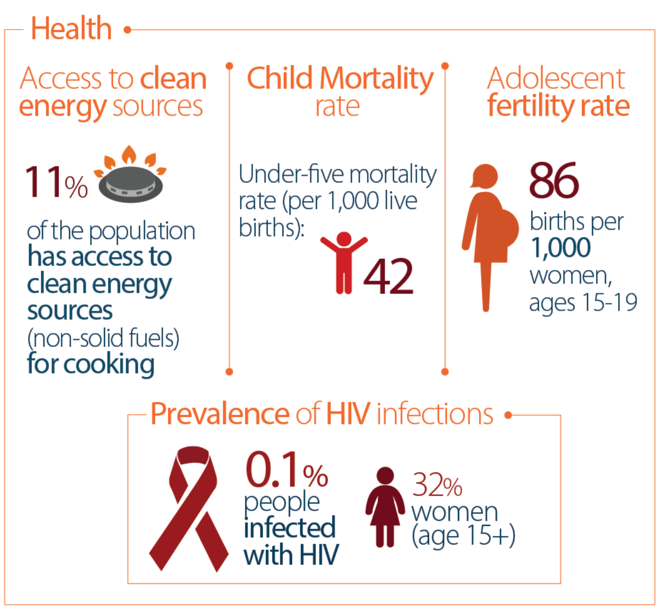
### Food security, nutrition, and health in Bangladesh [3, 6, 21]




6 Between 1997 and 2007, Bangladesh achieved one of the fastest reductions in child undernourishment in history. The rate of stunting among children under five decreased from 55% in 1996-97 to 36% in 2014. Maternal undernutrition, measured by body mass index (BMI) had also declined from 52% to 17% during the same period [19]. All this was attributed to the country's improved economic performance (with an economic growth of 6-7% per year).

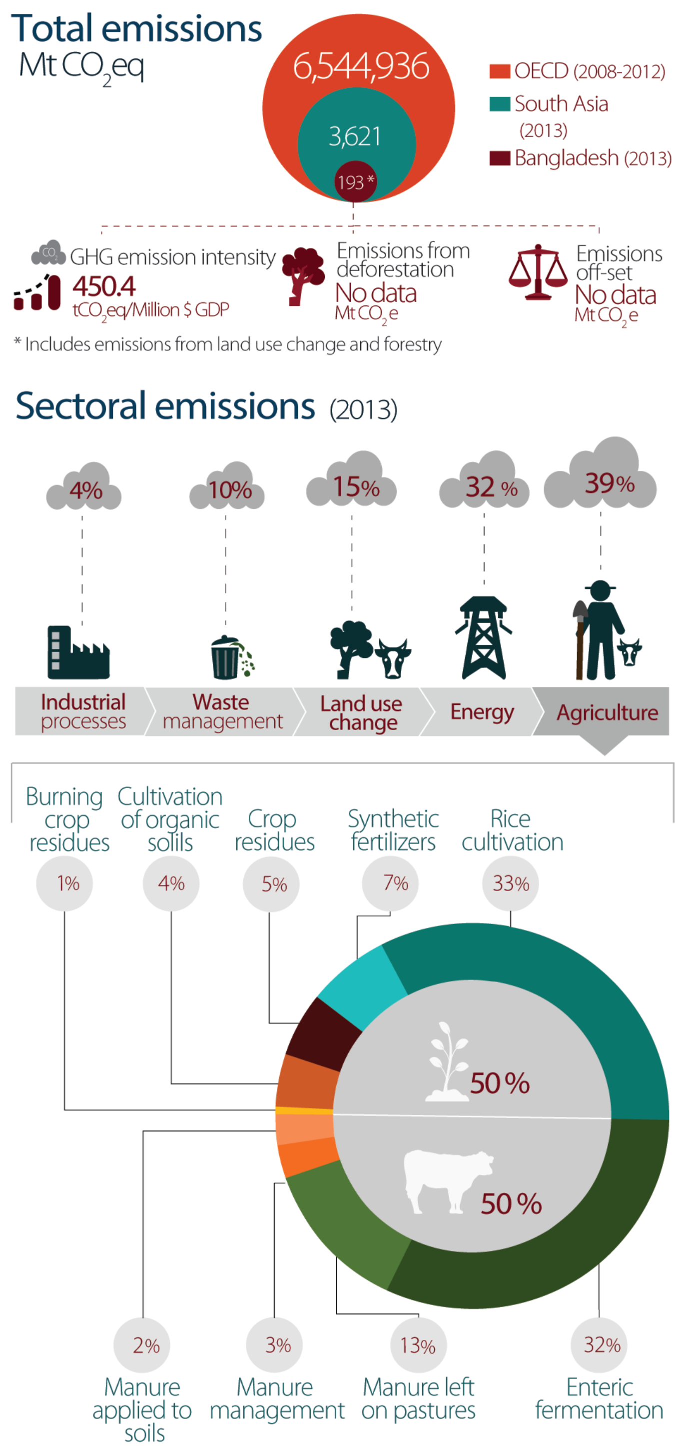



# Agricultural greenhouse gas emissions

Bangladesh's GHG emissions reached 192 megatons of CO2 in 2014, placing the country in the bottom quarter of emitters globally [5, 22]. While the CO2 intensity of the economy is relatively low, it has been increasing steadily over the past decades. Bangladesh's annual CO2 footprint has increased by 3.6% in 2011 compared to the year before, driven by GDP growth rates of 6-7%. Agriculture contributes to 39% of the country's GHG emissions. Cropland and enteric fermentation (livestock production) contributed equally to agricultural GHGs in 2013. Compared to other sectors, such as energy whose emissions increased by almost 500% between 1990 and 2013, agricultural emissions in Bangladesh have remained relatively stable, increasing by about 30% in that same time period [22]. Nevertheless, the agriculture and livestock sector remains the main source of emissions in the country in absolute terms.

## Greenhouse gas emissions in Bangladesh [6, 22]



The Department of Agriculture extension service recommends a variety of agricultural practices to farmers for mitigating GHG emissions, including: midseason drainage, off-season incorporation of rice straw[7], substitution of urea with ammonium sulphate, use of deep placed briquetted urea for rice, replacement of roughage with feed concentrates, use of dome digesters, conservation agriculture practices including zero or minimum tillage coupled with residue management, use of biofuel instead of fossil-fuels, high efficiency fertilizer application, and artificial and participatory woodlot plantation [23].

## Challenges for the agricultural sector

Agricultural growth and development is key for food security in Bangladesh, yet the sector is facing several challenges that hinder development and cause stagnating growth rates. Some of those challenges relate to: gradual loss of arable land, declining soil fertility and salinization; insufficient investment in agricultural research and training; inadequate credit support for farmers and an unfavorable land-tenure system, resulting in low level technology uptake of a predominantly small-scale farming structure; outmigration and labor shortage in rural areas resulting in rising wage rates; and the need to cope with increasing impacts of climate change and related extreme weather events [24, 25. 26, 27].

The overriding challenge in Bangladesh is to support farmers out of low profitability rice cultivation through the reduction of labor costs through improved mechanization and water conservation through on-farm irrigation efficiency. Promoting suitable mechanization in Bangladesh needs to be seen not only as a substitution of machines for scarce rural labor on profitability and efficiency grounds but as a potential rehabilitation, mitigation and adaptive strategy to address shrinking timer period between cropping systems, allowing climate vulnerable farmers quick planting and harvesting of crops as well as transportation and livelihood means [28].

Over the past decades, Bangladesh's high population growth led to a stark decline in per capita agricultural land availability. The trend is exacerbated by the increasing non-agricultural use of cultivable areas resulting from unplanned urbanization (e.g. for housing), road construction, and other infrastructure projects. Limited availability of farmland and on-farm livelihood opportunities further drives the rural labor force to seek employment in cities, further fueling urbanization trends while causing labor shortages in rural areas [27].

Declining land availability also means that, to sustain food production, crop productivity in Bangladesh has had to increase. The government sought to achieve this by subsidizing fertilizer use in the country, leading to a spectacular rise in fertilizer use from 0.36 kg/ha in 1995 to more than 298 kg/ha in 2007, and with it an almost three folds increase of crop yields per hectare over this same time period [26, 27]. Although this led the country to achieving rice self-sufficiency, the habit of growing rice predominantly in monoculture together with imbalanced use of chemical fertilizer and inadequate irrigation management also resulted in depletion of soil fertility and soil organic matter [12, 27].

Given these and other trends, crop growth rates of cereals have been declining over the past years, and rice yields remain below the levels registered in other South Asian countries. Wheat and maize imports in Bangladesh are expected to stay unchanged in the near future, to meet the national demand. Besides, the predominant focus on rice production (which accounts for 75% of crop production in the country) means that many farming households are under risk of malnourishment due to a lack of diversification [26]. To counteract this, the government adopted a Crop Diversification Program in 2008. Slowly but steadily, farmers are now increasingly engaged in diversifying production, focusing particularly on high value crops such as flowers or early potatoes, entering new markets, as well as integrating more livestock in to farming systems [26]. For example, farmers in the Northwest forgo monsoon rice production to grow early potatoes, getting a significantly higher price they would get during the usual potato season.

Finally, Bangladesh's growing livestock sector is plagued by a variety of constraints, such as inadequate availability of quality fodder and feed, lack of quality control, lack skilled labor and qualified personnel, vulnerability to climate change and insufficient veterinary and animal health services and related livestock research, among others [15]. Animal disease is responsible for almost 50% of all animal deaths in the country. Limited permanent grazing land, inefficient livestock marketing practices, and a lack of access to improved animal breeds further limit the sub-sector's performance and size [29]. A comprehensive livestock production plan was adopted by the GoB in 2005, but has yet to translate in to meaningful productivity gains in the sector.

# Agriculture and climate change

According to the Global Climate Risk Index[8], Bangladesh is the most climate change vulnerable country in the world [30]. Today, and in to the coming decades, the country is likely to be negatively affected by sea level rise and saltwater intrusion, mean temperature increases (1.7$^{\circ}$C by 2050), rainfall variability, and an increase in the frequency and intensity of extreme weather events. Each of these factors will have considerable impacts on agricultural production in the country.

Situated in an alluvial delta plain, Bangladesh has five major river systems that often change locations, depending on siltation and flow. The country is thus highly vulnerable to sea level rise and salinization of inland water sources. A 2009 study by the Bangladesh Soil Resource Development Institute [31] found approx. 62% of coastal land (1.06 million out of 1.7 million hectares) to be affected by some

7 Farmers in Bangladesh rarely burn the straw in their fields, given its value as cattle feed. Hence, emissions from straw burning represent less than 1% of GHG emissions in the country. In the villages that lack access to gas or cylinder gas, manure is burned for fuel.

8 The Index analyses the extent to which countries have been affected by the impacts of weather-related events (e.g. losses related to storms, floods, heat waves etc.)

degree of soil salinity, ranging from very slight (0.328 million hectares), slight (0.274 million hectares), moderate (0.189 million hectares), strong (0.161 million hectares) to very strong (0.101 million hectares). Salinization is expected to advance 8 km further north in the country by 2030, further reducing land availability for farming. While infusion of salt water into the rivers and canals remains a challenge for crop production, it also brings opportunities for salt-water shrimp production, which has expanded recently due to its higher profitability compared to other crops (such as rice) [32].

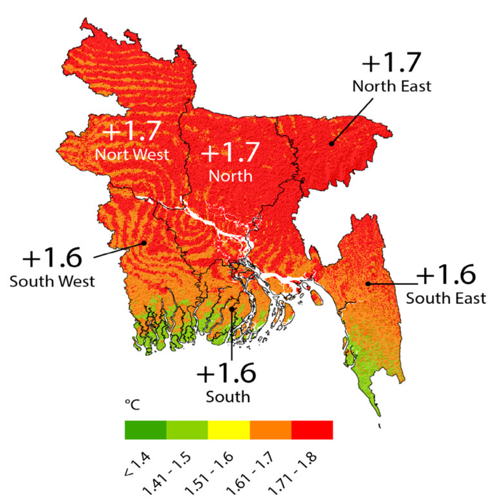
Approximately 60% of Bangladesh's area is characterized by a tropical savanna climate, while another 30% is considered tropical monsoon [33]. Rainfall patterns vary from North to South and from East to West in the country, except during monsoon months (May through September). The hilly areas of northwestern Bangladesh are prone to drought, for example, while the northeastern freshwater wetland often faces delayed rainfall or early flash flooding. While the central floodplains experience flash floods and riverbank erosion, and the hilly areas experience landslides, urban areas in Bangladesh are plagued by rainwater drainage issues [3]. Most rainfall in Bangladesh occurs in the summer months between June and October, while the winter months (November to February) receive only 4% of the annual rainfall. Early monsoon rain in April 2017, for example, caused heavy flooding in northeastern haor (vast low depression areas) that damaged pre-mature *boro* paddy. On the whole, rainfall is expected to increase in Bangladesh by 9-12% by 2050.

Since yields of summer monsoon rice depend on consistent, predictable rainfall, disruptions in normal monsoon behavior can produce significant losses in rice yields all over South Asia, including Bangladesh. Rain-fed monsoon rice, for example, which constitutes over 38% of total rice production in Bangladesh, is highly vulnerable to water supply volatility, caused by changes in seasonal monsoon occurrence [34]. On one hand, early monsoon arrival can cause flood damage when rice seedlings are submerged in early growth stages, especially when farmers are not using submergence-tolerant varieties. On the other hand, late monsoon arrival can lead to water stress. Results from the CERES-Rice model indicate that high water stress during flowering and maturing stages can lead to rice yield losses as high as 70% [35]. Increased concentration of carbon dioxide in the atmosphere may benefit *boro* rice production, yet these effects are most likely neutralized by rising temperatures during the flowering period and decreased sunlight during the winter crop season, both negatively impacting yield. Since this rice crop is 100% irrigated, fluctuations in rainfall are less likely to affect the crop.

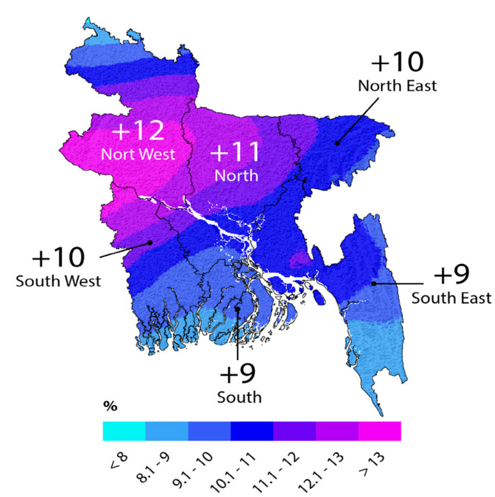
Extreme weather conditions (floods and cyclones) are expected to increase in frequency and intensity in Bangladesh [36, 37, 38]. Losses related to the 2007 and 2009 cyclones were estimated at around two million metric tons of rice, enough to feed 10 million people. The south, southwest, and southeast coastal regions of Bangladesh are increasingly susceptible to severe tropical cyclones and associated saltwater intrusion.

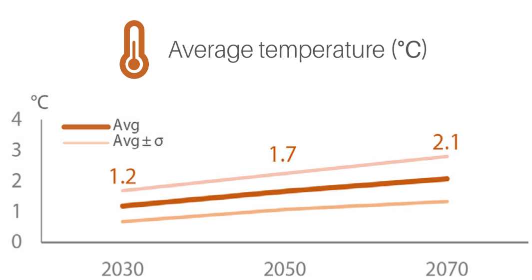
## Projected changes in temperature and precipitation in Bangladesh by 2050 [36, 37, 38]

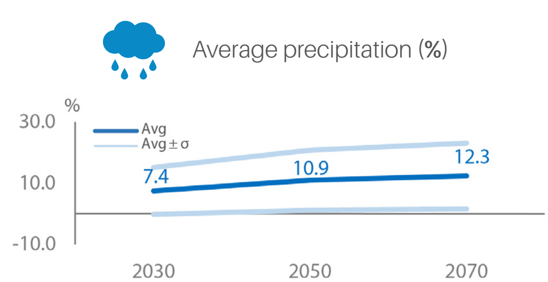
Changes in annual mean temperature (°C)




Changes in total precipitation (%)

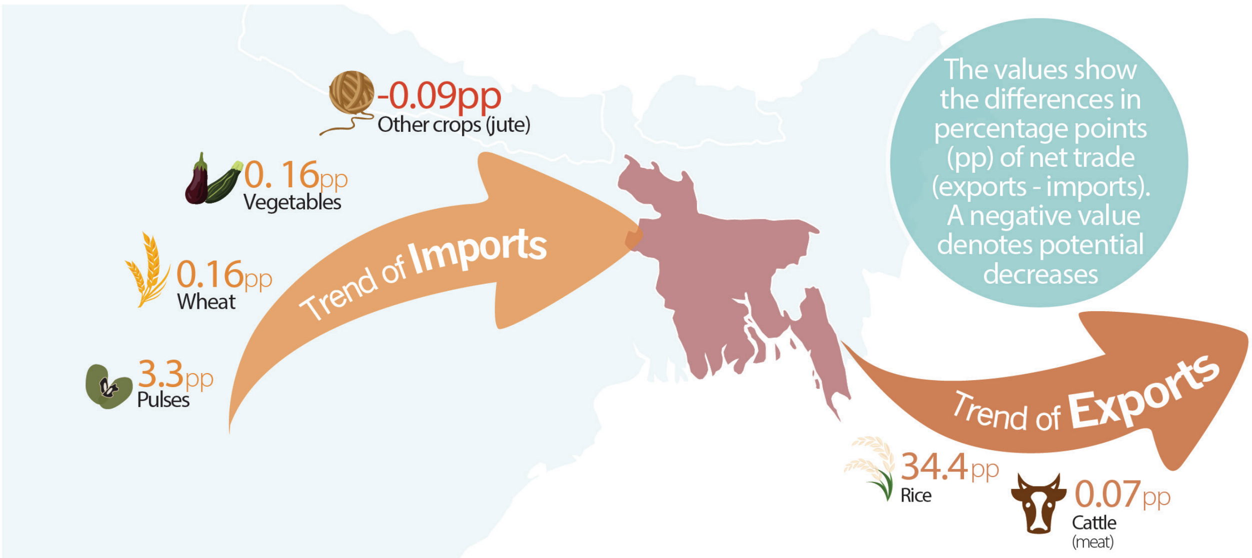


## Potential economic impacts of climate change

### The impact of climate change on net trade in Bangladesh (2020-2050)[39]




An analysis using the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT)[9] [398] for Bangladesh shows that climate change has mixed effects on agricultural production potentially contributing to increase in yields and land area for some crops, and decreases for others[10]. In general, most production systems in Bangladesh are projected to be at least somewhat adversely affected by climate change. The specific impacts depend on the production system in question, with pulses, wheat, and oilseed-rapeseed facing the most negative impact.

While subject to considerable within-country variability, the model demonstrates overall yield declines in maize, pulses, vegetables, jute and wheat, and increases for milk and meat yields by the year 2050. For example, 2050 pulse yields under climate change are 8.8% lower than the projected value if climate change did not occur. This is followed by wheat and oilseed-rapeseed with 6.4% and 6.3%, respectively, as the greatest reductions in yield. By 2050 rice, yields of vegetables (as a group), and other crop[11] (including jute) are 5.3%, 5.7%, and 3.3% less than the NoCC value in 2050, respectively.Cattle herd sizes are projected to increase substantially—by roughly 52% over the 2020 value—under both CC and NoCC scenarios, yet the increase is slightly greater under CC by 0.2 percentage points (pp). Furthermore, the impact of climate change on area cultivated is mostly negative, with the exception of rice and oilseed-rapeseed.

With regards to changes in agricultural net trade, the model also suggests that Bangladesh may become more dependent on imports of pulses, other crops (including jute), vegetables (as a group), and wheat. Thereby, the dependence on imports of other crops (including jute) is projected to be lower under conditions of climate change as compared to NoCC by 0.09pp, while the dependence on imports of pulses, vegetables (as a group), and wheat is projected to be greater under CC than NoCC by 3.3pp, 0.16pp, and 0.16pp, respectively.

Likewise, the modeled results suggest that cattle meat exports will increase both under the CC and NoCC scenarios (but the difference between scenarios is insubstantial at +0.07pp).

Most notably, the model results indicate that Bangladesh may transition from being a net importer to a net exporter of rice under both CC and NoCC. This transition is likely to be more pronounced under CC by 34pp as compared to the NoCC scenario.

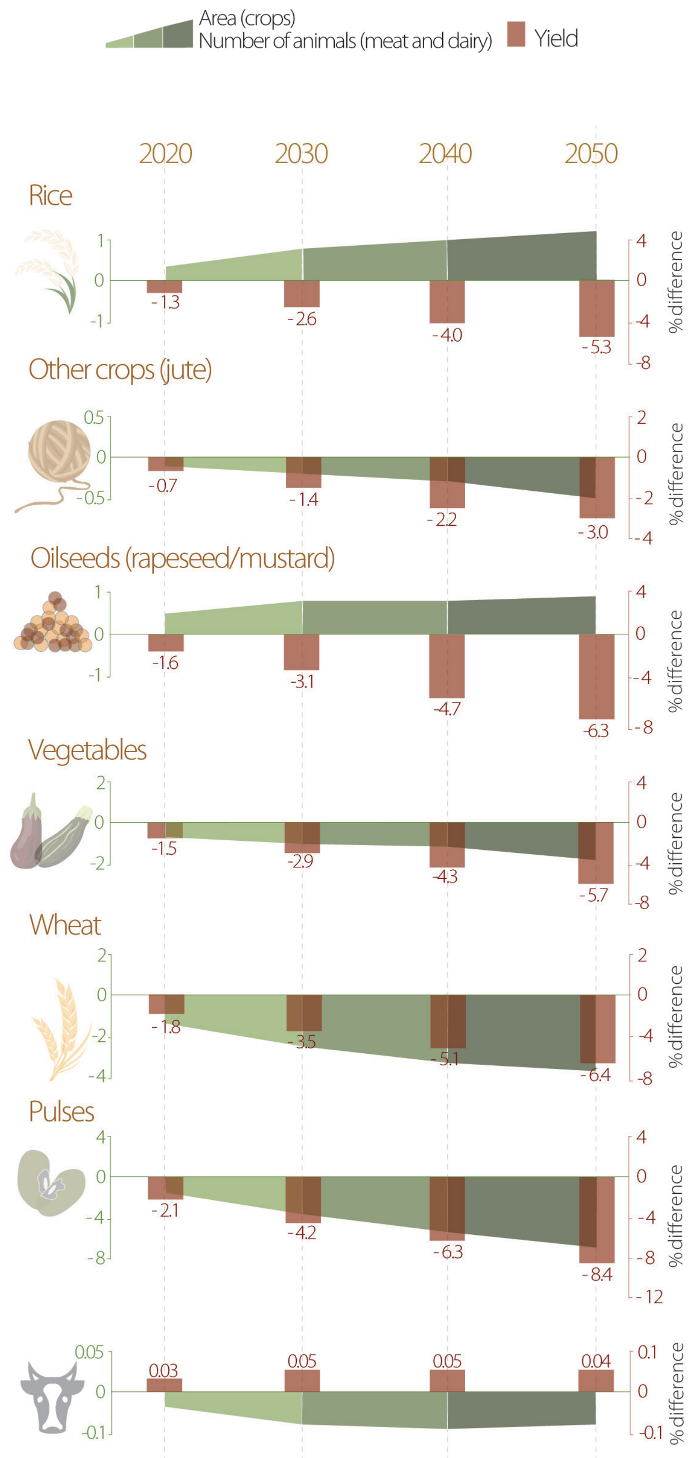
Ultimately, changes in demand are driven by relative commodity prices present in the global and national marketplace. For this reason it is important to examine changes in supply-side drivers.

9 IMPACT, developed by the International Food Policy Research Institute (IFRPI) [39], is a partial equilibrium model using a system of linear and non-linear equations designed to approximate supply and demand relationships at a global scale. This study used the standard IMPACT model version 3.2, less the IMPACT-Water module. The tool uses the General Algebraic Modeling System (GAMS) program to solve a system of supply and demand equations for equilibrium world prices for commodities. The tool generates results for agricultural yields, area, production, consumption, prices and trade, as well as indicators of food security.

10 The IMPACT model scenarios are defined by two major components: (i) the Shared Socioeconomic Pathways (SSPs), which are global pathways that represent alternative futures of societal evolution [40, 41] and (ii) the Representative Concentration Pathways (RCPs), which represent potential greenhouse gas emission levels in the atmosphere and the subsequent increase in solar energy that would be absorbed (radiative forcing) [42]. This study used SSP 2 and RCP 4.5 pathways.

11 The category "other crops" covers a variety of different types of crops, including jute, in accordance with suggestions made by IFPRI experts.

## Climate change impacts on yield, crop area and livestock numbers in Bangladesh [39]




*A negative value denotes potential decreases in area and yield expressed as percentage change in a climate change scenario vs. non climate change

# CSA technologies and practices

CSA technologies and practices present opportunities for addressing climate change challenges, as well as for economic growth and development of the agriculture sector. For this Bangladesh profile, practices are considered CSA if they enhance food security as well as at least one of the other objectives of CSA (adaptation and/or mitigation). Hundreds of technologies and approaches around the world fall under the heading of CSA.

Many of the CSA practices identified here have been used by farmers in the southern coastal plains of Bangladesh for centuries, in response to increasing floods and cyclones. Initially used for shrimp farming, for example, traditional gher farming (see Case Study below)—an aquaculture pond in non-saline wetlands with raised dikes for vegetable production—has grown increasingly complex, allowing for the production of shrimp, fish, and prawns. Climbing vine-type vegetables are also commonly grown on trellises over the pond.  Meanwhile, floating vegetable gardens have also been introduced in tidal flooded areas, using water hyacinth layered with soil—an old practice which is now expanding in the Southern coastal plains as a climate risk management strategy. Kangkong (water spinach) cultivation was always done near ponds, and with improved varieties, production can be expanded.

In low-lying waterlogged regions, farmers in Bangladesh have historically utilized a host of ridging and furrowing methods.  The Sorjan system, for example—a variation on pyramid cropping—is a system of tall beds for vegetable and crop production alternating with furrows, or trenches, planted with submergence tolerant plants or used for fish production. Rice field fish rings, or concrete rings in rice paddies that protect fish when paddies dry up, have also been implemented [43]. Production of small indigenous fish in these canals is an increasingly common practice in Bangladesh, offering even small pond holders access to nutritious food and better incomes.

The adoption rate of this practice is still low among farmers in the Northern and Southern regions. While these practices were first introduced decades ago, they are quickly expanding today. A variant of this practice is locally referred to as the 'hari' system in which gher operators grow fresh water fish in ponded water in the rainy season and then drain out excess water on their own expenses to enabling landowners to grow boro paddy in dry months [44]. Institutional support for the identification of appropriate rice varieties, and improved access to credit and technology packages can promote such practices in a more profitable and environmentally friendly way.

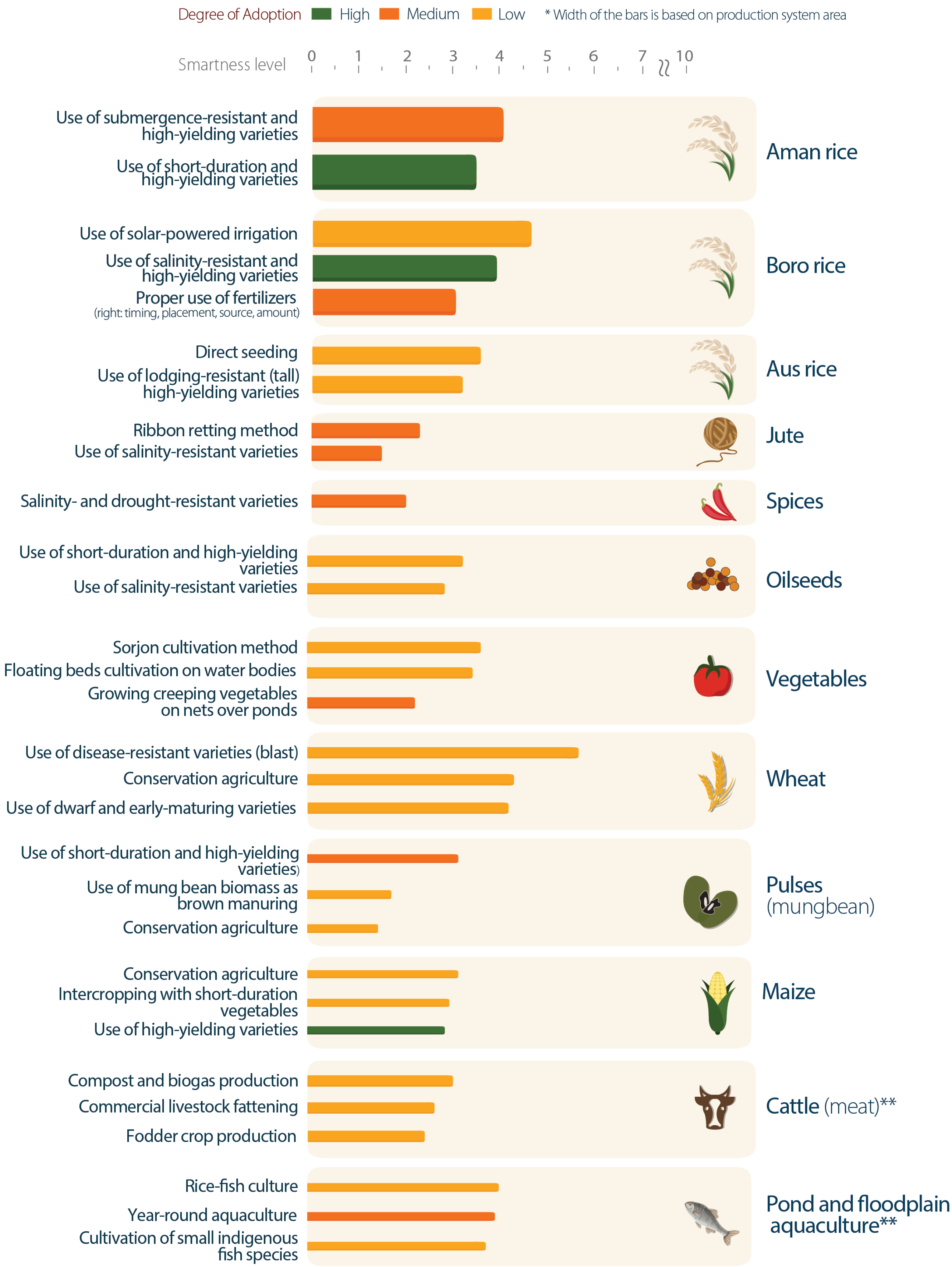
Over the past 40 years, saltwater intrusion into the tidal rivers of Bangladesh has become especially acute. Changes in the sea level are very likely to further exacerbate this situation. The use of salt-and submergence tolerant, high yielding crop varieties is therefore an important, if underutilized, adaptation strategy under these conditions. Access to improved seed in Bangladesh is constrained by a sluggish process between seed release and use (it takes around 15 years for seed to be readily available to growers). Most of the released seed is multiplied through the Bangladesh Agriculture Development Corporation, but because it is not 'marketed', new releases are not demanded and thus, not multiplied sufficiently. Consequently, adoption of tolerant varieties remains low throughout the country. However, in response to the losses caused by changes in seasonal monsoon occurrence, the availability of submergence-tolerant rice varieties, released seven years ago, has improved significantly over the past years, especially for the farmers in areas prone to flash flooding.

After the monsoon period, the winter in Bangladesh is dry, devoid of much rainfall. Thus, any salt in the ground is evaporated to the soil surface, rendering it saline. Vegetable towers—potted vegetables supported by bamboo and polythene—have been introduced to counter this salinity challenge.

Barriers to the adoption of these and other CSA practices by small-scale farmers in Bangladesh include the limited availability of credit, unfavorable extension staff to farmer ratios for the dissemination of new technologies and practices, and the limited implementation of novel financing mechanism and safety net protection. Index-based crop insurance, for example, was modeled by Oxfam in cooperation with a private insurer, yet the lack of a clear business model still makes it difficult for the GoB to scale up such interventions.

The following graphics present a selection of CSA practices with high climate smartness scores according to expert evaluations. The average climate smartness score is calculated based on the practice's individual scores on eight climate smartness dimensions that relate to the CSA pillars: yield (productivity); income, water, soil, risks (adaptation); energy, carbon and nitrogen (mitigation). A practice can have a negative/ positive/ zero impact on a selected CSA indicator, with 10 (+/-) indicating a 100% change (positive/ negative) and 0 indicating no change. Practices in the graphics have been selected for each production system key for food security identified in the study. A detailed explanation of the methodology and a more comprehensive list of practices analyzed for Bangladesh can be found in Annexes 3 and 4, respectively.

## Selected CSA practices and technologies for production systems key for food security in Bangladesh




** Unidentified production system area

# Case study: Ghers of Bangladesh

In Southern Bangladesh, the livelihoods and food security of many rural families depend upon half acre ponds. These ponds, or 'ghers' in Bangal, are dug with wide and tall embankments offering resilience against flood and cyclone damage and providing an elevated platform on which to grow vegetables and other crops. The ponds themselves serve as a bed for paddy rice and, following harvest, prawns. Ghers are a traditional farming method in low-lying, water abundant regions of Bangladesh.

This case study chronicles Radha Rani and her husband, Rabin Mandal, as they institute changes to their traditional gher practices. Radha joined a training classes in 2013 along with 24 women and men from her village to receive training based on indigenous knowledge and newly emerging gher management practices known to increase productivity. With this knowledge, Radha now dreams of a better future for her family.

Photo Md. Saifullah. Worldfish / CSISA-BD

After the training, Radha explained the new technologies to her husband who could not attend the classes and convinced him to integrate this new knowledge in to their existing practices. Now, they work as a team to prepare their own nursery and ensure the stocking density of the shrimp is adequate, buying quality feed and ensuring water quality. Radha also learned how to cultivate vegetables on the dikes, so she and Rabin purchased vegetable seeds including cucumber, cabbage, beans and ladies' finger (okra), which she later planted.

Recognizing Radha's enthusiasm, the trainer established a demonstration area in her gher site with a signboard showing both her and her husband's names. Radha's husband, a day laborer and originally skeptical of her ability to proficiently manage the gher operations, changed his attitude when watching Radha take on new responsibilities in his absence using the newly learned techniques. Radha, along with an entire community of empowered women, takes pride in her contributions now on their gher.

In November 2013, Radha and her husband harvested the first batch of prawns, which they sold for a total US$ 720 against a cost of US$ 420. By using the new techniques, they were able to achieve a 30% decrease in production costs and nearly seven times more income from the previous year. Meanwhile, their vegetable crops sold for US$ 134 against a cost of US$ 83. After the prawn, they have planted winter irrigated rice and are preparing the nursery to stock the next batch of prawn.

Given this level of return, it is no wonder that the gher movement in Bangladesh is attracting financing from domestic banks. Many private and government banks (such as Krishi Bank) are investing in ghers and pond excavations given their relatively low risk and profitable returns. Though they represent major landscape modifications, the economic and resilience benefits of creating ghers remain high, with potential to be replicated in other parts of the country.

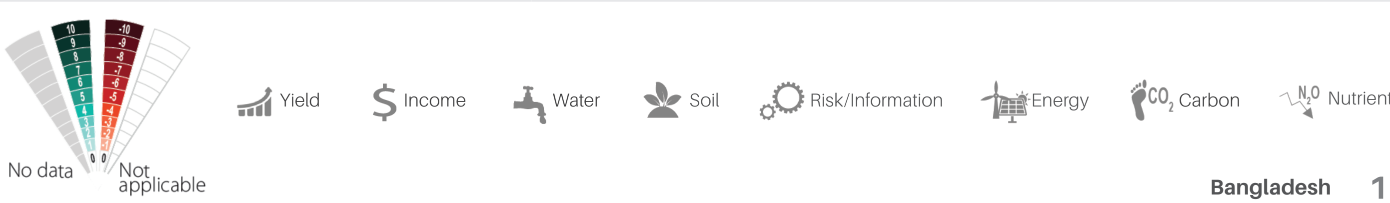
Radha's husband was exuberant about his wife's new ability to farm and increase their family's income. The neighboring women now meet with Radha and, just like her, feel encouraged to be involved with their husbands in the ghers. On a field day at Radha and Rabin's gher site, about 100 neighbors, both men and women, gathered to witness the transformation of Radha and Rani's farming operation. Seeing what can be accomplished by working together, gher farming in their community has now become a family affair.

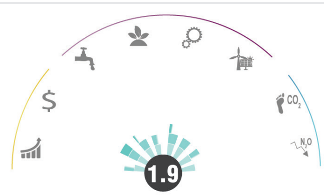
*(Adapted from the Cereal System of Intensification in South Asia project (CSISA WorldFish) used with permission from the author, Afrina Choudhury. This and further case studies can be found in: "Life-Changing Stories of Successful Women Farmers" of the Cereal Systems Initiative for South Asia in Bangladesh (CSISA-BD) [45]).*

**Table 1.** Detailed smartness assessment for top ongoing CSA practices by production system as implemented in Bangladesh.

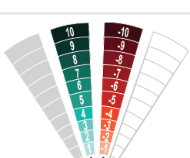
| CSA practice | Region and adoption rate (%) <30 30-60 60> | Predominant farm scale S: small scale M: medium scale L: large scale | Climate smartness | Impact on CSA Pillars |
|---|---|---|---|---|
| **Aman rice** (70% of total harvested area) | | | | |
| Use of submergence-resistant and high-yielding varieties | Northern >60% | S M |   | **Productivity** Promotes high yields per unit area, hence potential increase in income. **Adaptation** Reduces the risk of crop losses caused by temporary or permanent flood conditions. **Mitigation** Promotes above- and below-ground carbon sinks through increased accumulation of dry matter. |
| | Southern 30-60% | S M |   | |
| Use of short-duration and high-yielding varieties | Northern >60% | S M |   | **Productivity** Promotes high yields per unit area, hence potential increase in income. **Adaptation** Increases resilience to biotic stress and climate shocks. Enhances water use efficiency. **Mitigation** Provides moderate reduction in GHG emissions per unit of food produced. |
| | Southern 30-60% | S |   | |
| **Boro rice** (61% of total harvested area) | | | | |
| Use of solar-powered irrigation | Northern <30% | M L |   | **Productivity** Increases yield per unit area, especially during the dry season. Ensures income diversification. **Adaptation** Minimizes water use per unit of product, increasing water use efficiency and resilience to climate shocks. **Mitigation** Reduces GHG emissions due to reduced fuel/energy required for pumping and/or carrying water for irrigation. |
| | Southern <30% | M L |   | |
| Use of salinity-resistant and high-yielding varieties | Southern 30-60% | S M |   | **Productivity** Increases farmers' capacity to limit the crop exposure to climate risks. In the long term, increases in soil biomass accumulation can enhance soil fertility. **Adaptation** Increases in yield stability due to increased resilience to stress caused by salinity. **Mitigation** Provides moderate reduction in GHG emissions per unit of food produced. Promotes carbon sinks through increased accumulation of biomass. |

| CSA practice | Region and adoption rate (%) <30 30-60 60> | Predominant farm scale S: small scale M: medium scale L: large scale | Climate smartness | Impact on CSA Pillars |
|---|---|---|---|---|
| **Boro rice** (61% of total harvested area) | | | | |
| Use of salinity-resistant and high-yielding varieties | Northern 60%> | S M |  | **Productivity**<br>Increases farmers' capacity to limit the crop exposure to climate risks. In the long term, increases in soil biomass accumulation can enhances soil fertility.<br>**Adaptation**<br>Increases in yield stability due to increased resilience to stress caused by salinity.<br>**Mitigation**<br>Provides moderate reduction in GHG emissions per unit of food produced. Promotes carbon sinks through increased accumulation of biomass. |
| **Aus rice** (14% of total harvested area) | | | | |
| Direct seeding | Northern <30% | S M |  | **Productivity**<br>Leads to potential increases in yield in the long term.<br>**Adaptation**<br>Reduces soil degradation and erosion. Increases water availability. Frees up time for decision-making.<br>**Mitigation**<br>Reduces GHG emissions related with soil tilling. Increases soil carbon stock when implemented comprehensively. |
| | Southern <30% | S M |  | |
| Use of lodging-resistant (tall) high-yielding varieties | Southern <30% | S M |  | **Productivity**<br>Promotes high yields per unit area, hence potential increase in income.<br>**Adaptation**<br>Reduces the risk of crop losses caused by temporary or permanent flood conditions.<br>**Mitigation**<br>Promotes above- and below-ground carbon sinks through increased accumulation of dry matter. |
| | Northern <30% | S M |  | |
| **Jute** (9% of total harvested area) | | | | |
| Ribbon retting method | Northern 30-60% | S M |  | **Productivity**<br>Reduces fiber damage increasing the production of high-quality fiber.<br>**Adaptation**<br>Reduces time of conventional retting by 4–5 days. Can save half of the water normally. Reduces environmental pollution compared to the conventional retreat.<br>**Mitigation**<br>Provides moderate reduction GHG emissions per unit of produce. |

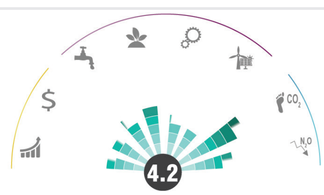
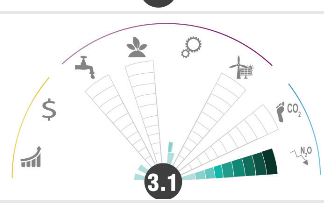


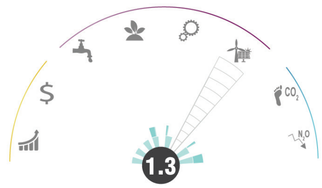
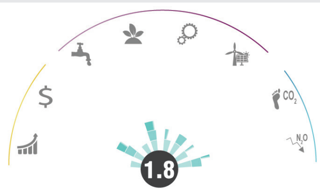
| CSA practice | Region and adoption rate (%) <30 30-60 60> | Predominant farm scale S: small scale M: medium scale L: large scale | Climate smartness | Impact on CSA Pillars |
|---|---|---|---|---|
| **Jute** (9% of total harvested area) | | | | |
| Ribbon retting method | Southern <30% | S M |   | **Productivity** Reduces fiber damage increasing the production of high-quality fiber. **Adaptation** Reduces time of conventional retting by 4–5 days. Can save half of the water normally. Reduces environmental pollution compared to the conventional retreat. **Mitigation** Provides moderate reduction GHG emissions per unit of produce. |
| Use of salinity-resistant varieties | Southern <30% | S M |   | **Productivity** Reduces time of conventional retting by 4–5 days. Can save half of the water normally. Reduces environmental pollution compared to the conventional retreat. **Adaptation** Reduces time of conventional retting by 4–5 days. Can save half of the water normally. Reduces environmental pollution compared to the conventional retreat. **Mitigation** Provides moderate reduction GHG emissions per unit of produce. |
| | Northern 30-60% | S M |   | |
| **Spices** (7% of total harvested area) | | | | |
| Salinity- and drought-resistant varieties | Southern <30% | S |   | **Productivity** Increases in yield stability due to increased resilience to salinity stress. In specific cases could enhance organoleptic properties of the produce. **Adaptation** Increases farmers' capacity to limit the crop exposure to climate risks. In the long term, increases in soil biomass accumulation can enhance soil fertility. **Mitigation** Provides moderate reduction in GHG emissions per unit of produce. Promotes carbon sinks through increased accumulation of below-ground biomass. |
| | Northern <30% | S |   | |
| **Oilseed** (5% of total harvested area) | | | | |
| Use of short-duration and high-yielding varieties | Southern <30% | S |   | **Productivity** Promotes high yields per unit area hence an increase in income and profit due to reduced production costs. **Adaptation** Optimizes the use of available soil moisture contributing to avoid crop loss. Increases water use efficiency. **Mitigation** Provides moderate reduction in GHG emissions per unit of food produced. |

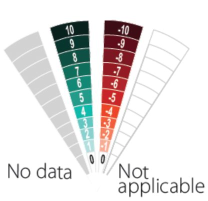
| CSA practice | Region and adoption rate (%) <30 30-60 60> | Predominant farm scale S: small scale M: medium scale L: large scale | Climate smartness | Impact on CSA Pillars |
|---|---|---|---|---|
| **Oilseed** (5% of total harvested area) | | | | |
| Use of short-duration and high-yielding varieties | Northern <30% | S |   | **Productivity** Promotes high yields per unit area hence an increase in income and profit due to reduced production costs. **Adaptation** Optimizes the use of available soil moisture contributing to avoid crop loss. Increases water use efficiency. **Mitigation** Provides moderate reduction in GHG emissions per unit of food produced. |
| Use of salinity-resistant varieties | Southern <30% | S |   | **Productivity** Increases in productivity stability due to increased resilience to stress caused by salinity. **Adaptation** Increases farmers' capacity to limit the crop exposure to climate risks. In the long term, increases in soil biomass acumulation can enhance soil fertility. **Mitigation** Provides moderate reduction GHG emissions per unit of food produced. Promotes carbon sinks through increased below-ground accumulation of biomass. |
| | Northern <30% | S |   | |
| **Vegetables** (Tomato, aroid gouds etc.)(5% of total harvested area) | | | | |
| Sorjon cultivation method | Southern <30% | S |   | **Productivity** Increase vegetable production throughout the year. Increases economic return from fallow land. **Adaptation** Increases farmers' capacity to limit the crop exposure to tidal water submergence. **Mitigation** Contributes to increase the above-ground biomass constituting a carbon sink. |
| | Northern <30% | S |   | |
| Floating beds cultivation on water bodies | Southern <30% | S |   | **Productivity** Increases in income due to harvesting of multiple crops in one season. Generates aditional additional income from the sale of seedlings produced. **Adaptation** Reduce risk of complete crop failure. Allows optimum use of natuaral and local available resources. Creates additional cropping area. **Mitigation** Protects soil structure and organic carbon reserves. Promotes fuel and energy savings due to reduced tillage. |



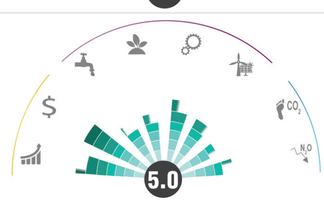

Yield · Income · Water · Soil · Risk/Information · Energy · $CO_2$ Carbon · $N_2O$ Nutrient

| CSA practice | Region and adoption rate (%) <30 30-60 60> | Predominant farm scale S: small scale M: medium scale L: large scale | Climate smartness | Impact on CSA Pillars |
|---|---|---|---|---|
| **Vegetables** (Tomato, aroid gouds etc.)(5% of total harvested area) | | | | |
| Floating beds cultivation on water bodies | Northern <30% | S |   | **Productivity** Increases in income due to harvesting of multiple crops in one season. Generates additional income from the sale of seedlings produced. **Adaptation** Reduce risk of complete crop failure. Allows optimum use of natuaral and local available resources. Creates additional cropping area. **Mitigation** Protects soil structure and organic carbon reserves. Promotes fuel and energy savings due to reduced tillage. |
| **Wheat** (5% of total harvested area) | | | | |
| Use of disease-resistance varieties (Blast) | Southern <30% | S |   | **Productivity** Reduces production costs. Enhance crop production and quality, hence potential increases in income. **Adaptation** Increases farmers' capacity to limit the crop exposure to crop damage caused by diseases. Reduces the need for external inputs for crop protection. **Mitigation** Reduces GHG emissions by reducing the use of synthetic pesticides (fungicides) therefore the carbon footprint reduction per unit of food produced. |
| | Northern <30% | S |   | |
| Conservation agriculture) | Southern <30% | M |   | **Productivity** Higher profits due to increased crop yields and reduced production costs. **Adaptation** Increases moisture retention due to mulching and cover crops. Reduces soil erosion. **Mitigation** Reduces fuel requirements for tillage. Mulching and cover crops increase soil carbon capture and soil organic matter. |
| | Northern <30% | S M |   | |
| **Pulses** (4% of total harvested area) | | | | |
| Use of short-duration and high-yielding varieties | Southern 30-60% | S M |   | **Productivity** Promotes high yields per unit area hence an increase in income and profit due to reduced production costs. **Adaptation** Increases water use efficiency. Reduces crop exposure to climate shocks due to a shorter crop cycle. **Mitigation** Provides moderate reduction in GHG emissions per unit of food produced. |
| | Northern 30-60% | S M |   | |

| CSA practice | Region and adoption rate (%) <30 30-60 60> | Predominant farm scale S: small scale M: medium scale L: large scale | Climate smartness | Impact on CSA Pillars |
|---|---|---|---|---|
| **Pulses** (4% of total harvested area) | | | | |
| Use of mung bean biomass as brown manuring | Southern <30% | S |  | **Productivity** Reduces the cost of crop production and hence increases profit **Adaptation** Improves soil health by increasing organic matter content and microbial activities. Increases possibility of farming in degraded soils. **Mitigation** Reduces requirements of synthetic fertilizers use, thereby related GHG emission during its production and use. Increases above- and below-ground biomass. |
| | Northern <30% | S |  | |
| **Maize** (3% of total harvested area) | | | | |
| Conservation agriculture | Southern <30% | S |  | **Productivity** Potential increases in profits due to increased crop yield and reduced production costs. **Adaptation** Increases moisture retention due to mulching and cover crops, reduced soil erosion caused by heavy rains, and soil tillage. **Mitigation** Reduces fossil fuel requirements for tillage. Mulching and cover crops increase soil carbon capture and SOM. |
| | Northern <30% | S |  | |
| Intercropping with short-duration vegetables | Southern <30% | S |  | **Productivity** Faster growth and higher feed conversion ratio due to proper housing. **Adaptation** Reduces exposure to adverse climatic conditions, reducing animal stresses (e.g. cold waves). **Mitigation** Allows better manure management, thereby reducing related GHG emissions. |
| | Northern <30% | S |  | |




Yield · Income · Water · Soil · Risk/Information · Energy · $CO_2$ Carbon · $N_2O$ Nutrient

| CSA practice | Region and adoption rate (%) <30 30-60 60> | Predominant farm scale S: small scale M: medium scale L: large scale | Climate smartness | Impact on CSA Pillars |
|---|---|---|---|---|
| **Cattle** (NA) | | | | |
| Compost and biogas production | Southern <30% | M L |  | **Productivity** Increases land productivity, product quality and income. Organic fertilizers produced can be used on forages to enhance productivity. **Adaptation** Promotes the use of organic waste and eliminates pathogens. Contribute to cover heating needs, reduces pressure on local resources such as timber. **Mitigation** Reduces the use of nitrogen-based fertilizers, thus reducing nitrous oxide emissions. Reduces methane emissions from manure, and promotes on-farm energy generation. |
| | Northern <30% | M L |  | |
| Commercial livestock fattening | Southern <30% | S |  | **Productivity** Increases total production and animal productivity per unit area. Increases income and food security. **Adaptation** Promotes the use of alternative feed sources. Integration of cut-and-carry and agroforestry systems can increase farmer's resilience to climate shocks. **Mitigation** Diversification of animal diet can lead to reductions in methane emissions, reducing the amount of GHG emissions per unit of food produced. |
| | Northern <30% | S |  | |
| **Pond and floodplain aquaculture** (NA) | | | | |
| Rice-fish culture | Southern <30% | S |  | **Productivity** Increases in household income and profit due to harvesting of multiple products. Increases productivity per unit area. **Adaptation** Integration of rice crop diversifies the production system, hence reduces the risk of complete failure. **Mitigation** Maintains or improves soil carbon stock and/or soil organic matter content. |
| | Northern <30% | M |  | |
| Year-round aquaculture | Southern <30% | S M L |  | **Productivity** Increases in household income and profit due to the possibility of harvesting of multiple products throughout the year. Increases productivity per unit area. **Adaptation** Allows production system diversification, hence reduces the risk of complete failure. Optimizes the use of available resources such as land. **Mitigation** Maintains or improves soil carbon stock and/or soil organic matter content. |
| | Northern <30% | L |  | |

# Institutions and policies for CSA

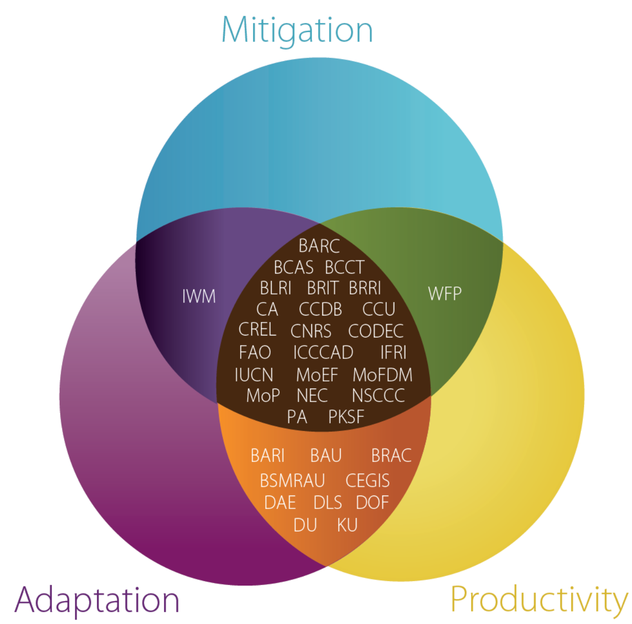
As Bangladesh is one of the countries most affected by climate change, a number of institutions have emerged to address climate-related challenges to the country's agricultural sector. Most universities and national agriculture research institutes, for example, have climate change units or committees that conduct research or help communities adapt to changing climates through direct interaction with farmers. One prominent example is the collaborative research on conservation agriculture and mechanization conducted jointly by Bangladesh Agricultural University and Murdoc University, Australia. Breeding programs of universities and national research institutes have historically collected data regarding changes in temperature or rainfall as part of their work programs, while others have screened for stress tolerance traits in new crop varieties. The Rural Development Academy in Bogra, for example, has been engaged in CSA research on SRI, AWD, raised bed rice cultivation and trichoderma compost use with direct budgetary support from the government.

Additionally, a large number of Non-Governmental Organizations (NGOs), bilateral, and multi-national organizations have initiated projects on climate change mitigation and adaptation in the country. The Delta Plan 2100, for example, funded by the Dutch Government, is a roadmap to alleviate the effects of sea level rise, including the infusion of salinity into Bangladesh's coastal rivers and canals. Meanwhile, the CGIAR has had offices in Bangladesh for decades including the International Rice Research Institute, the International Center for Maize and Wheat Improvement (CIMMYT), WorldFish, and the International Food Policy and Research Institute (IFPRI). WorldFish and CIMMYT are both currently undertaking projects for the CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS) in Bangladesh, coordinated from the regional International Centre for Tropical Agriculture offices in Delhi. Furthermore, BRAC, the largest international NGO in Bangladesh, is working on a modified System of Rice Intensification (SRI) and information sharing and awareness building about climate change adaptation. BRAC is also pursuing CSA practices promoting cultivation of sunflower in saline soils in southern districts of Bangladesh well as buy back sunflower seeds from farmers for oil extraction.

The institutions highlighted in the diagram represent those larger entities that have historically embedded CSA goals (i.e. adaptation, productivity and mitigation) into their research or development agendas. Of the 33 governmental, NGO, and private sector institutes listed, the International Center for Climate Change and Development (ICCCAD) occupies a central coordinating role, especially between the GoB and other actors. Still, coordination of climate change action between actors in the country remains problematic.

The Government of Bangladesh plays an active role in international forums on climate change, becoming a signatory member of the United Nations Framework Convention on Climate Change and the Kyoto Protocol, and through its commitment to the Bali Action Plan and the Paris Climate Agreement. In 1995, the National Environment Management Action Plan (NEMAP) for Bangladesh was formulated, addressing the country-specific climate change challenges identified in the country's Intergovernmental Panel for Climate Change Second Assessment Report. Later, two policies were approved by the GoB: the National Adaptation Programme of Action (NAPA) in 2005 and the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) later in 2009. The NEMAP, NAPA, and finally the BCCSAP were formulated through robust participatory processes involving civil society, NGOs, and other stakeholders. All the ministries and ministerial departments refer to these policies when planning and executing their work.

## Institutions for CSA in Bangladesh



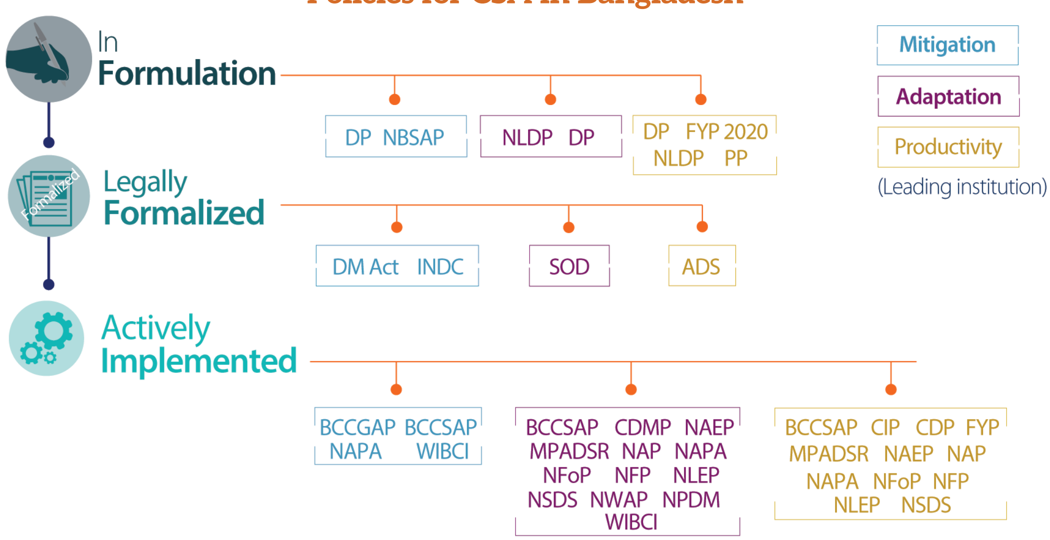

**BARC** Bangladesh agricultural Research Council **BARI** Bangladesh Agricultural Reseach Institute **BAU** Bangladesh Agricultural University **BCAS** Bangladesh Center for Advanced Studies **BCCT** Bangladesh Climate Change Trust **BINA** Bangladesh Institute of Nuclear Research **BJRI** Bangladesh Jute Research Institute **BLRI** Bangladesh Livestock Research Institute **BRAC** Bangladesh Rural Advancement Committee **BRRI** Bangladesh Rice Reseach Institute **BRIT** Bangladesh Resource Improvement Trust **BSMRAU** Bangobhondo Sheik Mujibur Rahman Agriculture University **CA** Christian Aid **CCDB** Christian Commission for Development in Bangladesh **CCU** Climate Change Unit **CEGIS** Center for Environmental and Geographic Information Services **CNRS** Center for Natural Resource Studies **CODEC** Community Development Centre **CREL** Climate Resilient Ecosystems and Livelihoods **DAE** Department of Agriculture Extension **DLS** Department of Livestock Services **DOF** Department of Fisheries **DU** Dhaka University **FAO** Food and Agriculture Organization of the United Nations **ICCCAD** International Center for Climate Change and Development **IFRI** International Food Policy Research Institute **IWM** International Water Modeling **IUCN** International Union for Conservation of Nature **KU** Khulna University **MoEF** Ministry of Environment and Forests **MoFDM** Ministry of Food and Disaster Management **MoP** Ministry of Planning **NEC** National Environment Committee **NSCCC** National Steering Committee on Climate Change **PA** Practical Action **PKSF** Palli Karma-Sahayak Foundation **WFP** World Food Program

The BCCSAP is built on six pillars, five of which are related to adaptation and capacity building and one to mitigation through low carbon development. The pillars are: a) food security, social protection and health; b) comprehensive disaster management; c) infrastructure development and protection; d) research and knowledge management; e) mitigation and low carbon development; and f) capacity building and institutional strengthening. Altogether, the BCCSAP has 44 programs and 145 projects under these thematic areas. A series of national level consultations with experts and stakeholders were carried out in the formulation process of the BCCSAP [25]. The BCCSAP has attracted over half a billion dollars spent on projects directed towards enhancing resilience through adaptation. The policy has been successful in attracting significant investment in solar energy systems for mitigation purposes. Additional resources have recently been obtained through the newly established Green Climate Fund, through partnerships with the United Nations Development Programme (UNDP) and the German Development Bank.

Another initiative relevant to CSA promotion in Bangladesh is the Policy Research and Strategy Support Program (PRSSP) for Food Security and Agricultural Development, funded by the United States Agency for International Development (USAID) and led by the Ministry of Agriculture and IFPRI. The PRSSP fills the need for demand-driven food and agriculture research, aiming to generate information on critical issues, strengthen analytical capacity within the country, and stimulate policy dialogue. Its main objectives are to work closely with GoB to provide policy and advisory services. It will also promote collaboration between institutions working in climate change and explore effective means to engage decision makers and stakeholder with evidence regarding climate interventions.

Bangladesh's Intended Nationally Determined Contributions (INDCs), submitted in 2015 to the UNFCCC, foresee an unconditional contribution of GHG reduction by 5% from Business as Usual (BAU) levels, and a conditional reduction of 15% from BAU by 2030, subject to sufficient international support. While these mitigation efforts focus solely on the power, transport and industries sectors, the INDCs also outline possible additional conditional agriculture sector contributions, which include: increasing farm mechanization to reduce number (and thus emissions) of draft cattle by 50%, increasing the use of manure and the share of organic fertilizer by 35%, and adopting alternate wetting and drying irrigation in 20% of all rice cultivation, compared to BAU levels. The agriculture targets remain listed as possibilities as they require improved availability of data-sets, as the country currently lacks the ability to quantify the sector's potential contribution to mitigation targets. For the same reasons, targets for the land use, land use change and forestry (LULUCF) sector were not quantified, yet foresee a continuation of coastal mangrove plantation, increased reforestation and afforestation efforts, and promotion of social and homestead forestry [46].

## Policies for CSA in Bangladesh




**BCCGAP** Bangladesh Climate Change and Gender Action Plan (2013) (GOB) **BCCSAP** Bangladesh Climate Change Strategy and Action Plan (2009) (MOA) **CDMP** Comprehensive Disaster Management Progamme (2004) (MoDMR) **CDP** Crop Diversification Programme (2013) (MOA) **CIP** Country Investment Plan for Food, Agriculture and Nutrition 2011-2015 (2010) (ERD) **DM Act** Disaster Management Act (2012) (GOB) **DP** Delta Plan 2100 (2018) (MOA) **FYP** Bangladesh 5-year Plan 2015 (2015) (GOB) **FYP 2020** 8th 5 Year Plan 2020-2025 (2019) (GOB) **INDC** Intended Nationally Determined Contribution (2015) (GOB) **MPADSR** Master Plan for Agricultural Development in the Southern Region of Bangladesh (2012) (MOA) **NAEP** New Agricultural Extension Policy 2012 (2012) (MOA) **NAP** National Agriculture Policy 2013 (2012) (MOA) **NAPA** National Adaptation Program of Action 2009 (2005) (MOA) **NBSAP** Bangladesh updated National Biodiversity Strategy and Action Plan (2016) (MoEF) **NFP** National Fisheries Policy 1998 (1998) (DoF) **NLDP** National Livestock Development Policy 2007 (2007) (DSL) **NLEP** National Livestock Extension Policy 2013 (2013) (DoF) **NFoP** National Food Policy (2006) (GOB) **NPDM** National Plan for Disaster Management **NSDS** National Sustainable Development Strategy (2010) (GOB) **NWAP** National Women's Advancement Policy (2011) (MoWCA) **PP** Perspective Plan to 2040 (2018) (GOB) **SOD** Standing orders on Disaster (2010) (MoDMR) **WIBCI** Weather Index-Based Crops Insurance (2015) (GOB)

The graphic shows a selection of 13 key policies, strategies and programs that relate to agriculture and climate change topics and are considered key enablers of CSA in the country. The policy cycle classification aims to show gaps and opportunities in policy-making, referring to the three main stages: policy formulation (referring to a policy that is in an initial formulation stage/consultation process), policy formalization (to indicate the presence of mechanisms for the policy to process at national level) and policy in active implementation (to indicate visible progress/outcomes toward achieving larger policy goals, through concrete strategies and action plans). For more information on the methodology, see Annex 6.

# Financing CSA

The Government of Bangladesh allocated US$1.73 billion to the agriculture sector for the 2016-17 period, representing 4% of the country's total budget[12] . In that same period, the Ministry of Environment and Forest was allocated US$ 125 million, an increase of five percent from last year. The budget for agricultural inputs subsidies was reduced substantially compared to the previous year, from US$ 1.5 billion to US $230 million in 2017. In terms of funds dedicated solely to climate change, the GoB's Climate Change Trust fund has recently received an additional US$ 12 million, raising the fund balance to US$ 375 million [47].

The total annual GoB budget spent on agriculture research in Bangladesh amounts to US$ 72 million. The Krishi Gobeshona Foundation—an agricultural research foundation—operates as an endowment trust fund with World Bank seed money for funding adaptive research projects. Most of the funds supporting agriculture research and any CSA practices comes from bilateral or multilateral funding sources. The World Bank, for example, supplemented the GoB with funds on agriculture research through the first phase of its National Agriculture Technical Project (NATP) and is currently starting NATP II with US$ 200 million to invest over five years.

Bangladesh is home to many micro-credit institutions including the Grameen Bank, a member-owned specialized institution established in Bangladesh by Nobel Peace Prize winner, Muhammad Yunus. The country also plays host to approximately 1,500 NGOs, commercial, and specialized banks such as Bangladesh Krishi Bank, Rajshahi Krishi Unnayan Bank, and a host ofgovernment-sponsored micro-finance projects and programs (the Bangladesh Rural Development Board, Swanirvar Bangladesh, and RD-12, for example). While these institutions provide micro-financing for agriculture, few offer macro-credit to facilitate larger-scale investments that can help the sector transition from subsistence farming to sustainable commercialized agriculture or help establish CSA practices. Banks require collateral for more macro credit and often growers do not possess sufficient capital, and most landowners hesitate using their land deeds for that purpose.

The increasing participation of private sector actors like ACI, PRAN, Lal Teer, and others in agricultural technology diffusion, promotion of scale-appropriate mechanization and seed development should be recognized and facilitated with continuing favorable public policies. This has also implications for wider scale out of CSA practices and technologies, some of which may require higher, long-term costs. Therefore, exploring the economic costs and benefits of CSA adoption, alongside environmental and social considerations, is key to understanding investment priorities.

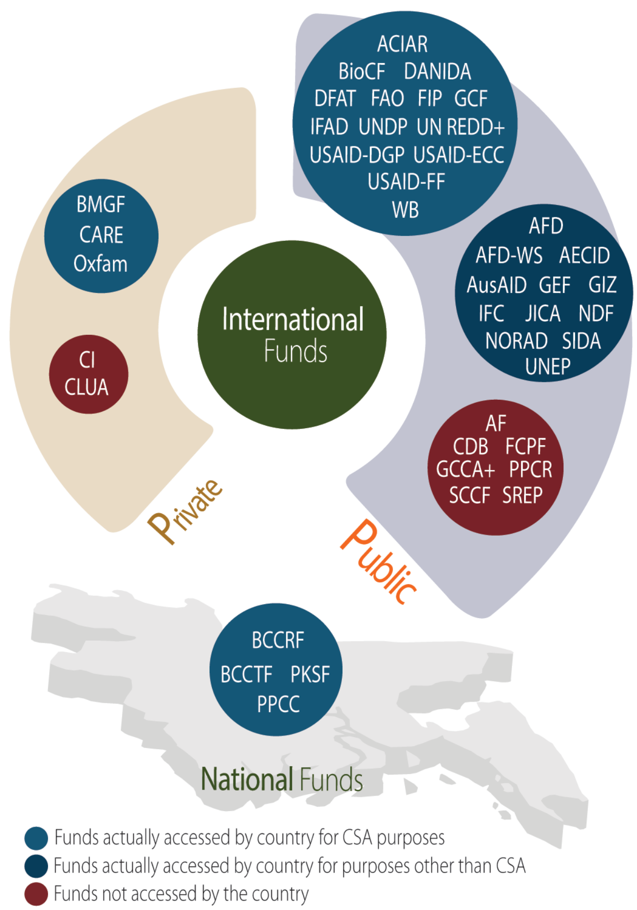
## Potential Finance

To date, Bangladesh has yet to attract significant funding from international sources dedicated to climate change adaptation or mitigation. Yet opportunities for CSA financing exist as the country is eligible for Global Environment Facility and GCF funding. Bangladesh will likely continue to be an attractive country for investors, both for development partners and the private sector. The country is one of the most active countries in South Asia when it comes to private 'impact investments', creating a ready space for CSA promotion and scale out, provided that enough information on costs, benefits, and outcomes of such investments are known to the investors. Continuation of funding and alignment of interventions with the major policy documents in Bangladesh i.e. Seventh Five Year Plan (2016-2020), Sustainable Development Goal implementation plan, and various sectoral plans, is also crucial for CSA advancement.

Additionally, while fewer United States Department of Agriculture and USAID Feed the Future projects are now focused on climate change, opportunities still exist to build an enabling environment for increased resilience, and, indirectly, to increase CSA adoption, by focusing on livelihoods, nutrition and health sectors. CSA-related funds from development partners in Europe, China, Japan are likely to emerge, given the international momentum for the topic and the high potential to invest in Bangladesh. The graphic highlights existing and potential financing opportunities for CSA in Bangladesh. The methodology can be found in Annex 7.

12 Agriculture sector allocations have remained constant over the past five years.

## Financing opportunities for CSA in Bangladesh




**AF** Adaptation Fund **ACIAR** Australian Cetre for International Agricultural Research **AECID** Spanish Agency for International Development **AFD** French Development Agency **AFD-WS** French Development Agency-Water and Sanitation **AusAID** Australian Agencyfor International Development **BCCRF** Bangladesh Climate Change Resilience Fund **BCCTF** Bangladesh Climate Change Trust Fund **BioCF** World Bank BioCarbon Fund **BMGF** Bill and Melinda Gates Foundation **CI** Conservation International **CDB** China Development Bank **CLUA** Climate and Land Use Alliance **DANIDA** Danish International Development Agency **DFAT** Department of Foreign Affairs and Trade **DFID** Department for International Development **FAO** Food and Agriculture Organization of the United Nations **FCPF** Forest Carbon Partnership Facility **FIP** Forest Investment Program **GCCA** Global Climate Change Alliance **GCF** Green Climate Fund **GEF** Global Environment Facility **GIZ** German Society for International Cooperation **IFAD** International Fund for Agricultural Development **IFC** International Finance Corporation **JICA** Japan International Cooperation Agency **NDF** Nordic Development Fund **NORAD** Norwegian Agency for Development and Cooperation **PKSF** Palli Karma Shahayak Foundation **PPCR** Pilot Program for Climate Resilience **SCCF** Special Climate Change Fund **SIDA** Swedish International Development Cooperation Agency **SREP** Scaling Up Renewable Energy in Low Income Countries Program **UNDP** United Nations Development Programme **UNEP** United Nations Environmental Programme **USAID-ECC** United States Agency for International Development – Environment and Climate Change **USAID-DGP** United States Agency for International Development – Development Grants Program **USAID-FF** United States Agency for International Development – Feed the Future **UN REDD** United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation **WB** The World Bank

# Outlook

Adaptation and mitigation in the agricultural sector is high on the political agenda in Bangladesh, as evidenced by the current policies and international commitments in support of climate smart agriculture. However, in order to create visible results at the farm level, such policies need effective implementation mechanisms and a clear roadmap for attracting additional funding required for operationalizing this vision. In 1997, the government started the process of developing a national Information, Communications and Technology (ICT) strategy that has become a core driver of reforms, employment, growth in various sectors, and improved governance. The ICT sector has increased significantly over the last years and it has the potential to facilitate higher adoption of CSA practices by farmers, through mobile phones and apps. The strengthening of village level information hubs under the Department of Agricultural Extension's Agricultural Information Service at the Union Parishad complex is a potential starting point in this regard.

Strengthening climate and technical information services and making them readily available to farmers would greatly improve their capacity to adapt to changes. For instance, salt intrusion in the canals prevents their use for commercial or household gardening. Knowing where and when this will occur, through community-based data measuring with simple salinity meters, would allow farmers to plan for appropriate response strategies. Additionally, advisory services on the technical implementation of more knowledge-intensive practices, such as the use of briquetted urea (which can reduce use of urea by 30%), through extension agents, could empower farmers to contribute to significant reductions in agricultural emissions. Development of Urea Super Granule applicator and reduction of drudgery in operating this small but delicate equipment is important for popularizing the practice. However, further debate around fertilizer subsidies is a precondition for involving private sector in accelerating the spread of this CSA technology.

Improved coordination among the various institutions implementing CSA projects and programs is essential for the development of a coherent, long-term vision for agricultural development in the country. One step towards achieving this goal is information provision and exchange, in a transparent manner, through multi-stakeholder platforms, joint CSA initiatives, and regular knowledge and experience-sharing opportunities among diverse actors involved in research, policy, and implementation.

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For further information and online versions of the Annexes

**Annex 1:** Bangladesh's agro-ecological zones
**Annex 2:** Selection of agriculture production systems key for food security in Bangladesh (methodology)
**Annex 3:** Methodology for assessing climate smartness of ongoing practices
**Annex 4:** Long list of CSA practices adopted in Bangladesh
**Annex 5:** Institutions for CSA in Bangladesh (methodology)
**Annex 6:** Policies for CSA in Bangladesh (methodology)
**Annex 5:** Assessing CSA finances (methodology)

This publication is a product of the collaborative effort by the International Center for Tropical Agriculture (CIAT), the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), the World Bank and the UK Government's Department for International Development (DFID) to identify country-specific baselines on CSA in Bangladesh. The document complements the CSA Profiles series developed between 2014 and 2016 by CIAT, CCAFS, the World Bank, and USAID for countries in Latin America, Asia and Africa.

The document was prepared under the co-leadership of Godefroy Grosjean (CIAT) and Andrew Jarvis (CIAT, CCAFS); It is based on a methodology prepared by CIAT, the World Bank and the Tropical Agricultural Research and Higher Education Center (CATIE) in 2014 and revisited in 2015 and 2017 by Andreea Nowak, Caitlin Corner-Dolloff, Miguel Lizarazo, Andy Jarvis, Evan Girvetz, Godefroy Grosjean, Felicitas Roehrig, Jennifer Twyman, Julian Ramirez, Carlos Navarro, Jaime Tarapues, Steve Prager, Carlos Eduardo Gonzalez (CIAT/CCAFS), Charles Spillane, Colm Duffy and Una Murray (National University Ireland Galway).

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This document should be cited as:

CIAT; World Bank. 2017. Climate-Smart Agriculture in Bangladesh. CSA Country Profiles for Asia Series. International Center for Tropical Agriculture (CIAT); World Bank. Washington, D.C. 28 p.

## Acknowledgments

Special thanks to representatives of the following institutions for providing information and support to this study: Bangladesh Agriculture Research Council (BARC); International Centre for Climate Change and Development (ICCCAD), Bangladesh, with special thanks to Dr. Saleemul Huq (Director);

This document has benefited from comments received from: Dr. M. A. Sattar Mandal (Senior Advisor to FAO-R Bangladesh), Manievel Sene (World Bank), Himanshu Sharma (World Bank)