

# Summary

Climate and agriculture are interrelated processes with climate change significantly affecting agriculture development and production. The book “Climate change and Agriculture: A Historical Analysis” provides a historical understanding of climate change and its impact on agriculture development and production. The book illustrates the role of climate in the origin of agriculture and societal development in the ancient world and drastic changes in climate within the shorter period in the present times. The influence of climate on agriculture was associated with emergence and decline of early societies, either facilitating the development of cities and technological progress or in the case of insufficient yield, leading to the collapse of civilization.

The climate change occurring due to natural causes as well as anthropogenic activities has been influencing human civilization since its inception. The resumption of warming trend during a stable Holocene period after an unstable climate of glacial-interglacial cycles created suitable conditions to pursue agriculture. Farming and availability of food made people settle down, evolve, and develop agrarian societies. Later, fluctuations in the climate brought about to rise and the downfall of colossal ancient civilizations like Harappan, Mayans, Mesopotamia and Ancient Egyptian, etc. In most cultures, the peak of civilization was marked by stable temperatures and monsoons and fall by weak monsoons and droughts with probable impact on agricultural yields.

Scientific evidence indicates abnormal variations in the climate and the effects of these variations on crop production. Revising the past and present climates help the researchers to understand a wide range of climate processes while projecting twenty-first century climate change. They can also assist in assessing the existing climatic conditions in regions with a high risk of crop failures. Comprehensive data of the Earth’s surface temperature from glacial to the present indicates that each of the past four decades has been successively warmer at the Earth’s surface than any of the previous decades. The impacts of climate change on human societies include the increase in temperature, rise in sea level, and changes in precipitation patterns that affect agriculture. While many factors continue to influence climate, scientists

believe that greenhouse gases in the atmosphere, aerosols, and changes in land use are contributing to the change. Warmer temperatures associated with climate change can extend the growing season but affect plant growth and development along with crop yield.

Climate scientists and archaeologists are finding plenty of evidences supporting that climate changes are partly to blame for the collapse of ancient civilizations. They rarely find any evidence that the ancestral societies made any attempts to change in the face of a drying climate, warming atmosphere, and other changes. History of the past societies offers the opportunity to protect the future of our society by learning from the experiences of our ancestors. With technology development and knowledge in the present era, several mitigations and adaptation options like changing planting dates, using tolerant varieties, alternative crops, resource management, intercropping, livestock management, agroforestry, etc. are available that the agriculture sector can undertake to cope with existing and future climate change. The impact of past changes on climate in the agricultural and social activities has been stepwise described in this book. This information will be highly informative, beneficial, and useful to the students, scientists, farmers, and policy-makers for planning their future programs.

# Glossary of Term

## A

**Adaptation** Action that helps cope with the effects of climate change – for example, construction of barriers to protect against rising sea levels or conversion to crops capable of surviving high temperatures and drought.

**Aforestation** Planting of new forests on lands that historically have not contained forest.

**Anthropogenic** Resulting from or produced by human beings.

**Anthropogenic emissions** Emissions of greenhouse gases, greenhouse gas precursors, and aerosols associated with human activities. These include burning of fossil fuels for energy, deforestation, and land use changes that result in net increase in emissions.

**Anthropogenic climate change** Man-made climate change – climate change caused by human activity as opposed to natural processes.

**Ashoka** A great king of Maurya period, when the agriculture and environmental protection was his top priority (304–232 BCE).

**Atmosphere** Gaseous envelope surrounding the earth. The dry atmosphere contains nitrogen 78% (volume), oxygen 20.9%, argon 0.93%, and radiatively active greenhouse gases such as carbon dioxide 0.04%. Atmosphere also contains highly variable amount of water vapor, clouds, and aerosols.

**Atmospheric aerosols** Microscopic particles suspended in the lower atmosphere that reflect sunlight back to space. These generally have a cooling effect on the planet and can mask global warming. They play a key role in the formation of clouds, fog, precipitation, and ozone depletion in the atmosphere.

**B**

**Biodiversity** The number and relative abundances of genetically different species and ecosystems in a particular area.

**Biofuel** A fuel derived from renewable, biological sources, including crops such as maize and sugar cane and some forms of waste.

**Biomass** The total mass of living organisms in a given area or volume, recently dead plant material often included as dead biomass.

**Biosphere** The part of the Earth system comprising all ecosystems and living organisms in the atmosphere, on land (terrestrial biosphere) or in the oceans (marine biosphere) including derived dead organic matter such as litter, soil organic matter, and oceanic detritus.

**C**

**Carbon dioxide (CO<sub>2</sub>)** Carbon dioxide is a gas in the Earth's atmosphere. It occurs naturally and is also a by-product of human activities such as burning fossil fuels. It is the principal greenhouse gas produced by human activity.

**Carbon dioxide (CO<sub>2</sub>) equivalent** Six greenhouse gases are limited by the Kyoto Protocol, and each has a different global warming potential. The overall warming effect of this cocktail of gases is often expressed in terms of carbon dioxide equivalent – the amount of CO<sub>2</sub> that would cause the same amount of warming.

**Carboniferous period** 354 million–290 million years ago. Large primitive trees developed.

**Carbon footprint** The amount of carbon emitted by an individual or organization in a given period of time, or the amount of carbon emitted during the manufacture of a product.

**Carbon sequestration** The process of storing carbon dioxide. This can happen naturally, as growing trees and plants turn CO<sub>2</sub> into biomass (wood, leaves, and so on). It can also refer to the capture and storage of CO<sub>2</sub> produced by industry.

**Carbon sink** Any process, activity, or mechanism that removes carbon from the atmosphere. The biggest carbon sinks are the world's oceans and forests, which absorb large amounts of carbon dioxide from the Earth's atmosphere.

**CFCs** The short name for chlorofluorocarbons – a family of gases that have contributed to stratospheric ozone depletion but which are also potent greenhouse gases. Emissions of CFCs around the developed world are being phased out due to an international control agreement, the 1989 Montreal Protocol.

**Clean Development Mechanism (CDM)** A program that enables developed countries or companies to earn credits by investing in greenhouse gas emission reduction or removal projects in developing countries. These credits can be used to offset emissions and bring the country or company below its mandatory target.

**Climate change** A pattern of change affecting global or regional climate, as measured by yardsticks such as average temperature and rainfall or an alteration in frequency of extreme weather conditions. This variation may be caused by both natural processes and human activity. Global warming is one aspect of climate change.

**Climate variability** Climate variability refers to variations in the mean state and other statistics of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability) or to variations in natural or anthropogenic external forcing.

**Conference of the parties** The supreme body of the United Nations Framework Convention on Climate Change (UNFCCC) comprising countries that have ratified or acceded to the UNFCCC.

## D

**Deforestation** The permanent removal of standing forests that can lead to significant levels of carbon dioxide emissions.

**$\delta^{18}\text{O}$  (delta-O-18)**  $\delta^{18}\text{O}$  or **delta-O-18** is a measure of the ratio of stable isotopes oxygen-18 ( $^{18}\text{O}$ ) and oxygen-16 ( $^{16}\text{O}$ ). It is commonly used as a measure of the temperature of precipitation.

**Devonian period** 417 million–354 million years ago. First club mosses, horse tails, and fern appeared as do the first seed-bearing plants (progymnosperm).

**Drought** The phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production system.

## E

**Eocene period** 54.8 million years–33.7 million years ago. Moderate cooling climate. Reglaciation of Antarctica and formation of its ice cap. Seafloor algae drawing massive amount of atmospheric  $\text{CO}_2$  lowering it from 3800ppmv down to 650 ppmv. Global temperature dropped 10 °C. Himalayas were formed. Orogeny of the Alps in Europe and Hellenic zone in Greece and Aegean Sea.

**Ecosystem** A system of interacting living organisms together with their physical environment. The extent of an ecosystem may range from very small spatial scales to ultimately, the entire Earth.

**Emissions** Emissions refer to the release of greenhouse gases and/or their precursors and aerosols into the atmosphere over a specified area and period of time.

**Erosion** The process of removal and transport of soil and rock by weathering, mass wasting, and the action of streams, glaciers, waves, winds, and underground water.

**Evapotranspiration** The combined process of evaporation from the Earth's surface and transpiration from vegetation.

**Fossil fuels** Natural resources, such as coal, oil, and natural gas, containing hydrocarbons. These fuels are formed in the Earth over millions of years and produce carbon dioxide when burnt.

## G

**Geological sequestration** The injection of carbon dioxide into underground geological formations. When CO<sub>2</sub> is injected into declining oil fields, it can help to recover more of the oil.

**Global average temperature** The mean surface temperature of the Earth measured from three main sources: satellites, monthly readings from a network of over 3000 surface temperature observation stations, and sea surface temperature measurements taken mainly from the fleet of merchant ships, naval ships, and data buoys.

**Global warming** The steady rise in global average temperature in recent decades, which experts believe is largely caused by man-made greenhouse gas emissions. The long-term trend continues upward, they suggest, even though the warmest year on record, according to the UK's Met Office, is 1998.

**Global warming potential (GWP)** A measure of a greenhouse gas's ability to absorb heat and warm the atmosphere over a given time period. It is measured relative to a similar mass of carbon dioxide, which has a GWP of 1.0. So, for example, methane has a GWP of 25 over 100 years, the metric used in the Kyoto Protocol. It is important to know the timescale, as gases are removed from the atmosphere at different rates.

**Greenhouse gases (GHGs)** Natural and industrial gases that trap heat from the Earth and warm the surface. The Kyoto Protocol restricts emissions of six greenhouse gases: natural (carbon dioxide, nitrous oxide, and methane) and industrial (perfluorocarbons, hydrofluorocarbons, and sulfur hexafluoride).

**Greenhouse effect** The insulating effect of certain gases in the atmosphere, which allow solar radiation to warm the earth and then prevent some of the heat from escaping. See also Natural greenhouse effect.

## H

**Halocarbons** Compounds containing carbon and either chlorine, bromine, or fluorine. Such compounds can act as powerful greenhouse gases in the atmosphere. The chlorine- and bromine-containing halocarbons are also involved in the depletion of the ozone layer.

**Holocene** 11.7 thousand years ago–present day, Quaternary ice age recedes, and the current interglacial begins. Rise of human civilization. Activities such as development of agriculture and domestication of animals started in this period. It started the Bronze Age (3300 BC) and Iron Age (1200 BC). Little ice age causes cooling in Northern Hemisphere from 1400 to 1850. Following industrial revolution atmospheric CO<sub>2</sub> levels rise from 280 ppmv to the current level 400 ppmv.

**Hydrofluorocarbons (HFCs)** Among the six greenhouse gases to be curbed under the Kyoto Protocol. They are produced commercially as a substitute for chlorofluorocarbons. HFCs largely are used in refrigeration and semiconductor manufacturing. The global warming potentials range from 1300 to 11,700.

## I

**Industrial revolution** A period of rapid industrial growth with far-reaching social and economic consequences beginning during the second half of the eighteenth century. It marks the beginning of a strong increase in the use of fossil fuels and emission of greenhouse gases, particularly fossil-induced carbon dioxide.

**IPCC** The Intergovernmental Panel on Climate Change is a scientific body established by the United Nations Environment Program and the World Meteorological Organization. It reviews and assesses the most recent scientific, technical, and socioeconomic work relevant to climate change, but does not carry out its own research. The IPCC was honored with the 2007 Nobel Peace Prize.

## J

**Joint implementation (JI)** An agreement between two parties whereby one party struggling to meet its emission reductions under the Kyoto Protocol earns emission reduction units from another party's emission removal project. The JI is a flexible and cost-efficient way of fulfilling Kyoto agreements while also encouraging foreign investment and technology transfer.

**K**

**Kyoto Protocol** A protocol attached to the UN Framework Convention on Climate Change, which sets legally binding commitments on greenhouse gas emissions. Industrialized countries agreed to reduce their combined emissions to 5.2% below 1990 levels during the 5-year period 2008–2012. It was agreed by governments at a 1997 UN conference in Kyoto, Japan, but did not legally come into force until 2005. A different set of countries agreed a second commitment period in 2013 that will run until 2020.

**L**

**Land use change** A change in the use or management of land by humans, which may lead to a change in land cover. It may have impact on the albedo, evapotranspiration, sources and sinks of greenhouse gases, or other properties of climate system and may thus have an impact on climate locally or globally.

**Methane** Methane is the second most important man-made greenhouse gas. Sources include both the natural world (wetlands, termites, wildfires) and human activity (agriculture, waste dumps, and leaks from coal mining).

**Miocene epoch** 23.8 million years–5.3 million years ago. Hellenic orogeny in Greece and the Aegean Sea slows but continues to this date. Middle Miocene disruption occurs, and widespread forests slowly draw in massive amounts of CO<sub>2</sub>, gradually lowering the level of atmospheric CO<sub>2</sub> from 650 ppmv to around 100 ppmv.

**Mitigation** Action that will reduce man-made climate change. This includes action to reduce greenhouse gas emissions or absorb greenhouse gases in the atmosphere.

**Montreal Protocol** The Montreal Protocol on substances that deplete the ozone layer was adopted in Montreal in 1987 and subsequently adjusted in London (1990). It controls the consumption and production of chlorine- and bromine-containing chemicals that destroy stratospheric ozone such as chlorofluorocarbons (CFCs) and many others.

**N**

**Natural greenhouse effect** The natural level of greenhouse gases in our atmosphere, which keeps the planet about 3 °C warmer than it would otherwise be – essential for life as we know it. Water vapor is the most important component of the natural greenhouse effect.



**Neolithic period** This era was between 4000 BC to 2500 BC. It is also known as the New Stone Age.

**Nitrous oxide** A powerful greenhouse gas emitted through soil cultivation practices, especially the use of commercial and organic fertilizers, fossil fuel combustion, nitric acid production, and biomass burning. One of the six greenhouse gases to be curbed under the Kyoto Protocol.

**NOAA** National Oceanic Atmospheric Administration Laboratory in Mauna Loa, Hawaii.

## O

**Ozone (O<sub>3</sub>)** Ozone, the triatomic form of oxygen (O<sub>3</sub>), is a gaseous atmospheric constituent. In the troposphere it is created both naturally and by photochemical reactions involving gases resulting from human activities. In high concentrations tropospheric ozone can be harmful to a wide range of living organisms. Tropospheric O<sub>3</sub> is created by the interaction between solar ultraviolet radiation and molecular oxygen (O<sub>2</sub>). Stratospheric Ozone plays a decisive role in the stratospheric radiative balance. Its concentration is highest in the ozone layer. Depletion of stratospheric ozone due to chemical reactions that may be enhanced by climate change results in an increased ground level flux of ultraviolet-B radiation.

## P

**Paleocene** 65 million years–54.8 million years ago, origin of tropical climate, modern plants appear, extinction of the Dinosaurs. Indian subcontinent collides with Asia 55 Ma. Himalayan orogeny starts between 52 and 48 Ma.

**Pleistocene** 2.6 million years–11.7 thousand years ago. It includes Quaternary ice age continuing with glaciations and interstadials, last glacial maximum (3000 years ago), and dawn of human Stone Age culture, and it ends with drays forming boundary with Holocene (2.6 million years–11.7 thousand years ago).

**Per capita emissions** The total amount of greenhouse gas emitted by a country per unit of population.

**ppm (350/450)** An abbreviation for parts per million, usually used as short for ppmv (parts per million by volume). The Intergovernmental Panel on Climate Change (IPCC) suggested in 2007 that the world should aim to stabilize greenhouse gas levels at 450 ppm CO<sub>2</sub> equivalent in order to avert dangerous climate change. Some countries most vulnerable to climate change argue that the safe upper limit is 350 ppm. Current levels of CO<sub>2</sub> only are about 407 ppm.

**Preindustrial levels of carbon dioxide** The levels of carbon dioxide in the atmosphere prior to the start of the industrial revolution. These levels are estimated to be about 280 parts per million (by volume). The current level is around 407 ppm.

## Q

**Quaternary period** An informal sub-era from 2.58 or 1.8 mya to today. It is associated with the Holocene and Pleistocene. It started during the cycle of glacial and interglacials around 2.6 mya.

## R

**Ramayana** Sage Valmiki wrote the Ramayana centuries ago. It has 7 chapters and 24,000 verses. It tells the story of lord Rama. He fights a battle with demon king Ravana of Lanka, who abducted his wife Sita.

**Ramcharit Manas** An epic poem in the Awadhi dialect of Hindi composed by poet Goswami Tulsidas (c1532–1623). It was an attempt by Tulsidas to reconcile the different stories of Rama.

**Radiocarbon dating** **Radiocarbon dating** (also referred to as **carbon dating** or **carbon-14 dating**) is a method for determining the age of an object containing organic material by using the properties of radiocarbon ( $^{14}\text{C}$ ), a radioactive isotope of carbon.

## S

**Stern reviews** A report on the economics of climate change led by Lord Nicholas Stern, a former World Bank economist. It was published on 30 October 2006 and argued that the cost of dealing with the consequences of climate change in the future would be higher than taking action to mitigate the problem now.

**Stratosphere** The highly stratified region of atmosphere above the troposphere extending from about 10 km to about 50 km.

## T

**Tertiary period** An informal sub-era from 65.5 to 2.58 or 1.8 million years ago. It is divided into 5 epochs: Paleocene, Eocene, Oligocene, Miocene, and Pliocene.

**Troposphere** The **troposphere** is the lowest layer of Earth's atmosphere and is also where nearly all weather conditions take place.

## U

**UNFCCC** The United Nations Framework Convention on Climate Change is one of a series of international agreements on global environmental issues adopted at the 1992 Earth Summit in Rio de Janeiro. The UNFCCC aims to prevent "dangerous" human interference with the climate system. It entered into force on 21 March 1994 and has been ratified by 192 countries.

## W

**Weather** The state of the atmosphere with regard to temperature, cloudiness, rainfall, wind, and other meteorological conditions. It is not the same as climate which is the average weather over a much longer period.

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