Dinesh Chandra Uprety
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Technologies for Greenhouse Gas Assessment in Crop Studies

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Foreword

The disastrous effects of climate change on agricultural crop productivity and livestock call for an urgent attention and serious efforts towards developing methods and tools to investigate their vulnerability to climatic stresses. The climatic changes, since time immemorial, are known to affect the agricultural systems, but the methods to measure these effects have been developed in recent times only. The senior author, Dr. Uprety, has been systematically following the climate change impacts on crops since 1992 at Indian Agricultural Research Institute, New Delhi. Therefore, he has a long experience of studying the responses of crop plants to various attributes of climate change. He was successful in developing first South Asian facilities such as FACE and OTC to study the responses of crop plants to the rising atmospheric carbon dioxide. Further, the methods and technologies for conducting experiments to analyse the responses of crop plants to climate change stresses are credited to him along with Dr. P. Saxena of Hindu College, Delhi University. The data generated using these methods and technologies would help in developing mathematical models and identifying plant types to meet the challenges of climatic stresses. The technologies included in this book are relevant primarily to the crops, livestock and forestry sector, and particularly focus on the most vulnerable group of stakeholders, the small landholders and producers of crop plants. Further, the book describes various technologies and methods that include simulation of future climate changes to study the responses of crop plants to climatic stresses and their physiological and biochemical characterization. The research-based outcomes, following the technologies described in this book, are likely to indicate the policies that influence the ability of farmers to adapt to climate change and also to identify the vulnerable areas. Both the authors, Dr. Uprety and Dr. Saxena, have long experience of publishing state-of-the-art books and research papers in peer-reviewed impact factor journals. I am confident that this book will have a landmark value for diverse range of stakeholders, including scientists, students, farmers, researchers and policy people, so as to meet the challenges of climatic stresses on agriculture systems. The authors deserve appreciation for bringing out this timely publication.

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R. S. Rawal

Preface

This book is in continuation of our previous books on climate change and agriculture, wherein it was considered that literature on the methodology for climate change research related to agriculture is reported in a fabricated manner and there is an urgent need to have a consolidated account in the form of a book on technologies, methods, adaptation strategies and climatic stress mitigation options. The accurate measurements and reporting of environmental parameters in agricultural research determine the quality assurance for farmers, researchers and policymakers because the fate of farmers depends on the crop's productivity through which policymakers support the farmers by releasing the inputs to sustain the food security of countries. The outcome of the studies related to the impact assessment analysis of climate change stresses, using the technologies described in this book, can have significant effect, when subsequent experiments to investigate plants and animals at a molecular, biochemical or genetic level are considered. This book is written in a simple understandable language without any ambiguity. Our objective in this book is to make young researchers to collect realistic biological information on crops and livestock using various methods of simulating the future climate changes. This book will not only be useful for teachers and research scholars but also be of great value to farmers and policymakers in understanding the adverse effects of climatic stresses and their mitigation through soil amendments, selection of crops/cultivars, alteration of food habits and protection of the livestock.

New Delhi, Delhi, India

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Abbreviations

ACCase	Acetyl-CoA carboxylase
AFOLU	Agriculture, forestry and other land use
AGM	Above-ground mass
ANPP	Above-ground net primary production
AOT	Accumulated exposure over a threshold of 40 ppbv
APX	Ascorbate peroxidase
ASC_{apo}	Ascorbate in apoplast
ASPAT	Aspartate aminotransferase
AWDT	Alternate wetting and drying technology
bLs	Backward Lagrangian stochastic
BT	Basal temperature
CAT	Catalase
CBL	Convective boundary layer
CBP	Carbon Benefits Project
CFU	Colony-forming unit
COT	Cumulative exposure over a threshold
CRDS	Cavity ring-down spectroscopy
CRIDA	Central Research Institute for Dryland Agriculture, Hyderabad, India
DACT	Degree above canopy threshold
DBH	Diameter at breast height
DC	Dry combustion
DHA	Dehydroascorbate
EEG	Easily extractable glomalin
EF	Emission factor
FAO	Food and Agriculture Organization
FID	Flame ionization detector
GCM	Global climate models
IRGA	Infrared gas analyser
IHF	Integrated horizontal flux
IMO	International Meteorological Organization
IRT	Infrared thermal radiometer
INS	Inelastic neutron scattering
IPCC	Intergovernmental Panel on Climate Change

IR	Infrared radiations
EA	Elemental analyser
EC	Eddy covariance
EGM	Environmental gas monitor
ESA	European Space Agency
ESR	Electron spin resonance
EE8	Earth Explorer 8
ECD	Electron capture detector
FACE	Free air carbon dioxide enrichment
FATE	Free air temperature enrichment
FCPF	Forest Carbon Partnership Facility
FG	Flux gradient technique
FRB	Ferrihydrite-reducing bacteria
FTIR	Fourier transform infrared spectroscopy
GC	Gas chromatography
GHG	Greenhouse gases
GS	Glutamine synthase
GWP	Global warming potential
IRFD	Infrared flux density
LIBS	Laser-induced breakdown spectroscopy
LIDAR	Light direction and ranging system
LOI	Loss on ignition
MBC	Microbial biomass carbon
MIR	Mid-infrared radiations
MMD	Modified mass difference approach
MSWL	Municipal solid waste landfills
NASA	National Aeronautics and Space Administration
NBC	Nocturnal boundary layer
NDIR	Non-dispersive infrared analyser
NEE	Net ecosystem exchange
NEP	Net ecosystem production
NPP	Net primary productivity
PAR	Photosynthetic active radiations
PAS	Photoacoustic spectroscopy
PID	Proportional integrative differential
PLS	Partial least squares regression
POC	Particulate organic carbon
QCL	Quantum cascade lasers
IRGA	Infrared gas analyser
RE	Ecosystem respiration
REA	Relaxed eddy accumulation
RS	Remote sensing
RADAR	Radio detection and ranging
REDD	Reducing emission from deforestation and degradation
RMC	Readily mineralized carbon

ROS	Reactive oxygen species
RTD	Resistance temperature device
RWC	Relative water content
SIC	Soil inorganic carbon
SPAR	Soil plant atmosphere research
SOC	Soil organic carbon
SOM	Soil organic matter
SRB	Sulphate-reducing bacteria
SRC	Soil respiration chamber
TBARS	Thiobarbituric acid-reactive substances
TC	Total carbon
TCD	Thermal conductivity detector
TDL	Tuneable diode lasers
TGG	Temperature gradient greenhouse
TGC	Temperature gradient chamber
TOMS	Total ozone mapping spectrometer
SOD	Superoxide dismutase
SUM 60	Sum of hourly ozone concentration equal to 60 ppbv over the daylight period
RCM	Regional climate models
UNEP	United Nations Environment Programme
UNFCC	United Nations Framework Convention on Climate Change
WSC	Water-soluble carbon
VFT	Vertical flux technique
VNIR	Visible near-infrared radiations
VOC	Volatile organic compounds
VR	Ventilation rate

Introduction

1

1.1 General Introduction

The climate is a weather condition prevailing in a place over many years and is influenced by various complex systems consisting of atmosphere, land, snow and ice, water bodies including oceans, living plants and animals. Earth's climate has changed many times during the history of the planet. Historically, natural factors such as volcanic eruptions, changes in earth's orbit and energy released from the sun contributed significantly to the changes in earth's climate. However, human activities have been immensely contributing to the climate change since the industrial revolution. The major components of climate change, which affect the agriculture, are (1) changes in land use and land cover, (2) changes in the atmospheric concentration of greenhouse gases, (3) decline in the biodiversity and (4) changes in the climate.

Accumulation of greenhouse gases (GHGs), like carbon dioxide (CO_2), water vapour (H_2O), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3) in the atmosphere, which absorb and emit heat radiations by increasing and decreasing their atmospheric concentrations, either holds or releases more of the heat from the sun. If we define climate as C, the climate change can be defined as climate's time rate of change, i.e. $\Delta C/\Delta t$. Similarly climate dynamics explains the causes of climate change, i.e. $\Delta^2 C/\Delta t^2$. Scientists study all the three terms to explain the climate change. However, social scientists define science as S and science chronology as $\Delta S/\Delta t$ and the science dynamics attempts to explain the underlying causes of change, i.e. $\Delta^2 S/\Delta t^2$ (Uprety et al. 2019). Climate change is the outcome of all these changes including climate dynamics and science dynamics. Climate has changed only modestly during pre-industrial period but it changed dramatically after industrial revolution. This is because climate dynamics now has a new element in the form of anthropogenic inputs. Science has also advanced significantly during last several years; similarly science dynamics including intellectual, social and technical factors have also expanded enormously. Therefore, climate ideas and the

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practice of climate science are both changing faster than climate. Greenhouses are important tools for scientists and engineers, studying the effect of climate change parameters on the growth and development of a large number of crop plants.

Food security of the large growing population of the world depends on various agricultural crops. The cultivation of these crops involves growing of cultivars using a sizable amount of fertilizers and pesticides. Application of these ingredients depletes the soil and pollutes the water causing reduction in nutrients and decrease in the biodiversity contributing significantly to the climate change. Agricultural emissions of GHG's (CO_2, CH_4 and N_2O) particularly linked to the conversion of forest lands to agricultural fields for crops and livestock production amounting to 25% of the global greenhouse gas emissions. The sustainability of crop production becomes difficult due to its vulnerability to such climate change effects. Thus, it is the need of the hour that next-generation crops and plants must be water- and nutrient-use efficient and must have sustainable yield over a wider range of environmental conditions. Pastor et al. (2019) suggested that to cater the need of 9.8 billion population by 2050, plant biology needs to change to meet the challenges of climate change. Favourable genes and alleles are required to be alienated to produce such plants (Nutan et al. 2020) which are newer with changed physiological and molecular architecture and could sustain its productivity under climatic stresses. Zafar et al. (2020) suggested that the CRISPR/Cas 9 genes provide greater production of improved crop varieties with better sustainability of yield and resilience to climate change.

1.2 Importance of Technologies in Climate Change Research on Agriculture

Global carbon emissions hit an all-time high in 2019 breaking the previous record set in 2018. Emissions from industrial activities and burning of fossil fuels have added 36.8 billion metric tons of CO_2 in the atmosphere. The total carbon emissions from all human activities including agriculture and land use have been calculated as 43.1 billion tons. The emissions from coal, oil and natural gas increased by 2% globally in 2018. The fossil fuel emissions increased 0.6%. Canadell et al. (2019) attributed this slow increase to the 10% decline in the use of coal in USA. The global carbon emissions were static between 2014 and 2016 and emissions began to rise again in 2017. According to 'Climate Wire' (28th Nov, 2019), UNEP has warned that to keep the rise in earth's temperature within 2 °C, CO_2 emissions must fall by 25%. However, WMO data showed that the drastic cut in CO_2 output will not be able to prevent warming by 3 °C. It is also presumed that coal use will decline by 0.9%; however, emissions from oil consumption will grow by 0.9% and emissions from natural gas may grow by 2.6% in the following year. This fast increase in emissions may be attributed to the expansions of cheaper natural gas. The continuous increase in the coal consumption much in Asia, particularly China and India, has remained a primary challenge to global climate action.