



EDITED BY PAVAN KUMAR ■ RAM KUMAR SINGH
MANOJ KUMAR ■ MEENU RANI ■ PARDEEP SHARMA

CLIMATE IMPACTS ON SUSTAINABLE NATURAL RESOURCE MANAGEMENT



WILEY

Table of Contents

[Cover](#)

[Title Page](#)

[Copyright Page](#)

[About the Editors](#)

[List of Contributors](#)

[Foreword](#)

[Preface](#)

[Section 1: Sustainable Natural Resource Management](#)

[1 Impact of Local REDD+ Intervention on
Greenhouse Gas Emissions in East Kalimantan
Province, Indonesia](#)

[1.1 Introduction](#)

[1.2 Materials and Methods](#)

[1.3 Results](#)

[1.4 Discussion](#)

[1.5 Conclusions](#)

[Acknowledgement](#)

[Author Contribution](#)

[List of Appendix](#)

[References](#)

[2 Role of Geospatial Technologies in Natural
Resource Management](#)

[2.1 Introduction](#)

[2.2 Applications of Geospatial Technology in
Natural Resource Management](#)

[2.3 LiDAR Technology](#)

[2.4 Artificial Intelligence and Remote Sensing](#)

[2.5 Machine Learning Tools for Natural Resource Management](#)

[2.6 Applications of Unmanned Aerial Systems in Natural Resource Management](#)

[2.7 Google Earth Engine as a Platform for Environmental Monitoring and NRM](#)

[2.8 Conclusion](#)

[References](#)

[3 Estimation of Snow Cover Area Using MicrowaveSAR Dataset](#)

[3.1 Introduction](#)

[3.2 Classification Technique](#)

[3.3 Statistical Parameters](#)

[3.4 Error and Accuracy Assessment](#)

[3.5 Study Area](#)

[3.6 Methodology](#)

[3.7 Result and Discussion](#)

[3.8 Conclusion and Future Perspective](#)

[References](#)

[Section 2: Determinants of Forest Productivity](#)

[4 Forest Cover Change Detection Across Recent Three Decades in Persian Oak Forests Using Convolutional Neural Network](#)

[4.1 Introduction](#)

[4.2 Materials and Methods](#)

[4.3 Results and Discussion](#)

[4.4 Conclusion and Future Prospects](#)

[References](#)

5 The Interlinked Mechanisms of Productivity for Developing Process-Based Forest Growth Models

5.1 Introduction

5.2 Productivity: Definition and Associated Components

5.3 Various Processes and Components Driving Forest Productivity

5.4 Different Approaches to Productivity Assessment

5.5 Evolution of Process-Based Models

5.6 Conclusion

References

6 Allometric Equations for the Estimation of Biomass and Carbon in the Sub-tropical Pine Forests of India

6.1 Introduction

6.2 Chir Pine - a Boon or Bane?

6.3 Forest Carbon and Forest Biomass

6.4 Composition of Forest Biomass

6.5 Allometric Equations for Biomass Estimation

6.6 Biomass and Carbon Stock Estimation in Chir Pine Forests of India Using Allometric Equations

6.7 Conclusion

References

Section 3: Agriculture and Climate Change

7 Characterization of Stress-Prone Areas for Dissemination of Suitable Rice Varieties and their Adoption in Eastern India:

7.1 Introduction

[7.2 Materials and Method \(for Submergence-prone: Assam\)](#)

[7.3 Results and Discussion](#)

[7.4 Conclusions](#)

[References](#)

[8 Farmers' Perspective and Adaptation Efforts to Tackle the Impacts of Climate Change](#)

[8.1 Introduction](#)

[8.2 Methodology](#)

[8.3 Results and Analysis](#)

[8.4 Understanding the Farmer's Perception of Climate Change](#)

[8.5 Adaptation Efforts](#)

[8.6 Conclusion](#)

[References](#)

[Section 4: Water Resource Management and Riverine Health](#)

[9 Multicriteria Drought Severity Analysis in Monaragala District Sri Lanka by Utilizing Remote Sensing and GIS](#)

[9.1 Introduction](#)

[9.2 Methodology](#)

[9.3 Meteorological Drought of Monaragala District](#)

[9.4 Agricultural Drought of Monaragala District](#)

[9.5 Hydrological Drought of Monaragala District](#)

[9.6 Drought Risk Area Map of Monaragala District](#)

[9.7 Conclusion and Recommendations](#)

[9.8 Conclusion](#)

[9.9 Recommendation](#)

[References](#)

[10 Comparative Evaluation of Predicted Hydrologic Response Under Two Extremities of Sustainability Using Transformed Landuse-Landcover and CORDEX-Based Climatic Scenarios](#)

[10.1 Introduction](#)

[10.2 A Brief Account of the Kangshabati River Basin, the Study Area](#)

[10.3 Data and Methodological Description](#)

[10.4 Results and Observations](#)

[10.5 Conclusion](#)

[References](#)

[11 Riverine Health a Function of Riverscape Variable: A Case Study of the River Ganga in Varanasi](#)

[11.1 Introduction](#)

[11.2 Material and Methods](#)

[11.3 Result and Discussion](#)

[11.4 Conclusions](#)

[References](#)

[Section 5: Climate Change Threat on Natural Resources](#)

[12 Socio-Economic Impacts of Climate Change](#)

[12.1 Introduction](#)

[12.2 Trends in Climate Variables](#)

[12.3 Welfare Impact of Climate Change](#)

[12.4 Impact on Agriculture](#)

[12.5 Impact of Climate Change on Society](#)

[12.6 Conclusion](#)

[References](#)

[13 The Political Economy of Vulnerable Environment in the Age of Climate Change: A Kerala Experience](#)

[13.1 Introduction](#)

[13.2 Climate Change in Kerala](#)

[13.3 Climate and Sea Level Change Projections](#)

[13.4 Natural Disasters Associated with Climate Change](#)

[13.5 The Political Economy of Climate Change and Associated Disasters](#)

[13.6 Who Are the Affected?](#)

[13.7 Conclusion and Suggestions](#)

[References](#)

[14 Land Use/Land Cover \(LULC\) Changes in Cameron Highlands, Malaysia: Explore the Impact of the LULC Changes on Land Surface Temperature \(LST\) Using Remote Sensing](#)

[14.1 Introduction](#)

[14.2 Effectiveness of Usage of Satellite Imagery in Land Use/Land Cover \(LULC\) Change](#)

[14.3 The Impact of LULC Changes on Land Surface Temperature \(LST\)](#)

[14.4 Methodology](#)

[14.5 Land Use/Cover Changes in Cameron Highland from 2009 to 2019](#)

[14.6 Land Surface Temperature Analysis of Comparative Sensors between Landsat Satellite Data and MODIS](#)

[14.7 The LULC Effect on LST in Cameron Highlands](#)

[14.8 Conclusions](#)

[References](#)

[Section 6: Linkages between Natural Resources and Biotic-Abiotic Stressors](#)

[15 Emerging Roles of Osmoprotectants in Alleviating Abiotic Stress Response Under Changing Climatic Conditions](#)

[15.1 Introduction](#)

[15.2 Role of Osmoprotectant Under Abiotic Stress](#)

[15.3 Role of Osmoprotectants Under Drought Stress](#)

[15.4 Role of Osmoprotectants Under Salinity Stress](#)

[15.5 Role of Osmoprotectants Under Cold Stress](#)

[15.6 Role of Osmoprotectants Under Submergence Stress](#)

[15.7 Role of Osmoprotectants Under Low Light Stress](#)

[15.8 Mechanisms of Osmoprotectants Under Multiple Abiotic Stress](#)

[15.9 Approaches to Improve Osmoprotectants to Confer Abiotic Stress Tolerance](#)

[15.10 Metabolic Engineering Approach](#)

[15.11 Future Prospect for Osmoprotectants Under Changing Climatic Conditions](#)

[References](#)

[16 Growth Variability of Conifers in Temperate Region of Western Himalayas](#)

[16.1 Introduction](#)

[16.2 Material and Methods](#)

[16.3 Results](#)

[16.4 Discussion](#)

[16.5 Conclusion](#)

[References](#)

[17 Process-Based Carbon Sequestration Study with Reference to the Energy-Water-Carbon Flux in a Forest Ecosystem](#)

[17.1 Introduction](#)

[17.2 Concept of Soil-Vegetation-Atmosphere-Transfer \(SVAT\)](#)

[17.3 History of Flux Measurements and Recent Advances-Different Methods](#)

[17.4 Exchange Flux Measurements over Forest Ecosystems](#)

[17.5 Ecosystem Flux Measurements Network Worldwide and Indian Scenario](#)

[17.6 State of the Current Knowledge at Forest Research Institute, Dehradun](#)

[17.7 Research Gaps and Future Needs](#)

[17.8 Conclusion](#)

[References](#)

[Index](#)

[End User License Agreement](#)

List of Tables

Chapter 1

[Table 1.1 Land cover classes and their carbon stocks for estimating carbon...](#)

[Table 1.2 Ten largest GHG emitters from land-based sector from 2000 to 2016...](#)

Chapter 3

[Table 3.1 Confusion matrix for four class.](#)

[Table 3.2 Cerro Laukaru, Chile SIR-C dataset specification.](#)

[Table 3.3 Unsupervised classification for Cerro Laukaru, Chile SIR-C image.](#)

[Table 3.4 SAR statistical parameter for unsupervised classification of Cerro...](#)

[Table 3.5 Class population of supervised classification for Cerro Laukaru, C...](#)

[Table 3.6 Confusion matrix of Wishart supervised classification for Cerro La...](#)

[Table 3.7 Confusion matrix of SVM classification for Cerro Laukaru, Chile SI...](#)

[Table 3.8 Class population of Wishart classification with respective class f...](#)

[Table 3.9 Class population of SVM classification with respective class for C...](#)

[Table 3.10 Error and accuracy assessment of Wishart supervised classificatio...](#)

[Table 3.11 Error and accuracy assessment of SVM supervised classification f...](#)

Chapter 4

[Table 4.1 Change matrix of land use classes \(area in hectares\) during 1980-2...](#)

Chapter 5

[Table 5.1 Approaches for estimating forest productivity.](#)

Chapter 6

[Table 6.1 Taxonomic classification of *Pinus roxburghii*.](#)

[Table 6.2 Various methods for vegetation carbon estimation using inventory-b...](#)

[Table 6.3 Equations and default values used in various biomass and carbon es...](#)

Chapter 7

[Table 7.1 Crop area and farm families affected due to flood in Assam \(2007-2...](#)

[Table 7.2 Rice-growing environments and productivity constraints.](#)

[Table 7.3 Sahabhazi dhan yield comparison with other adjacent variety \(2012-...](#)

[Table 7.4 Targeted dissemination of STRVs in Assam and Uttar Pradesh during ...](#)

[Table 7.5 Targeted dissemination of STRVs in Odisha during 2016-2020.](#)

[Table 7.6 Yield advantage of sub 1 varieties over other traditionally grown ...](#)

[Table 7.7 Adoption of Sahbhazi Dhan in eastern India states.](#)

Chapter 9

[Table 9.1 Rainfall decile ranges and respective drought severity class.](#)

[Table 9.2 Agricultural drought risk classification using VCI.](#)

[Table 9.3 Drought severity parameters based on stream density in Monaragala ...](#)

[Table 9.4 Drought severity parameters based on water source in Monaragala Di...](#)

[Table 9.5 Percentage areas of Meteorological, Agricultural and Hydrological ...](#)

[Table 9.6 Drought severity type and the percentage that affects for each div...](#)

Chapter 10

[Table 10.1 Data used in SWAT model.](#)

[Table 10.2 List of driving models used in multi-model ensemble.](#)

[Table 10.3 Historical and projected LULC maps used in the study.](#)

[Table 10.4 Trends in climatic parameter in response to different climatic s...](#)

[Table 10.5 Catchment specific trend in volumetric runoff \(in cumecs\) for di...](#)

[Table 10.6 Catchment specific trend in surface runoff depth \(in mm\) for dif...](#)

Chapter 11

[Table 11.1 Water quality parameters assessed, instruments and methods used,...](#)

[Table 11.2 Spearman correlation coefficients between land uses and water qu...](#)

Chapter 12

[Table 12.1 Welfare impact of climate change.](#)

[Table 12.2 Key climate change risks, its major driving elements, adaptation...](#)

Chapter 14

[Table 14.1 Description of land cover used in the study.](#)

[Table 14.2 The distribution of land cover/land use extent in 2009 and 2019 ...](#)

[Table 14.3 Non-parametric ANOVA test of significance on land cover change.](#)

[Table 14.4 Confusion matrix of the year 2019 for land cover classification.](#)

[Table 14.5 The temperature in^oC of LST obtained from Met Malaysia, MODIS, a...](#)

Chapter 15

[Table 15.1 List of transgenic plants engineered for stress tolerance using ...](#)

Chapter 16

[Table 16.1 The increment sampling sites of conifers in SFD Tangmar.](#)

[Table 16.2 Species-wise average diameter increments \(mm\).](#)

[Table 16.3 Site-wise average diameter increments \(mm\).](#)

[Table 16.4 Diameter class-wise average diameter increments \(mm\).](#)

List of Illustrations

Chapter 1

[Figure 1.1 Annual GHG emissions \(Mt CO₂-yr⁻¹\) from 2000 to 2016.](#)

[Figure 1.2 Percentage of GHG emissions from the land-based sector \(2000–2016...](#)

[Figure 1.3 The trend lines of annual GHG emissions for predicting future tra...](#)

[Figure 1.4 The percentage of REDD+ progress in East Kalimantan for 2030. Sou...](#)

Chapter 2

[Figure 2.1 Different components of remote sensing used for collecting a wide...](#)

[Figure 2.2 Applications of geospatial techniques for forest resource assessm...](#)

[Figure 2.3 Representation of multiple spatial layers that can be developed w...](#)

[Figure 2.4 Development of thematic maps and their integration for the priori...](#)

[Figure 2.5 Applications of geospatial techniques for crop monitoring and man...](#)

[Figure 2.6 Satellite and LiDAR data fusion for natural resource management....](#)

[Figure 2.7 Various applications of Google Earth Engine for natural resource ...](#)

Chapter 3

[Figure 3.1 Support vectors machine, \(a\) nonlinearly separable case, \(b\) line...](#)

[Figure 3.2 Location of study area \(a\) map of Chile, \(b\) selected area of Cer...](#)

[Figure 3.3 \(a\) Level 1 quad pol dataset for Cerro Laukaru, Chile SIR-C SAR i...](#)

[Figure 3.4 \(a\) Entropy, \(b\) Anisotropy, \(c\) Alpha for Cerro Laukaru, Chile S...](#)

[Figure 3.5 Unsupervised classification for Cerro Laukaru, Chile SIR-C SAR im...](#)

[Figure 3.6 Graph for comparison between unsupervised classifications for Cer...](#)

[Figure 3.7 Graph of SAR statistical parameter for unsupervised classificatio...](#)

[Figure 3.8 Supervised classification image for Cerro Laukaru, Chile SIR-C SA...](#)

[Figure 3.9 Graph of omission error for Cerro Laukaru, Chile SIR-C SAR image....](#)

[Figure 3.10 Graph of commission error for Cerro Laukaru, Chile SIR-C SAR ima...](#)

[Figure 3.11 Graph of accuracy assessment Cerro Laukaru, Chile SIR-C SAR imag...](#)

Chapter 4

[Figure 4.1 Map and landscapes of the study area: \(a\) Location of the study a...](#)

[Figure 4.2 Landsat scenes of study area which acquired on \(a\) 2000 and \(b\) 2...](#)

[Figure 4.3 The land cover maps generated by CNNs model for \(a\) Landsat-5 TM ...](#)

[Figure 4.4 Change detection maps: \(a\) 1980-2000, \(b\) 2000-2020.](#)

Chapter 5

[Figure 5.1 Interlinkages of plant traits and abiotic factors with the growth...](#)

[Figure 5.2 Processes and elements controlling plant productivity.](#)

Chapter 6

[Figure 6.1 Map showing distribution of Indian Himalayan subtropical pine for...](#)

[Figure 6.2 Indigenous Pine species found in India. \(*Pinus roxburghii*, *Pinus ...*](#)

[Figure 6.3 The upright forest biomass pyramid indicating that the primary pr...](#)

[Figure 6.4 Approximate distribution of biomass in different components of a ...](#)

[Figure 6.5 Various conversion factors used in biomass estimation studies....](#)

[Figure 6.6 Methodological steps adopted for estimating forest biomass and ca...](#)

Chapter 7

[Figure 7.1 Location map of study area.](#)

[Figure 7.2 Methodology for targeted dissemination of submergence-tolerant ri...](#)

[Figure 7.3 Methodology for targeted dissemination for drought-tolerant rice ...](#)

[Figure 7.4 Potential sites for the dissemination of Sub 1 rice varieties.](#)

[Figure 7.5 Methodology for targeted dissemination for drought-tolerant rice ...](#)

[Figure 7.6 Yield of Sub 1 rice varieties in submergence condition, Assam.](#)

[Figure 7.7 Yield advantage of STRVs in drought-prone ecology in Assam.](#)

[Figure 7.8 Submergence tolerance of BINA dhan 11 vs other adjacent varieties...](#)

[Figure 7.9 Increasing seed sale of Bina dhan 11 in Odisha from 2016 to 2019....](#)

Chapter 8

[Figure 8.1 Study area. Map data: Google, DigitalGlobe.](#)

[Figure 8.2 Average monthly rainfall \(mm\) – May.](#)

[Figure 8.3 Average monthly rainfall \(mm\) – June.](#)

[Figure 8.4 Average monthly rainfall \(mm\) – July.](#)

[Figure 8.5 Average monthly rainfall \(mm\) – August.](#)

[Figure 8.6 Average monthly rainfall \(mm\) – September.](#)

[Figure 8.7 Average monthly rainfall \(mm\) – October.](#)

[Figure 8.8 Average monthly rainfall \(mm\) – November.](#)

[Figure 8.9 Average annual rainfall \(mm\) – May to November.](#)

[Figure 8.10 Number of rainy days in May.](#)

[Figure 8.11 Number of rainy days in June.](#)

[Figure 8.12 Number of rainy days in July.](#)

[Figure 8.13 Number of rainy days in August.](#)

[Figure 8.14 Number of rainy days in September.](#)

[Figure 8.15 Number of rainy days in October.](#)

[Figure 8.16 Number of rainy days in November.](#)

[Figure 8.17 Average rainy days \(annual\).](#)

[Figure 8.18 Percentage change in rainfall - May.](#)

[Figure 8.19 Percentage change in rainfall - June.](#)

[Figure 8.20 Percentage change in rainfall - July.](#)

[Figure 8.21 Percentage change in rainfall - August.](#)

[Figure 8.22 Percentage change in rainfall -
September.](#)

[Figure 8.23 Percentage change in rainfall -
October.](#)

[Figure 8.24 Percentage change in rainfall -
November.](#)

[Figure 8.25 Percentage change in rainfall - Annual.](#)

[Figure 8.26 Annual household income.](#)

[Figure 8.27 Understanding farmers' \(respondents'\)
perception of climate chan...](#)

[Figure 8.28 Scale used to represent confidence
level of the respondents.](#)

Chapter 9

[Figure 9.1 Study area, Monaragala District, Uva
Province of Sri Lanka;](#)

[Figure 9.2 The complete workflow of the
experiments conducted under the stud...](#)

[Figure 9.3 Rainfall data-based Meteorological
drought analysis map of Monara...](#)

[Figure 9.4 MODIS satellite image data-based
Agricultural drought analysis ma...](#)

[Figure 9.5 Stream density-based drought severity
classification map of Monar...](#)

[Figure 9.6 Irrigated area and water source-based drought severity classifica...](#)

[Figure 9.7 Stream density, irrigated area, and water source-based Hydrologic...](#)

[Figure 9.8 Drought risk area map \(combination of Meteorological, Agricultura...](#)

[Figure 9.9 Spatial percentage of coverage of the drought risk area \(combinat...](#)

[Figure 9.10 The percentage of the drought level in each divisional sectarian...](#)

Chapter 10

[Figure 10.1 A study map of Kangsabati River Basin \(KRB\) showing elevation an...](#)

[Figure 10.2 Taylor diagram for deviation of RCMs \(historical run\) from IMD o...](#)

[Figure 10.3 Flowchart of the methodology followed in the study.](#)

[Figure 10.4 Spatial trends in climatic parameter \(a\) Precipitation \(b\) Maxim...](#)

[Figure 10.5 Temporal variation in areal extent of different land use types L...](#)

[Figure 10.6 Maps depicting LULC scenario for \(a\) Historical time period. 198...](#)

[Figure 10.7 Trends in volumetric runoff for \(a\) LULC scenario 1 representing...](#)

[Figure 10.8 Intra-seasonal comparison in volumetric runoff for different LUL...](#)

[Figure 10.9 Trends in surface runoff depth for \(a\) LULC scenario 1 represent...](#)

[Figure 10.10 Intra-seasonal comparison in surface runoff depth for different...](#)

Chapter 11

[Figure 11.1 Riverine ecosystem as affected by various landscape variables. B...](#)

[Figure 11.2 Location Map representing sampling and survey sites.](#)

[Figure 11.3 LULC statistics of study region.](#)

[Figure 11.4 Percent distribution of Cyanophycean, Bacillariophycean, and Chl...](#)

[Figure 11.5 Respondents' dependency on the River Ganga for their livelihoods...](#)

[Figure 11.6 Tourists' perceptions of different reasons of pollution in the r...](#)

[Figure 11.7 Percentage of \(a\) locals and tourists \(b\) Indians and foreigners...](#)

[Figure 11.8 Tourists' perceptions of different reasons for pollution in the ...](#)

Chapter 12

[Figure 12.1 Global land-ocean temperature index.](#)

[Figure 12.2 Emission entity contribution in top atmosphere radiative forcing...](#)

[Figure 12.3 The modeling chain of CGETemp - Temperature, Prec is precipi...](#)

[Figure 12.4 Socio-economic impacts of climate change.](#)

Chapter 14

[Figure 14.1 Cameron Highlands captured from satellite imagery. A map of Peni...](#)

[Figure 14.2 Satellite imageries from Landsat 7 ETM+ and 8 \(OLI\) TIRS: From l...](#)

[Figure 14.3 Several land use/land cover types in Cameron Highlands: Primary ...](#)

[Figure 14.4 The land use/cover changes maps from classified satellite images...](#)

[Figure 14.5 Relative change in land use/cover in Cameron Highlands: generall...](#)

[Figure 14.6 Land surface temperature \(LST\) for the year 2009 in Cameron High...](#)

[Figure 14.7 Images are showing a land surface temperature series for the yea...](#)

[Figure 14.8 Mean maximum value of Met Malaysia air temperature data.](#)

[Figure 14.9 Mean minimum value of Met Malaysia air temperature data.](#)

[Figure 14.10 Highest recorded values of Met Malaysia air temperature data....](#)

Chapter 15

[Figure 15.1 Schematic representation of mechanism of osmoprotectants under m...](#)

Chapter 16

[Figure 16.1 Study area map with sampling locations.](#)

[Figure 16.2 Species-wise average trend of diameter increments \(mm\).](#)

[Figure 16.3 Site-wise average trend of diameter increment \(mm\).](#)

[Figure 16.4 Diameter class-wise average trend of diameter increment \(mm\).](#)

Chapter 17

[Figure 17.1 Schematic representation of the inter-connectedness of water, ca...](#)

[Figure 17.2 Worldwide flux measurement.](#)

Climate Impacts on Sustainable Natural Resource Management

Edited by

Pavan Kumar

*College of Horticulture and Forestry
Rani Lakshmi Bai Central Agricultural University
Gwalior Road, Jhansi-284003, Jhansi, India*

Ram Kumar Singh

*Hexagon Geospatial
Gurgaon, India*

Manoj Kumar

*GIS Centre
Forest Research Institute, PO: New Forest
Dehradun - 248006, Uttarakhand, India*

Meenu Rani

*Department of Geography
Kumaun University
Nainital-263001, Uttarakhand, India*

Pardeep Sharma

*Department of Geography,
Government College for Women, Hisar-125001, Haryana,
India*

WILEY Blackwell

This edition first published 2022
© 2022 John Wiley & Sons Ltd

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, except as permitted by law. Advice on how to obtain permission to reuse material from this title is available at <http://www.wiley.com/go/permissions>.

The right of Pavan Kumar, Ram Kumar Singh, Manoj Kumar, Meenu Rani, and Pardeep Sharma to be identified as the authors of the editorial material in this work has been asserted in accordance with law.

Registered Offices

John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA
John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Editorial Office

9600 Garsington Road, Oxford, OX4 2DQ, UK

For details of our global editorial offices, customer services, and more information about Wiley products visit us at www.wiley.com.

Wiley also publishes its books in a variety of electronic formats and by print-on-demand. Some content that appears in standard print versions of this book may not be available in other formats.

Limit of Liability/Disclaimer of Warranty

The contents of this work are intended to further general scientific research, understanding, and discussion only and are not intended and should not be relied upon as recommending or promoting scientific method, diagnosis, or treatment by physicians for any particular patient. In view of ongoing research, equipment modifications, changes in governmental regulations, and the constant flow of information relating to the use of medicines, equipment, and devices, the reader is urged to review and evaluate the information provided in the package insert or instructions for each medicine, equipment, or device for, among other things, any changes in the instructions or indication of usage and for added warnings and precautions. While the publisher and authors have used their best efforts in preparing this work, they make no representations or warranties with respect to the accuracy or completeness of the contents of this work and specifically disclaim all warranties, including without limitation any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives, written sales materials or promotional statements for this work. The fact that an organization, website, or product is referred to in this work as a citation and/or potential source of further information does not mean that the publisher and authors endorse the information or services the organization, website, or product may provide or recommendations it may make. This work is sold with the understanding that the publisher is not engaged in rendering professional services. The advice and strategies contained herein may not be suitable for

your situation. You should consult with a specialist where appropriate. Further, readers should be aware that websites listed in this work may have changed or disappeared between when this work was written and when it is read. Neither the publisher nor authors shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

Library of Congress Cataloging-in-Publication Data

Names: Kumar, Pavan (Professor of forestry); Singh, Ram Kumar; Kumar, Manoj; Rani, Meenu; Sharma, Pardeep editors.

Title: Climate impacts on sustainable natural resource management / edited by Pavan Kumar, Ram Kumar Singh, Manoj Kumar, Meenu Rani, Pardeep Sharma.

Description: Hoboken, NJ : John Wiley & Sons, Ltd, 2022. | Includes bibliographical references and index.

Identifiers: LCCN 2021038152 (print) | LCCN 2021038153 (ebook) | ISBN 9781119793373 (cloth) | ISBN 9781119793380 (adobe pdf) | ISBN 9781119793397 (epub)

Subjects: LCSH: Natural resources--Management--Case studies. | Renewable natural resources--Case studies. | Climatic changes--Case studies.

Classification: LCC HC85 .C56 2022 (print) | LCC HC85 (ebook) | DDC 333.7-dc23

LC record available at <https://lcn.loc.gov/2021038152>

LC ebook record available at <https://lcn.loc.gov/2021038153>

Cover Design: Wiley

Cover Images: © Josephine Julian/Shutterstock, Ratnakorn Piyasirisorost/Getty, japatino/Getty, Patrick Orton/Getty

About the Editors

Dr. Pavan Kumar is a faculty member at the College of Horticulture and Forestry, Rani Lakshmi Bai Central Agricultural University, Jhansi, U.P., India. He obtained his Ph.D degree from the Faculty of Natural Sciences, Jamia Millia Islamia, New Delhi. He did BSc (Botany) and MSc (Environmental Science) at Banaras Hindu University, Varanasi, India and subsequently obtained a Master's degree in Remote Sensing (M. Tech) from Birla Institute of Technology, Mesra Ranchi, India. His current research interests include resilient agriculture and climate change studies. He is a recipient of an Innovation China National Academy Award for Remote Sensing. Dr. Kumar has published 50 research papers in international journals and authored several books. He has visited countries like USA, France, the Netherlands, Italy, China, Indonesia, Brazil, and Malaysia for various academic/scientific assignments, workshops, and conferences. Dr. Kumar is a member of the International Association for Vegetation Science, USA and the Institution of Geospatial and Remote Sensing, Malaysia.

Dr. Ram Kumar Singh works with Hexagon Geospatial to provide innovative geospatial solutions in the capacity of Deputy Manager. Dr. Singh is also affiliated to the TERI School of Advanced Studies New Delhi as a senior researcher. He earned a Ph.D in Natural Resources from the Department of Natural Resources, TERI School of Advanced Studies New Delhi. He obtained M.Sc. in Remote Sensing and GIS from the Symbiosis Institute of Geoinformatics, Pune, India and an Engineering in Electronics and Instrumentation degree from Samrat Ashok Technological Institute, Vidisha, India. Dr. Singh has worked on remote sensing applications as a Research

Fellow in the National Informatics Centre, New Delhi. Dr. Singh has authored several peer-reviewed scientific research papers and presented works at many national and international conferences. Dr. Singh is an adjunct faculty for teaching M.Sc. Environment Management and Forestry, along with the Ph.D course at the Forest Research Institute Deemed to be University, Dehradun, India. Dr. Singh is a member of the American Geophysical Union, Washington, D.C., United States and the European Geosciences Union, Munich, Germany.

Dr. Manoj Kumar is a senior scientist working as In-charge of GIS Centre at the Forest Research Institute (FRI), Dehradun, India. The FRI is a premier research institute of the Government of India credited with initiating forestry research in the Asia Pacific region after its establishment in 1905 as the Imperial Forest Research Institute. Dr. Kumar primarily works in the field of forestry, environment, climate change, and related interdisciplinary fields with wider applications of Information Technology, Remote Sensing and GIS tools with a working experience of more than 15 years. He has initiated work on developing forest growth simulation model to study functional relationship of plants with the environment that could be used for climate change impact studies and has published high-impact international papers on various themes of agriculture, forestry, environment and climate change. He has successfully implemented more than 20 research projects funded by national and international agencies.

Dr. Meenu Rani is a senior research fellow in the Department of Geography, Kumaun University, Nainital, Uttarakhand, India. Dr. Rani received her M. Tech degree in Remote Sensing from Birla Institute of Technology, Ranchi, India. She has working experience in the major disciplines of agriculture and forestry while working with Haryana Space Application Centre, Indian Council of

Agricultural Research and GB Pant National Institute of Himalayan Environment and Sustainable Development. Dr. Rani has authored several peer-reviewed scientific research papers and presented works at many national and international conferences in the USA, Italy, and China. She has been awarded with various fellowships from the International Association for Ecology, Future Earth Coast, and the SCAR Scientific Research Programme. She was awarded early career scientists achievement in 2017 at Columbia University, New York, USA.

Dr. Pardeep Sharma is a Assistant Professor in Department of Geography, GCW, Hisar (Haryana) India. Dr. Sharma completed his Bachelors in Geography and subsequently obtained his Master's degree in Geography. He specialized in remote sensing and GIS and hydrological studies. His area of interest includes coastal ecosystem conservation and management, climate change, and disaster management. He has made a remarkable contribution in water-related researches such as coastal landscape vulnerability and flood vulnerability. He has presented his research at various national and international conferences.

List of Contributors

Madhoolika Agarwal

Institute of Science
Department of Botany
Banaras Hindu University
Varanasi - 221005, India
Email: madhoo58@yahoo.com

Mohammad Ajaz-ul-Islam

Division of Natural Resource Management
Faculty of Forestry
Sher-e-Kashmir University of Agricultural Sciences and
Technology of Kashmir
Benhama Ganderbal, J&K - 191201, India

Mohamad Azani Alias

Department of Forestry Science & Biodiversity
Faculty of Forestry and Environment
Universiti Putra, Malaysia
Email: azani@upm.edu.my

K.A.M. Chathuranga

Department of Spatial Sciences
Faculty of Built Environment and Spatial Sciences
General Sir John Kotelawala Defense University
Southern Campus
Sooriyawewa, Sri Lanka

Goutam Kumar Dash

Division of Crop Physiology and Biochemistry
ICAR-National Rice Research Institute
Cuttack
Odisha, India
Deepali Dash
Department of Plant Physiology