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Chaitanya B. Pande · Kanak N. Moharir · Sudhir Kumar Singh · Quoc Bao Pham · Ahmed Elbeltagi *Editors*

Climate Change Impacts on Natural Resources, Ecosystems and Agricultural Systems

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Dedicated to my parents

Preface

This book on the impact of climate change on natural resources, landscape and agricultural ecosystems describes the contributing aspects of climate change related to natural resources, soil erosion, irrigation planning, water, landscape, sustainable crop yield agriculture, biomass estimation, problems of climate change and discusses the related resulting mitigation system. Natural resources and agricultural ecosystems include factors from nearby regions where climate change, landscape, and agricultural practices directly or indirectly interface with the water, vegetation, irrigation planning, and ecology present. Changes in climatic situations impact all natural resources, ecology, and landscape of agricultural systems, which can possibly poorly affect their productivity. This book covers the various aspects of soil erosion, soil compaction, soil nutrients, aquifer, water of climate change in respect to vegetation's, crops, pest, water and sustainable yield for the development of the climate change factors and agricultural sector, sustainable development and management for the future. It also focuses on the use of precision techniques, remote sensing, GIS technologies, IoT, and climate-related technology for sustainability of ecology, natural resources, and agricultural area along with the capacity and flexibility of natural resources, ecology, and agricultural societies under climate change. Climate change, natural resources, landscape, irrigation planning, water, sustainable yield, and agricultural ecosystems include both theoretical and applied aspects, and help as guideline information for future research. This is a very important book for researchers, scientists, NGOs, and academicians working in the fields of climate change, environmental sciences, agricultural engineering, remote sensing, natural resources management, GIS, hydrology, soil sciences, agricultural microbiology, plant pathology, and agronomy.

This volume comprises 29 chapters contributed by various researchers, scientists, and professors from around the world. It includes research work by professors, planners, scientists, and research scholars from various universities, international organizations, and institutions of India as well as of other countries. The chapters provide an in-depth analysis of climate change, impact analysis, sustainability of agroecosystems, vulnerability assessment of stakeholders, climate-smart farming, land use and land cover change detection, precision farming, land surface temperature, flood impact analysis, crop yield, irrigation to mitigate agriculture, and climate change impacts on natural resources, agriculture, and ecosystems.

We sincerely thank Robert Doe, Publishing Editor, Springer, and Fairle T Thattil (Ms.) for their generous assistance, constant support, and patience in finalizing this book.

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About the Editors

Chaitanya B. Pande (IITM, Pune) received his PhD from Sant Gadge Baba Amravati University, Amravati. He has more than a decade of university, research, and industrial experience. Dr. Pande is a reviewer of *Earth Science Research Journal*, *American Journal of Geophysics, Geochemistry and Geosystems*, *Sustainable Water Resources Management* (Springer journal), *Modeling Earth Systems and Environment* (Springer journal), *Applied Geomatics*, (Springer journal), *Journal of Agriculture Sciences* (Bioinfo Publication), *Applied Water Science* (Springer), *Journal of the Institution of Engineers (India): Series A* (Springer), *Groundwater Sustainable Development* (Elsevier journal), and *Environmental Sustainable Development* (Springer journal). He has published 40 research papers in international journals with Springer, Taylor and Francis, and Elsevier with more than 1280 citations. He has published two books with Springer Nature. He has presented more than 20 research papers in national and international conferences. His research interests include remote sensing, GIS, machine learning, Google Earth Engine, climate change, drone applications, watershed management, hydrological modeling, land use and land cover analysis, groundwater quality, urban planning, hydro-geochemistry, groundwater modeling, geology, hyperspectral remote sensing, remote sensing and GIS application in natural resources management, watershed management, and environmental monitoring and assessment subjects.

Kanak N. Moharir works in the Department of Earth Science, Banasthali University, Aliyabad, Rajasthan. With more than 8 years of teaching and research experience, she has published more than 45 research papers in various national and international journals and has presented 15 research papers in national and international conferences with more than 700 citations. Her research interests include remote sensing, watershed management hydrology, land use and land cover, aquifer mapping, groundwater modeling, hydrogeology, geomorphology, and geology. She is a reviewer of eight Springer journals and other journals.

Sudhir Kumar Singh, PhD, offers basics of remote sensing and GIS, and remote sensing and satellite meteorology courses to MTech students at K. Banerjee Centre of Atmospheric and Ocean Studies, University of Allahabad, Prayagraj, India. He has worked on the application of geochemical and hydrological model (SWAT) to study the impact of land use/land cover change on water quality and quantity of drought-affected river basin. He has opted for a challenge to study land use and land cover in a north-eastern part of Punjab using multi-date satellite data. He has also studied the impact of land use and land cover change on groundwater quality in the Lower Shiwalik hills: remote sensing and GIS-based approach. These studies also have socio-economic and environmental implications in achieving the objectives of sustainability. Sudhir has worked as PI and co-PI funded by University Grants Commission, Department of Science and Technology, New Delhi, India, and Ministry of Earth Sciences, Government of India. He has published his results in peer-reviewed journals with high impact factors. Also, he is part of the BRICS international team studying the impact of land use/land cover and climate change on river basins. His research focuses on remote sensing and geographical information system applications in the environment with special reference to land use/land cover change and water resource management. Sudhir has published more than 167 research papers in international journals with Springer, Elsevier, and Taylor and Francis with more than 5535 citations. He has published two edited books and one reference book. He has worked as an associate editor with the *Arabian Journal of Geoscience* and *Water Science Conservation and Engineering* and has been the guest editor of many leading journals such as Physics, Chemistry and Earth, Remote Sensing and Water.

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Chapter 1
Impact of Climate Change on Livelihood Security and Biodiversity – Issues and Mitigation Strategies

Gyanaranjan Sahoo, Prasannajit Mishra, Afaq Majid Wani, Amita Sharma, Debasis Mishra, Dharitri Patra, Ipsita Mishra, and Monalisa Behera

Abstract Climate change is one of the most pressing issues of our day, posing a threat to the lives and livelihoods of billions of people worldwide. Natural disasters, biodiversity loss, and rising temperatures destroy crops, diminish ecosystems, put livelihoods in jeopardy, and accelerate the spread of fatal diseases. Climate change mixes population trends, migration, and greater urbanisation, putting the most vulnerable people at risk. Climate change is the most important impediment to achieving sustainable development through biodiversity conservation, and it threatens to impoverish millions of people. Species distributions have changed to higher altitudes at a median pace of 11.0 m and 16.9 km per decade to higher latitudes as a result of climate change. As a result, under migration scenarios, extinction rates for 1103 species range from 21–23% with unrestricted migration to 38–52% with no migration. When an environmental change happens on a period shorter than the plant's life, a plastic phenotypic may emerge as a reaction. Phenotypic flexibility, on

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the other hand, might protect species against the enduring impacts of climate change. Climate change also has an impact on food security, especially in people and areas that rely on rainfed agriculture. Crops and plants have growth and yield limits that must be respected. As a result, agricultural productivity in Africa alone might plummet by more than 30% by 2050. Climate change is already wreaking havoc on people's lives, especially the impoverished. Because rural people rely on natural resources, their livelihoods are jeopardised by frequent climate change. The impact of climate change on natural resource-based rural livelihoods is anticipated to be uneven and ecosystem resilience will be strengthened as a result of biodiversity conservation, and ecosystems will be better able to deliver critical functions in the face of increasing climate stresses. Moreover, as a consequence of global influence, the warming trend has changed significantly over the years. In addition to ensuring the livelihood security of rural people, a number of adaptation approaches species and ecosystems in a changing climate may be recommended.

Keywords Biodiversity · Climate change · Livelihood security · Mitigation · Rural · Strategies · Sustainable development

Introduction

Global warming has become commonplace, with heads of state, scientists, and environmental activists frequently making dire pronouncements. Extreme weather events, unpredictably changing global weather patterns, epidemics, and devastating infernos are all examples of climate change and the spread of exotic classes of flora and fauna in new regions is undoubtedly changing global climate (Trew and Maclean 2021; Chinnasamy and Srivastava 2021). Changes in weather patterns, according to sceptics of global warming, are a natural component of the Earth's temperature fluctuation, while the majority of scientists say they are most likely as a result of human-caused imbalances in heat-trapping greenhouse gases (GHG) in the atmosphere (Sahoo et al. 2021). Climate change is a worldwide subject that scientists have been concerned about since the nineteenth century, and its effects may still be seen today. Regional Circulation Models (RCM) project the average yearly temperature is anticipated to rise by 1.4 °C by 2030, 2.8 °C by 2060, and 4.7 °C by 2090 (IPCC 2021). Tropical countries have a high reliance on agriculture and related activities for their livelihoods and household economies, making them particularly susceptible to climate change. Climate change might affect food production, resulting in an increase in hunger, poverty, malnutrition, food insecurity, and food availability (IPCC 2019). Coastal subsistence farming is particularly susceptible to heat and water stress, and as a result, growing seasons will be shortened (Ajit et al. 2013; FAO 2019; Pande et al. 2021a; Orimoloye et al. 2022). Because of global warming, rising temperatures are becoming more common and intense, destabilising food prices, and hindering the region's growth and development (Inder et al. 2018). Rapid land usage, ineffective land management, overexploitation, and increased fossil fuel burning for industrial and residential purposes are all key causes of climate change in tropical countries (Pande et al. 2021b).

The United Nations Framework Convention on Climate Change (UNFCCC) has yet to define what constitutes harmful interference with the climate system as a result of human activity, as well as allowed constraints for ecological implications, food supply, and cost-effective growth (Trew and Maclean 2021). However, arbitrary stabilising limits ranging from 450 ppm to 750 ppm have developed as a result of this. In 1990, the Advisory Group on Greenhouse Gases (AGGG) of the World Meteorological Organization (WMO), the International Council on Science (ICSU), and the United Nations Environment Programme (UNEP) developed two primary temperature indications or verges, each with diverse degrees of hazard (Barnosky et al. 2011). It was claimed that a temperature intensification of more than 1.0 °C higher than before the industrial revolution "may elicit rapid, unpredictable, and nonlinear responses that could lead to extensive ecosystem damage," with the current rise in temperatures of more than 0.1 °C per span. A temperature increase of 2.0 °C was also gritty to be "an upper limit beyond which the odds of severe ecological harm, as well as nonlinear reactions, are expected to rapidly develop." One of the key findings of the IPCC TAR is that global warming would almost certainly result in significant lost revenues in many poor nations, notably in Africa, at all degrees of warming, with these losses increasing as temperatures rise (IPCC 2021). Global temperature and rainfall are anticipated to increase, conferring to the IPCC (2021) statement, and climate change is anticipated to be one of the most noteworthy causes of habitat destruction at all stages over the next 50–100 years, compounding the consequences of prior actions challenges to habitat destruction. Climate change, global warming, economic crises, deforestation, and other factors are all threatening to rural livelihoods. This fact demonstrates the detrimental impact on rural livelihoods, forcing people to relocate to other areas, particularly cities (Ali and Erenstein 2017). People in rural and urban areas may contribute to the creation of a sustainable society by engaging in constructive activities (Brito-Morales et al. 2018). Rural and urban residents should maintain an interdependent connection in which city residents provide specialists to rural areas to educate and train them, while rural residents provide diverse food products to meet the needs of metropolitan society (Midgley and Bond 2015).

"A livelihood comprises the capacities, assets (stores, resources, claims, and access) and activities essential for a means of living," including one of the next interpretations of livelihood by Chambers and Conway. A livelihood is justified if it can withstand and sustainable when it can cope, retain or increase its functions, and provide viable income-generating possibilities (IUCN 2016). Other concerns such as agriculture policy, market conditions, other economic opportunities, other factors and position families with different asset access in a variety of scenarios affecting and complicating their livelihood choices. Diversified strategies in terms of flexibility must be viewed as a wide variety of options for actors with varied resource availability starting points, as well as for the same families over the course of their lifetimes or demographic cycles (Verma 2019). These decision-making processes may also be thought of as a blend of free will and necessity, as well as a duality of structure vs. agency. Selections are made, but they are frequently "given" or constrained by significant preconditions or constraints (Trull et al. 2018).

Environment alteration, depletion of resources, environmental issues, species extinction, and habitat loss events, sometimes known as the "evil five" biodiversity intimidations, are the primary causes of contemporary biodiversity loss (Brook et al. 2005; Sonwa et al. 2017). The loss of biodiversity has an ecological impact (Gusli et al. 2020), with environmental change being the primary cause. Environmental factors, in combination with other factors, play a vital role in determining how organisms operate and spread. Environmental changes have had and will continue to have a major influence on species distributions, both now and in the future (Fardila et al. 2017). Only a few studies, on the other hand, have directly quantified biodiversity extinctions as a result of climate change. As a consequence, predictions may be able to provide light on the many components of climate change, as well as the dangers to global biodiversity that they pose (IPCC 2020). Despite the difficulty of distinguishing the effects of climate change from those of other multiple impacts for a variety of species, expectations may give insight into climate change's numerous constituents and their concept which refers intimidations to species diversity (Trull et al. 2018). Tubiello and Rosenzweig (2008) provide a paradigm for analysing vulnerability in the agricultural sector based on exposure, sensitivity, and adaptability. Table 1.1 shows the agriculture sector's vulnerability indicators. The exposure relates to biophysical markers, as shown in the Table. Soil and climate (temperature/precipitation), crop calendar, water availability, and yields can all be used as exposure indicators. On the subject of exposure, history and current climatic drifts and inconsistency in Asia reveal that they are often characterised by rising surface air temperatures, which are more prominent during the winter than during the summer (IPCC 2007). Increasing temperature movements have been recorded across Asia's sub-regions. In various places of Asia, the pragmatic rise over the last few decades have ranged from less than 10 °C to 30 °C per century. The increase in surface temperatures is reported to be more dramatic in North Asia. Inter-annual, inter-seasonal, and regional variability in rainfall patterns has been

Table 1.1 Framework for vulnerability criteria

Categories	Vulnerability criteria	Measurement class
Biophysical indicators	Exposure	Soil and climate Crop calendar Water availability and storage Biomass/yield
Agricultural system characteristics	Sensitivity	Land resources Inputs and technology Irrigation share Production
Socio-economic data	Adaptive capacity	Rural welfare Poverty and nutrition Protection and trade Crop insurance

Source: Adapted from Tubiello and Rosenzweig (2008) documented in Asia in recent decades. It should be noted that annual mean rainfall is dropping in North-East and North China, Pakistan's coastal belts and dry plains, sections of North-East India, Indonesia, the Philippines, and some areas of Japan. Annual mean rainfall, nevertheless, is increasing in Western China, the South-East coast of China, the Changjiang Valley, Bangladesh, the Arabian Peninsula, and the western shores of the Philippines (IPCC 2007). The frequency of more severe rainfall events has increased in many parts of Asia, resulting in significant floods and landslides, although rainfall intensity and total annual precipitation have reduced as a result of changes in extreme climatic events. Global warming, as well as other shocks and perturbations, is critical for the agricultural industry, as well as for individuals seeking to safeguard and improve their livelihoods. Effective climate change adaptation requires adaptive ability, knowledge, and skills, as well as the resilience of livelihoods and alternatives, resources, and access to suitable frameworks (Sahoo and Wani 2020). While farm-level climate change adaptation requires more public- and private-sector expenditure, technology advancements, government initiatives, and insurance schemes all require additional public- and private-sector spending (Brown et al. 2018a, b). Climate change, at its current rate and severity, will almost probably outstrip the ability of a wide range of plants to acclimate to new weather conditions, subsequent in growing loss of habitat (Keith et al. 2008; Loarie et al. 2009; Bellard et al. 2012). In the face of climate change, climate velocity is defined as the rate and direction at which a species must migrate to preserve its current climatic conditions (Brito-Morales et al. 2018). This is seen in Africa, where environmental degradation, climate change, and rapid population growth all pose serious threats, expanding populations have unanticipatedly serious negative effects (Midgley et al. 2002; Barlow et al. 2018). As a result of this transition, a higher environmental issue is in growing market, leading to land use changes and the use of unsustainable species (Sahoo et al. 2020a). Furthermore, these variations have a major impact on biodiversity and ecological processes. This article focuses on how climate change impacts people's livelihoods, as well as biodiversity loss and the strategic actions taken to protect biodiversity and offer livelihood stability for rural people (Ali and Erenstein 2017). Framework for Vulnerability Criteria is shown in Table 1.1.

Influence of Environmental Change

Agriculture may be jeopardised by global climate change, social protection, and subsistence agriculture for a variety of people, including the impoverished in Asian countries. The negative impact on small-scale farmers will be amplified. Farmers, fishermen, and people who rely on the forest for their livelihood, who are already fragile and food insecure, are anticipated to suffer as a result of global climate change (Sahoo et al. 2020a). Farmers may benefit from agriculture adaptation and mitigation. The surviving methods might be useful in developing long-term adaption strategies. Farmers have a lot of potential to store carbon in the soil provided appropriate legislative reforms are implemented.

The Issue of Water

In agricultural production, water is the most valuable element. Improving rural living conditions necessitates the development of groundwater resources management (Khadri and Pande 2016). Agriculture must contend with urbanisation, water, and industry for water. As previously said, small-scale farmers rely on water more than large-scale farms (Abdisa et al. 2017; Kouadri et al. 2022). The World Health Organization has extra canal water access. Several parts of the Asian country are running out of water. In the future, marginal and small farmers will confront more water-related challenges. As a result, water management will become increasingly important for these farmers (Barrios et al. 2018).

Diversification

Indian diets have shifted away from cereals and towards high-priced items such as milk and meat, as well as vegetables and fruits. Diet diversity in India is mostly due to rising conservatism as a result of rapid urbanisation, rising greater women's participation in employment generation, increased household earnings, and the effect of globalisation (Sahoo et al. 2021). Hi-value goods have bloomed with the rise of the middle class, with the consequences apparent in the increased demand for high-value processed foods (Matata and Adan 2018). In India, there is an increasing demand for non-food grain products. In Asian countries, physical property expenditure on non-cereal food items continues to be relatively high. In rural regions, it is three times higher than grains, while in urban areas, it is almost ten times higher. Fruit and vegetable intake increased the most per capita, followed by edible oils.

Susceptibility and Hazard

There is ample evidence to indicate that the poorest of the poor are exposed to a variety of hazards that might affects people, groups, or entire populations, all of which can have devastating consequences for their livelihoods and well-being. They need greater individual or family exposure to a variety of hazards. (a) Morbid obesity, sickness, accidents, and incapacity are all examples of nutrition disruptions; (b) many people labour in the informal economy, which has a substantial threat of wage stagnation; (c) crop hazards, life cycle dangers, cultural threats, and unique threats for disadvantaged teams are all factors to consider (Barrios et al. 2018). Droughts, floods, cyclones, structural change policies, and other community risks must also be addressed. These dangers are particularly dangerous for small and marginal farms. Borrowing, asset sales, savings defrayal, family and government help, swelling labour supply, child labour, healthy labour, demand reduction, migration, and so on are some of the household heading processes. To deal with the negative impacts of risks and vulnerabilities, comprehensive social protection programmes are required (Pande and Moharir 2021).

The Impacts on Urban Livelihoods

Climate change affects urban livelihoods in both direct and indirect ways. Urban populations are overly reliant on services like water and electricity being delivered on time. When these amenities are threatened by climate change, city inhabitants are more powerless than their rural counterparts, who can at least dig wells and gather firewood for cooking. Furthermore, reduced/disrupted water and energy supplies have an influence on industrial productivity and profitability; livelihoods based on low-input market gardening, particularly among the urban poor; human health; and overall living standards (Abdisa et al. 2017).

Heavy Rainfall and Floods

Extreme occurrences such as cyclones and the storm surges and inland flooding that accompany them have a significant impact on infrastructure and livelihoods, particularly in the informal sector in metropolitan areas. Flooding caused by cyclones and severe rainfall causes damage to highways, bridges, stores, homes, and other infrastructure (Chen et al. 2011). Floods cause business losses when trade is interrupted, items are lost, and flood and water damage is repaired. Furthermore, strong rains and floods have a negative impact on the informal sector, notably street selling, as they are unable to conduct their enterprises (Sahoo et al. 2019). Their livelihood and food security are frequently reliant on revenue obtained from daily commodity transactions (Brook et al. 2008). Climate change adaptation, as well as other shocks and perturbations, is essential for the agricultural business, as well as for people trying to protect and enhance their livelihoods. Environmental management requires responsiveness, awareness, and competencies, as well as the resilience of incomes and options, resources, and exposure to suitable authorities (Bezabih et al. 2014). Climate change adaptation requires increased public and private sector spending, technological breakthroughs, and legislative reforms, whereas farm-level climate change adaptation provides a range of solutions, including floods and private sector expenditures (Paavola 2004). Agricultural and animal management practices, the usage and control of forests, and a wide range of on-farm and off-farm integrated or globalised survival options, as well as variations in agricultural and animal management practices, land use and land management, and a range of on-farm and off-farm integrated or a variety of sources of income are all options. People and families are already adjusting to changing climatic circumstances, despite the fact that climate change has yet to be assimilated into mainstream advance strategies in European countries (FAO 2020).

Around 85% of the world's agrarians are smallholder farmers. The preponderance of these people is common in poor countries in South Asia and sub-Saharan Africa, but they also control rural areas of a number of higher-income countries, counting CEEC, Western Balkan countries, and Bosnia and Herzegovina (OECD 2014). These regions are characterised by poverty is pervasive in rural areas, with a significant rural population, widespread poverty, and enormous expanses of low agricultural output due to perpetually declining a limited supply of resources, and a constricted market, and major climate threats. Small-scale farmers are reliant on subsistence farming and existence, and many lack the means and capacity to adapt to climate change's consequences (Sahoo et al. 2020a). Lower agricultural productivity may have an influence on food security, nutrition, income, and happiness. As a result of climate change, farmers will face greater risks and uncertainties. Modern agricultural alterations have a direct and indirect influence on food security, and also income creation and dissemination, and hence farm produce demand (Verma 2019).

Several alternative approaches will be necessary to minimise the intensity of climate change impacts. Both in relation to the perceived socio-economic choices and agricultural increased efficiency. The most significant drivers of adaptation, according to empirical research across disciplines, are resource, institutional, informational, and financial limitations (Rahman and Hickey 2019). Modifications can also be planned (public) or unplanned (private), with the latter dependent on how climate change perspectives are agriculture outcome. Furthermore, due to conflicting social backgrounds and societal goals, independent adaptations will almost likely be insufficient to address the climate change which has the potential to cause damage and even maladaptation (Swaminathan and Kesavan 2012). As a result, policies must "mainstream" climate change response strategy and resource development in order to allow and encourage successful climate change adaptation development and capacity building. Agriculture can acclimatise to climate change through a variety of management approaches and the adoption of new technology. When it comes to adapting and embracing new techniques and technologies, there is no "one-size-fits-all" solution (OECD 2014). Effective variation should be based on appropriate, regional, and empirical data that is regularly changed as a result of fresh research. Because of the scale of climate change and its unpredictability, as well as the ability to respond to these changes, the degree of sustainable adaptation is directly linked to vulnerability, whether for assessment or implementation. Poverty and, as a result, a lack of agility are frequently shaped by restricted access to assets and capacities for earning a living (Abdisa et al. 2017). Unfortunately, depending just on financial resources may exaggerate people's adaptable capacity, and socio-cognitive factors should be included to generate more realistic adaption simulations and societal consequences.

Combined Effect Between Food Security and Climate Change Mitigation

Climate change vindication has never been a vital driver of agricultural activities, and it is unlikely to be in the future. Rural households are plainly uninterested in carbon sequestration on farms for climate change mitigation, especially if mitigation approaches do not result in immediate financial or welfare improvements (Workie and Debella 2017). Smallholder ranchers might be reluctant to surrender any of their frequently pitiful homestead benefits to sequester carbon. Carbon-sequestering land use procedures should either be financed to the degree that they are comparable to inevitable benefits from elective land uses, or they should be beneficial by their own doing – with no pay – if such ranchers are to add to relief regardless (IPCC 2013). With biocarbon projects actually attempting to defeat monetary, institutional, and administration hindrances, the most obvious opportunity with regards to sequestering carbon for an enormous scope on Africa's ranches is through advancements that further develop food security while likewise giving supportability administrations (for example, expanded parkland tree cover, diverse cultivating, intercropping, and land sharing practices) (Ignaciuk and Mason-D'Croz 2014). Agroforestry is one of the few land use practices that can help with food security as well as climate change mitigation. It is also less likely to have a detrimental impact on non-carbon ecosystem services like water cycle regulation and biodiversity protection, both of which are important components of "climate-smart agriculture," than other options (Rahman and Hickey 2019). Agriculture and forestry are responsible for approximately a third of all human greenhouse gas emissions. As a result, mitigation initiatives should concentrate on these industries. However, it should be remembered that seas, lakes, forests, and agricultural areas all trap and store huge amounts of carbon, helping to mitigate climate change (FAO 2020). Agricultural methods may contribute significantly to raising soil carbon sinks and reducing GHG emissions at a cheap cost. In other words, in agriculture, forestry, and fisheries, sustainable production and consumption should be the driving factors for lowering GHG emissions.

Mitigating Methane Emissions Through New Irrigation Schemes (Bohol, Philippines)

Bohol Island is one of the major rice-growing areas in the Philippines' Visayas region. Two older reservoirs (Malinao and Capayas Dams) were beset by issues and unable to produce adequate water for the second crop season (November to April) prior to the construction of the Bohol Integrated Irrigation System (BIIS) in 2007. Farmers' penchant for permanently flooded rice-growing conditions exacerbated the situation, as did the practice of uneven water distribution. In response to deteriorating rice yield, the National Irrigation Administration (NIA) devised an action plan for the BIIS (FAO 2009). Among the projects were the construction of a new dam (Bayongan Dam; funded by a loan from the Japan Bank for International Cooperation) and the adoption of Alternate-Wetting and Drying (AWD), a water-saving technology developed by the International Rice Research Institute (IRRI) in collaboration with national research institutes. The apparent efficacy of AWD on pilot farms, along with specific farmer training programmes, was able to debunk the widely held idea that non-flooded rice fields would result in output losses. Because of the extensive usage of AWD, irrigation water was used more efficiently, allowing cropping intensity to be increased from 119% to 160% (related to the maximum of 200% in these double cropping systems). Furthermore, as compared to continuous flooding of rice fields, the new IPCC methodology (IPCC 2007) states that "multiple aeration," to which the AWD adheres, can reduce methane emissions by up to 48%. As a consequence, AWD offers several benefits, including lower methane emissions (mitigation), decreased water usage (adaptation in water-scarce locations), enhanced output, and contribution to food security. Source: FAO 2010

Challenges

Substantial rising temperatures provide both difficulties and solutions for rethinking sustainability aspirations that do not appear to be simple to comprehend. Despite the fact that conservation concepts and practices have evolved through time, there are major institutional and cognitive barriers to shifting ecological perspectives and reconfiguring goals (Harvey et al. 2014). The following are some of the institutional impediments to rethinking and reconfiguring objectives: (1) laws and principles; (2) rules and procedures for leadership; (3) people and economic investment; and (4) science and information (Montoya and Raffaelli 2010). Lawful obligations and rules, in specific, may extant problematic obstacles. Several current regulations, such as the Endangered Species Act, impose certain techniques on managers, limiting their freedom to change aims and management objectives. Several recent legal studies (Matocha et al. 2012; Mora et al. 2011) provide some insight into the complexities of Federal conservation rules as they pertain to global climate change variation. Psychological impediments, on the other hand, will be challenging to eliminate. Due to a strong aversion to making trade-offs, which are referred to in the scientific literature as "protected values," many conservationists, according to Nye et al. (2010), find it tough to progress the well-known aims of regenerating and safeguarding current patterns of richness, as well as sustainability goals chosen in advance. Doney et al. (2012) further speculated that conservationists' general aversion to "giving up on anything" might explain the restricted range of transformational adaptation techniques as comparison to keeping the current order.

Several environmentalists think that using the high conservation value (HCV) method is a good way to identify and mitigate the negative consequences of unmanaged natural resource use (Monzon et al. 2011). However, as its reach has broadened and diversified, HCV users and assessors have speculated, scrutinised, and criticised its appropriateness for biodiversity conservation (OECD 2014). The HCV idea is evolving from a heuristic learning-by-experience model to a comprehensive management tool that allows for improved prioritising of components such as ecosystem services, biodiversity, and socio-economic-cultural values.

Some of the major research problems in this area include the following:

1. Primary and secondary research are covered in a comprehensive spatiotemporal, contextual, and particular manner
2. Development of HCV component, category, and definition interpretations at the federal provincial, regional, and municipal levels
3. Difficulties in putting a management plan in place at the landscape level
4. Participation of the public and FPIC implementation
5. HCVs are prioritised for retention depending on their human significance and vulnerabilities.

Environmental and economic NGOs, as well as wealthy individuals, have backed the HCV method. This community of partners demonstrates how the HCV approach may benefit a wide number of stakeholders while simultaneously balancing ethical, cultural, and political concerns (Pacifici et al. 2015). However, in agricultural settings, it is frequently misappropriated, resulting in low-quality HCV assessments (Mora et al. 2011). This makes distinguishing between technique flaws and those induced by bad application more challenging.

Climate Change's Impact on Biodiversity

As a consequence of a wide range of human-caused activities, biodiversity is disappearing and becoming increasingly vulnerable around the world (Fardila et al. 2017; Barlow et al. 2018). "A semi-permanent or permanent qualitative or quantitative decline in elements of biodiversity and their potential to produce products and services, to be restricted at world, regional, and national levels," according to the Convention on Biological Diversity (CBD COP VII/30). According to fossil records, a private vertebrate species went extinct after an average of one million years (Lambin and Meyfroidt 2011). Therefore, only one species out of a million ought to go inexistent. Nevertheless, the present ascertained elimination rate is 2.6 vertebrate species per 10,000 per year (Whiteside and Ward 2011). Environmental change is one of the most genuine dangers to the locale's biodiversity and biological system administrations (Workie and Dabella 2017; Matata and Adan 2018). One of the most serious dangers to biodiversity is climate change, as per the United Nations Framework Convention on Climate Change and thus the CBD. As indicated by a review distributed in Nature (Thomas et al. 2004), worldwide environmental change may bring about the termination of a greater magnitude 1,000,000 earthbound species in the following fifty years. The most powerless are uncommon species, divided environments, and districts previously upset by contamination and deforestation.

Populations of Species Fluctuations

According to scientific investigations, some taxa have shifted their species ranges in response to rapid changes in temperature and precipitation regimes, primarily towards higher elevations and temperature inversions (Nye et al. 2010; Burrows et al. 2011; Chen et al. 2011; Doney et al. 2012). According to Groffman et al., plants and animals in terrestrial ecosystems migrated at a rate of 0.011 km per decade towards various altitudes and 16.9 km per decade towards warmer temperatures (2014). The spatial bounds of east African species and habitats have shifted dramatically as a result of climate change. To adapt to rising temperatures, current migration rates must be significantly greater than those observed in previous post-glacial periods (Bajramovic et al. 2014, Bland et al. 2015). Climate change is influencing Africa's natural variety. For example, the Ethiopian wolf (Canis simensis) is struggling to adapt to prolonged droughts and diminishing water and other resource availability. Ecologists are particularly vulnerable and respond as a result of their relatively restricted nutritional, thermal, and habitat niche breadths (Lowder et al. 2016; Montoya and Raffaelli 2010) and associated with generally stable ecosystems (Walther 2010). Extreme weather events threaten the habitats that support Ethiopia's endangered and distinctive species. Climate change, for example, is expected to enhance the likelihood of local extinction of the Ethiopian wolf (*C. simensis*), Africa's most endangered species, according to study. According to Rosenzweig and Parry (1994), *C. simensis* was discovered about 2500 metres above sea level in Gojjam and northern Showa in the early twentieth century. In recent decades, the species' distribution has migrated to higher heights, and it is now known to exist at elevations of over 3000 metres above sea level, with the tallest peaks reaching up to 3700 metres (Rosenzweig and Parry 1994). Prospective conservation area classifications and preservation of environmental specialising groups in Ethiopia must include estimates of future climate change and associated changes in plant and animal species' geographic ranges to assure adequacy. Unquestionably, the environment has the power to change the migration patterns (and timings) of species that depend on seasonal wetlands (like migratory birds) and keep track of seasonal changes in vegetation (like herbivores), leading to increased interactions with people, particularly in regions where rainfall is significant (Kumar and Verma 2017). Wild animals that cannot migrate or travel are endangered in Africa. In Ethiopia, land use patterns can hinder animals from altering their migratory pathways, according to Pacifici et al. (2015). Big-scale agricultural growth, for example, has been shown to disrupt migratory routes, resulting in a reduction in large animal populations (Williams and Jackson 2007).

Responses from Various Populations

Global warming causes the depletion of non-renewable ecosystems and the relocation of habitat ranges to more appropriate areas, altering the number of species populations (Erasmus et al. 2002; Walther 2010). In response to fast changes in temperature and precipitation regimes, *C. simensis* has already extended its geographic distribution to higher altitudes. New combinations of taxa, unusual interspecific interactions, and, in the worst-case scenario, extinction might arise from these changes (Paudel Khatiwada et al. 2017). Like a consequence, the shift in *C. simensis* habitat might signal a population decrease. Further, if climate change decreases a species' range to a few key areas and a severe weather event occurs, the population decline and destruction of the species would likely increase in the future. When it comes to climate change, species kinds are less likely to move in large groupings and are more likely to split apart (Walther 2010; Barnosky et al. 2011).

Changes in Phenology

Variations in plant morphology, or the periodic sequencing of life circumstances, have been seen in Africa as a function of temperature, humidity, and sunshine variations (Workie and Debella 2017). Variations in plant leaf development, blossoming, and blooming, as well as changes in animal spawning, reproduction, and migratory periods, are examples of phenological occurrences (Whiteside and Ward 2011; Burrows et al. 2011). Extreme weather has a more nuanced impact on biodiversity. Elephants (*Loxodonta africana*) reproduce all year in Africa, with powerful males mating in the rainy season and inferior males mating in the dry. Changes in the severity or duration of rainy and dry seasons may have an impact on relative breeding rates and, as a result, genetic patterns in these populations (Butchart et al. 2010) Longer growing seasons would entail higher crop production expenses because food crop farming is Africa's most significant agricultural business. Many formerly vulnerable species are projected to experience an increased risk of population loss and extinction due to the time it takes for many species to adjust to climate change (Thomas et al. 2004). While the influence of environmental issues on the possibility of extinction is still debated, environmentalists are particularly concerned about this effect (de Coninck and Puig 2015). Outside of nature conservation, there is rising worry about climate change's possible negative consequences for biodiversity, which directly threaten biodiversity-based ecosystem services. Ecosystem "tipping points," in which ecosystem thresholds may result in ecosystem loss or permanent changes, as well as a catastrophic disaster, are a major cause of concern.

Climate Change, Biodiversity, and Ecosystem Services

Climate changes, natural resource conservation, and environmental productivity, biodiversity is the broad range of goods and services that people can obtain from the nature (Sahoo and Wani 2020; Sahoo et al. 2021; Brown et al. 2018a, b). Because of environmental resources, at least 40% of the globalised trade and 80% of the GDP of emerging regions comes directly from biological capital. Reduced or declining biodiversity in any component that does not already contribute to habitat conjugation would have a major influence on the perceived importance of ecological services (Bommarco et al. 2018).

Feedbacks to Climate

Without natural ecosystems, the carbon cycle is incomplete. The consequences of climate change on natural ecosystems can have large positive feedback effects on the temperature system, and weather patterns and habitat have a nonlinear connection (Sharma and Mishra 2011). According to the IPCC, land use change accounts for 20% of total anthropogenic emissions, a proportion that may rise as a result of climate change. This linkage is not typically included in climate models, but it is a burgeoning subject of study, particularly in light of the IPCC 4AR's concerns about ecosystems' ability to withstand global warming. Increased soil respiration when temperatures rise, particularly in the arctic (IPCC 2013), will be substantial feedback to the climate system, perhaps adding 200 ppm CO_2 to the atmosphere by 2100. Even though the precise dynamics are unknown, according to new study, the two principal soil carbon storage mechanisms have positive feedback, permafrost and peatland, which may be significant (Gusli et al. 2020). Permafrost warming emissions, for example, have been projected to vary from a worldwide increase of lOOPgC by 2100 to a rise of 40–100 Pg from Canada and Alaska alone by 2100 (FAO 2020). A 10% warming of Siberian permafrost is expected to release 40 Pg by 2050, an increase that will not be reduced by the projected advance of the treeline into the tundra. Changes in natural systems brought on by the demise of soil invertebrates in low-diversity environments can also affect carbon flows (IUCN 2016).

Peat emissions are linked to the state of the water table, which is extremely vulnerable to climate change (Brown et al. 2018a, b). Moreover, according to an experimental research, climate change will alter peat diversity and abundance, with photosynthetic organisms predominating at the expense of peat generating species, lowering peat's carbon storage potential (Dhyani et al. 2020). Such feedbacks can be generated by a number of causes other than rising temperatures. One subject that has gotten little consideration in the literature is the potential effects of sea level rise.

Sustainable Biodiversity Management in the Face of Climate Impacts

The Next Steps

An essential first step was the establishment of the Ad Hoc Technical Expert Group (AHTEG) on Biodiversity and Climate Change-A COP proposal. Its mandate suggests ways to improve the combination of biodiversity concerns and ancient and local biodiversity-related data, with explicit relevance for communities and sectors affected by climate change, to recognise opportunities and potential detrimental effects on biodiversity, sustainability, and long-term usage, as well as communities for biodiversity conservation and sustainable use (Butchart et al. 2010; Barnosky et al. 2011).

Climate Change's Effects on Livelihoods and Resilience Measures

Adaptation Approaches

In the non-agricultural sector, events as well as the implementation of farming methods and technology, the questioned families indicated a variety of adaptation strategies (Abebe et al. 2013). The variations in agricultural methods used show that, in terms of both the quantity and types of practices employed, geography has a major influence in climate (and climate change) variation in nations. However, despite considerable variations in overall earnings availability, there was no difference in agricultural practices adoption depending on wealth group (FAO 2020). The most prevalent non-agricultural method was off-farm employment, with one or more family members working off-farm in 57.7% of the families questioned. Off-farm activities was the strongest in the centre area due to stronger monetary implications. Other non-agricultural occupations were tolerated to varying degrees depending on region and income level (Inder et al. 2018). Certain families chose to lease out sections of their property, either due to a lack of labour and interest in farming, or because some plots were too far away from their farm. Household members from the central region are more likely to relocate to urban areas, particularly those who are younger and more educated. Low-income households were also much more likely to migrate to cities. While migration is an essential adaptive technique. The most vulnerable individuals of society may lack the power to flee deteriorating conditions and instead opt to remain put (Gusli et al. 2020). These populations are referred to be "stuck" and "vulnerable" in two ways. The usage of both organic and mineral fertilisers, which was embraced by 94.9% of the families in this research, is particularly noteworthy. Increased fertilisation is clearly one of