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Current State and Future Impacts of Climate Change on Biodiversity

Ashok Kumar Rathoure and Pawan Bharati Chauhan

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Current State and Future Impacts of Climate Change on Biodiversity

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Some natural and some artificial activities are responsible for global warming, which is not only affecting the environment but also humans at an alarming rate. The effects of global warming are seen in growing biodiversity. There are many greenhouse gases, which form a thin layer in the atmosphere making the Earth's surface warmer day by day. The presence of carbon dioxide, methane, nitrous oxide, and water vapors are responsible for global warming. Global warming behaves like greenhouse in which a glass chamber is incorporated that allows the sunrays to pass inside the chamber but does not allow reflecting back from the glass. Due to this, the inside temperature of the chamber becomes hotter in comparison to the outside temperature. The maintenance of the temperature inside the chamber helps plant growth.

Two terms that are enjoying increasing overwhelming global literature advocacy and discussion are urban farming and climate change. While there is increasing advocacy towards the relevance of urban agriculture for urban dwellers and how it translates into a mitigation strategy against climate change variability and adaptation to urban poverty, the effect of some urban farming activities and how it serves as a driver to climate change needs to be investigated. In most of the urban periphery where there is availability of a large expanse of land areas, farming activities are usually practised in form of settlement farm, livestock rearing, or plantation agriculture. The study based on quantitative and qualitative data from urban farmers in Ibadan argues that the location of urban farmlands is dependent on climatic factor such as access to land. The study identified that climate variability as reported by the urban farmers has resulted in the increased use of fertilizer for farming by urban farmers, and the main activity that is pro-climate change and variability is bush burning.

This chapter aims to analyze the implications that urban sustainability, socio-ecosystems, and ecosystem services have as the bases to design the urban green growth strategies. The method used is the analytic based on the theoretical and conceptual literature reviews on the topics described. Urban sustainability and environmental performance integrates biodiversity and socio-ecosystems for the provision of better quality ecosystem services supported by green infrastructure design into the green projects aimed to achieve economic and environmental benefits. It is concluded that the ecosystem services and human well-being may suffer irreversible severe declines if sustainability is not built based on biodiversity of socio ecosystems, green infrastructure, and natural capital.

With climate change and the massive extinction of biodiversity, this chapter seeks to address the ecological and economic significance of bryophytes. The objective of this chapter is to contribute to the general knowledge of this plant group to spur research and interest in conservation efforts. Ecologically, this chapter x-rays their habit, habitat, distribution, ecophysiology, and reproduction. Bryophytes terrestrialization begun several millions of years ago but is currently threatened by climate change and poor conservation efforts. Economically, this chapter highlights the multifarious uses and applications of bryophytes with a view to promoting diversification, sustainable utilization, and innovative application.

Many studies in recent years have investigated the effects of climate change on the future of biodiversity. In this chapter, the authors first examined the different possible effects of climate change that can operate at individual, population, species, community, ecosystem, notably showing that species can respond to climate challenges by shifting their climatic change. Climate change is one of the most important global environmental challenges that affect all the natural ecosystems of the world. Due to the fragile environment, mountain ecosystems are the most vulnerable to the impact of climate change. Climatic change will affect vegetation, humans, animals, and ecosystem that will impact on biodiversity. Mountains have been recognized as important ecosystems by the Convention on Biological Diversity. Climate change will not only threaten the biodiversity, but also affect the socio-economic condition of the indigenous people of the state. Various activities like habitat loss, deforestation, and exploitation amplify the impact of climate change on biodiversity.

Wetlands show a diversity of appearances like salt marshes, tidal wetlands, inland freshwater wetlands, riparian wetlands, peat lands, and many other types. Each of the types host diverse biotic communities of flora and fauna. This biodiversity changes according to the physical and chemical properties of wetlands, climate, and the geological location. This biodiversity regulates the local ecosystem, carbon sequestration, fuelwood supply, fishery-based industries, and on many other ecological and socioeconomic aspects. In addition, the wetlands have other ecological aspects like maintaining freshwater quality by sedimentation, nutrient conservation, etc. However, around the world, the wetlands are subjected to several types of threats like both anthropogenic and natural. This study is a short review work on some of the outcomes of the studies of researchers around the world to see the importance of different types of wetlands, the threats to them by anthropogenic or natural causes, and focus areas for management strategy development.

Home garden is a complex multi-functional land use system that combines multiple farming components of the homestead and provides environmental services, household needs, and employment and income generation opportunities to the households. Predicted climate changes have serious implications for crop and livestock yields particularly in tropical regions. Home garden may act as a cushion to the adverse climate shocks. There is dearth of in-depth study of home garden ecosystem in India. The authors have selected 100 households in Garhbeta-1 block, which is in the dry zone in the district of Paschim Medinipur in West Bengal, India for the study. The main objectives of the chapter include (1) identification of the key characteristics of the home garden, (2) assessing biodiversity in home gardens, (3) identifying the pattern of climate change from the household perceptions and the problems in home garden, and (4) the changes made in the home gardens.

Gynocardia odorata R. Br (Achariaceae) is an important medicinal plant. It is indigenous to Indian subcontinent and grows extensively in the tropical forests of Western Ghats and Hilly regions of North Eastern India. The plant has long been used in the traditional system of medicine to treat various cutaneous and subcutaneous diseases. The chapter deals with the different scientific studies and reports available in different aspects of this plant in the areas like morpho-taxonomy, ethnobotany, phytochemistry, and pharmacognosy.

Wetland conservation is aimed at protecting and preserving areas where water exists (e.g., swamps, marshes, blogs, etc.). These wetlands make up 6% of the Earth's surface. Freshwater wetlands are utilised for cultivation of paddy, for basic water needs, for fishing, as a source of food by habitat loss, one main reason being anthropogenic activities. Wetland ecosystems are a home to birds and aquatic fauna. They are the breeding and nursing grounds for these species. They are the most productive ecosystem on Earth. Apart from this, wetlands are important as they reduce the impact of floods, control pollution, and also regulate climate. On our planet, there are regions that have large number of endemic species. Most of these are heavily threatened biodiversity hotspots. Thirty-five such regions have been identified in the world. Conservation strategies need to be framed and implemented in a very effective way and with no further wastage of time before the wetlands and hotspots disappear completely.

Uttarakhand has a rich tradition to conserve its immense array of biological and cultural diversity. An annotated checklist on butterfly diversity and distribution across protected areas of state Uttarakhand is provided here which is a culmination of published literature over a period of the last 38 years (1981-2018). The list comprises 393 butterfly species under 188 genera and six families. The local status was also assigned to the compiled species of butterflies after critical review of referred literature, wherein 22.70% of the total species were found 'rare' while 41 species of butterflies are entirely lacking published record from the last many decades. A total of 51 species compiled in the present checklist, which was reported based on its presence or absence unique and rare to a particular protected area, are the species of concern as they might face extinction through slight alterations in their habitats.

In the present study, the authors have elaborated a case study for the biodiversity assessment for Asian Highway 48 (Chainage 84.775 km to 87.690 km) passing through Jaldapara National Park located in Alipurdwar District of West Bengal state of India. The objectives of the study were to assess the biological diversity within the specified area (1.65 km2) to establish the baseline status of floral and faunal species. Here, we have covered flora and fauna for the assessment as well as quantitative study covering frequency, density, dominance, IVI, Shannon Wiener Index, variance, etc. The area is ecologically sensitive as endangered species were observed; animals like elephants used to cross the road very frequently. Therefore, it is strongly recommended to prepare the conservation plan for elephants and other REET species in the Jaldapara National Park to conserve the endangered species in situ.

Biodiversity sustains human livelihoods and life itself. An estimated 40% of the global economy is based on biological products and processes. As the biodiversity harbours a great amount of diversity with respect to species diversity, crop diversity, etc., which provides a rich amount of a well-evolved systems over time and background support for rich resources, the mining is a destructive activity generated by human beings for providing strength and security to their living standards. The mining in the concerned zones provides raw materials in the form of crusher, gravels and stones, etc. for construction of roads, railway lines, and other infrastructure. It results in the loss of biodiversity of both flora and fauna and physiographic features of the concerned region. After the mining operation in any area is over, the sign of same lie for decades and maybe forever. It results in creation of so many environment-related problems and health hazards. Mining poses serious and highly specific threats to biodiversity.

Rapid urbanization, population explosion, and developing technology have degraded natural habitat of flora and fauna. They can't get proper natural habitat and environment. Because of these reasons, they can't survive. They are in danger. We have to save them. If we can't save them, our whole ecological cycle will be disturbed, and it will create problems for us. So, we have to find reasons for extinction of flora and fauna. For that, it is necessary to do biological survey/assessment. From biological survey/assessment we can find/assess what type of impact are harmful for flora-fauna, how it will affect flora-fauna, what is the reason behind extinction of flora-fauna. From biodiversity survey we can provide and create natural habitat for flora-fauna. So, impact assessment is very important consideration. Every industry/plant or any type of activity should do biodiversity survey. This chapter explores a survey methodology for biodiversity assessment.

Methods for surveying and monitoring fauna will depend on the types of fauna that the study is looking for. Animal diversity assessment goal is the conservation of animals and their interaction between biodiversity. Assessment also includes their habitat and taking actions to conserve the faunal species. Animal diversity includes vertebrate animals and invertebrate animals. Faunal diversity includes odonate (predators), coleoptera, hymenoptera (pollinators), herpetofauna, avifauna, fish, mammals, and butterflies. Animal diversity assessment describes their food, habitat, ecology, and their population. Animal diversity

Foreword

Much of the gaps that existed in the field of climate and loss of biodiversity have been covered substantially through the assessment carried out by the Intergovernmental Panel on Climate Change (IPCC) and more recently by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). Yet the area covered under these two subjects requires much further study and research and more widespread dissemination of information so that the public is made aware not only of projections on climate change but also how these have been impacting on loss of biodiversity and how they are likely to cause substantial damage to ecosystems and the services they provide to all living species in the future.

Even from the point of view of economic activities carried out by human society, the depletion and degradation of biodiversity resources can have serious impacts which not only affect economic productivity but also human health. It is, therefore, important to not only focus on the ecosystems such as wetlands, which urbanization and expansion of human habitat have destroyed in several parts of the world, reducing the vital services they provide, but also in respect of species such as butterflies and bees which have a major impact on agricultural output.

It is indeed, commendable that a group of researchers should publish a product spanning the areas of climate change and its impacts on biodiversity. In this age of narrow specialization, we often lose sight of the larger picture and the integrated nature of human and ecological systems which are crucial for the sustainability of the species. Hence, every publication that deals with such issues with rigour needs to be commended.

R. K. Pachauri
Independent Researcher, India

Preface

Biodiversity and biodiversity-based ecosystems services are intrinsically dependent on the climate. During the twentieth century, climate change has posed major threats to biodiversity in Africa, and impacts are expected to increase as climate change continues and perhaps even accelerates. The potential adverse effects of climate change have posed serious threat to all species of the planet in many ways. Species' functional characteristics strongly influence ecosystem properties. Although significant numbers of studies have already explored the interrelationship between biodiversity, ecosystem services and climate change more focused studies have now begun to appear with the goal of investigating and analysing the negative consequences of climate change on life support systems. In order to distinguish the need and best practices for adaptation and mitigation, both global and location-specific research and evaluation activities are required, *e.g.* projecting current and future climate change impacts, assessing vulnerabilities including climate-related hazards for effective decisions for climate risk management, evaluating resilience and adaptive capacity and evaluating current and future adaptation and mitigation activities, including possible new opportunities that may arise from climate change. Increasingly, governments, institutions and businesses are taking steps to try and achieve sustainable development, in that they are developing responses to mitigate and adapt to the threats and opportunities of climate change.

Marine ecosystems are of huge importance to the biology of the planet because they are among the largest of earth's aquatic ecosystems and play significant role for the overall health of both marine and terrestrial environments. Also, marine ecosystems usually have a large biodiversity and are therefore thought to have a good resistance against invasive species. The changing climate however is having a major adverse impact on marine ecosystems. Given their global importance, coastal marine environments are a major focus of concern regarding the potential impacts of anthropogenic climate change. Global climate change has attracted much scientific and public attention in recent years. Intergovernmental Panel on Climate Change (IPCC) defines climate change as one of the most important factors affecting disaster risk.

Biological responses to climate change vary widely among species and populations; some responses are positive, leading to increased growth rates or range expansions, while others are negative, resulting in localized or widespread declines. Many species have already shifted their geographical ranges, generally poleward, towards higher elevations, or to deeper depths in marine environments. Species have altered the temporal patterns of seasonal migrations and other life cycle events (phenology), showed changes in population demographics or in some cases are adapting in place to the new environmental conditions. These shifts will likely bring about new assemblages of species, cause novel interspecific interactions and in worst case scenarios result in some extinctions. The International Union for Conservation of Nature (IUCN) Red List of Threatened Species provides one of the most comprehensive evaluations of the conservation status of global populations of plants and animals. Of the 4,161 terrestrial and aquatic species currently recognized by the IUCN as being threatened by climate change, 33 percent are at risk from habitat shifts and alteration due to climate change, 29 percent due to temperature extremes, and 28 percent due to drought. Evaluating species at risk due to climate change is a relatively new effort by the IUCN, and as is true for other assessments, it is difficult to disentangle the impacts of climate change from other anthropogenic stressors for a range of species. Consequently, evaluations may provide insight into the relative distribution of climate threats to global biodiversity, but may not fully capture the cumulative impacts and synergistic interactions with other anthropogenic stressors.

Climate change is causing many species to shift their geographical ranges, distributions and phenologies at faster rates than were previously thought; however, these rates are not uniform across species. Increasing evidence suggests that range shifts and novel climates will result in new community assemblages, new associations among species and promote interactions that have not existed in the past.

ORGANIZATION OF THE BOOK

Current State and Future Impacts of Climate Change on Biodiversity is a pivotal reference source that provides vital research on biological systems and how climate change influences their lives. The book is organized into 15 chapters. A brief description of each of the chapters follows:

Chapter 1 present the current scenario of global warming and biodiversity. In present scenario, some natural and some artificial activities are responsible for global warming which is not only affecting the environment but also the human creatures at alarming rate. The effects of global warming are seen in growing biodiversity. There are many greenhouse gases which forms the thin layer in the atmosphere making the earth's surface warmer day by day. The presence of carbon dioxide, methane, nitrous oxide and water vapors are responsible for the global warming. Global warming behaves like greenhouse in which a glass chamber is incorporated which allows the sun rays to pass inside the chamber but does not allow reflecting back from the glass. Due to which inside temperature of the chamber becomes hotter in comparison to the outside temperature. The maintenance of the temperature inside the chamber helps plants for their growth.

Chapter 2 representing the climate variability and urban agricultural activities in Ibadan, Nigeria. Two terms that are enjoying increasing over-whelming global literature advocacy and discussion are urban farming and climate change. While there is increasing advocacy towards the relevance of urban agriculture for urban dwellers and how it translates into a mitigation strategy against climate change variability and adaptation to urban poverty the effect of some urban farming activities and how it serves a driver to climate change needs to be investigated. In most of the urban periphery where there is availability of a large expanse of land areas, farming activities are usually practiced in form of settlement farm, livestock rearing or plantation agriculture. The study based on quantitative and qualitative data from urban farmers in Ibadan argues that the location of urban farmlands is dependent on climatic factor such as access to land. The study identified that climate variability as reported by the urban farmers has resulted into the increased use of fertilizer for farming by urban farmers and the main activity that is pro-climate change and variability is bush burning.

Chapter 3 presents Implications of urban sustainability, socio-ecosystems and ecosystem services. This chapter aims to analyze the implications that urban sustainability, socio-ecosystems and ecosystem services have as the bases to design the urban green growth strategies. The method used is the analytic based on the theoretical and conceptual literature reviews on the topics described. Urban sustainability and environmental performance integrate biodiversity and socio-ecosystems for the provision of better-quality ecosystem services supported by green infrastructure design into the green projects aimed to achieve economic and environmental benefits. It is concluded that the ecosystem services and human well-being may suffer irreversible severe declines if sustainability is not built based on biodiversity of socio ecosystems, green infrastructure and natural capital.

Chapter 4 shows the ecological and economic significance of bryophytes. With climate change and the massive extinction of biodiversity, this chapter seeks to address the ecological and economic significance of bryophytes. The objective of this chapter is to contribute to the general knowledge of this plant group to spur research and interest's conservation efforts. Ecologically, this chapter x-rays their habit, habitat, distribution, ecophysiology, and reproduction. Bryophytes terrestrialization begun several millions of years ago but are currently threatened by climate change and poor conservation effort. Economically, this chapter highlights the multifarious uses and applications of bryophytes with a view to promoting diversification, sustainable utilization, and innovative application.

Chapter 5 is speaking about climate conditions and biodiversity decline. Many studies in recent years have investigated the effects of climate change on the future of biodiversity. In this chapter, we first examine the different possible effects of climate change that can operate at individual, population, species, community, ecosystem, notably showing that species can respond to climate challenges by shifting their climatic change. Climate change is one of the most important global environmental challenges that affect all the natural ecosystems of the world. Due to the fragile environment, mountain ecosystems are the most vulnerable to the impact of climate change. Climatic change will affect vegetation, humans, animals and ecosystem that will impact on biodiversity. Mountains have been recognized as important ecosystems by the Convention on Biological Diversity. Climate change will not only threaten the biodiversity, but also affect the socio-economic condition of the indigenous people of the state. Various activities like habitat loss, deforestation and over exploitation amplify the impact of climate change on biodiversity.

Chapter 6 present the reviews on ecological and economic importance of wetlands and their vulnerability. Wetlands show a diversity of appearances like salt marshes, tidal wetlands, inland freshwater wetland, riparian wetlands, peat lands and many other types. Each of the types hosts diverse biotic communities of flora and fauna. This biodiversity changes according to the physical and chemical properties of wetlands, climate and the geological location. This biodiversity regulates the local ecosystem, carbon sequestration, fuelwood supply, fishery-based industries and on many other ecological and socioeconomic aspects. Besides the wetlands have other ecological aspects like maintaining freshwater quality by sedimentation, nutrient conservation etc. However, around the world the wetlands are subjected to several types of threats like- both anthropogenic and natural.

Chapter 7 illustrates the Biodiversity and Impacts of Climate Change in Home Gardens – Evidences from a Study in West Bengal, India. Home Garden is a complex sustainable land use system that combines multiple farming components of the homestead and provides environmental services, household needs, and employment and income generation opportunities to the households. Predicted climate changes have serious implications for crop and livestock yields particularly in tropical regions. Home garden may act as a cushion to the adverse climate shocks. There is dearth of in-depth study of home garden ecosystem in India. We have selected 100 households in Garhbeta-1 block, which is in the dry zone in the district of Paschim Medinipur in West Bengal, India for our study.

Chapter 8 is about *Gynocardia odorata* R. Br., a potent medicinal plant of Assam. *Gynocardia odorata* R. Br (Achariaceae) is an important medicinal plant. It is indigenous to Indian subcontinent and grows extensively in the tropical forests of Western Ghats and Hilly regions of North Eastern India. The plant has long been used in the traditional system of medicine to treat various cutaneous and subcutaneous diseases. The present review deals with the different scientific studies and reports available in different aspects of this plant in the areas like Morpho-taxonomy, Ethnobotany, Phytochemistry and Pharmacognosy.

Chapter 9 presents the wetland and biodiversity hotspot conservation. Wetland conservation is aimed at protecting and preserving areas where water exists, e.g. swamps, marshes, blogs, etc. these wetlands make up 6% of the earth's surface. Freshwater wetlands are utilized for cultivation of paddy, for basic water needs, for fishing, as a source of food by habitat loss, one main reason being anthropogenic activities. Wetland ecosystems are a home to birds and aquatic fauna. They are the breeding and nursing grounds for these species. They are the most productive ecosystem on earth. Apart from this, wetlands are important as they reduce the impact of floods, control pollution and also regulate climate. On our planet, there are regions that have large number of endemic species. Most of these are heavily threatened biodiversity hotspots. Thirty-five such regions have been identified in the world. Conservation strategies need to be framed and implemented in a very effective way and with no further wastage of time before the wetlands and hotspots disappear completely.

In Chapter 10, the authors have presented an insight into the butterflies (Lepidoptera, Papilionoidea) associated with protected area network of Uttarakhand, Western Himalaya. Uttarakhand has a rich tradition to conserve its immense array of biological and cultural diversity. An annotated checklist on butterfly diversity and distribution across protected areas of state Uttarakhand is provided here which is a culmination of published literature over a period of last 38 years (1981-2018). The list comprises 393 butterfly species under 188 genera and six families. The local status was also assigned to the compiled species of butterflies after critical review of referred literature, wherein 22.70% of the total species were found 'rare' while 41 species of butterflies are entirely lacking published record from the last many decades, hence needs verification. A total of 51 species compiled in the present checklist which was reported based on its presence or absence unique and rare to a particular protected area, are the species of concern as they might face brink of extinction through slight alterations in their habitats.

Chapter 11 indicates the biodiversity assessment for Asian Highway – 48 (near Jaldapara National Park) from Bhutan to Bangladesh passing through India. A case study for the biodiversity assessment for Asian Highway - 48 (Chainage 84.775 km to 87.690 km) passing through Jaldapara National Park located in Alipurdwar District of West Bengal state of India has been presented. The objectives of the study were to assess the biological diversity within the specified area (1.65 km^2) to establish the baseline status of floral and faunal species. Here we have covered flora and fauna for the assessment as well as quantitative study covering frequency, density, dominance, IVI, Shannon Wiener Index, variance, etc. The area is ecologically sensitive as endangered species were observed, the animal like elephants used to cross the road very frequently.

Chapter 12 is about the sand mining and biodiversity decline with reference to rajasthan area. Biodiversity sustains human livelihoods and life itself. An estimated 40% of the global economy is based on biological products and processes. As the biodiversity harbours a great amount of diversity with respect to species diversity, crop diversity, etc. which provides a rich amount of a well evolved system over time background support for rich resources. The mining is a destructive activity generated by human being for providing strength and security to his living standard. The mining in the concerned zones provides raw materials in the form of crusher, gravels and stones, etc. for construction of roads, railway lines and other infrastructures. It results in the loss of biodiversity of both flora and fauna and physiographic features of the concerned region. After the mining operation in any area is over, the sign of same lie for decades and may be forever. It results in creation of so many environment related problems and health hazards. Mining poses serious and highly specific threats to biodiversity.

Chapter 13 presents the overview on survey methodology for biodiversity assessment. Day by day, due to rapid urbanization, population explosion and developing technology leads to degrade natural habitat of Flora and Fauna. They can't get proper natural habitat and environment. Because of these reasons, they can't survive. They are in danger. We have to save them. If we can't save them, our whole ecological cycle will be disturbed and it will create problems for us. So, from above reasons we have to find reasons for extinction of flora-fauna. For that, it is necessary to do biological survey/assessment. From biological survey/assessment we can find/assess what type of impact are harmful for flora-fauna, how will it affect flora-fauna, what is the reason behind extinction of flora-fauna. From biodiversity survey we can provide and create natural habitat for flora-fauna. So, impact assessment is very important consideration. Every industry/plant or any type of activity should do biodiversity survey.

Chapter 14 is speaking about techniques to assess animal diversity- faunal Assessment. Methods for surveying and monitoring fauna will depend on the types of fauna that the study is looking for. Animal diversity assessment goal is the conservation of animal and their interaction between biodiversity. Assessment also include their habitat and take actions against conserve the faunal species. Animal diversity include vertebrate animal and invertebrate animal. Faunal diversity includes Odonate (predators), coleoptera, Hymenoptera (Pollinators), herpetofauna, avifauna, fish, mammals and butterflies. Animal diversity assessment describe their food, habitat, ecology and their population. Animal diversity assessment technique describe impact of pollution on their environment.

Chapter 15 is about techniques to assess plant diversity: floral assessment. Understanding the unequal distribution of species diversity is one of the greatest challenges in ecology. Standardized sampling protocol for diversity assessment are there for essential to reflect diversity patterns across spatial scales and to compare the diversities of different ecosystems. Measurements of biodiversity at the level of species or inhabitants are directed towards the fulfillment of an index of the number of species and their relative abundances in a given landscape. Massive loss of valuable plant species in the past centuries and its adverse impact on environmental and socioeconomic values has caused the conservation of plant resources. Appropriate identification and characterization of plant materials is important for the successful conservation of plant resources and to ensure their sustainable use.

CONCLUSION

Our collective understanding of biodiversity and its importance to ecosystems and the services they provide is advancing across all scales of biological organization. While longstanding threats remain such as habitat conversion and loss, the impacts of climate change on biodiversity are evident and are likely to become increasingly significant in the future. Establishing and implementing climate adaptation planning will be critical to the success of resource management under uncertain future conditions. Vulnerability assessments are one tool that will assist adaptation planning; however, the rigor and application of the frameworks are still in the process of being developed and require further testing. Efforts that incorporate adaptive management principles into their practices should be closely monitored with an aim to inform and improve the effectiveness of future adaptation planning and response. Policies for protecting and managing biodiversity will also need to incorporate new flexibility to allow actions to be taken under uncertainty. Lastly, improved observation capabilities, more sophisticated data infrastructures and modeling platforms, as well as coordinated, landscape-level monitoring approaches will continue to be essential in improving climate change research.

Editors

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Editors

Chapter 1
Global Warming and Biodiversity

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ABSTRACT

Some natural and some artificial activities are responsible for global warming, which is not only affecting the environment but also humans at an alarming rate. The effects of global warming are seen in growing biodiversity. There are many greenhouse gases, which form a thin layer in the atmosphere making the Earth's surface warmer day by day. The presence of carbon dioxide, methane, nitrous oxide, and water vapors are responsible for global warming. Global warming behaves like greenhouse in which a glass chamber is incorporated that allows the sunrays to pass inside the chamber but does not allow reflecting back from the glass. Due to this, the inside temperature of the chamber becomes hotter in comparison to the outside temperature. The maintenance of the temperature inside the chamber helps plant growth.

INTRODUCTION

Since industrial revolution, as greenhouse gases are increasing at high rate, these gases are resulting in the increase in temperature of earth's atmosphere. In present scenario, increase in temperature is majorly due to human activities (Eichenlaub et al., 1990). It is mainly caused when there is increase in the carbon dioxide level, greenhouse gases when fossil fuels are burned as also due to deforestation. When these gases increase without any change in the other gases in the atmosphere will result in increase in

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temperature of the planet (Ahrens, 1995). There is increase in concentration of the atmospheric gases as recorded. The concentration of methane in the atmosphere is 149 per cent and the concentration of carbon dioxide is 31 per cent. During last few centuries there is a rapid increase in the temperature mainly due to the gases which evolve from industries. The results of increase in gases have shown increase in the sea level (Geiger et al., 1995). The long terms of global warming results in the melting up of polar ice with coastal flooding. This global warming also results in extinction of the species, increase in tropical storms, melting up of the snow, increase in the tropical disease. Global warming is also caused due to increase in carbon dioxide, nitrous oxide, methane level, deforestation, burning of wood, coal and petroleum.

The Earth's atmosphere is becoming warmer day by day as earth absorbs 76% of the solar energy which reaching to the earth. The gases in the atmosphere for e.g. Carbon dioxide, methane, ozone, chlorofluorocarbon and water vapours are known as greenhouse gases. These gases absorb heat by restricting heat to move away from earth, hence resulting in increase of the atmosphere temperature known as global warming (Kellogg, 1991).

There are many places on earth where the temperature is very low, for these types of places glass cover is used called as greenhouse to grow different flowers, fruits and vegetables. This greenhouse chamber allows the heat to cross the glass where it gets trapped inside the chamber and does not allow the heat and light to pass out the glass chamber making the internal environment hotter and suitable for the growth of the plants. In the similar way ozone layer is protecting the earth's atmosphere from the upcoming direct sun rays which are reaching the earth surface. It also protects the living beings from the direct ultraviolet rays falling on the earth's surface. Hence in the same way this full chamber is known as natural greenhouse effect as it maintains the temperature near the earth's surface and making the atmosphere warmer (Lindzen, 1990). In artificial greenhouse the sun light enter the glass, increases the temperature of the soil and atmosphere which helps in the growth of the plants, flowers, fruits and vegetables. When the soil and the atmosphere inside the chamber increases they in turn releases infrared radiations which in turn are partly absorbed inside the glass and partly gets reflected out from the glass. In the same way in the case of the earth's atmosphere carbon dioxide absorbs heat contributing to the global warming. Other gases which are also involved in the greenhouse effect are ozone, CFC's, methane and nitrous oxide (Michaels & Stooksbury, 1992). These gases are emitted naturally as well as through manmade activities. The use of the compounds releasing the greenhouses gases should be controlled otherwise the temperature of the atmosphere will reach to the urge of species extinction. The increase in the global temperature also results in the increase of the diseases like malaria, yellow fever and dengue.

In present scenario research is going on the reducing the global warming. Scientists are practicing techniques to reduce the gases which are responsible for the global warming. Climate can be defined as the change in the weather for long period of time. Climate is a type of change in weather pattern for certain period of time. The changes in the climate are also due to some human activities (Barnett et al., 2005). The natural cause of global warming is volcanic eruption, changes in the orbit of the earth around the sun. The artificial cause of the raise in the temperature is due to manmade activities like increase in the emission of the industrial pollutants and burning of fossil fuels, cutting and clearing of the forests (deforestation). Our atmosphere is having many gases, like water vapour, carbon dioxide; these gases are absorbed by the earth's surface. Short wave radiations are absorbed by the earth (Loevinsohn, 1994). Gases like carbon dioxide and water vapor gets absorbed in the surface. The emission of the gases is due to some human activities, which allows long wave radiations to get absorbed in the earth's surface. There some additional traces which are involved in the absorption of the harmful gases in the earth's surface. These additional traces are CFC (chlorofloro carbons), nitrous oxide, aerosols, methane, ozone, carbon dioxide, which increases the temperature of the atmosphere resulting in the global warming. The rise in carbon dioxide level is due to increases in the gases from the industries, and they also get emitted from the burning fossil fuels. The level of carbon dioxide is increasing rapidly in the present scenario (Flavin, 1989).

BACKGROUND

Svante Arrhenius, a Swedish scientist was the first one who claimed that global warming can be enhanced by the combustion of fossil fuel. He also drew a relation between atmospheric CO_2 and its role in increasing the temperature. However, if greenhouse effect was not there then our earth would have been so cold that it would have been unfit for survival of human being. Nitrous oxide, carbon di oxide and water vapours are the major contributors of global warming. In 1940s when infrared spectroscopy was discovered for measuring long wave radiation through which it was ultimately proved that increased amount of carbon di oxide results in higher absorption of infrared radiation (Flavin, 1989). As a matter of fact, the speculations that oceans absorb most of the radiation were still believed. Revelle also said that as the population of the world is doubling with every passing decade it also plays a major role in the increase of carbon di oxide emission. In the year 1997, Kyoto protocol was signed by President Bill Clinton, this concept emerged from UNFCCC that imposed ban of emission of GHGs. Another aspect of it was for reducing the emission of 41 greenhouse gases which were affecting the environment of earth (Ahrens, 1995).

CAUSES OF GLOBAL WARMING

Greenhouse gases places a crucial role in global warming. Most of the chemical compounds act as major greenhouse gases. These gases capture the solar radiation and do not allow them to pass through the atmosphere resulting in enhancing the temperature of earth, because of these phenomena the earth passes on the heat in the form of infrared radiations. These infrared radiations are invisible to human eyes. Out of the entire portion some of the infrared radiations pass back into the space (Araùjo et al., 2011). The greenhouse gases play a major role in capturing such radiations on the surface of earth. This phenomenon is known as Greenhouse effect. As a matter of fact, greenhouse effect plays a crucial role for the survival of biotic components of earth. However, if greenhouse effect is not there then the temperature of earth would elevate to about 60°F, thus the survival of life on earth would be very difficult. There are several greenhouse gases present in atmosphere which are produced as a result of several natural activities and manmade activities (Flavin, 1989). The name of major activities are:

1. Carbon dioxide (CO_2)
2. Methane (CH_4)
3. Nitrous oxide (N_2O)

Industrial Gases, including hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.

Apart from these greenhouse gases there are several other gases which make a protective layer over the surface of earth which prevents the incoming of harmful radiations on the surface of earth (Kroeker et al., 2011).

Our planet earth consists of several gases which cover it as a shield and prevents us from harmful radiations. If the proportion of these gases is maintained accurately then they are a boon for us but if the percentage of these gases goes out of proportion then they cause global warming which is a worldwide threat these days. The greenhouse gases like carbon di oxide, nitrous oxide *etc.* absorbs such radiations which ultimately cause a high in temperature of earth. The gases which absorb the solar radiations are referred as the greenhouse gases (Daly, 2000). Some of the most common greenhouse gases are:

1. Ozone (O_3)
2. Methane (CH_4)
3. Nitrous oxide (N_2O)
4. Water vapor (H_2O)
5. Carbon dioxide (CO_2)
6. Chlorofluorocarbons (CFCs)

Let us individually discuss about the causative agents and the adverse effects of such greenhouse gases:

- **Water Vapor:** Water vapor are made as a result of precipitation, it is one of the major contributors in enhancing the temperature of earth. It increases the temperature of earth by increasing the humidity, clouds as well as amount of precipitation. In many ways it acts as a feedback mechanism for the greenhouse effect (Karl, 1998).
- **Carbon Dioxide**: Another very prominent contributor of the greenhouse effect is CO_2 it is released by several natural as well as artificial processes as well. Natural processes like respiration, volcanic eruptions majorly contribute in increasing carbon di oxide production on the other hand man made processes like power plants, deforestation and burning of fossil fuels increases the level of its release into the atmosphere (Carpenter et al., 2009).
- **Methane**: It is released in minute amounts but undoubtedly possess an immense threat to the environment. It is emitted inside the atmosphere both by natural sources as well as manmade causes. Some of the factors which plays a crucial role in methane emission are decomposition of trash, agricultural practices, rice cultivation. It has a larger tendency to absorb the atmospheric gases (Karl, 1998).
- **Nitrous Oxide**: However, besides methane nitrous oxide is also a major greenhouse gas it is produced by soil cultivation in which it is largely produced by organic fertilizers and pesticides. Biomass burning also underwrites for its upsurge in atmosphere.
- **Chlorofluorocarbons (CFCs):** Well it is the most famous gas in increasing the greenhouse effect, it is purely of industrial origin and is used in almost all the equipment's and gadgets. Many countries came together and signed a treaty stating that it majorly causes ozone depletion thus needs to be controlled (Biggs et al., 2008).

EFFECTS OF GLOBAL WARMING

Green House Effect

Greenhouse effect is generally seen in colder and in hilly regions, where plants do not get full sunlight and temperature for their growth. In these region a chamber made up glass is incorporated in which these plants are kept, the sunlight falling on the glass allows the rays to pass inside the glass but does not allow the light to pass out from the glass, hence making the inner environment warmer for the growth of fruits, vegetables and flowers. The temperature inside the chamber or the glass is always higher than the outside temperature. This is known as greenhouse effect (Harries et al., 2001). Our solar system is having many planets, in which few planets are cold and some are hot. Earth is the only planet where life is possible because of certain conditions which support the life. This is due to the thin layer formed of greenhouse gases like nitrous oxide, methane, carbon dioxide and water vapor. These gases form the atmosphere which acts like a glass same as in the greenhouse. The atmosphere allows sun's rays to fall inside the atmosphere or the thin layer but does not the reflection of the rays from the earth. The rays passing inside the atmosphere get absorbed hence warming up the earth's surface. From 18th century, the concentrations of the gases which are present in the atmosphere are increasing at rapid rate. The carbon dioxide has the concentration of about 50%. The increase in the concentration is due to the result of human activities which raises the temperature of the earth's atmosphere making it warmer same as in the case of the greenhouse effect. The artificial increase of the greenhouse gases leads to greenhouse effect which changes the temperature of the earth's surface leading to global warming.

Earth basically enjoys the atmosphere as it is having steady temperature. Present researches have proved that human activities have destroyed approximately 91% of the atmosphere in very drastic manner which has resulted into global warming.

Climate Change

In present era, as compared to past years the temperature of the earth is increasing at rapid rate which is also known as global warming (Jones et al., 2003). The change in the temperature will result in global warming which will have bad impacts in the future for all living beings (Alo & Wang, 2008). The effect of global warming is mainly seen in the rise in ocean and sea levels (Dasgupta et al., 2007). The melting of ice and glaciers results in the raising of the water level, this effect reduces fresh water supply. Other effects of global warming are changes in weather condition both natural and manmade; this also affects the ocean resulting in acidification (Wei et al., 2009).

The Rise of Sea Level

The effect of global warming is also seen in the level of sea and oceans. The melting up of the atlantic zone, ice caps and glaciers due to global warming results in increase of the sea and ocean level which may show an outcome of disasters like tsunami (Creffier, 2007). The rise in sea level results in the economic impacts with low-lying coastal areas causing soil erosion (Raper & Braithwaite, 2006).

Agricultural Impact

The effect of global warming is also seen in the case of agriculture. As the level of carbon dioxide increases in the atmosphere, the growth of the crops increases twice the level of the normal growth. The change in the climatic conditions may result in the increase of the crop production at the faster rate (Challinor et al., 2010).

PREVENTION OF GLOBAL WARMING

Global warming is the root cause for the rise in temperature as well as in climate changes. Global warming starts when sunlight reaches the earth. The clouds, and reflective ground surface sends back the few radiations back, absorbing the remaining radiations. Oceans, land and air are involved in the absorbance of the sunlight (Woodward et al., 2004). The continuous heating up of the atmosphere making the life more feasible. Earth surface becomes warmer; the solar energy is radiated by infrared radiations and gets propagated outside the earth, making the earth's environment cold. However, there are some moving out radiations gets re- absorbed by methane, ozone, water vapors, carbon dioxide which is radiated back to the earth's surface making the atmosphere warmer. These gases are known as greenhouse gases because these gases have the power to trap the heat energy. The trapping up of the heat energy is also necessary because without the absorption of the energy the surface of the earth would so cold that life is not possible to exist (Lippsett, 2005). The quandary starts with the concentration of the greenhouse gases which are artificially increased by the human activities rapidly. It is been observed that greenhouse gases are hindered by human activities enhancing global warming effect (Perkins, 2007). Methane gas is produced by the landfills and decomposition of the agriculture biomass and animal manure. Nitrous oxide is released through many nitrogenous compounds like fertilizers which includes diammonium phosphate, urea. These gases when enters the ecosystem remains in the atmosphere for years and decades (Carpenter et al., 2009). Global warming can be controlled by some of the human activities which are as follows:

1. Regular incandescent light bulbs can be replaced by the compact fluorescent light bulbs.
2. Minimum use of fossil fuels.
3. Use of new technology vehicles, producing less pollution.
4. Use of solar energy, which is renewable source of energy saving money and reducing carbon level in the environment.
5. Use of electronic gadgets should be minimum; lights should be turned off when not in use.
6. Planting more trees will help in reducing the carbon dioxide level. As plants will utilize the carbon dioxide during the process of photosynthesis, which is the main cause of global warming.

BIODIVERSITY

Biodiversity is the region in which living organism live in their respective niche. It was noticed earlier that due to increase in the global warming conditions the biodiversity will move towards loss resulting in anthropogenic stressors (Bellard et al., 2012). The role of the human being is to save the traces of the organism which are about to get extinct by controlling the activities which are responsible for their respective extinction (Willis et al., 2010).

Biodiversity basically deals with the structure and function of the ecosystem. The loss of any biodiversity will result in the impacts on the ecosystem persistence, function and services (Raxworthy et al., 2007). The foundation of the species deal with the trophic processes or by providing habitat forming, or by providing the availability of resources to the species. Such species which provide services to the humans in the form of food, flood protection and storm and also maintains the quality of the water. In many cases interactive role of the species will result in the system to predict how climate will respond to the change, finally affecting the benefits to the society support (Baldwin et al., 2010). The change in climate results in the impacts on multiple scales of biodiversity including the ecosystem, genes, species and community. The responses of the biological system will result in the change in the climate not also among species but also among the population. The changes seen are sometime positive to the environment and sometimes they are negative. Positive responses are increase in the growth rate or expansion in the growth range. Negative responses are declination of the species (Salafsky et al., 2008). There are many species that have shifted the geographical range, some of them have moved towards the pole and some of them went to the deeper depths in marine ecosystem. The changes in the climate have resulted in the shifting of the species from on part of the area to the other, resulting in change in demography. These shifts in the demography of the species have resulted in interspecific interactions resulting in the extinction of the species. Few examples of the climate- induced extinctions are change in the velocity and magnitude of the climate resulting in the changes in environmental conditions leading to the increase in the extinction level (Dawson et al., 2011).

Genetic variation in the ecosystem is seen through the changes in the environment resulting in the genetic diversity and traits showing short and long term time scales. As the rate in the global warming increase there is the change in the selection of the population that will survive in the new ecosystem and others will lead to the declination of the species in the new environmental conditions. Evolutionary changes are more predictable when genetic diversity is absent or when the alleles occur at very low frequency within the population. In the new changed environment genes arise from the mutation and shuffling of the gene. When there is increase in the change of the environmental conditions, at such a time population extinct at very fast rate before important genes have to change increasing the fitness in the population. The rate of increase in the evolution will be due to genetic variations in the differing changes in the environmental tolerances which exist in the population. Due to evolution and changes in the gene due to mutation results in the difficulty of the determination of phenotypic change in the genetic pool (Angelstam et al., 2004). It is very difficult to identify which gene is responsible for adapting the changes in the new environment. Therefore, it is very necessary to maintain the genetic diversity in the ecosystem to minimize the intended losses of the traits to enhance the survival of the population for adaptive evolution. The changes in the phenotype respond to the changes in the environment which is due to the adaptation, phenotypic plasticity or both. Phenotypic plasticity is not responsible for the rapid changes in the changes of the climate. The mechanism involved in biochemical adaptation results in the physiological responses. The changes in the physiological response results in the change in the molecular adaptation, membrane properties results in the fluctuation in the environment (Baillie et al., 2004). The physiological responses are very much limited in population, which results in the impacts in the fitness by increasing the demand in the energy by each individual. Ectotherms are very much sensitive to the changes in the environment due to change in the temperature, these changes effects metabolic rates. From different thermal environments, heat shock proteins get affected due to the raise in the environmental change (Bell & Gonzalez, 2009). Today studies have shown changes in the behavior of the organism, morphology, and other life history traits with changing conditions in the traits. The changes in the behavior, physiology and morphology of the organism results in the change in the characteristics of reproduction, change in the size and number of the offsprings, and the lifespan. The shifts in the temperature results in the availability of the food and indirectly links to the changes in the size of the body. For example, the female polar bear living in the arctic zone reproduce successively and was linked to the size of the body or body conditions with lower availability of optimal sea ice habitat (Biggs et al., 2008).

The responses related to the demography results directly or indirectly on the behavior. The organismal level results in the responses to the changes in the climate which affects the individual fitness and population dynamics which determines the viability of the species. The mate- swapping behavior is observed in increasing the genetic diversity among offspring under the survival conditions (Brook et al., 2008).

The shifting up of the species is due to the changes in the precipitation regimes and temperature. Generally, population moves towards the pole or towards the depths in the ocean to track the changes in the temperature. Increase in the temperature affects the food chain as well as the food web by increasing the consumption and growth rate. Increase in the temperature results in the consumption and interaction of the marine consumers. The poleward range results in the expansion of the lower altitude species strengthening of the predator *i.e.* top – down control.

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Chapter 2
Climate Variability and Urban Agricultural Activities in Ibadan, Nigeria

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ABSTRACT

Two terms that are enjoying increasing overwhelming global literature advocacy and discussion are urban farming and climate change. While there is increasing advocacy towards the relevance of urban agriculture for urban dwellers and how it translates into a mitigation strategy against climate change variability and adaptation to urban poverty, the effect of some urban farming activities and how it serves as a driver to climate change needs to be investigated. In most of the urban periphery where there is availability of a large expanse of land areas, farming activities are usually practised in form of settlement farm, livestock rearing, or plantation agriculture. The study based on quantitative and qualitative data from urban farmers in Ibadan argues that the location of urban farmlands is dependent on climatic factor such as access to land. The study identified that climate variability as reported by the urban farmers has resulted in the increased use of fertilizer for farming by urban farmers, and the main activity that is pro-climate change and variability is bush burning.

INTRODUCTION

The global evidence and effect of climate change is no longer hidden. Adhikari et al. (2015) reported that extreme climate conditions resulting in an increased global warming effect is not just a local phenomenon but rather a country-wide experience. The country-wide climatic experience was identified by Hartmann et al. (2013) who reported an increased and increasing global temperature. Hartmann et al. (2013) and Adhikari et al. (2015) identified that the global temperature has increased by 0.72°C which is still expected to increase to between 0.3°C and 0.7°C by 2023 with an increase of 0.3–4.8°C by the end of the 21st century. Niang et al. (2014) forecasted a 4°C Africa temperature by the end of the century.

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The findings of Barrios et al. (2010) argued that slow growth experienced in Africa can be traced to erratic rainfall pattern. Narrating the climate change effect in Africa, Henderson et al. (2017) reported that the diversity and dynamic nature of Africa climate has resulted in negative effect from diverse moisture conditions and a drier environment.

BACKGROUND

In Africa, Gonzalex-Sanchez et al. (2018) reported that the Intergovernmental Panel on Climate Change (IPCC) Africa temperature expected increase alert of between 2-6ºC within the next 100 years, which expected to result in rising average temperature and varying rainfall patterns which will birth incidences of aridity, drought, floods and subsequently a decline in food production. The effect on the changing and varying climate can be said to be multi-sectoral and multi-dynamic in nature. Its effect is felt in energy (Scott et al., 1994; Iwayemi, 2008; Oyedepo, 2012; Schaeffer et al., 2012), transportation accessibility, connectivity (Chapman, 2007; Amosun et al., 2012; Dillimono & Dickinson, 2015; Bakun et al., 2015; Metzler et al., 2019), health conditions (Popoola & Alli, 2015; Ryan et al., 2015) and food security status (Wahab & Popoola, 2018, 2019) of people and places.

Climate change as a stressor is expected to affect the quantity and quality of food produced across Africa (Connolly-Boutin & Smit, 2016). Henderson (2017) argues that the coming decades will be characterized by a decline in crop yield owing to the changing climate. Schroth et al. (2016) reported that in Nigeria, Togo, Guinea and Cote D'Ivoire, climate change has been a main identifier for the projected threat to the production of cocoa. Conway et al. (2015) states that the climate change experience in Southern Africa which has resulted in an expected 20% drop in precipitation is expected to result in shortages, reduced availability and crop yield. Thornton and Herrero (2015) reported that the threat of climate change in Africa's food system and livelihood security is a result of her heavy dependence on a rain-fed system of agriculture. In Cape Town South Africa, the water crisis is a result of drought and increasing aridity which has been traced to climatic driven environmental factors (Wolski, 2017; Fallon, 2018).

Mugambiwa & Dzomonda (2018) concluded that the threat from climate change can no longer be hidden as communities and people's livelihood sources and survival strategies are now questioned and faulted. Taiwo (2014) identified that limited capacity in forecast, mitigation and adaptation are major issue and challenge in Nigeria. He identified that wetland farming has been the result of urban farmers trying to cope with the declining precipitation and increasing aridity. He went further to put forward that with resilience dropping and the best adaptation technique not yet proffered, the capacity of urban farmers to respond to climate change adequately needs to be invested upon and further investigated. Forecasting the costing from climate change (heat). Parkes et al. (2019) projected that estimated energy costs to prevent climate heat-stress is predicated at $51bn by 2035 and $487bn by 2076 with the most noticeable cost expected to be in the densely populated area of Nigeria. In addition, Abraham & Fonta (2018) reported a 63% relationship between climate change exposure and farming finance. Their study further revealed that over 96% sourcing for financial inclusion and support was targeted at mitigating the effects of climate change on their farms which they perceive to be exposed to.

While adaptation and mitigation remains the two mechanism of response to climate change and variability adverse effects, the roles of some urban agricultural activities towards the changing climate remains to be investigated. Activities of man across the globe have limited the adaptation and mitigation against the perceived and evident effects of climate change. This study argues that these anthropogenic activities are likewise peculiar to urban farmers as it attempts to investigate some of the activities engaged upon by urban farmers and its perceived effects on the changing climate.

Borrowing the idea of the streetlight effect of climate change in Africa (Hendrix, 2017), rather than a subjectivity of generalization to space to only a few locations (countries), this study argues that the evolution, dynamics and understanding of climate change amongst urban farmers has been restricted to the effects on the farming system rather than the trigger effect of the urban farming activities on climate change. The guiding questions to this study are what are the farming activities engaged in by urban farmers and do these urban farming activities results into climate variability and change? The necessity for this was well established in the finding of Ayeni et al. (2016) that farming and farm related activities such as bush burning has an effect on landcover changes and this in its own results in varying and changing climatic conditions.

LITERATURE REVIEW: THINKING THROUGH AFRICA-NIGERIA EXPERIENCE OF CLIMATE CHANGE IMPACT ON AGRICULTURE

The exposure and susceptibility of developing countries to climate change has over the years been reported. The susceptibility of countries in this region has been attributed to their limited capacity to adapt and mitigate the climate change and variability effects. The response to the susceptibility of climate change is drawn from the knowledge of the changing climate. Although, Africa countries have been identified as the lowest contributor to climate change and global warming, the region represents the most susceptible to its negative outcomes. Ford et al. (2015) reported that the heavy reliance of a climate driven environment capacity is one factor that will continually expose African nations to climate change susceptibility. Focusing on adaptive capacity of Africa, they argued that African dependence is too climate sensitive and thus a little difference in climate related events exposes the African nations to climate change shock and stress.

The necessity for climate change adaptation is birthed from the climate change shock prediction of over a 50% drop in crop yields owing to the stress from a decline in water is predicted in Africa (IPCC, 2007). Abraham & Fonta (2018) reported that while farmers in Nigeria over the years adapted to climate change, the scale and cost of adaptive and resilient strategies has continually increased. Identifying the colossal limitations to the adaptation to climate change in Africa, Adenle et al. (2017) reported that "climate data, scenarios and impacts models are insufficient for supporting adaptation (particularly as they relate to food systems and rural livelihoods); the adaptation response to date has been limited, fragmented, divorced from the national planning processes, and with limited engagement with local expertise; adaptation policies and programs are too narrowly focused on explicit responses to climate change rather than responses to climate variability or broader development issues; and adaptation finance is insufficient, and procedures for accessing it present challenges to governments capacities". These adaptation limitations can be said to be politically driven, technically or institutionally, organizationally defined and socio-economically and biophysically dependent.

Speaking about the socio-economic features as a driver to the adaptation technique in Kenya, Roncoli et al. (2010) identified livelihood diversification and mixed and integrated farming as an adaptation technique. Adaptation experience in Nigeria as reported by Wahab & Popoola (2018) show that adaptive strategies used by urban farmers were mainly biophysically dependent. In their study, Wahab & Popoola (2018) mentioned that the adaptive techniques used includes planting of short-season crops, changing of planting dates, irrigation, planting of drought and flood-resistant crops, planting of cover crops and crop rotation. In the study of Taiwo (2014) six factors (proximity to water, proximity to residence, access to land, proximity to market, suitable fertile soils, and availability of labour) were identified to dictate urban agricultural location in Lagos, Nigeria. From the mentioned factors, two (proximity to water which results into wetland farming and suitable fertile soils) can be linked to changing climate. The relevance of location, cultural identity and affiliations, earlier perceptions and indigenous beliefs to climate variability and change response has been identified by (Wahab & Popoola, 2018; 2019). Climate change adaptation has been extensively discussed (Tucker et al., 2010; Badmos et al., 2017) over the years. Investigating climate change issue along the streetlight effect conceptual thinking of Hendrix (2017) is the approach in which this study is focused. About the streetlight effect of climate change in Africa, this study is aimed at investigating the effect of the identified urban farming activities by farmers in Ibadan with the aim to discussing that these activities can be seen as a major driver and a negative effect to climate change on urban agriculture. The study argues that rather than focus on the misconception to the understanding and perception of the negative effect of climate change (Grothmann & Patt, 2005), there can be an arguably twist of the add on activities such as extensive chemical fertilizer use, bush burning and over-grazing by urban farmers that continually trigger urban climate change and variability.

MATERIALS AND METHODOLOGY

This study made use of survey research design to examine the relationship between climate change and urban agricultural activities and location in Ibadan, Oyo State Nigeria. For the study, two types of data that were used in the study are obtained from both secondary and primary sources. A structure questionnaire was used as the main data capturing tool for primary data. The questionnaires gather information about farming activities, available land in hectares and factors that influence urban agriculture activities. Field observation and interviews were conducted for 12 urban farmers which were selected randomly across the urban LGAs amongst the previously identified farmers.

Secondary data on the population of farmers was obtained from Oyo State Agricultural Development Programme (OYSADEP) office Ibadan (Table 1). Other information was sourced from the internet, journals and text books. According to the sample frame obtained from Oyo State Agricultural Development Programme OYSADEP (2015) Ibadan, there are a total of 4073 registered farmers in Ibadan metropolis (Ibadan North, Ibadan North-East, Ibadan North-West, Ibadan South-East, and Ibadan South-West). Table 1 provides the number of farmers registered in each Local Government Area of Ibadan metropolis.

The sample size for this study was calculated by setting the margin for error at 6%, the confidence level at 94.2% and response distribution at 50%. After calculation, the sample size of 236 urban farmers were derived. The study further took into consideration the difficulty in locating the respondents, taking into consideration the "lowest cost approach" and the difficulty of applying a mathematical model in selecting the sampling size for the research focus, studies of Yusuf et al. (2008) who considered a sample of 230 farming households in Ibadan metropolis and Odewumi et al. (2013) that administered 145 questionnaires to urban farmers using a cluster sampling technique.

For this research there is a sample frame of 4073 farmers registered in Five Local Government Areas in Ibadan metropolis (Ibadan North, Ibadan North-East, Ibadan North-West, Ibadan South-East, and Ibadan South-West), which are distributed into 59 wards. A percentage number of 5.79% of the total sample frame is selected to represent the total population and serve as the sample size. The 5.79% sample

Table 1. List of the total number of registered farmers according to ward and local government area

LGA	Number Farmers Wards	Number of Registered Farmers	Sample Size (5.79%)
Ibadan North	12 wards	1256	72
Ibadan North-East	11 wards	605	35
Ibadan North-West	16 wards	462	27
Ibadan South-East	8 wards	930	54
Ibadan South-West	12 wards	820	48
TOTAL	59 Wards	4073 Registered Farmers	**236**

Source: (OYSADEP 2015; Author's compilation 2019)

size amount to a total of 236 questionnaires to be administered within the 59 wards of farmers division in Ibadan metropolis (Table 1). The number of questionnaires administered in each Local Government are as follows: Ibadan North (72 respondents), Ibadan North-East (35 respondents), Ibadan North-West (27 respondents), Ibadan South-East (54 respondents), and Ibadan South-West (48 respondents).

The targeted respondents are registered farmers within the Ibadan metropolis. This study adopted multiple sampling techniques. Purposive sampling was used by the researcher to identify select farmers across the study area. Then for easy identification of urban farmers within the study area, snow ball sampling was also applied. Accidental sampling was also adopted for farmers meetings in various local government areas. The interviewees were selected using convenience sampling techniques based ease on access, proximity and availability as the questionnaire. Administration was done during the farming work period (9am and 4p.m). The relevance of convenience sampling and other non-probabilistic sampling techniques to this study has been identified by Cooper & Schindler (2008) and Muagambiwa & Dzomonda (2018) that the ease of access and availability of respondents coupled with self-reporting nature of the study is necessary to engage in this type of sampling technique.

URBAN FARMING ACTIVITIES AND CLIMATE CHANGE IN IBADAN

Ayanlade & Jegede (2016) reported that in the unstable and changing global climate, effective coping mechanism is dependent on climate and its effective knowledge. This study opines that the climate variability effect can be traced to the nature of activities amongst urban farmers. Using data captured from 236 urban farmers in Ibadan using both quantitative and qualitative data technique, this study examines the urban agricultural activities engaged upon. Studies (Ayanlade et al., 2010; Moyo et al., 2012; Karl et al., 2009; Loveland et al., 2012; Walthall et al., 2012 and Lynn et al., 2013) have identified the various problems encountered by climate variability. Ayanlade et al. (2010), in their study on impacts of climate variability on tuber crops in guinea savanna part of Nigeria using GIS approach identified variation in planting seasons and a drop in crop yield as a problem facing farming. They observed that cumulative variation in rainfall truly influences yam and cassava yields during the second decade (1980-1989) leading to momentous reduction in the crop yield. They opined that the increase in yield recorded in 1990-2000 decade in all stations may perhaps be attributed to the increase in rainfall during the planting and growing seasons within the periods. But 1980-1989 experienced a very low rainfall during planting and growing seasons that had been due to a greater number of drought episodes.

Moyo et al. (2012) stated that the year to year variability of rainfall is a significant constraint to the sustainability of rainfed farming systems in poorer countries in Sub-Saharan Africa (SSA). The researchers noted the high levels of soil water depletion resulting from high rates of evapotranspiration usually lead to crop wilting, and ultimately crop failure, which the farmers may be attributing to a decline in rainfall. Asserting this, an urban female farmer reported thus:

"...The loss we (family farm along floodplain) have experience as a result of these delayed rainfall cannot be explained, almost all the Ugwu (native vegetable and scientific name of African spinach) got dry as a result of late rainfall, the worse was that the water (Eleyele river channel) we use for irrigation was also getting dry and only machine can be used to irrigate as fetching was difficult but we don't have the pumping machine…" **Female Urban Farmer, Ibadan**

This experience shows a limitation to adaptation to the shock of the climate change. The reported floodplain experience poses a more increased threat to the inland farming by urban farmers as a result of climate change. The researcher went further to query the reason for the decline in floodplain water. Field observation revealed that urban indiscriminate waste disposal has led to the blocking of the water drainage channels making it marshy, dirty, difficult to fetch and unsafe for irrigation of food crops. Studies by Popoola et al. (2015) and Adeleye et al. (2019) have identified the effect of indiscriminate waste disposal on water channel.

Further, Karl et al. (2009) identified that there is already substantial evidence of impacts to transportation systems associated with extreme events, such as severe storms with high winds, floods, droughts (affecting barge traffic), and heat waves (affecting rail systems and airports in particular), as well as coastal erosion. Disruptions to transportation systems related to climate change have already caused large economic as well as personal losses, and these impacts are expected to increase in response to a changing climate. The experience caused by climate variability effect on crop yield and farming activity, an inland urban farmer along an open space also asserted that the climate variability effect is real. Speaking he said this:

"...By now all farmers (rural and urban) have began to experience the changing climate. For instance, I also have a farm in the village and my farm labourers have told me now that they couldn't access the town owing to eroded bridge that links us. In this my farm (urban farmland) the soil is dry and no longer that nutritious as when we started using it for maize and vegetable farming (see Plate 1). It should be because it's not even up to two-years of use, now I am looking for another farm to relocate to form farming. Mine (in the context of his farm experience) is even better, my friends entire farm was cleared off by erosion and even the small hurt they usually sleep when doing breeding of the birds and also early morning vegetable harvest has been waste away the long rainfall of early last year …" **Male Urban Farmer, Ibadan**

Loveland et al. (2012) identified the effect of climate change on land cover and land use changes through improvement on forestry and altering agricultural management practices to increase carbon storage in soil. Lynn et al. (2013) opined the impacts of climate change on tribal traditional foods in the USA. Climate change has the potential to affect the patterns and productivity of crop, livestock, and fishery systems at the local, national, and global scales (Walthall et al., 2012). The climate variability and change effect as an event in Ibadan has also affected access to officials. Identifying his own experience,

Figure 1. Vegetable stunted growth owing to extreme weather conditions and poor soil condition
Source: Author's Field Survey, 2019

a farmer reported that "… *The worst of it is even that the government officials* (agriculture extension officer) *that were expected to train us of soybean farming are complaining of the road condition…"* Olaniran & Babatunde (1987) observed that rainfall distribution and the occurrence of moisture stress condition during vegetative period are critical for the yield formation of maize crop at Kabba, Kogi State. Alam & Toriman (2011) opined that due to variation in climatic elements, which results in long-term water and other resource shortages, degrading soil condition, disease and pest outbreaks on crops and livestock and so on will affect the output and economic returns of various crop farmers. Thus, farmers will be expecting losses, primarily, due to a reduction in agricultural productivity, crop yields and a loss of farm productivity. Identifying this effect, an interview with an extension officer met during the field worker accidentally reported thus:

"...The climate issue is a major issue in Ibadan considering the traditional arrangement of the city and also the education level of many of these urban farmers, adaptation has been difficult for them most especially the crop farmers. I can tell you that the last year flood affect a lot of farms especially those close to wetland and floodplains… this year is different late rain and increase temperature has greatly affect vegetable production and egg and piggery production, the cost of feed has been on the increase owing to lack of main feed product (maize) which is affected by lack of enough rainfall also, yet the cost of egg and dairy product is not increasing, price of vegetable can't be increased as many won't buy… I can tell you this is serious climate change experience and yet the forecasts, seminars and trainings we have been attending still tells us to be prepared and brace up for the coming climate variability experience in the years to come …" **Agriculture Extension Officer, Ibadan**

The resultant effect of climate variability in the study shows that 46 respondents out of the total of 236 respondents are faced with the problem of farm produce shortage, 105 respondents are faced with problem of poor crop yield, 42 respondents stated that a delay in the harvesting period is a resultant effect of climate variability, 13 respondents stated that increase in the cost of fertilizer is a function of

Figure 2. Drying up of tomato plant owing to high temperature
Source: (Author's Field Survey, 2019)

Table 2. Resultant effect of climate variability on crop yield

Response	Number of Respondents	%
Shortage of farm produce	46	19.5
Poor crop yield	105	44.5
Delay in harvesting	42	17.8
Increase in cost of fertilizer	13	5.5
Outbreak of pests and diseases	30	12.7
Total	236	100

Source: (Author's Field Survey, 2019)

climate variability, while the remaining 30 respondents identified the invasion of pests and diseases as the resultant effect of climate variability on crop yield. This can be seen in Table 2. Effect of climate variability leading to loss of farm produce due to high temperature can be seen in Plate 2. Actions of irrigation also enhances invasion of pests and diseases because most of the water used for irrigation are not clean and this results in an increase in cost through the use of a pesticide as seen in Plate 3, thus reducing farm produce and profits. Drop in soil nutrient due to climate variability leads to a drop in crop yield and stunted growth of crops. Plate 1-3 shows this effect.

Figure 3. Pesticide used by vegetable farmers to control the effect of pests and diseases

Figure 4. Bush burning on a farm in Samonda area which led to death of some banana stand

Nature of activities practiced by farmers varies from one location to another. This is often determined by the nature of the soil, size of farm and the type of crop to be planted. The study was also aimed at identifying the type of activities in which urban farmers engage upon. Result finding as shown in Table 3 shows that 191 respondents occasionally engage in land clearing and 74 respondents occasionally engage in bush burning. Excessive bush burning often leads to loss of soil nutrient, loss of farm produce. This can be seen in Figure 4.

From the sampled respondents, 47 respondents occasionally engage in over grazing of animals, 117 respondents occasionally engage in the application of fertilizer, 93 respondents occasionally engage in mulching and 79 respondents occasionally engage in the use of decompose. The use of decompose often serves as a substitute for chemical fertilizer and also encourages zero waste on farms. Examples of such decompose material can be seen in Figure 5.

Figure 5. Waste remains of a poultry farm used as organic manure at Eleyele floodplain

From the urban farmers sampled, 74 respondents occasionally engage in bush fallowing, and 74 respondents occasionally engage in farm mechanization. Evidence based on interview revealed that bush fallowing by urban farmers can be traced to a decline of soil nutrients, flooding and erosion which can be traced to climate change. Reporting this, a farmer who engages in vegetable farming along the floodplain of Orogun River stated thus:

"...I farm closer to the floodplain because of ease of irrigation, good soil moisture and nutrient but since the last flood, I have decided to move uphill the floodplain area to reduce erosion and flooding effect …" **Male Urban Farmer, Ibadan**

In this study, 43 respondents rarely engage in land clearing, 107 respondents rarely engage in bush burning, 90 respondents rarely engage in over-grazing of animals, 71 respondents rarely engage in application of fertilizer, 70 respondents rarely engage in mulching, 76 respondents rarely engage in use of decompose, 89 respondents rarely engage in bush fallowing, and 69 respondents rarely engage in farm mechanization. Two respondents stated that they never engage in land clearing, 55 respondents stated that they never engage in bush burning, 99 respondents stated that they never engage in over grazing of animals, 48 respondents stated that they never engage in application of fertilizer, 73 respondents stated that they never engage in mulching, 81 respondents stated that they never engage in the use of decompose, 73 respondents stated that they never engage in bush fallowing, and 93 respondents stated that they never engage in farm mechanization.

The variation in the type of activity engagement in varies with the type of crop planted, the size of the land and finance. While floodplain farmers often at times use family labour, the land that is used is subjected to little clearance and most times no burning or selective burning. Farmers farming large hectares of land along the periphery of Ibadan metropolis are subjected to heavy land tilling and bush burning. Vegetable farmers are less concerned about burning and farm mechanization because it often reduces the nutrient level of the land and the size of the farm is not as big as to require heavy machinery for land tilling. Over grazing is not a common activity amongst the framers in the study area. Farm mechanization is often in the form of simple farm tools such as pumping machines and knapsack sprayer as shown in Plate 6.

Figure 6. Knapsack sprayer used for fumigation and machine used for irrigation on a farmlands

Table 3. Level at which farmers engage in certain activities

Response	Land Clearing		Bush Burning		Open-grazing of Animals		Application of Fertilizer		Mulching		Use of Decompose		Bush Fallowing		Farm Mechanization	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Occasionally	191	80.9	74	31.4	47	19.9	117	49.6	93	39.4	79	33.5	74	31.4	74	31.4
Rarely	43	18.2	107	45.3	90	38.1	71	30.1	70	29.7	76	32.2	89	37.7	69	29.2
Never engage in such	2	0.8	55	23.3	99	41.9	48	20.3	73	30.9	81	34.3	73	30.9	93	39.4
Total	236	100	236	100	236	100	236	100	236	100	236	100	236	100	236	100

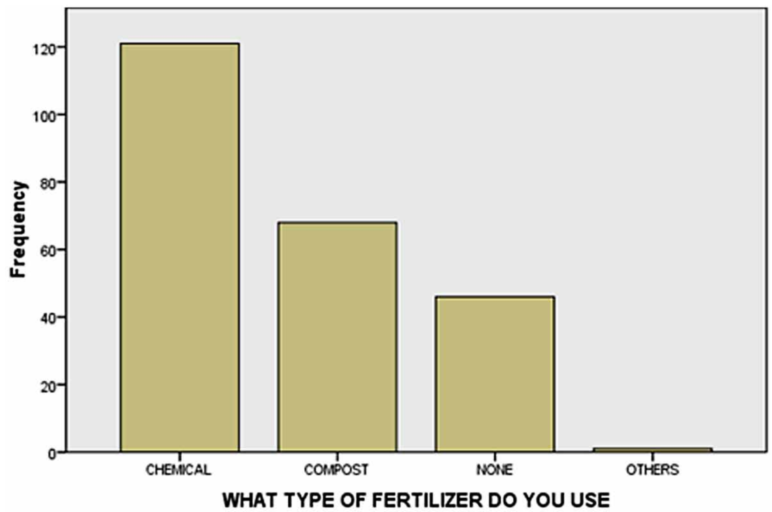
Source: (Author's Field Survey, 2019)

The choice of the use of fertilizer is dependent on the crop that is planted. Figure 1 shows that 51.3% of the total respondents make use of a chemical fertilizer, 28.8% make use of compost or organic fertilizer, 19.5% do not engage in the use of fertilizer while the remaining 0.4% did not identify the choice of fertilizer used. The most common chemical fertilizer used is the NPK and URREA fertilizer, while the remains from pig and poultry farms are used as compost manure. Bush fallowing is practiced during the rainy and dry season along the floodplains of Ibadan. Urban agricultural farmers during the rainy season move upland away from the river to prevent erosion and flooding and during the dry season move closer to the river. The choice of bush fallowing is dependent on land availability.

CONTRIBUTION OF IBADAN URBAN FARMING ACTIVITIES TO CLIMATE CHANGE

Climate change and variability effect and impact have overly been investigated. However, the contribution of some farming activities towards the changing climate remains under-discussed. While some of the adaptation responses have been identified to be pro climate change (Woods et al., 2017) many is anti-climate change. This study attempts to take a closer look at some of these farm activities and how it is perceived to be a contributory factor to the varying and changing climate. For instance, 76.7% of the

Figure 7. Type of fertilizer used by farmers



sampled respondents engage in activities such as bush burning (see Plate 4 and Table 3). Corroborating the anti-climate spontaneous farming activities, a farmer said:

"...What do you expect me to do, the cost of hiring a labourer to weed is high even more than interest on a vegetable farm. The best for me to do is to just burn once it is dry or during dry season… it saves my cost and time…" **Male Urban Farmers, Ibadan**

This assertion puts an activity of spontaneity of the present farm activity and needs the futuristic mitigation against the effect of climate change at the farmers micro level. These climate driven activities as it may are somewhat an anti-climate mitigation mechanism. This finding relates to the argument posed by Woods et al. (2017) that Danish farmers are often incremental and flexible in their adaptation to climate change.

Bush burning is perceived as a quick fix to the farming needs towards the new upcoming crop planting season. Studies (Subair, 2009; Ayeni et al., 2016) have identified bush burning to be the main cause of the decline in surface water, land cover, urban land surface exposure to insolation and soil nutrient loss. As identified by Ayeni et al. (2014), there exist some demeaning culture and socio-cultural activities within the South Western region where Ibadan is located. Based on field observation and the analysis as presented in Table 3, bush burning is a common form of activity amongst the urban farmers in Ibadan. This often translates into increased urban farmland exposure to sunlight insolation thereby resulting into increased space temperature and urban farm heat island which directly affects soil nutrients and a drop in crop yield. This act is not only focused on the urban farming area but its implication has a deforestation factor and how it contributed to climate change. Abiodun & Bayode (2014) has reported an increase in deforestation associated with an increase in city sprawl and densification.

Reporting the changing in land cover of the city (Oluseyi, 2006; Mengistu & Salami, 2007; Oladele & Oladimeji, 2011; Fabeku et al., 2018; Wahab et al., 2018) reported that the land cover of Ibadan has reduced and that deforestation is on the incline (Olanrewaju et al., 2018; Bello et al., 2018). This study argues that two contributory factors to urban deforestation of Ibadan is the bush burning (76.7%) and open grazing as reported by 58.0% of the sampled urban farmers. Amosu et al. (2012) and Ayeni et al (2016) has argued that these two acts are a major driver to the increased decline in surface water in the region (both inland and hydro-setting). Studies (Liu et al., 2010; Herrero et al., 2013; Thornton & Herrero, 2015) that examined the effect of mixed cropping and an open grazing system found them to be a contributing factor to greenhouse gasses. Herrero et al. (2013) identified that over 63% of greenhouse gas emission in Africa is from animals many of which are reared using open-grazing system. Although the relevance of the system to soil nitrogen manure nutrient cannot be ignored (Liu et al., 2010), their contributory effect to climate change owing to the voracious eating consumption pattern of ruminant animals on an open grazing system is also a factor that limits the extent of plant cover. Havlik et al. (2014) argued that why grazing cannot be ignored (especially in Africa and a traditional, organic setting like Ibadan) the need for mixed-cropping, controlled and monitored grazing needs to be put in place to serve as a mitigation mechanism to greenhouse gas.

The relevance of controlled over grazing has being traced to the need for controlled urban farm erosion as reported by some of the farmers during an interview. In USA, pasture land erosion is mainly traced to over grazing, this study although without vivid empirical evidence argues that over grazing along farm areas needs to be controlled as many of the floodplain areas are grazing zones for nomadic farmers (Gefu & Kolawole, 2002; Loth, 2004; International Crisis Group, 2018) has identified that nomadic farmers in Nigeria usually move along the floodplain and river paths for fresh green grass, based on the assertions of urban farmers who had engaged in upland fallow along the floodplain as result of erosion and flooding, this study argues that the effect of deforestation and over-grazing along river paths as a contributory factor to the negative effect of climate variability such as erosion and flood must be investigated.

Behnke et al. (1993); Bartels et al. (2013); and Pimentel & Burgess (2013) states that Africa (Nigeria include) is characterised with heavy grazing which results in erosion of over 80% of farming areas. With an average deforestation rate of 3.4 million ha per annum in Africa (FAOSTAT, 2014), traced to over grazing, slash and burning vegetation (Ngaira, 2003), Africa has been exposed to increased greenhouse gas and fossil fuel emissions (Valentini et al., 2014; Hickman et al., 2014; González-Sánchez et al., 2018). The study of Pimentel & Burgess (2013) drew a link of sync between rainfall variability, deforestation for domestic fire wood, over grazing, incidences of drought to be a contributory factor to soil exposure and immediate climate variability. The increasing deforestation was also identified in the study of Suckall et al. (2015). Although has mentioned earlier, the percentage of these urban activity contribution to climate change and variability cannot be clearly listed, nonetheless, its effects are undeniable.

Excessive use of fertilizer has been sermonized to contribute to greenhouse gas generation and emission. Brevik (2012) identified the pollution (land, air and water) potential of chemical fertilizers and how it can translate into health hazards and complication. Bryan et al. (2013) reinstated the need for the effective management and optimization in the use of the appropriate fertilizer in the face of the varying climatic conditions. Their study which was household based, identified that the uncontrolled use of chemical fertilizer as a soil nutrient supplement will further harm the atmosphere and environment and is uncontrolled. Control from the perspective of this study is seen in the application of the right fertilizer and application in the right quantity and location. Studies (Rosenzweig & Hillell, 1998; Enete, 2014) identified the effect of fertilizer on the environment and argued the improper application of fertilizer will lead to a decline in soil fertility and the release of N_2O into the environment. Rosenzweig & Hillell (1998) estimated that an average of about 0.1% to 1.5% in various applied agricultural fertilizers is released into the atmosphere and this increases the greenhouse gas content of the earth.

CONCLUSION

As much as the Third World Countries are more exposed to the changing and varying climate, urban farming activities are pro climate variability and change. As much as the climate is changing, the identifier that there is a human side to the changing climate needs to be continuously investigated and explained to urban farmers. Urban dwellers and farmers more importantly must be sensitized to the fact that some of the farming activities are against the climate changing mitigation process. Farmers in urban areas need to be educated on activities such as bush burning, indiscriminate animal open-grazing and bush fallowing and their negative impact on the climate.

The study concludes that rather than the spontaneity in farming activity decisions, and yearly farming activities, farmers need to be educated as to the futuristic contribution of such activities to the changing climate and be extensively and effectively controlled. The study identifies that rather than open grazing of animals which uncontrollably devour urban land cover, ranch and locational farming must be considered and explored by urban farmers. The need for improved mixed cropping to control the rate of bush fallowing must be checked and controlled. This study believes all this is based on effective and responsive extension service and education by agricultural experts.

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Chapter 3
Implications of Urban Sustainability, Socio-Ecosystems, and Ecosystem Services

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ABSTRACT

This chapter aims to analyze the implications that urban sustainability, socio-ecosystems, and ecosystem services have as the bases to design the urban green growth strategies. The method used is the analytic based on the theoretical and conceptual literature reviews on the topics described. Urban sustainability and environmental performance integrates biodiversity and socio-ecosystems for the provision of better quality ecosystem services supported by green infrastructure design into the green projects aimed to achieve economic and environmental benefits. It is concluded that the ecosystem services and human well-being may suffer irreversible severe declines if sustainability is not built based on biodiversity of socio ecosystems, green infrastructure, and natural capital.

INTRODUCTION

Livelihoods, health, and survival of human beings are completely dependent on natural environment and ecosystem services, beyond culture and technology.

Urban sustainable development is based on the relationship with its socio-ecosystems and urban green growth that provide critical ecosystem services useful to improve human wellbeing and health while at the same time buffer against natural disasters and disturbances. Urban sustainable planning, design and

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development based on the socio-ecosystems and green infrastructure provide complementary benefits and opportunities of ecosystem services to benefit the cities, such as creating habitats, reducing energy demand, retaining storm water and rainwater, reduce runoffs, creating green spaces for amenities, recreation and education, etc.

The socio-ecosystems changes are long term challenges to urban sustainability because the regime shifts that have an impact on the ecosystem services availability. Growth of urban sustainability based on green infrastructure to develop the socio-ecosystems is needed to provide efficient and environmentally friendly technology, giving support to the availability of ecosystem services as the benefits obtained from nature. People moving from rural to urban settlements consume ecosystem services experiencing separation from nature.

Changes on urban sustainability are dependent on the availability of ecosystem services, which can be caused by changes in the social dynamics due to cascading and feedbacks changes intensifying the incremental ecosystems and their services changes. Some of this urban sustainability changes can be predictable, but other of these changes in ecosystems and ecosystem services are difficult to reverse given their impact magnitude. To a certain extent, there is a disagreement on the future scenarios of ecosystem services despite that there is agreement on many factors determining these scenarios, among which may include the role of governments at all levels of governance, technology, learning, resilience of ecosystems, etc.

This paper intends to address some of the implications involved in this complex and uncertain relationships existing between urban sustainability, socio-ecosystems and the ecosystem services.

URBAN SUSTAINABILITY

The new development path supports economic growth, social inclusion and equality, and environmental sustainability, in such a way that ensures the greening of a more inclusive growth. Urban green growth strategies aligned economics with sustainable development to foster environmentally sustainable and socially inclusive development. Sustainability emerged from the global development context (Adams & Jeanrenaud, 2008; Mebaratu, 1998) and is considered as a process or trajectory (Childers et al., 2014). Two pioneering works to sustainability are Design for Human Ecosystems and Regenerative Design for Sustainable Development of John T. Lyle (1999, 1994) (McHarg, 1994; McHarg, 1969).

The founding concept of sustainability is equity across time and space defined as the capacity to support the quality of life of the current generation without impairing the capacity of future generations to meet their own needs for well-being. That is, the well-being of one person, place or region should not be at the expense of the well-being of others. The concept of sustainability is based on ecological principles of resource conservation in ecosystems, mass balance in systems and assimilated resources in allocation trade-offs of closed systems (Gunderson & Holling, 2002; Ostrom, 2009). Sustainability is the core concept of sustainable ecosystem management aimed to balance human needs in the long-term sustainability of ecosystems. Procedural sustainability is essential to sustainable ecosystem management (Binder et al., 2010).

The sustainability goals of an urban area promoting environmental integrity and resilience of the ecosystem, economic feasibility, social inclusion and cohesion lead to the adaptive processes and a cycle of human institutions (Ernstson et al., 2010). In short, sustainable economic growth, increasing resilience and reducing poverty.

The pillars of sustainability are the economic feasibility, social well-being and environmental integrity. These pillars of sustainability are science-based related with decisions emerging from political, power and social relationships and from biological and material systems (Pincetl, 2012) addressing biophysical hazards, social vulnerabilities and institutional inertia (Biggs et al., 2010; Walker et al., 2004). In comparative terms, urban sustainability draws upon resources from regional contexts and the connections beyond their boundaries with resources and wastes (Rees, 2000).

Sustainability mechanisms try to reduce the urban negative impacts of the challenges posed by the global climate changes and to open new opportunities of urban development (Symes et al., 2005). Urban ecosystems are threatened by climate change. Urban ecosystems are vulnerable to climate change and the assessment of factors contributing and the impact is critical for any natural disturbances and disasters, essential to the ecosystem functioning over time and space. If global greenhouse gas emissions rates decline, climate change is less severe and pose less threats to urban socio-ecosystems and natural spaces. Adaptive governance approaches involving learning mechanisms are required for a transition toward greater sustainability and resilience.

Economic sustainable development through green growth can be achieved by systemic changes in economic growth patterns. Sustainable and efficient green growth patterns require inclusive green growth. Transition to green economy is the basis for sustainable development supported by inclusive governance approaches and stakeholder's experiences, knowledge and initiatives to manage the planning and implementing processes. Transition from green economy towards greening of growth and environmental concerns is a challenge of governance and policy framework. Urban governance approaches may contribute to formulating and implementing strategies and policies and setting the targets aimed to the transition management to achieve urban green growth and sustainable development. Unfortunately, at global governance level, the system and practices do not meet the green growth and sustainable development challenges.

Implementation of urban sustainable policies must take into account individual, community and global interests. Deepening into policy solutions, green growth is one path to sustainable development. Green growth may reduce natural resource consumption and alleviate pressure on commodities, mitigate the impacts of adverse environmental effects while fostering economic, social and environmental resilience. Greening economic growth strategies synergizes economic growth and environmental sustainability and protection characterized by investments in economic activities that enhances the earth's natural capital and reduces ecological and environmental risks.

Green behaviors are conditioned by the individual´s thinking green and expanding at the organizational level as green business (Go green members program, 2014). Thinking green in social systems expands to green business and leads to green economy supported by eco-innovative initiatives for an efficient use of natural and environmental resources through engineering and social structures to enhance the capacity to deliver sustainable and inclusive growth (Eco-innovation action plan, 2011). Moreover, the concept goes to urban level as green cities and towards green economy which includes all the upper social levels (UNEP, 2010).

Industrial shareholders and analysts more than government officials in some specific cases, are more sensitized to the corporation's ecological and social footprints and their impacts on sustainable development, climate change and poverty, and recognize the social responsibility in environmental protection. Green and sustainable chemistry are searching for new pathways and catalysts for environmental chemical processing methods, as for example, conversion of renewable biomass into other ecological materials. These concerns are going beyond the borders of product life cycles into the natural capital and its economic flows and ecosystem services.

Sustainable industrial ecology networks are developed to address sustainable issues and achieve incremental improvements to optimize results in ecological industry. Industrial ecology framework transforms industrial systems in a closed-loop ecosystem model with cyclical flows where the waste of one natural resource is recycled as a nutrient of other species. Industrial ecology networks recycle spent biodegradable o durable materials into other new applications. Industrial ecology eliminates the waste by innovation to convert the wastes into useful byproducts.

Green sustainable buildings are becoming a sustainable design practice involving materials and energy renewable efficiency, respect for natural environments, utilization of ecosystem services, etc. Some protocols are now used to evaluate the environmental performance of sustainable buildings and campuses. Design of sustainable systems include requirements to address inherent resilience, sometimes achieved through simplicity reducing failures and disruptions.

The sustainability urban plans usually articulate a number of specific targets (Symes et al., 2005). The way urban spaces are envisaged and shared ultimately impact the way global changes are addressed. Sustainable urban planning must take into account the occurrence of many variables. Cities are resources destructors and polluters and the most disturbing environment sustainability in direct or indirect manner (UN, 2007). However, the urbanization processes expose the dual effects on sustainable environment. The United Nations endorsed the New Urban Agenda in 2016 to implementation of new paradigm in urban planning, building and managing aimed to achieve a Sustainable Development Goals.

New urban ecosystems can be constructed where industrial business, shopping centers have been before and have demolished under an urban ecological restoration projects to restore the original natural systems. The inputs of this New Urban Agenda are the identification of critical issues and challenges, structural policy priorities and constraints, knowledge of valuable resource to urban actors involved on sustainable housing and urban development. The new urban development is supported by government incentives implemented to generate benefits in the sustainable green development.

Some targets of sustainable urban plans include green resources conservation, green energy efficiency, waste management, reuse and recycle materials (Munier, 2011; Platt, 2006; Symes et al., 2005). Urban sustainable planning incorporates nature into the urban settlements and try to preserve the surrounding landscape (Jacobs 1961; Howard 1965; McHarg 1992). Sustainable urban planning investments in green infrastructure and green transport improves urban mobility, public health and access to markets, while reduce emissions, air and water pollution. Urban ecological rehabilitation, restoration and re-greening areas in a city planning and design provide opportunities to build a more climate-resilient urban ecosystem and connect with the development of urban green spaces and ecological systems that contribute to enhance the well-being and health of residents, are socially and ecologically desired.

Urban and regional sustainable planning policies and supply chain management strategies have an impact on the mobility systems. For example, sustainable urban transportation systems with shorter journey distances and times, balance urban and regional competitive economic growth, social inclusive and equity development and sustainable environment, creating more loveable cities. Sustainable mobility is conceived as moving freely and gaining access, communication, trading and establishing relationships without the sacrifice of essential human and ecological values.

At the center of this conception are the evolution of transportation technologies and their supporting infrastructures (World Business Council for Sustainable Development. Geneva, 2002). Sustainable Supply Chain Systems should generate ecological footprint using renewable materials and energies, urban land use and industrial wastes and emissions management. In acceptable environmental impacts, the rate of resources replenishment is faster that the consumed and waste does not exceed the capacity of the ecosystem.

The interactions between socio ecosystems, ecosystem services and urban ecological resilience are potential that requires more attention in urban sustainable planning. Urban sustainable planning and design must consider the connectivity of urban landscapes to land uses and its socio-ecological determination and significance to maintain the socio- ecosystem services and resilience. Cities that integrate urban forests, green areas, parks, etc. into biodiversity in urban sustainable planning and design are well positioned in their socio-ecosystems services and to become more resilient.

SOCIO-ECOSYSTEM

The concept of green growth is based on the complementarity of the economic, social and environmental systems, that is socio-ecosystems. The term ecosystem describes the entire system of living organisms in interaction with biotic factors such as air, water and minerals occupying a given space (Tansley, 1935). The socio-ecological system concept contends that the integral parts of any ecosystem are the humans, their social and political systems and the equitable sustainable governance. Ecosystem integrity is the degree to change from their natural state due to the interventions of human. Interventions in socio economic systems can be modeled through computer simulations.

An ecosystem is a flexible model incorporating the urban systems, social structures and infrastructure (Burch, 1988; Naveh, 2000). The metaphorical implications concept of the ecosystem concept stimulates the transdisciplinary dialogue with society, the ecosystem models and experimental frameworks of reference of urban ecological processes (Felson et al., 2013; Felson & Pickett, 2005; McGrath, 2013b).

Ecosystem ecology focuses on the fluxes and transformations of matter, information and energy among and cross the ecosystem components. Ecological theory based on socio ecosystem development and succession is reflected on the system composition of free resources to accumulate and conserve in adaptive cycle traced in system dynamics (Holling & Gunderson, 2002) of connectedness, wealth or capital, and resilience. The organismal component of a human ecosystem includes institutional and social arrangements, structures and interactions, from small to large and from persistent to temporary (Naveh, 2000; Pickett & Grove, 2009; Ostrom, 2005).

The study of urban ecosystems integrates physical processes, economic and social factors, nonlinear feedback across a broad range of scales and disparate process phenomena (Urban Security 1999). Most of urban settlements are located in areas with high levels of biodiversity supporting high ecosystems productivity (Hansen et al., (2004); Ricketts and Imhoff, 2003). Biodiversity preservation cannot reduce other kinds of anthropogenic stresses to ecosystems. Biodiversity within species maintains the ecosystem processes with individual species responding to environmental fluctuations (Frost et al., 1995, Ives et al., 1999, Cottingham et al., 2001, Elmqvist et al., 2003, Norberg, 2004, Folke et al., 2005). Species acting across a range of space and time scales are an element of ecosystem diversity (Peterson et al., 1998).

Biophysical and social adaptive processes are across space in human ecosystems (Cumming et al., 2006) including individuals and institutions through the interconnectivity of organisms in physical environments (Ostrom 2005). Adaptive processes are supported by a variety of sources, among which are general ecological theory, biological ecosystems structures, genetic variations and evolution, regulatory population feedbacks, etc. (Gunderson et al., 2002; Walker et al., 2004, Scheiner & Willig, 2011).

Management of the socio-ecosystem feedback has crucial implications on the development of society and human systems (Diamond, 2005). Socio-ecosystems can be modified by people which in turn, its feedbacks change human systems, economies, society, livelihoods, life quality, health, etc. In complex socio–ecological environments, social and ecological change is continuous based in the relationships between people and ecosystems but the consequences are difficult to predict.

A substantive application of landscape and ecosystem ecology to urban eco systems consider the spatial heterogeneity of structures, flows and controls across the complexity of the urban socio ecosystem (Forman, 2008), the social and biophysical disturbances in urban structure, process and change (McGrath, 2013a; Shane, 2013) and the ecological interactions and connections between infrastructure and biophysical processes in urban areas (Pickett et al., 2008, 2001). Spatial landscape structure and ecosystem processes on landscape designs are relevant for the maintenance of biodiversity through seed dispersal, species movement and pollination (Hobbs, 1997; Kendle and Forbes, 1997).

Habitat configuration and composition affect the individuals, communities and populations that inhabit landscape and together with patches complement the natural resources forming ecological functional units among species confined to urban ecosystems (Guerry and Hunter, 2002, Quin et al., 2004; Blair, 1996; Melles et al., 2003). Biophysical components and processes can have benefits to the urban socio ecosystem functions as it is the case that embedded green areas contribute to the prevention of pollution and higher proportions of trees are associated with low rates of crime (Troy et al., 2012).

Green public areas available in the urban context of historic center not always are capable to perform the ecosystem functions. This situation requires other types of private interventions such as urban green roofs and other greening actions to become fundamental elements of the ecological greening network and bring other economic, environmental and social benefits. Ecosystems networks formed by different stakeholders such as experts, scientists, technicians, managers, citizens, etc., depending upon shared interests, trust and experiences, they are involved in knowledge creation, technological innovation, social learning, information and communication technologies, etc. (Olsson et al., 2006).

It is widely accepted that resource extraction is leading to accelerated reduction of biodiversity and degradation of the socio-ecological system but conservation takes account human social and economic needs (Grumbine, 1994; Szaro et al., 1998). Industries of natural resource extraction might have appropriate land use and socio ecosystem protection. Poverty is closely related to ecosystem degradation (Biggs et al., 2004). Some poverty mitigation strategies may increase the pressures on socio-ecosystems and may compromise the benefits. Ecosystem degradation is tolerated by wealthy people despite the increasing demand for cleanup of some aspects of the environment (Stern, 1998; Khanna & Plassmann, 2004; Gergel et al., 2004).

Ecological land-use complementation promotes response diversity as referring to diversity of responses to environmental disturbances among in the same ecosystem functions, a critical mechanism for the maintenance of ecosystem processes (Elmqvist et al., 2003). Ecological land-use complementation (ELC) provides the habitat for the species and the landscape complementation function of other ecosystem processes and functions. The urban ecosystems are complex diversity of land uses and vegetative land of any landscapes (Foresman et al., 1997). Urban land use areas have influence on biodiversity and terrestrial ecosystems (Sala et al., 2000) and continues to intensify in urban areas overlapping location of areas that are rich in biodiversity (Ricketts & Imhoff, 2003).

Ecosystems management is an approach used to analyze all these issues. The concept of ecosystems management is based on the recognition that species interact each other and with a surrounding environment. According to the Ecological Society of America, ecosystems management have the purposes to protect the entire habitats and the particular species, maintains the native ecosystems, manage resilience and disturbances and establish buffer areas around core reserves (Grumbine, 1994).

The sustainable socio-ecological management system takes into account the complex connections of the entire ecosystems to deliver the ecosystems services, balancing the human economic social and cultural needs with the ecosystem sustainability. Ecosystem management applies ecological science to resource management to long-term sustainability of ecosystems and to deliver the essential ecosystem goods and services to society (Chapin et al., 2011). Ecosystem management can be reactive and proactive. A sustainable ecosystem management system must have defined the boundaries, determine components and interactions, use local and traditional knowledge to assess integrity and conditions, evaluate the supply and demand, carrying capacity, thresholds and tipping points, implement actions, set the levels of extraction, restore degradation and improve connectivity (Brussard et al., 1998; Slocombe, 1998; Tallis et al., 2010).

A flexible adaptive management approach to socio-ecological systems has the functions of monitoring, learning, and feedback adjustment of strategies and goals to meet the changing human needs, incorporate new information and make resilient corrections. Adaptive management deal with complexity and uncertainty of the socio-ecological system (Williams, 2011). Environmental management that incorporates risk and cost (Carpenter, 2003), under an adaptive approach accelerate social learning to develop planning, controlling and evaluating by absorbing uncertainty. In doing so, environmental management creates the capacity to cope with social and ecological change and strategically manipulate the socio-ecological process to get the effective functioning of the socio-ecosystems (Holling, 1973).

The ecosystem management and governance has an institutional context and regulatory frameworks which condition the recommendations in the management system, the supranational, international, national and local governance levels and the place-based ecosystem services management. Ecosystem governance structures and functions rest on the diverse sectors and span across the supranational to the most local level practices (Young, 2002).

Institutional socio ecosystem determines its management and governance structures, functions and processes and the ecosystem services (Vatn, 2005). The new institutional governance of socio ecosystems should pursues government regulations to encourage green value and wealth by protecting natural resources and biodiversity with efficiency, innovation, and sustainable budget. Institutional governance capacity of socio-ecosystems is the capacity to transform, adapt and innovate (Folke et al., 2010; Gunderson, 2000; Gunderson & Folke, 2011; Olsson et al., 2004).

Technological development is shaped and shapes the ecosystem management approaches. Green engineering and design for environment in socio ecosystems have impacts in design process. In Techno Garden approach, the globalized economy is supported with substantial investments in environmental technology with engineered ecosystems and market solutions to environmental problems (MA 2005a). Interventions are designed decisions in socio-ecosystems.

Design and implementation of a portfolio-based approach for managing ecosystems is a challenging task to enhance system resilience and reducing impacts of human-engineered or natural disasters. The portfolio approach for managing ecosystems may have different strategies and goals applied to specific conditions. The MA scenarios are a tool for analyzing different assumptions, building socio-ecosystem decisions and policies and for exploring logical consequences.

System design practices are contributing to building sustainable socio-ecological systems and green sustainable development. Green environmental development policies to be effective require a proper mix of financial incentives to strengthen the interventions for the creation and establishment of green infrastructures aimed to overcome the socio-ecosystem crisis. Urban local governments and private companies must invest on green infrastructure if they are concerned with the improvement of the urban environment, the socio-ecosystem and the quality of life. Innovation and adaptation to change of socio ecological systems are facilitated by cooperation between stakeholder groups (Chapin et al., 2011).

Knowledge and skills acquired and applied to enhance community environmental development and to foster leadership action helps to create a more resilient socio ecosystem in the face of disasters and disturbances. Natural ecosystems connectivity is built through greater economies of scale and scope, economic efficiency, social integration and inclusion, and sustainable development approaches. The connectivity of the ecosystem is the element that facilitates effective operation and interactions of the different linked nodes such as greenbelts, greenways, ecological corridors, etc.

Ecologists now are supporting the argument that the socio-ecology systems may have multiple equilibria (Holling, 1965; Lewontin, 1969). After being disturbed, a socio-ecosystem system may have new conditions which set feedbacks preventing to returning to its previous equilibrium of disturbance (Carpenter, 2003). A specific equilibrium on an ecosystem with multiple equilibria with the potential to cross thresholds, is depending on the set of conditions. Recovering of the entire ecosystems requires the support of development partners and non-governmental organizations. Socio ecosystem requires protection given the variability of disasters and disturbances (Koch et al., 2009).

Self-organization refers to the emergence of ecosystem patterns as the result of evolution of species (Levin, 2005). Biodiversity is a form of insurance to buffer ecosystems against losses of species and reduce the functions (McCann, 2000; Naeem, 2002,a, b). The capacity of the ecosystem includes the recovering from management mistakes (Fischer et al., 2006). Ecosystems and social systems are mutually reinforcing having positive feedback in such a way that any change has an impact between each other in a virtuous cycle. Any community well-being improvement leads to the ecosystem protection. The socio ecosystem has the ability to recover from disasters and shocks, which may be improved by and institutional and cultural framework and high degree of social capital and cohesion.

Diversified economies with biodiversity-rich ecosystems can have some specific resources more vulnerable to weather shocks where ecosystems can lose species but still maintains the ecosystem performance (Briguglio et al., 2009; Rose, 2007). Specifically, some communities highly dependent on natural resources are more vulnerable. A decrease in biodiversity may tend to reduce ecosystem stability as the decreasing in managerial diversity of a corporation reduces its ability of survival and longevity. Regulations imposed upon industrial activities have impacts of perturbations and disasters upon biodiversity and complex bio ecosystems.

Large-scale damage caused by disasters have a high impact on human communities and socio- ecosystems. However, restoration of some ecosystems after disturbances may preset some difficulties. Also, socio-ecosystems can be measured after disturbances. (DeAngelis, 1980; Neubert & Caswell, 1997; Pimm & Lawton, 1980). Ecosystems crossings critical thresholds of disturbance or disaster might have difficulties to restore and in absence of system dynamics the ecosystem is launched down to unpredictable trajectory.

An ecosystem may cross a threshold from one ecological state to another, and the restoration is impeded by biotic such as the invasion of exotic species and abiotic barriers. Changes in landscapes structures and dominant hierarchies of species, loss of native species, biochemical processes, biotic and physical processes and feed backs, etc. are some conditions that may prevent ecosystems to return to pre-disturbance state (Ehrenfeld & Toth, 1997; Suding et al., 2004) and launch it to unpredictable trajectory. Ecosystems can provoke also cascading changes such as the case studied by Brashares et al. (2004) where after the collapse of coastal fisheries has increased the bush meat hunting or the ecological adverse consequences caused by the drylands now covering more than 40% of the surface of the Earth (MA 2005b). Socio-ecosystems are often more complex to accurately model regime shifts and simulate results.

Ecosystem functions provide cultural benefits to urban population. Cities are complicated socio–ecosystems with dynamically interconnected components over space and time (Pickett et al., 2001). Building urban ecological functions for leading to land uses accommodation as the result of the development of knowledge on urban ecosystems functioning and stronger partnerships among urban planner and designers, ecologists, landscape designers, urban residents, etc., contributes to improve better urban resilience (Felson & Pickett, 2005).

Urban socio ecosystems are assessed in multisector policies and actions using indicators such as urban green infrastructure and green services. Stakeholder´s negotiations should set the goals and indicators. The assessment of long term sustainable ecosystems requires indicators of ecosystem resilience and health to determine the level of exploitation. The impact assessment of life cycle flows in terms of the ecosystem perturbations.

The ecosystem health is based on resilience considered as the ability of maintaining structure and functions under stress, productivity or vigor, organization or functional diversity (Rapport et al., 1998). The sustainable ecosystem management requires suitable indicators for management and monitoring to ensure the balance of needs and the prioritized goals in every stage of the model ecosystem structure of biodiversity, functions, quality regulations, and other socioeconomic indicators.

Bio complexity challenges the integrated system evaluation addressing the dynamic web of interrelationships arising when components of the global ecosystems biological, physical, chemical, and the human dimensions interact (National Science Foundation, 2002).

SOCIO-ECOSYSTEM SERVICES

Ecosystem services is a concept that integrates strategies for long term green economic growth and competitiveness with improvement of welfare and poverty reduction by investing in natural capital. The ecosystem services have the objectives to analyze and manage interconnections and modularity in practical specific situations.

Identification of the ecosystem services and how are affected by alternate states of the system. Ecosystem services are categorized as supporting such as in the case of biodiversity, provisioning, regulating, or cultural (TEEB, 2011). Ecosystem services are the ecosystem functions ranging from material goods to non-market services that used, consumed and enjoyed by humans (Crossman et al., 2013; Gómez-Baggethun et al., 2013). Some ecosystem services are the eco-tourism potential, flood control, water regulation, which can be developed as economic growth, social development and environmental sustainability strategies. Ecosystems services are also provided by species.

Urban farming and agriculture initiatives and urban local-scale greening are efforts that facilitate the provision of ecosystem services such as clean fresh water, air purification, carbon sequestration and storage, temperature regulation, storm water runoff and management, healthy and affordable food production and supply, equitable access to recreation, gardening opportunities, etc. These ecosystem services are locally produced and managed by private, non-governmental organizations and local authorities, challenging the densification, decreasing urban land availability.

The economic analysis based on the ecosystem services includes energy savings and continuity benefits. Green economy capitalizes the economic value on natural capital investments and provides incentives for maintaining its function to secure ecosystem services, saving on green infrastructure development, contributing to the adaptation of the ecosystem, and improving human health and environmental security. Natural capital management is an analysis framework that goes beyond the product life cycle of companies and their economic flows to sustain the ecosystem services

Natural capital provides ecosystem goods and services subject to natural resource management decisions, the growing population and per capita consumption. The ecosystem services and functions framework unites biodiversity conservation with human health and well-being goals to benefit people living in urban settlements. Urban settlements depend on biodiversity and ecosystems to sustain ecosystem services for benefiting human health and well-being (TEEB, 2011), although the connection between biodiversity and human livelihoods not always is clear. Biodiversity supports the ecological structure and functions to produce the ecosystem services. Urban ecosystem biodiversity is integral to functioning and provision of ecosystem services to the population (Gómez-Baggethun et al., 2013).

The type of ecosystem can be provisioning, regulating and cultural and the production, management, regulation and strategically planning scales of the ecosystem services, community, city, local, regional or global. Management mechanisms are in relationship with the scale of ecosystem service production regulating water supply, storm water quality, etc., enhancing educational and recreational activities supported by ecological functions and processes (New York Restoration Project 2013a). Consumed ecosystem services can be produced and managed at multiple spatial scales by an array of government agencies, nonprofits organizations, community groups and even by private firms. Urban ecosystem services consumption depending on biodiversity over the scale of urban production can be produced in cooperation with other institutions.

The sensitivity scales of socio ecosystems may shift and vary on functions and damages and their abilities and capacities to provide and supply ecosystem services and goods. Ecosystem services are usually produced at local, regional level and at all spatial scales including the global, well beyond the urban boundaries but provide benefits to residents of the city. However, operationally spatial problems may exist between the locations where the ecosystem services are produced and supplied and the places where are consumed or demanded. The service providing units (SPUs) noted by Kremen (2005) make reference to the ecosystem type and environmental conditions depending of the scale of production and supporting the ecosystem services.

Communities should maintain a flow of valuable ecosystem services taking into consideration socio ecological changes, disasters and disturbances. Affected communities by reduction of natural capital and environmental services are vulnerable to the impacts of disasters and disturbances are more vulnerable than other communities with lower ecosystem degradation and environmental disturbances (CBD & WHO, 2015)

Ecology for human nature interactions is crucial in urban systems for the production of urban ecosystems services (Bolund and Hunhammar, 1999; TEEB, 2011; Gómez-Baggethun et al., 2013). Biodiversity, urban green infrastructure and ecosystem services perform diverse relevant functions, models and indicators in the urban socioecosystem. The ecosystem services framework links urban social and urban ecological infrastructure for the benefits of ecosystems and human beings. A spatial approach to managing ecosystems have a buffer against uncertainties and disturbances ensuring that all the ecosystems provide similar amounts of ecosystem services. More ecosystem services occurring at one time will be tradeoffs between services.

The ecosystems provide diverse ecosystem services to the community with some impacts (Adger, 2000). In the relationship between human beings and nature, feedbacks between human behavior and wellbeing, ecosystem services, environmental conditions support the resilience of socio-ecosystems. The resilience of socio ecosystem is related to ecosystem services. The resilience of ecosystem services is subject to the resilient ecosystems. In other words, ecosystems lead to generate ecosystem services. Socio ecosystems produce and supply ecosystem services valuable for increasing the resilience. The critical components of an ecosystem service should be determining to measure resilience in relation to the production functions of the ecosystem dynamics.

Human-engineered services replace some ecosystem services. Human-engineered services may protect some services but may increase other vulnerabilities undermining and eroding the provision of other ecosystem services. Engineering resilience measurement poses several challenges such as the speed of recovery to previous conditions of disturbance depending of the ecosystem service or system component and the type and severity of disturbance. Weakening ecosystem resilience may compromise the ecosystem services requiring human-engineering services to replace ecosystem services.

Ecosystems services are related to resilience responding to complex and uncertain systems while focusing on natural disturbances, disasters, long term stresses, etc. (Ives & Carpenter, 2007). Ecosystems are subject to disturbances and disasters leading to declination of ecosystem services. Communities can suffer the loss of ecosystems services and being severely impacted by the disasters and disruption of ecosystems. Diversified economic and social community structures are in better position to cope the ecosystem disasters and disturbances affecting the provision of ecosystem services. Ecosystems lacking resilience are vulnerable to disturbances reducing the production and supply of ecosystem services.

To stabilize complex systems it is necessary to provide a constant flow of ecosystem services increasing system resilience and reducing vulnerability (Gunderson et al., 1995). Resilient ecosystems produce, maintain, and supply stable ecosystems services with a speedy recovery from disasters and disturbances. Ecosystem services recovery and ecosystem restoration are defined in terms of measures to be monitored. Some components of the ecosystem services may recover at different speed such as the case of species diversity. The ecosystems services recovery and ecosystem restoration can be planned using knowledge and monitored.

The predictive capability of the ecosystems services and functions is required to restore them including. Eco systems with low level of resilience either restore slowly the provision of ecosystem services and increase resilience or may switch of regime failing to return to previous conditions. However, restoration of ecosystem services follows different pattern that the restoration of the ecosystem structure. Ecosystems structures and functions may affect differently the ecosystem services and any change in the ecosystem does not necessarily affect the ecosystem services which may have different outcomes after disturbances.

Maximizing a specific ecosystem service may be counterproductive to resilience or other ecosystem services. The system resilience maintains the conditions to sustain the provision of ecosystem services which are important contribution to the human wellbeing. Transitions from landscape to residential developments leads to declining of agricultural land, water quality and other critical ecosystem services, which are necessary to protect for urban residents.

Ecosystem services as products of interacting ecosystems is a governance system. Institutional analysis of ecosystem services focusses on the governance institutions of the ecosystem services, the institutional mismatching, and institutions contributing to the perception of ecosystem services. The socio ecosystem institutional governance framework condition the ecosystem services (Norgaard, 2009).

The multilevel institutional governance system of ecosystem services has a wide range of goals and responsibilities of policy design, making and implementation with intricacies in governance structures and overlapping jurisdictions among the international, national, local and community levels, including non-state actors and civil society. The ecosystem services focus shifts to value the benefits by institutions that identify and allocate them (Norgaard, 2009). Studies estimating the monetary value of benefits of ecosystem services conducted by Elmqvist et al. (2015) based on quantification in biophysical units in urban ecosystems analyzed provided up to USD 17,772 in benefits per hectare per year.

Sustainable management of natural capital of ecosystem services to achieve particular value ecosystem and biodiversity values are at the base of management of natural resources supported by a governance strategy and policy on ecological infrastructure. Management strategy and policies of urban ecosystem services may have multiple goals aimed to improve synergy and decrease the tradeoffs. Ecosystem services provide the baseline for policy, planning and management improvements in transitional states for a more sustainable resilient city.

Planning and management of natural and human-controlled processes altering the relationships between urban biodiversity and urban ecosystem processes are essential functions to deliver socio ecosystem services. Ecosystem services, human well-being, competitiveness and governance are the challenges of the sustainable ecosystems management. Increasing the resilience of the ecosystem services requires the management complex systemic dynamics and variability affecting the socio-ecosystem. Management addresses the matching between production and consumption of ecosystem services.

Ecosystem services are embedded in institutions, relay on landscapes and are governed by natural resource sector organizations, administrations, and land use planning (Primmer & Furman, 2012). Urban government ensures protection of nature and urban ecosystem processes to support then urban ecosystem services. Urban ecosystem services are included in planning, policing and managing for the development of urban resilience. Changes over time and space of the ecosystem functioning is crucial to planning, policing, and management of urban ecosystem services. Complex urban systems designing, planning and managing require urban ecosystems to become resilient to changes of the system and sustainable management to provide reliable ecosystems services. System design is moving from controllable traditional products and services to unpredictable industrial socio ecology systems where economic, political, biological and ecological threats have become glocal concerns.

Urban green spaces may be undermined by development, planning and designing processes of existing urban nature, ecological functioning, connectivity and ability to provide ecosystem services (Yli-Pelkonen & Niemelä, 2005). Vacant lots providing ecosystem services require mapping the social needs in high density populated and low income urban areas that tend to decrease the access to green spaces (Kremer et al., 2013; McPhearson et al., 2013). A small fraction of consumed food is produced in local urban agriculture, while most comes directly from regional farms in a variety of ways, such as the green-markets (Gittleman et al., 2010; Cohen & Ackerman, 2011) in a promising trends in developing urban ecosystem services. Other trends of producing urban food and provide other ecosystem services are the urban farms, private gardens, community gardens, roof farms, etc. These ecosystem services provided are the habitat to biodiversity, recreation opportunities, runoff retention, socio-ecological support, etc. (McPhearson & Tidball, 2013).

Practice communities can enhance contacts and exchange knowledge and experiences to design, implement and evaluate urban green infrastructure, biodiversity and urban ecosystem services. Local community groups and non-profit organizations operating urban farming may use agriculture as a means to provide ecosystem services, economic, educational, and other community benefits (EcoStation: NY Inc., 2013; Farming Concrete, 2011; The Battery Conservancy, 2012; Added Value, 2013). Green local partnerships between local community groups, non-profit organizations and agencies involved in planning, designing and managing policy for the provision of ecosystem services to community residents have a critical role on site project.

The institutional policy analysis may determine the distribution of rights to allocate benefits and values from the ecosystem services. The governance complexity and uncertainty of ecosystems services are challenged by assigned rights and coordination of ecosystems biophysical structures and functions, the policy formulation and management practices at the different governance levels and their institutional interplay. One limitation to manage the complexity of the socio ecological system dynamics is the availability of data useful to know how to restore and increase the resilience of ecosystem services.

Management of sustainable natural resources requires market financial incentives and payments for ecosystem services schemes. Payments for ecosystem services is a policy of rights assumed to use and produce ecosystem services, in accordance with rights already determined and governance systems in place. For example, the right to clean water and beautiful landscape may determine the right of a fisherman to a fishing quota. Investing in ecosystems services through the payments approach does not necessarily is a tradeoff between the needs of landowners, resource users and the objectives of other multiple stakeholders.

Spatial multi-scale assessment of urban green infrastructure and urban ecosystem services framework can be connected to urban local policies involving a network of organizations to develop and use different governance levels. Evaluation of the structural and functional role of the urban green infrastructure takes into account the contributions on multi-scales urban development and the relationship of biodiversity and urban ecosystem services.

Further research on the obstacles for using the ecosystem services framework and the potential solutions to achieve sustainable urban resilience is required. Urban biodiversity influencing ecosystem services production and supply is a process that requires further analysis (Faeth et al., 2011). Research is required to analyses inequalities between the urban spatial distributions between supply and demand of ecosystem services.

RECOMMENDATIONS

The results of this theoretical and conceptual literature review leads to an assessment used to integrate, adapt, conserve, and monitor biodiversity linked to urban sustainability, healthy socio-ecosystems management and the outcomes in ecosystem services provided to the cities, in such a way that learning from biodiversity changes and enhance the urban ecosystems resilience. Well-functioning and healthy ecosystem services contribute to the sustainability of the city. Urban ecosystems must integrate uncertainty in change into city management processes in delivering sustainable ecosystem services supported by practical techniques. Urban communities can protect their natural resources and spaces, natural landscapes, engineering infrastructure and urban ecosystems through the use of asset management systems techniques for the provision of urban ecosystem services, the operating budgets for their maintenance and support, the integrating value and other several options such as zoning and rights for land acquisition and development. Urban sustainability and environmental performance integrates biodiversity and socio-ecosystems for the provision of better quality ecosystem services supported by green infrastructure design into the green projects aimed to achieve economic and environmental benefits in energy, water, air quality, transportation and logistics, waste and materials, climate, bio economics, etc. Urban ecosystem services benefit population offering opportunities for recreation and education besides clean air and water, flood control, etc. Feedbacks resulting in poor performance of the ecosystem services tend to intensify human modification by creating degradation of socio-ecosystems and poverty.

Green and natural infrastructure and urban ecosystems should be integrated into asset management of sustainable development programs to ensure the ecosystems functions are properly to yield the expected environmental services. In sustainable urban planning and development, ecological policies for green interventions are implemented to improve urban ecosystems services quality, the environmental sustainability and to instrument the measure of the ecological value through the use of ecological indexes.

CONCLUSION

The performance of biodiversity and socio-ecosystem services resilience can be promoted by implementing green infrastructure technology in adaptive management frame under the scenarios approaches to analyze the impact and effects of green policies on urban sustainability. The socio–ecological feedbacks are the base for absorbing uncertainty and ambiguity in different urban sustainability scenarios which pose a unique challenge for regime shifts in ecosystem services. Finally, the ecosystem services and human wellbeing may suffer irreversible severe declines if sustainability is not built based on biodiversity of socio ecosystems, green infrastructure and natural capital.

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Chapter 4
Ecological and Economic Significance of Bryophytes

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ABSTRACT

With climate change and the massive extinction of biodiversity, this chapter seeks to address the ecological and economic significance of bryophytes. The objective of this chapter is to contribute to the general knowledge of this plant group to spur research and interest in conservation efforts. Ecologically, this chapter x-rays their habit, habitat, distribution, ecophysiology, and reproduction. Bryophytes terrestrialization begun several millions of years ago but is currently threatened by climate change and poor conservation efforts. Economically, this chapter highlights the multifarious uses and applications of bryophytes with a view to promoting diversification, sustainable utilization, and innovative application.

INTRODUCTION

Bryophytes are spore-producing, non-vascular land plants that exhibit a clear division of their plant body into photosynthetic and storage zones (Lakna, 2017). They are the second largest division of plants after angiosperms but are less known because of their size (Chandra et al., 2017). Members of this plant division include liverworts (Hepaticopsida or Hepaticae), hornworts (Anthocerotopsida or Anthocerotae) and mosses (Bryopsida or Musci). Bryophytes are considered as the amphibians of the plant kingdom because they inhabit amphibious zones. These plant amphibians were once considered an evolutionary failure due to poor knowledge about inter and intraspecific genetic variations (During & van Tooren, 1987). However, this plant group continuously survived on Earth at least 75 million years before the age of the dinosaurs. Bryophytes are found in diverse habitats (albeit seasonal) as groups of individuals with characteristic features (shape and structure) depending on their family, genus or species (Mägdefrau, 1982). Bryophytes have been found in almost all terrestrial habitats as well as forming biological associations with other organisms. They are mostly found growing in moist, shady places, producing phenolic compounds, which deter herbivores (Lakna, 2017). However, they prefer mesic environments

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that are damp, humid and shaded from excessive sunlight. According to Hanson and Rice (2014), they are often the dominant life form at high latitudes and elevations. They lack specialized lignified vascular tissue, xylem and phloem, which are present in higher and vascular plants. More so, vascular plants differ from bryophytes in possessing two types of apical meristem, those of the shoot and root (Graham et al., 2000). Nonetheless, bryophytes are the main primary producers in different ecosystems globally and influence different biogeochemical activities including nutrient cycling and availability. They are critical to understanding early land plant evolution because bryophytes and pteridophytes – are largely recognized as early grades of land plant evolution (Qui & Palmer, 1999). They possess embryos but lack seeds. They exhibit a distinct alternation of generation between the dominant gametophyte stage and the dependent sporophyte stage. The unbranched sporophyte produces spores, which are mostly wind dispersed and depends on the dominant stage for nourishment. Although they are mostly autotrophs, some bryophytes like liverworts do not contain chlorophyll. Hence, they form a symbiotic relationship with food (Lakna, 2017).

The aim of this chapter is to discuss the ecologic and economic significance of this plant group, which have suffered neglect due to poor knowledge and understanding of their relevance.

BACKGROUND

Renzaglia et al. (2000) established that extant bryophytes were paraphyletic while the results of Nishiyama et al. (2004) supports monophyly for modern bryophytes based on chloroplast phylogeny, which may represent several lineages along the evolutionary path to vascular plants. However, their exact phylogeny remains unresolved, especially with regard to which group of bryophytes (liverworts, mosses or hornworts) represents the earliest form of land plants (Qiu & Palmer, 1999).

Compared to their vascular counterpart, they are rarely collected and characterized. Hence, many taxonomic gaps continue to exist. Although this group of plants is characteristically small and limited in size, they consist of about 20,000 plant species *(*Levetin & McMahon, 2012). Climate change is also causing a decline in bryophytes species, which is also heightened the neglect of this plant group in research. This extent of this decline can be ascertained through a comparative assessment of older records (Lockhart et al., 2012) i.e. if such records exist. Bryophyte Flora is not present in many biogeographic regions and where they exist, may not be sufficient. However, it is not too late to collect, document and characterizes these plant groups as a way to checkmate future declines. Mölder et al. (2015) opined that the collection of data on bryophyte distribution has been neglected for so long that it has affected their identification, use, and conservation. The objective of the chapter is to contribute to the knowledge of the plant group and to spur research interests on the group.

ORIGIN AND DISTRIBUTION OF BRYOPHYTES

Bryophytes are the first plant group to colonize open ground through the process of adaptive radiation described as terrestrialization and were also among the pioneers of terrestrial photosynthesis (Hanson & Rice, 2014). Among bryophytes, liverworts are resolved as the first divergence of land plants (Stotler & Crandall-Stotler, 2016). The process of terrestrialization is estimated to have begun around 500 million years ago and much is credited to their photosynthetic abilities. The combination of neontology, paleontology, and molecular phylogenetics reveal that bryophytes inherited many physiological traits necessary from terrestrial existence from ancestral algae including spore, body desiccation-resistance, degradation-resistance lignin-like phenolic cell wall polymers (Graham et al., 2014). Transition to land required an interface between water and land and while fossil record is sparse, brackish water seems the most probable origin of land vegetation (Proctor, 2014). More so, bryophytes will require desiccation tolerance alongside other modifications (like size) for the transition and may have been derived from bacterial and algal species that have desiccation tolerant spores or resting stages.

Bryophyte lineages: liverworts (Marchantiophyta), hornworts (Anthocerotophyta), and mosses (Bryophyta) may only superficially related due to independent evolution from their green algal ancestor, Charophytes (Qiu et al., 2006; Crandall-Stotler & Bartholomew-Began, 2007). Hornworts and liverworts represent the earliest evolving while mosses are likely the closest sister group to vascular plants (Crandall-Stotler & Bartholomew-Began, 2007; Chang & Graham, 2011; Ligrone et al., 2012). Raven & Edwards (2014) inferred that bryophytes probably evolved from charophycean green algae based on fossil record from spores and resemblance in being desiccation tolerant and poikilohydric. The authors added that homoiohydry in modern-day bryophytes developed much later as a requirement for their subsequent survival since environment, and environmental conditions evolve alongside organism. The relative complex morphologies in their photosynthetic structure enabled them to meet the light harvesting requirements, whereas higher atmospheric CO_2 concentrations in the early Phanerozoic era would have permitted higher rates of photosynthesis (Raven & Edwards, 2014).

For organisms that began their existence in aquatic environments, migration to a land or near land habit will require continuous and elaborate adaptations. For instance, on a short-term, within the tropics, some bryophytes thalli may appear greyish, dried and brittle during dry seasons but transform to a bright green colour when supplied with water or at the onset of the rainy season. Thus, on land, bryophytes had to adjust to the reduced surface area to volume ratio and minimize water loss. Earlier in bryophyte evolution, there was a persistent challenge of remaining in the photic zone but on land, water is limiting while the available light and CO_2 require elaborate organelles for their absorption and use (Proctor, 2014).

Together, the three bryophyte divisions have around 25,000 representative species. The mosses are the most abundant followed by liverworts and then the hornworts. It may be suggested that more bryophyte species are yet to be discovered especially in tropical regions of the world, where taxonomic and general information are rare. The true mosses show several evolutionary advances over the liverworts, hornworts, and other mosses by possessing rhizoids, calyptra, hadrom (single strand conducting hydroids) and leptoms for conducting nutrients and photosynthates. Besides their ecological value, modern representatives of this plant division contain the legacy of adaptations that led to the greening of the Earth (Hanson & Rice, 2014). Epiphytic bryophytes are commonly found on trees. The tree species, management structure, trunk girth and distance to nearest neighbouring trees may be used to explain the observed diversity and variation in bryophyte cover (Whitelaw & Burton, 2015). Forests also provide numerous types of habitat for bryophytes, especially the ground floor (Jiang et al., 2015). Due to their lack of seeds and flowers, they are grouped among other cryptogams or thallophytes. A group that also contains algae, fungi, and ferns.

Collection for herbarium storage and other purposes remains paramount. To this end, important floras are Paton's, "The Liverwort Flora of the British Isles (1999)", Smith's, "The Moss Flora of Britain and Ireland (2004)". Others are "Mosses and Liverworts of Britain and Ireland: a field guide" by Atherton et al. (2010), and Hills et al. (2008) Attributes of British and Irish Mosses, Liverworts and Hornworts. Nordic flora is illustrated with photographs and coloured drawings have been published recently and cover, amongst other taxa, Dicranales, Grimmiales, and Pottiales by Hallingbäck et al. (2006; 2008). After collected, in temperate environments, they can be readily processed (by drying indoors) and stored in simple paper packets folded much like an envelope but without any sticky margin (Preston et al., 2012). The method of folding packets is outlined by Rothero & Blackstock (2005) and is described in various handbooks to mosses and liverworts (Preston et al., 2012). The required information on the packets is outlined in Preston et al. (2012).

The distribution of bryophyte requires a favorable microhabitat and microclimate for their establishment (Valente et al., 2013). The species composition and richness within bryophyte communities are influenced by external factors, especially water, light, and temperature, hence their roles are biological indicators (Mägdefrau, 1982; Frahm & Gradstein, 1991). More so, their sensitivity to elevational variations have been documented by van Reenen & Gradstein (1983); (1984); Kessler (2000); Frahm (1990); Frahm & Gradstein (1991); Andrew et al. (2003); Grau et al. (2007); Ah-Peng et al. (2007) and suggest that their species richness and distribution may increase, decrease, have humped-back shape or no trend with increasing and decreasing elevations depending on the biogeographic region. As a result, Andrew et al. (2003) suggested the possibility of making reliable generalizations regarding observable changes in bryophyte diversity along latitudinal and altitudinal gradients according to bryophyte distribution. Other environmental factors that influence bryophyte distribution within a geographical location are insolation, frost, fog, temperature, precipitation, lithology, evapotranspiration rate, humidity, thermicity and soil pH. The application of ecological niche modelling to estimate bryophyte species distribution within a location is a viable method (Sergio et al., 2007). Despite having a wider distribution than vascular plants, bryophytes are often excluded in plant diversity surveys and collection due to difficulties in identification, fewer specialists, less taxonomic literatures especially in tropical areas, time consuming and the high financial cost requirements for searching and identifying bryophytes (Andrew et al., 2003; Ah-Peng et al., 2007; Sun et al., 2013).

BOTANICAL CLASSIFICATION, DESCRIPTION, AND PHYSICAL CHARACTERISTICS

Bryophytes are macroscopic plants and their size varies from a millimetre tall to several millimeters' long strands. The protonema produced from the germinating spore forms one to several buds, each of which can grow to become an 'individual'. The individuals are thus at the very outset part of an assemblage. Bryophyte assemblages are modified by external conditions to provide the characteristics, which can be described as the life form (Mägdefrau, 1982). Their adaptation to a terrestrial mode of life is considered partial because water remains an indispensable part of their life cycle. This contributed to their reference as the amphibians of the plant kingdom.

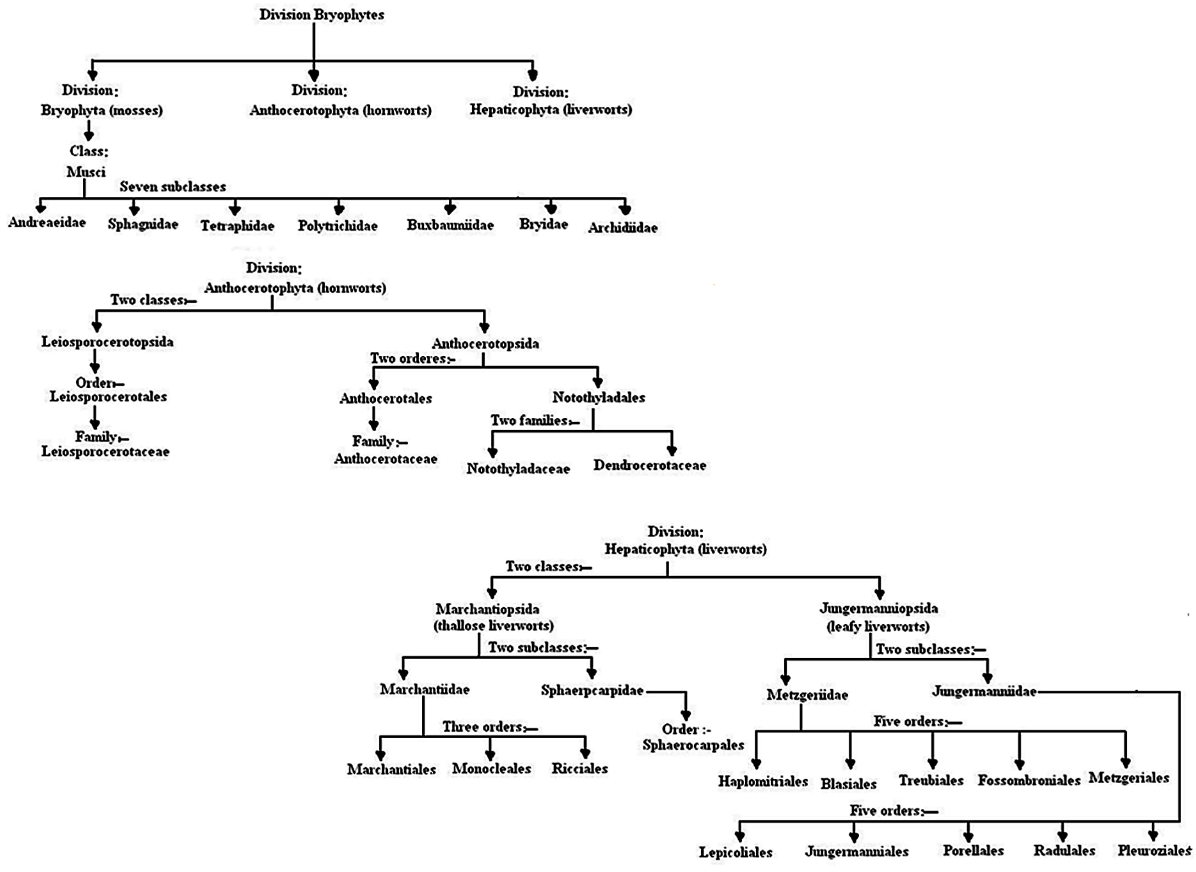
They lack vascular tissues, true roots, stems, and leaves. Comparative morphology and developmental studies revealed that their meristems are derived from simpler forms but the genetic basis for expressional differences is unknown (Graham et al., 2000).

Their plant body is called the thallus (or thalli), which sometimes appear leafy and is covered by a cutin-like epidermal shield to prevent them from drying up due to water loss. The epidermal shield varies from one species to another as well as from one biogeographic region to another to suit their environmental requirement for survival. The thallus grows prostrate and is attached to a substratum through the hair-like rhizoids. The plant body may be erect in some bryophytes. Their root-like structure is called rhizoid and is mainly used for absorbing substrates and attaching to surfaces. As photosynthetic organisms, bryophytes require water, light, CO_2 and other essential chemicals from the environment.

Their multicellular reproductive structures are held in jackets and are still primitive in its water requirement for sexual reproduction. The sperms are often biflagellate while the archegonium houses the female sex organs. The sporogonium is concerned with the production of wind dispensed, non-motile, undifferentiated cutinized homospores, which germinate to give rise to the gametophyte plant directly or indirectly through a protonema. The spores are within the meiospores or gonospores category. The enlarged venter (i.e. the swollen basal region of the archegonium) protects the embryo is called calyptra and it disintegrates as soon as the spores are released.

Asakawa et al. (2013) suggested that bryophytes are taxonomically between algae and pteridophytes. Marchantiophyta. Bryophyte classification has transitioned from morphological based features to a high anatomical examination of very fine morphological detail and cellular structure to molecular-based methods (Australian National Herbarium, 2008). The classification of bryophyte is far from over as many taxonomic revisions are ongoing with immense potentials for new discovery due to advanced technology. The early systems of bryophyte classification is similar to those of other plant groups and are done artificially where grouping was only for convenience based on (observable) evident characters (Asthana, 2006). On this basis, Braun (1864) for the first time introduced the name 'Bryophyta' but at that time Algae, Fungi, Lichen and mosses were also included in this group. Schimper (1879) placed Bryophyta at the level of division and since then it occupies the same rank till date. Eichler (1883) for the first time included two groups Hepaticae and Musci and since then it becomes a tradition to divide Bryophyta into, at least, these two classes. Some bryologists placed liverworts and hornworts (Anthocerotes) in a single class while others placed them into two different classes. Subsequent workers divided the group into three classes: Hepaticae, Anthocerotae and Musci, after raising the order Anthocerotales up to the class level due to many characters which are remarkably different. This system of classification is more natural, placing liverworts, hornworts, and mosses in three different classes: Hepaticae, Anthocerotae, and Musci respectively (Asthana, 2006). Levels of classification above the genus are in such a state of

Figure 1. Bryophyte divisions, their classes, and orders
Source: Adapted from Kumar, 2009



flux that the most useful indicator of the taxonomic extent of the bryophytes can be gained from approximate numbers of genera and species (Miller, 1982). Although renewed interest in bryophyte and training of future bryologist will be handy for meeting this challenge. Liverwort contains metabolites that are valuable for their chemotaxonomic classification (Asakawa et al., 2013).

There are three main taxonomic bryophyte divisions: mosses (Bryophyta), liverworts (Marchantiophyta or Hepatophyta) and hornworts (Anthocerotophyta) with different sub taxonomic representatives (Figure 1, Kumar, 2009).

Mosses have erect or creeping stem-like structures with tiny leaf-like outgrowths, but hornworts and some liverworts have only a flat thallus and no leave-like protrusions. They are generally small but very conspicuous as extensive mats or cushions on walls, rocks and tree trunks, and as pioneer colonists of disturbed habitats.

Specialized tissue in some moss gametophytes includes chlorenchyma, parenchyma, epidermis, water-conducting hydroids, and sugar-conducting leptoids. The sporophyte and gametophyte have very different morphologies (heteromorphic generations) and the sporophyte is usually partly dependent on the gametophyte.

General characteristics of bryophytes include:

1. Dominant homothallic or heterothallic gametophyte (n) stage that is morphologically different from the dependent sporophytic stage (2n) (i.e. heteromorphic generations).
2. Small photosynthetic plants with no vascular differentiation, cuticle, and stomata.
3. Presence of thalloid, rhizoids, caulalia and phyllids.
4. Female and male reproductive structures are called archegonium and antheridium respectively.
5. Ovum is nonmotile and remains in the archegonium while the spermatozoids are motile.
6. Reproduction requires water or chemical.
7. The sporophytic plant is produced from meiosis and possess a basal foot, elevating seta and a capsule (sporangium).

Division - Bryophyta (Mosses)

1. Bryophyta contains approximately 15,000 species. Common examples are granite mosses, peat mosses, dung mosses, true mosses, *Mnium*, and *Sphagnum*.
2. Mosses are mostly terrestrial and often epiphytic.
3. Dominant gametophyte (n) with erect of the prostrate thallus and spirally arranged, variable shaped phyllids (leaf-like structures) and rhizoids for attachment to the substratum and for absorption. Rhizoid are absent in except *Takakia* and *Sphagnum.*
4. Some family (e.g. Polytrichaceae) possess hydroids (tissue hydrom), for water and mineral conduction and leptoids (tissue leptom) for conducting photosynthates conduction.
5. They have a sporic (diplohaplontic) life cycle, which is oogamous. Most spore germination may be exosporic but also endosporic as in *Andreaea*, *Drummondia*, and *Leucodon.*
6. Mosses have radial symmetry, in that a cut down the long axis of an individual gives two similar halves.
7. Phyllids consist of a single cell layer that is traversed by a midrib and toothed or rounded margins. The phyllids of Mnium may be a single cell thick, but with a midrib with hydroids and leptoids while that of Polytrichum have layers of cells and filamentous strands of photosynthetic cells. The phyllids may be isophyllous or anisophyllous.
8. Hydroids are used for conducting water and leptoids for conducting sugars, which are similar to the xylem and phloem of vascular plants respectively.
9. Short-lived, highly branched and uniserate protonema are formed after spore germination gives rise to caulonema (plastid rich cells for nutrient absorption) and chloronema (chloroplast rich cells for photosynthesis).
10. The Moss stem consists of an epidermal layer, a cortex, and a central strand of thin-walled, hydrolyzed water-conducting cells, called hydroids.
11. The male and female gametangia may be on the same thallus (homothallic or monoecious) or on separate gametophytes (heterothallic or dioecious) with jacketed antheridium and archegonium for protection against desiccation. Spore dispersal is controlled by hygroscopic movement of peristome teeth or spore capsule but members of Splachnaceae e.g. *Tayloria gunnii* (Figure 2) rely on insects (Goffinet et al., 2004; Gallenmüller et al., 2018).

Figure 2. Tayloria gunnii ([Wilson] J.H. Willis, Splachnaceae, Splachnales)
Source: Australian National Herbarium (2008)

Figure 3. New Zealand leafy liverwort Leiomitra lanata ([Hook] R.M. Schust, Trichocoleaceae)
Source: Australian National Herbarium (2008)

Figure 4. Hornworts, Phaeoceros carolinianus ([Michx] Prosk., Notothyladaceae)
Source: Asakawa et al. (2013)

Division - Hepatophyta (Liverworts)

1. Liverworts contain approximately 8000 species. Common ones are *Marchantia*, *Conocephalum,* and *Porella*.
2. Small liver-shaped plants found in diverse environments.
3. Leafy filaments less than 0.02 in (0.5 mm) in diameter, to plants exceeding 8 in (20 cm) in size.
4. Liverworts are made up of flat, lobed thalli.
5. The plant body may be thallose and leafy.
6. Stalked, multicellular, flask-shaped archegonia consisting of an elongated upper portion called neck and lower swollen portion -venter.
7. The neck consists of jacketed rows of cells, which encloses a larger egg cell or the ovum and the smaller ventral canal cell just above the egg.
8. Antheridia consist of rounded structure mass of cells called the androcytes that gives rise to the antherozoids.
9. Using *Leiomitra lanata* (Figure 3) De Lucia et al. (2003) emphasized the contribution of bryophytes to carbon exchange within temperate forests.

Table 1. Differences between the three bryophyte divisions

Feature	Bryophyta	Hepaticophyta	Anthocerotophyta
Protonema	Filamentous, forming many buds	Globose, forming one bud	Globose, forming one bud
Gametophyte	Leafy shoot	Leafy shoot or thallus; either simple or with air chambers	Simple thallus
Growth of sporophyte	Apical	Apical	Grows continuously from a basal meristem
Arrangement and form of leaf-like structures	Spiral, undivided with a midvein	In three rows; divided into two lobes with no midveins	Not applicable
Branches	Developing from stem epidermis	Developing from leaf initial cells or inner stem cells, rarely stem epiderma	Not applicable
Gemmae	Common on leaves, stems, rhizoid or protonema	Common on leaves	Not applicable
Paraphyses	Usually associated with antheridia and archegonia	Usually lacking but they often have mucilaginous filaments	Not applicable
Special organelles	None or simple, small oil bodies	Oil bodies	Single plastids with pyrenoids
Water-conducting cells	Present in both generations	Present in a few thalloid forms	Absent
Rhizoids	Brown and multicellular	Hyaline and one-celled	Hyaline and one-celled
Gametangial position	Apical clusters	Apical clusters (sometimes leaf-like) or on the upper surface of the thallus	Sunken in thallus and scattered
Stomates	Present in sporophyte capsule	Absent in both generations	Present in both generations
Seta	Photosynthetic and emergent from the gametophyte early in the development	Hyaline, elongating just prior to spore release	Absent
Capsule	Fixed sized and complex with an operculum, theca, and neck	Undifferentiated, spherical or elongated (also of fixed size)	Undifferentiated, horn-shaped, growing continuously from a basal meristem
Sterile cells in the capsule	Columella	Spirally thickened elaters	Columella and pseudoelaters
Calyptra	Ruptures and persist at the apex of seta and capsule. It influences the capsule shape	Ruptures and persist at the apex of seta and capsule. It influences the capsule shape	Not applicable

Source: Adapted from Kumar (2009); Crandall-Stotler (1996); Gradstein et al. (2001)

Division – Hornworts

1. Hornworts contains approximately 1,000 species common example is Anthoceros.
2. Irregular lobed or branching thalli with guard cells on the underside.
3. Characteristic long and slender horn-like or needle-like sporangia produced by the sporophyte stage, hence the name hornworts.
4. The sporophyte is separated into a capsule and foot. Seta is absent and sometimes the capsule also. The capsule is cylindrical ‘horn’ like and is not determinate in growth.
5. Dominant gametophyte form is a flat, green-bodied plant with embedded reproductive organs.
6. The rhizoids are unicellular, smooth walled and simple.

7. The thallus may be compact or spongy with no air chambers and pores.
8. The epidermal cells usually have single, large, plate-like chloroplast with conspicuous pyrenoid bodies.
9. Endothecium forms from the central sterile portion-columella but are sometimes absent as in *Notothylas* species.
10. Gametangia are located inside the thallus.
11. Nitrogen-fixing cyanobacteria may live symbiotically with hornworts.
12. Unlike the typical black or brown spores of *Anthoceros*, members of the genus *Phaeoceros* (Figure 4) have unique yellow horn and spores.

The major distinction between the bryophyte divisions is presented in Table 1.

ECOLOGICAL IMPORTANCE OF BRYOPHYTES

1. Ecophysiology of the Group

Bryophytes are widely distributed globally where they contribute to nutrient cycling, water retention, water availability, higher plant biomass, and community maintenance (Jiang et al., 2015). Therefore, other members of the ecological community benefit from the ecosystem services, functions, and processes of bryophytes. For instance, other plants ecologically benefit from the water collected by bryophytes by using it to conduct internal processes (Lakna, 2017). This kind of services may be broadly referred to as 'buffer system'. Bryophytes perform the environmental quality indicative function because of their sensitivity to levels of moisture in the atmosphere as well as the diversity of chemical groups. The responses of bryophytes to environmental variabilities is a reflection of their ecological and reproductive strategies to ensure their establishment, persistence, and dispersal (Batista et al., 2018). An earlier hypothesis suggesting that bryophyte fertility decreases with increasing latitude and therefore climatic severity have been discredited by the results of Smith & Convey (2002). More so, their sex expression is continuous over long periods regardless of seasons, sites and minimal environmental variations but there may be a seasonal effect on the maturation of gametangia and sporophytes (Maciel-Silva & Válio, 2011).

Carbon fixation in mosses saturates at moderate irradiances. Protection against excess excitation energy in mosses involves a high capacity for photosynthetic electron transport to oxygen and high non-photochemical quenching, activated at high irradiance, alongside high reactive oxygen species tolerance (Proctor and Smirnoff, 2011). Even with their vascular limitations, bryophytes, and mosses, in particular can occupy large surface areas including even those polluted with heavy metals due to their unique biochemically driven life cycle strategies and physiological behaviors (Glime, 2017a). As poikilohydric organisms bryophytes equilibrate more or less rapidly with external moisture conditions (Wagner et al., 2014). More so, due to their Poikilohydric strategy for water and nutrients, bryophytes survival and growth are highly dependent on their external environment (Marschall, 2017). The author further posited that they are able to lose most of their cell water without dying up, only to resume normal metabolism after rehydration, gaining positive carbon balance over wet-dry cycles and can maintain efficient photosynthesis under low light conditions, have low chlorophyll *a/b* ratios, and their optimum growth is possible within a limited temperature range.

Although bryophytes are abundant everywhere, the tropical forests tend to hold a huge diversity of bryophytes, particularly liverworts and mosses but their abundance and ecological importance contrast strongly with the availability of information on the ecophysiology of this plant group in the tropics (Wagner et al., 2014). Small size and lack of lignified vascular tissue have enhanced the selection for physiological means of drought survival, including metabolic shutdown and the ability to revive with a minimum or at least sustainable level of destruction (Glime, 2017a). Factors that influence bryophyte ecophysiology include vertical gradients of light, humidity, wind speed and temporal variability inside a forest (Wagner et al., 2014). More so, leaching and decomposition of bryophyte organic material result in a pulsed release of nutrients after rehydration of dry mosses while many bryophytes spend most of their lives in a dry and inactive state. Carbon gain and growth are restricted to periods of sufficient hydration and capturing and storing moisture are crucial abilities for bryophytes (Wagner et al., 2014). Although air humidity correlates with moss cover within the tropical lowlands, there is no correlation between bryomass and precipitation. Due to the ability of bryophytes to provide moisture, appropriate temperature, and also organic matter and minerals after their death, they play an important role in the maintenance and replenishment of forest cover (Saxena & Harinder, 2004). Tropical montane forests and temperate rainforests, appears to be particularly favorable for bryophyte growth. This tropical environment sets particular limits and requirements for bryophyte functioning and growth. They have a relatively low optimal temperature for growth and a low acclimatization potential for high temperatures (Marschall, 2017). Considering that temperature acclimatization is importance for the physiological basis of altitudinal distribution, bryophytes with their small and resistant spores are able to disperse over long distances by wind. Increase in epiphytic bryomass with increasing water content often result from interactions related to water storage and transport processes at different scales and are determined by various morphological traits including the density, size, and disposition of phylloid, as well as by whole-clump architecture (Romero et al., 2005). In relatively wet habitats, bryophytes are likely to display a low intensity of the photochemistry of photosynthesis (Liepiņa & Ievinsh, 2013).

2. Bryophyte Reproduction and Propagation

Bryophyte cultivation may be required for physiological and biochemical research. More so, some bryophyte species add to the beauty of gardens, front and backyards as well as landscapes. Schneider et al. (1967) developed standard substrates for cultivating liverwort, *Marchantia polymorpha* using vermiculite, perlite, glass cloth, nutrient agar, and nutrient solution. The authors added that selected culture conditions and vessels are specially adapted to each substrate. Shaw (1986) also outlined other methods for cultivating some economically important bryophytes.

Mosses can be established easily into diverse environments through transplanting or blending moss fragments in a blender. Fragmentation is common and occurs when they are naturally broken by storm or animals (e.g. *Papillaria flavolimbata*) or artificially when lawn mowing result in fragments been cut. Thus, fragmentation is a form of vegetative reproduction in bryophytes. Many bryophytes contain zones of weakness that may easily fragment. The most preferred site for moss establishment would be those with moss already on it, shady and most areas. Watering is required until moss germinates, which could be approximately five weeks after transplanting fragments. When managing orchards, managers should proactively consider bryophyte community characteristic for the benefit of biodiversity since they are useful indicators of habitat quality and structure (Davies et al., 2007; Whitelaw & Burton, 2015).

Bryophytes have dioecious and monoecious representatives on the basis of their sexual mode of reproduction. About 70% of liverworts species are dioecious, 55 - 60% of moss species whereas in hornworts monoecy is dominant (Wyatt 1982, 1994; Vanderpoorten & Goffinet, 2009). Out-crossing occurs in dioecious species, hence establishment from spores hardly ever results directly in gametophores occurring close enough in time and space whereas self-fertilization dominates monoecious species (During & van Tooren, 1987; Maciel-Silva & Pôrto, 2014). According to Maciel-Silva & Pôrto (2014), self-fertilization in monoicous bryophytes can be prevented through protandry (*i.e.* through the maturation of antheridia before the archegonia on the same plant) and protogyny (*i.e.* through the maturation of archegonia before the antheridia). Gamete dispersal distances are also very low. Self-incompatibility has not yet been shown to occur in bryophytes, but several less absolute mechanisms promoting outbreeding have been found, mostly involving temporal separation of the sexes (Wyatt, 1982). Many species that do not possess such specialized propagula show indeterminate growth and branching followed by a gradual falling apart of the ramets (*i.e.* a clonal offshoot and can be called genets) (During & van Tooren, 1987).

Bryophytes lack the complexities associated with vascular plant reproduction. Reproduction occurs through spores borne on the gametophytes often as a ‘headdress’. These spores require water for formation (for the movement of sperms to fertilize the eggs) and wind for dispersal. Spore capsules (and sometimes a stalk called seta) are produced after the sperm has fertilized the eggs. Fertilization of gametes forms the gametophyte with the spore capsules called sporophyte. Gametophytes may bear propagules on the rhizoids, on short specialized rhizoids on the stem, on leaf lamina or Costa, on leaf tips, even on specialized ‘splash-cup’ Gemma heads as in *Tetraphis pellucida* (During & van Tooren, 1987).

Generally, bryophytes can reproduce asexually when sporophytes release spores and sexually when gametes fuse to form a zygote. The latter involves the mixing of the genes of two independent parents while in the former, there is no such mixing and each new plant is derived from just one parent plant. The gametophytes of mosses and leafy liverworts are the stems and leaves while in hornworts and thallose liverworts, it is the flattish sheet (Australia National Botanical Garden, 2012). These are responsible for the production of gametes. The spores are antheridia (male organ *i.e.* produces sperm) and archegonia (female organ *i.e.* produces eggs), which appear like umbrellas on the gametophytic plant in *Marchantia polymorpha*. Spores germinate to give rise to the gametophyte.

Frey & Kurschner (2011) suggested that asexual reproduction in bryophyte occur:

1. Dioeciously through regeneration from specialized caducous organs or by the production of specialized propagules like gemmae and protonemal cells.
2. By the fragmentation of their plant body.
3. Clonally (i.e. self-cloning due to the endogenous mechanism or forced cloning due to external influences). That results in ramets (independent daughter plants also called merriments).

Asexual reproduction is also capable of occurring through structures like gemmae, propagules, and regeneration of fragments that are able to form new plants (Maciel-Silva & Pôrto, 2014). The process of germination begins in the capsule, mother cells of spores (sporocytes), which split meiotically into tetrads of haploid spores. These are dispersed and germinate into a filamentous phase called protonema with chloronema, caulonema, and Rhizoids cells. In leafy liverworts, the gametophyte possesses rhizoids, caulid (stem), and phyllids (leaves). Sexual reproduction in bryophytes involves the release of motile male gametes into the environment and requires successful navigation of these naked cells from the male to the female sex organs via an external water source (Shaw & Enzaglia, 2004).

Figure 5. The lifecycle of a typical moss
Source: Krempels (1996)

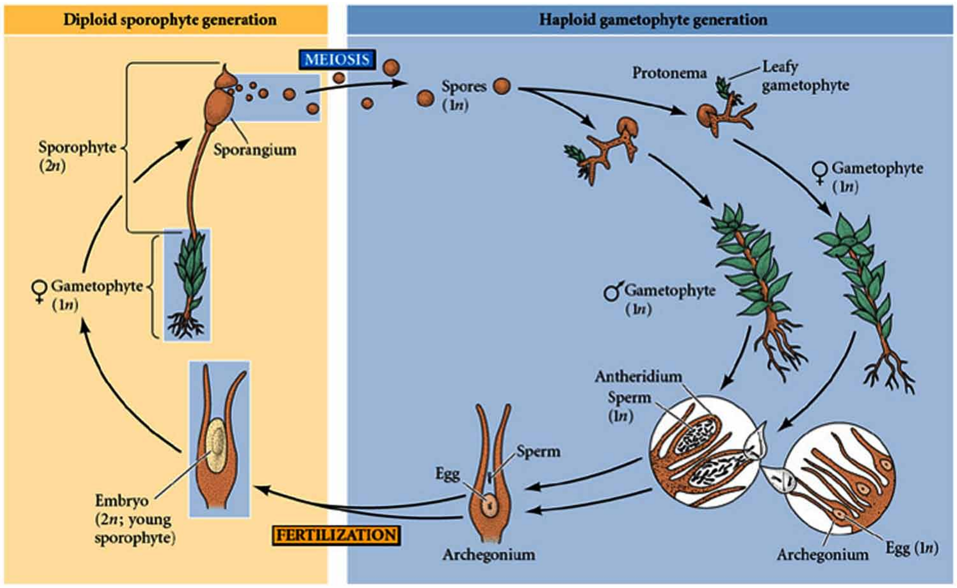


Figure 6. The lifecycle of Marchantia (Liverworts)
Source: Krempels (1996)

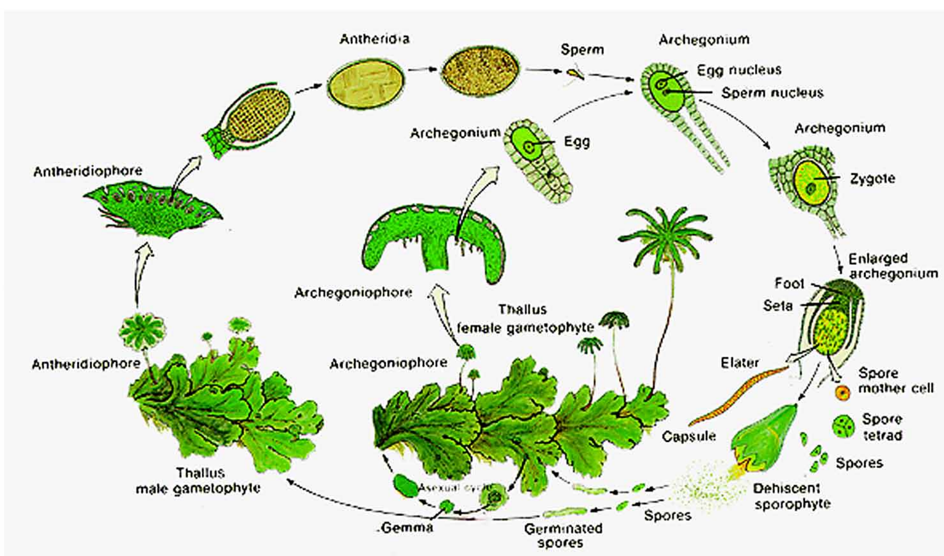
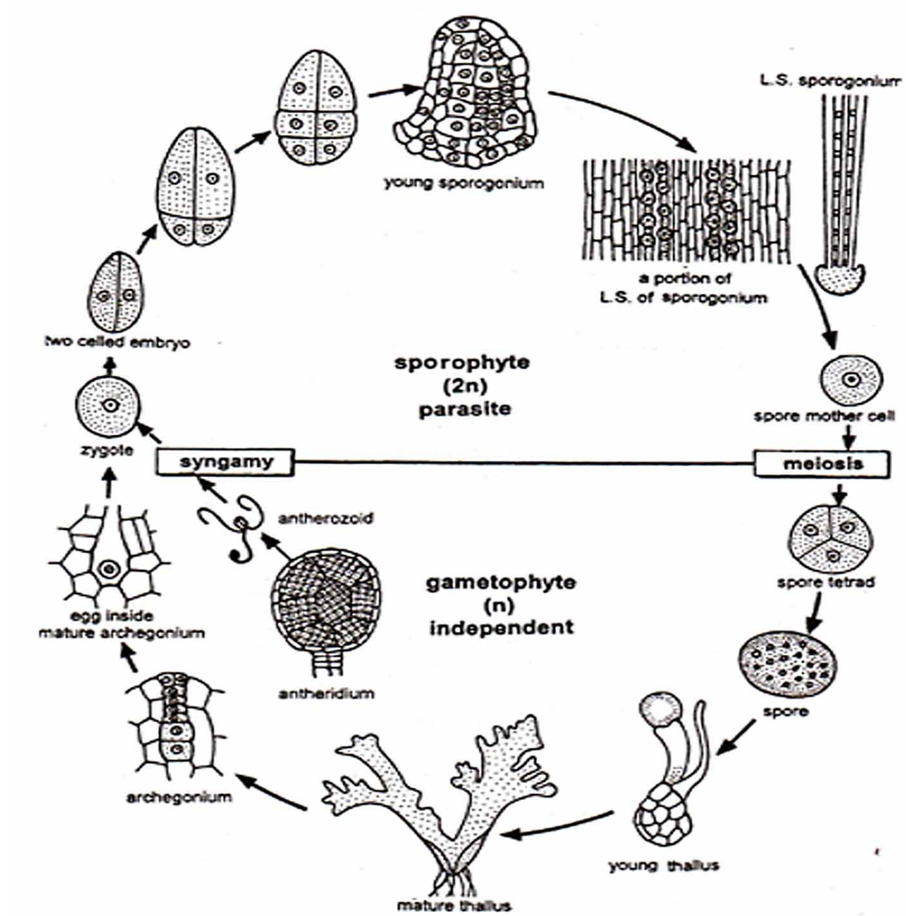


Figure 7. The lifecycle of Anthocero (Hornwort)



Spore output per sporophyte is in the range of 50,000-600,000 in many moss species with small spore size whereas, in mosses with somewhat larger spores, numbers are in the range 5,000-10,000 per sporophyte. Among hepatics (liverworts), spore output is low in many Marchantiales (Longton & Schuster, 1983; During & van Tooren, 1987). Although bryophytes maintain their populations mostly through asexual reproduction, sexual reproduction result in the production of numerous spores but their subsequent establishments may be difficult (During & van Tooren, 1987). Asexual reproduction enables bryophytes propagules to rapidly colonize an area following disturbance, thereby reducing the chances of extinction. Regarding genetic and population variations, the remarkable rapid fine-scale dynamics found in many bryophyte populations contribute ole in the maintenance and determination of community diversity (During & van Tooren, 1987).

A typical moss sporophyte is produced by the fusion of gametes. The terminal disk-shaped antheridium in mosses consists of a spore-containing capsule on a stalk (seta, may be absent), a sterile jacket, and spermatogenic tissue. Through meiosis, the sporophyte produces haploid spores, which develops into the next generation of gametophyte plants. By mitotic division of haploid spermatogenic tissues, the flagellated chemotactic sperms are developed and at the right time swim through water to the eggs in the archegonium. The antheridia also have filamentous cells called paraphyses, which swell up with water and squeeze the antheridia to help expel sperm. The peristome becomes visible with spaces through which the spores escape. The composite cells produced by mitosis in the archegonium consists of a stalk, a venter surrounds the egg, and a long neck filled with canal cells. The neck disintegrates while the ventral canal cells provide chemicals involved in sperm chemotaxis to fuse with the egg. After fusion of egg and sperm zygote is formed which diploid.

Gametophyte plant is produced by the germination of a haploid spore. As a spore germinates, it produces a mostly ephemeral branched filament of photosynthetic cells called a protonema. This branching filament is similar to a green alga. The protonema produces a caulonema filament which can produce either a leafy moss gametophyte or a hard, dry bulbil for asexual reproduction. The moss gametophyte produces male and female gametangia. The typical moss lifecycle is presented in Figure 5.

In liverworts, spores from the sporophyte develop into gametes (*i.e.* longer gametophyte stage) that are later fertilized to produce a zygote and then the sporophyte. The antheridiophores (male stalk) contain the sperm-generating antheridia while the archegoniophores (female stalk) contain the ovum-bearing archegonia. The antheridia release sperm, which swims up the archegoniophore and into the archegonium. Fertilization occurs in the archegonium, and the resulting zygote then grows into a sporophyte on the archegoniophore. The sporophyte grows a single sporangium, within which meiosis takes place to produce spores that will be released into the environment. The release spore germinates to produce the gametophyte and the cycle begins all over again (Figure 6).

Hornworts begin its lifecycle as a haploid spore with a germ tube. The germ tube divides to form the thalloid, which becomes the gametophyte (Figure 7).

3. Management of Bryophytes

Bryophyte control may be required after heavy infestations on the soil-substrate surface may cause irrigation water and liquid fertilizers to leach (Svenson, 1997; 1998; Svenson et al., 1997). Therefore, more water, fertilizers, and pesticides may be required. Regulating bryophyte population reduces the potential for environmental pollution due to the use of excess polluting chemicals.

More so, liverworts may provide refuge for fungus gnats, which are proven to damage roots and spread crop diseases. Liverworts cannot be effectively controlled chemically by using conventional herbicides except by using a cinnamon oil extract treatment (with a cinnamic aldehyde as the active ingredient, which must be used with caution because it is generally phytotoxic) and Mogeton (active ingredient: quinoclamine). These chemicals are not effective against moss. Meadowfoam seed meal (left over after the crop's oil has been extracted) can be used for effective liverwort and moss control. The seed meal is a natural product and may provide less environmental risk. Another product that is routinely effective is vinegar (acetic acid). The cost to remove bryophytes by hand is extremely time-consuming. Some fungus that grows on liverworts is currently been tested for use as a potential biocontrol agent. In the case of bryophyte infestation;

1. Do not overwater. Rather allow the surface of the growing medium to dry between irrigation cycles or switch to sub-irrigation systems.
2. Do not apply excess nitrogen or phosphorus fertilizers.
3. Surface applications of slow-release iron sulphate and/or copper sulphate help prevent liverwort infestations. Zinc sulphate or zinc chloride fertilizers can help control liverworts, but the amount applied to kill the liverwort is often toxic to nursery crops.
4. Liverworts generally die if the crop's canopy will provide sufficient shade to the surface of the growing medium.

ECONOMIC IMPORTANCE OF BRYOPHYTES

There is limited information on the diverse economic relevance of bryophyte. For instance, Chandra et al. (2017) reported that in spite of their implication in popular herbal and food remedy among the tribal people of Africa, America, Europe, Poland, Argentina, Australia, New Zealand, Turkey, Japan, Taiwan, Pakistan, China, Nepal and India; very limited knowledge is available about the medicinal properties of bryophytes. The most commonly used bryophytes are *Marchantia*, *Sphagnum*, *Polytrichum*, *Conocephalum*, *Climacium*, *Hylocomium*, *Hypnum*, *Rhytidiadelphus*, *Thuidium*, *Antitrichia*, *Bryum*, *Dicranum*, *Fontinalis*, *Funaria*, *Philonotis*, *Pleurozium* and *Rhizomnium* (Harris, 2008; Glime, 2017b). From the ancient times, bryophytes were used in packing, plugging as well as in decoration (Chandra et al., 2017). Bryophytes are considered to be nutritionally useless to humans because no references concerning use as foods for humans have been found unlike their use as medicines (Asakawa et al., 2013). Some bryophytes are attractive to herbivores. Mosses are used for decorative purposes in homes (Saxena & Harinder, 2004). *Marchantia polymorpha* is used in the winery to soaks up the wine and makes a tasty treat (Glime, 2017b).

Their durability and elasticity may be the reason why they are used to stuff and fill in chinks in wooden buildings, industrial and domestic upholstery, hassocks, between the panes of glass in double-glazed windows, balls, and dolls (Thomas & Jackson 1985; Pant & Tewari 1990; Glime, 2017b). *Neckera complanata*, a species that has been used in bedding in Europe while Sphagnum is used in America as an absorbent to serves as an insulator to keep warm, dry or cool (Glime, 2017b). Sphagnum has been implicated in making clothes, soap, and ointment for dressing wounds. A number of mosses make ideal lamp wicks including *Dicranum elongatum*, *Racomitrium lanuginosum,* and *Sphagnum* (Glime, 2017b). Tribal people use these plants to cure various ailments in their daily lives including to cure hepatic disorders, skin diseases, cardiovascular diseases, antitumor properties, used as antipyretic, antimicrobial, wound healing, etc. (Chandra et al., 2017). More so, active constituents of bryophytes are widely used as antibacterial, antifungal, cytotoxic, antitumor and insecticidal (Asakawa, 2007; Ucuncu et al., 2010).

The phytochemistry of bryophytes is not a hot topic because of their very small size and the difficulty associated with their collection and identification (Asakawa et al., 2013).

Liverworts contain a number of mono-, sesqui- and di-terpenoids, aromatic compounds like bibenzyl, bis-bibenzyls, acetogenins, sesquiterpenes, diterpenes and lipophilic aromatics, which are enantiomers of those found in higher plants that are produced from its cellular oil body (Huang et al., 2009; Asakawa et al., 2013). These authors upon investigation verified that these chemical compounds derived from liverworts display a characteristic odor, and can have interesting biological activities including allergenic contact dermatitis, antimicrobial, anticancer, antifungal and antiviral, cytotoxic, insecticidal, insect antifeedant, superoxide anion radical release, 5-lipoxygenase, calmodulin, hyaluronidase, cyclooxygenase, DNA polymerase β, and α-glucosidase. Phytochemical evaluation of bryophytes became popular since the last decades with the use of new methods in gas chromatography, mass spectrometry, nuclear magnetic resonance, high-performance liquid chromatography and thin layer chromatography and x-ray to isolate and structurally elucidate bioactive molecules present in bryophytes (Banerjee, 2001; Dey & Mukherjee, 2015). Phytochemical investigations implicate the presence of biologically active metabolites from carbohydrates, lipid, protein, steroids, polyphenols, terpenoids, organic acids, sugar alcohols, fatty acids, aliphatic compounds, acetogenins, phenylquinones, and aromatic and phenolic (Pant, 1998; Saxena & Harinder, 2004). They have also found application in phytotherapy (Drobnik & Strebel, 2014). Hepaticology, the scientific study of liver shaped plant bodies evolved from liverworts through the "Doctrine of Signature" concepts. It is essentially post-Linnaean although 'Hepatics' started a long time ago in the pre-Linnaean period (Asthana, 2006). According to this concept, God would sign each plant in some ways to indicate its medicinal value, hence the resemblance of a plant or its parts to indicates the cure of any ailment or disease of that particular organ in that particular plant (Asthana, 2006).

The economic cost of their roles in erosion control, environmental bioindicators, as material for seedbeds, fuel, medicines and food sources, pesticides, nitrogen fixation, moss gardening, treatment of waste, construction, clothing, furnishing, packing, genetic engineering and for soil conditioning and culturing remain invaluable in sustainable terms (Saxena & Harinder, 2004; Glime, 2007). Due to their high-water holding capacity, bryophytes are used in horticulture as a soil conditioner and additives for cultivation (Saxena & Harinder, 2004). Hornworts form symbiotic relationships with nitrogen=fixing bacteria and produce pores that may be homologous to stomata. Peat result when plant matter such as Sphagnum accumulates under waterlogged conditions without completely undergoing decomposition due to lack of sufficient oxygen, appropriate temperatures, nutrients, and pH. This matter can be used as peat fuel and may be harvested/dugged out in blocks, dried, and burned for heat in Ireland, Russia, Ireland, Finland, Sweden, Germany, United States and Poland. They have also been implicated in agriculture to increase the water-holding capacity of and lightens the soil. Physiologists and even medical scientists are realizing the potential of the bryophytes in understanding gene function and in producing needed proteins (Glime, 2017a). Bryophytes are good environmental indicators. For instance, mosses are also good indicators of acid rain, because they lack a protective epidermis and cuticle and, hence, are more susceptible than the vascular plants (Saxena & Harinder, 2004).

CONCLUSION

Due to their sensitivity to environmental change, bryophytes have been implicated in many studies where they are used as indicator species to monitor climate change. Only a few studies have considered the impacts of climate change on bryophytes despite obvious vulnerabilities to their diversity and the ecosystem. Global climate modellers are realizing that massive peatlands make substantial contributions to the modification of global temperatures and water movement. In future, the exploration of bryophyte ecophysiology in the changing climatic conditions will be required to provide new information that will assist bryophyte conservation. The reproductive biology of bryophyte is a relatively unexplored area with many species and ecosystems unexplored especially in the tropics as well as studies on their natural history that will identify and characterize interesting systems for research.

Bryophytes diversity and distribution are related to environmental factors, which is helpful in understanding the ecological niche of various bryophytes. Nature reserve, especially in the humid environment, is an important area of biodiversity conservation and is a vital ecological region that preserves a large number of ground bryophytes. IUCN distribution criteria such as population reduction, the geographic range within occurrence area, declining population size, population restrictions and quantitative analysis are critical for the evaluation of bryophyte threatened status with a view to promoting their conservation. A major advantage of working on bryophytes compared to many other groups of plants is the ease of preparing and examining herbarium specimens. Apart from ethnomedicinal uses, some bryophytes possess against different cancer cell lines and this property of bryophytes needs to be more focused on the future. There is a need to investigate how bryophyte species respond to climate change. Since their diversity and distribution is threatened by global climate variabilities.

In conclusion, several unexplored topics with regards to understanding salient aspects of bryophytes. The group will benefit from extended surveys and collection. This group continues to adapt to changing global conditions and may hold the key to future survival on planet earth.

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Chapter 5
Climate Conditions and Biodiversity Decline:
Impact Assessment

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ABSTRACT

Many studies in recent years have investigated the effects of climate change on the future of biodiversity. In this chapter, the authors first examined the different possible effects of climate change that can operate at individual, population, species, community, ecosystem, notably showing that species can respond to climate challenges by shifting their climatic change. Climate change is one of the most important global environmental challenges that affect all the natural ecosystems of the world. Due to the fragile environment, mountain ecosystems are the most vulnerable to the impact of climate change. Climatic change will affect vegetation, humans, animals, and ecosystem that will impact on biodiversity. Mountains have been recognized as important ecosystems by the Convention on Biological Diversity. Climate change will not only threaten the biodiversity, but also affect the socio-economic condition of the indigenous people of the state. Various activities like habitat loss, deforestation, and exploitation amplify the impact of climate change on biodiversity.

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INTRODUCTION

Climate change impacts on biodiversity are projected to increase in magnitude and pervasiveness as CO_2 levels and temperatures continue to rise, and extreme events (*e.g.*, heat and storms) increase in frequency and intensity (IPCC, 2007). A range of methods and approaches are being employed to predict the impacts of climate change on biodiversity including historical trends and relationships, experiments, and model projections. As these methods have become more sophisticated, so has our understanding of projected impacts, particularly on aquatic and marine systems, which have been less well studied compared to terrestrial systems. Although there are many ways to categorize the modelling approaches used to assess potential impacts of climate change on biodiversity, most can be described as either empirical (correlative) or process-based (mechanistic). Projections of species distributions often come from empirical models that relate observed occurrences to current or historical climate conditions, and predict future distributions using projected changes in the geographic distributions of abiotic variables (*e.g.*, temperature). These models, which are often referred to as climate envelope, niche, or species distribution models, have the advantage of being relatively easy to apply to large numbers of species, and have been used to project potential shifts in areas of climatic suitability for plants and animals at varying scales across the United States (Staudinger et al., 2013). Similar empirical models have been used to project changes in biomes and vegetation types (Rehfeldt et al., 2012). Despite their flexibility, empirical models generally do not directly model biotic interactions (*e.g.*, competition), account for evolution, or address dispersal; these limitations can lead to an overestimation of the ability of species to track climatic changes, and an underestimation of extinction rates. In contrast, process-based models are designed to specifically account for a number of the mechanisms that determine species distributions or vegetation patterns, and can simulate physiological responses, population processes, dispersal, ecosystem functions, and plant growth. Some examples include spatially explicit, individual-based population models, dynamic global vegetation models (DGVM), and forest gap models (Staudinger et al., 2013). There have been several recent efforts to integrate individual empirical and process-based models to ensembles of such models to improve projections of the impacts of climate change on various components of biodiversity (Araujo & New, 2007).

These include efforts to:

1. Account for dispersal or movement in empirical models of changes in species or population distributions.
2. Combine metapopulation models with projected shifts in climatic suitability.
3. Integrate multiple mechanisms into projected changes in the distribution of marine species.
4. Combine niche models with physiological mechanistic models.

These new and increasingly sophisticated methods of linking niche models, trophic models, dynamic vegetation models, and global climate models with socioeconomic scenarios are increasing our abilities to predict and evaluate future impacts of climate change on biodiversity (Staudinger et al., 2013). Biodiversity has a significant impact on ecosystems productivity and stability, and on the services they generate. Specifically: crop genetic diversity increases the yield of commercial agricultural crops; tree species diversity enhances and/or stabilises wood production in plantations; plant species diversity produces more fodder in grasslands; fish species diversity is associated with more stable catches. Furthermore, biodiversity makes ecosystem productivity more resilient to climate extremes (Dilys et al., 2019).

BACKGROUND

Biodiversity is the variability among living organisms, including genetic and structural difference between individual and within and between individual and within and between species. Biodiversity plays a direct role in climate regulation. Biodiversity conservation will lead to strengthening of ecosystem resilience and will improve the ability of ecosystem to provide important services during increasing climate pressures (Mgbemene, 2011). This review basically focuses on the importance of biodiversity, the consequences faced by the plants, animals, humans and ecosystem owing to the global warming and climate change and the possible mitigation and adaptation strategies in terms of biodiversity conservation which can protect the planet from the consequences of climate change. Global warming is the increase in the world's average temperature occurring due to increasing emission of the greenhouse gases (GHGs) which results in an enhanced greenhouse effect. Climate change refers to a statistically significant change in either the mean state of the climate or in its variability persisting for decades or longer (Sofia & Fox, 1994). Climate change results due to both; natural and anthropogenic drivers. Natural drivers involve the contribution of plants, animals and humans naturally by processes of respiration, death and decomposition. Earth's climate variability is also caused by changes in the solar radiations, Milankovitch cycle, volcanic eruption, plate tectonics, ocean circulations, earthquakes and so on (Kunzig, 2008). The concentration of CO_2 has increased from pre-industrial concentration of 280 ppm to 392 ppm in 2010. It is all due to the burning of fossil fuel to generate the electricity in power plants, industrialization, deforestation, mechanization of agricultural practices, increasing vehicular transportation (In India, vehicles have increased from 350 million to 40 billion since 1947) (SIAM, 2010), land use changes, urbanization, industrialization and the disposal of subsequent waste generated out of it all. Industrialization affects our environment and ultimately contributes to climate change. Industrialization not only involves technological innovations; it also involves economic and social transformation of the human society. With industrialization come opportunities as well as challenges. The challenges include coping with higher temperatures, more extreme weather conditions, changing human life styles and changing philosophies. Due to these challenges, industrialization must take into account climate change and its consequences for example, changing human life styles and philosophies have major impact on our environment and this has to be considered (Mgbemene, 2011)

GLOBAL CLIMATE CHANGE

Global climate change is one of the most contentious topics in environmentalism, ecology and politics (Watson et al., 1996). Human-induced increases of atmospheric concentrations of gases such as carbon dioxide, methane, nitrous oxide and chlorofluorocarbons (CFCs) may result in unparalleled increases in global temperature (Houghton, 1995). This would happen through an intensification of the so-called greenhouse effect *i.e.* the absorption of infrared radiation by gases and its re radiation back toward the surface of the earth. Measurements over the past 130 years show that atmospheric temperatures have already risen considerably and have been the highest in the last few years. In 1996, the Intergovernmental Panel on Climate Change (IPCC) issued its Second Assessment Report (Watson et al., 1996), which represents the degree of consensus on various climate change issues. Under the IPCC business-as-usual scenario (*i.e.* no reduction in carbon dioxide emissions) global environmental change in the next century may include an increase of atmospheric carbon dioxide concentrations from 350 parts per million by volume in 1993 to 525 parts per million by volume in 2050. This may imply a 0.3°C rise in global mean temperature per decade (Kappelle et al., 1999) Recent climate models calculate a potential rise of the global mean surface temperature of about 1 to 3.5°C by 2100 (Watson et al., 1996). Such a change could be 10 to 50 1386 times faster as the natural average rate of temperature change since the end of the last glaciation. However, projected rises in temperature will not be equally distributed over the globe. Mean temperatures at the poles are expected to increase much more (0.8°C per decade) than those in equatorial regions (0.1°C per decade). A rise of global temperatures has been predicted to be accompanied by increased frequency and destructiveness of hurricanes, more protracted droughts, longer and hotter heat waves, more severe rainy periods and significant changes in the area of the great ice sheets of Antarctica. However, there appears to be no hard evidence to substantiate all these assertions (Kappelle et al., 1999).

BIODIVERSITY

Origin of Biodiversity

The Earth's biological resources are very important to humanity's economic and social development. As a result, there is a growing recognition that biological diversity is a global asset of tremendous value to present and future generations. At a similar time, the threat to species and ecosystems has never been so great. In response, the United Nations Environment Programme (UNEP) convened the Ad Hoc Working Group of Experts on Biological Diversity in November 1988 to explore the need for an. international convention on biological diversity. Soon after, in May 1989, it established the Ad Hoc Working Group of Technical and Legal Experts to prepare an international legal instrument for the conservation and sustainable use of biological diversity. By February 1991, the Ad Hoc Working Group had become known as the Intergovernmental Negotiating Committee. Its work culminated on 22 May 1992 with the Nairobi Conference for the Adoption of the Agreed Text of the Convention on Biological Diversity. The Convention was opened for signature on 5 June 1992 at the United Nations Conference on Environment and Development (the Rio Earth Summit). The Convention entered into force on 29 December 1993, which was 90 days after the 30th ratification. The first session of the Conference of the Parties was scheduled for 28 November – 9 December 1994 in the Bahamas. The Convention on Biological Diversity was inspired by the world community's growing commitment to sustainable development.

A simple definition of biodiversity defines is that the totality of genes, species, and ecosystems of a region. An advantage of this definition is that it seems to explain most instances of its use, and one possibly unified view of the normally 3 levels at which biodiversity has been identified.

1. Biodiversity may be defined as the totality of different organisms, the genes they contain, and the ecosystems they form.
2. The Convention on Biological Diversity defines biodiversity as the variability among living organisms from all sources including, among other things, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems.

Biodiversity is considered at three levels: genetic diversity, species diversity, and ecosystem diversity (Negi, 1993).

1. Genetic Diversity

It is basically different type of species expressed at the genetic level by each individual in a species. No individuals belonging to the same species are exactly similar. As an example, in the species of human beings, each human shows a lot of diversity in comparison to another human. People living in different regions show a great level of variation.

Example:

1. Rice varieties: All rice varieties belong to the species "*Oryza sativa*". However, there are thousands of rice varieties that show variation at the genetic level in the form of different size, shape, colour and nutrient content.
2. Teak wood varieties: The various teak wood varieties available are - Indian teak, Burma teak, Malaysian teak etc.

2. Species Diversity

It is the biodiversity observed within a community. It stands for the quantity and distribution of species. The number of species in a region varies widely depending upon the varied environmental conditions. As an example, it is typically observed that civilizations residing beside water bodies show more species than the one compared to the areas away from water bodies.

Example:

1. The total number of species living on earth is approximately more than 2 million. However, only around 1.5 million are found and assigned scientific names.
   a. **Plant Species:** Apple, Mango, Wheat, Grapes, Rice etc.
   b. **Animal Species:** Lion, Tiger, Elephant, Deer etc.

3. Ecosystem Diversity

The enormous range of terrestrial and aquatic environments on earth has been classified into a variety of ecosystems. Major habitat types include tropical rain forests, grasslands, wetlands, coral reefs and mangroves. Studies of ecosystem diversity are carried out on totally different scales: from one ecosystem to a whole region containing many different ecosystems. Regions containing a great variety of ecosystems are rich in biodiversity, but individual ecosystems containing endemic species also make a significant contribution to global biodiversity (Southeast Asian Fisheries Development Centre, 1994). Biodiversity is distributed uniformly across the globe. It is substantially greater in some areas than in the others. Generally, species diversity increases from the poles towards the tropics- for instance, among the terrestrial systems, the tropical moist forests, which cover only 57% of the earth's land area, possess as much as over 50% of the world's species (Singh, 2006). Table 1 shows impact of habitat, climate change, invasive change, overexploitation and pollution on different types of ecosystem.

Table 1. Impact on Different types of Ecosystem

S. No.	Type of Ecosystems	Impact				
		Habitat Change	Climate Change	Invasive Species	Over-exploitation	Pollution (Nitrogen, Phosphorus)
1	**Forest**					
1.1	Boreal	Slow	Slow	Slow	Slow	Moderate
		Increase Impact	Very Rapid Increase Impact	Increase Impact	Continue Impact	Very Rapid Increase Impact
1.2	Temperate	High	Slow	Slow	Moderate	Moderate
		Decreasing Impact	Very Rapid Increase Impact	Rapid Increase Impact	Continue Impact	Very Rapid Increase Impact
1.3	Tropical	Very high	Slow	Slow	Moderate	Moderate
		Very Rapid Increase Impact	Very Rapid Increase Impact	Rapid Increase Impact	Increase Impact	Very Rapid Increase Impact
2	**Dryland**					
2.1	Temperate grassland	Very high	Slow	Moderate	Slow	Very high
		Increase Impact	Very Rapid Increase Impact	Continue Impact	Continue Impact	Very Rapid Increase Impact
2.2	Mediterranean	High	Slow	High	Moderate	Slow
		Increase Impact	Very Rapid Increase Impact	Very Rapid Increase Impact	Continue Impact	Very Rapid Increase Impact
2.3	Tropical grassland and savannah	High	Moderate	Slow	Very high	Moderate
		Increase Impact	Very Rapid Increase Impact	Very Rapid Increase Impact	Continue Impact	Very Rapid Increase Impact
2.4	Dessert	Slow	Moderate	Moderate	Slow	Slow
		Continue Impact	Very Rapid Increase Impact	Continue Impact	Continue Impact	Very Rapid Increase Impact
3	Inland water	Very high	Slow	High	Moderate	Very high
		Very Rapid Increase Impact	Very Rapid Increase Impact	Very Rapid Increase Impact	Continue Impact	Very Rapid Increase Impact
4	Costal	Very high	Moderate	High	High	Very high
			Very Rapid Increase Impact	Increase Impact	Increase Impact	Very Rapid Increase Impact
5	Marine	Moderate	Slow	Slow	Very high	Slow
		Very Rapid Increase Impact	Very Rapid Increase Impact	Continue Impact	Increase Impact	Very Rapid Increase Impact
6	Island	High	Slow	Very high	High	Slow
		Continue Impact	Very Rapid Increase Impact	Continue Impact	Continue Impact	Very Rapid Increase Impact
7	Mountain	High	Moderate	Slow	Slow	Slow
		Continue Impact	Very Rapid Increase Impact	Continue Impact	Continue Impact	Very Rapid Increase Impact
8	Polar	Slow	High	Slow	Moderate	Moderate
		Increase Impact	Very Rapid Increase Impact	Continue Impact	Increase Impact	Very Rapid Increase Impact

4. Biodiversity and Its Importance

Biodiversity is the variability among living organisms, including genetic and structural difference between individual and within and between individual and within and between species. The world biodiversity has a total of 1,263,500 species of plants and animals while India has only 51,828 species (Oza, 2009). It provides us with all the necessities of life and sustains and nourishes us. Biodiversity plays a direct role in climate regulation. Climate always changes resulting in evolutionary changes in the species. Biodiversity is important in following ways (Rathore & Jasrai, 2013):

1. **Soil Formation and Maintenance of Soil Quality:** The activities of microbes and animal (bacteria, algae, fungi, millipedes, etc) condition soils, break down organic matter, form soil and prevent soil erosion.
2. **Maintain Air Quality:** Plants purify the air and regulate the composition of the atmosphere, by taking in CO_2 during photosynthesis and liberating oxygen in the atmosphere.
3. **Maintain Water Quality:** Trees and forest soils purify water; prevent siltation of rivers and reservoirs arising due to soil erosion and landslides.
4. **Pest control:** Conserving biodiversity can control 99% of potential crop pests.
5. **Detoxification and Decomposition of Wastes:** About 130 billion metric tons of organic waste (including industrial wastes) is processed every year by earth's decomposing organisms.
6. **Pollination and Crop Production:** Without plant and animal (bees, butterflies, bats, birds) interactions, no pollination will be possible and hence would lead to decline in crop yield.
7. **Climate Stabilization:** Oceans, soil and vegetation are huge carbon sinks and help reduce the CO_2 in atmosphere. In rainforests the surface temperature is maintained by regular rains, while in cold regions the temperature is regulated by forests acting as insulators and windbreaks.
8. **Prevention and Mitigation of Natural Disasters:** Ecosystem biodiversity (forest, salt marshes, mangrove) prevents erosion, nutrient loss, landslides, floods and impacts of storms.
9. **Provision of Food Security:** biodiversity in terms of plants and animals is the ultimate source of food, fibre, fuel and shelter.

Biodiversity conservation will lead to strengthening of ecosystem resilience and will improve the ability of ecosystem to provide important services during increasing climate pressures (Rathore & Jasrai, 2013).

BIODIVERSITY PROFILE OF INDIA

India is the seventh largest country in the world and Asia's second largest nation with an area of 3,287,263 square km. India, known for its rich heritage of biological diversity, has so far documented over 91,200 species of animals and 45,500 species of plants in its ten bio-geographic regions. India is also a vast repository of Traditional Knowledge (TK) associated with biological resources. India ranks among the top ten species-rich nations and shows high endemism. India has four global biodiversity hot spots (Eastern Himalaya, Indo-Burma, Western Ghats and Sri Lanka, and Sunderland). The varied edaphic, climatic and topographic conditions and years of geological stability have resulted in a wide range of ecosystems and habitats such as forests, grasslands, wetlands, deserts, and coastal and marine ecosystem. Inventories of faunal diversity in India are being progressively updated and analysed with several new discoveries.

So far, nearly 91,212 of faunal species (7.43% of the world's faunal species) have been recorded in the country. Endemic rich Indian fauna is manifested most prominently in Amphibia (61.2%) and Reptilian (47%). Likewise, Indian fish fauna includes two endemic families and 127 monotypic genera. As per the International Union for Conservation of Nature (IUCN) Red List (2008), India has 413 globally threatened faunal species, which is approximately 4.9% of the world's total number of threatened faunal species.

The Pride of India lies in its nearly 6,500 native plants which are still used in the indigenous health-care systems. It is a country with rich biodiversity. Today, India has 59,353 insect species, 2,546 fish species, 240 amphibian species, 460 reptile species, 1,232 bird species and 397 mammal species, of which 18.4 per cent are endemic and 10.8 per cent are threatened. India is the home to at least 18,664 species of vascular plants, of which 26.8 per cent are endemic (Balasubramanian, 2017). India is one of the top twelve mega diversity countries and has biodiversity hotspots in the biodiversity rich areas of the Western Ghats and the Eastern Himalayas. In opinion of a Ministry of Environment and Forest Report, the country is estimated to have over 49,219 plant species and 81,251 animal species representing 12.5% of the world's flora and 6.6% of its fauna. Only 44 species of Indian mammal and 55 bird species have a range that is confined entirely to within Indian territorial limits (Biodiversity Profile of India, 2012). With only 2.4 per cent of the total land area of the world, the known biological diversity of India contributes to about 8 per cent to the known global biological diversity. It has been estimated that at least 10 per cent of the country's recorded wild flora, and ten percent of its wild fauna, are on the threatened list. It is also heartening to note that many of them are on the verge of extinction (Balasubramanian, 2017). Endemism in the Indian reptilian and amphibian fauna is high. There are around 187 endemic reptiles, and 110 endemic amphibian species (Biodiversity Profile of India, 2012).

IMPACTS OF CLIMATE CHANGE ON BIODIVERSITY

Ecosystem and Biodiversity are fundamental to life on our planet. Climate change is affecting the habitats of several species, which must either adapt or migrate to areas with more favourable conditions. Even small changes in average temperatures can have a significant effect upon ecosystems. Most plants and animals live in areas with very specific climate conditions, such as temperature and rainfall patterns, that enable them to thrive. Any change in the climate of an area can affect the plants and animals living there, as well as the makeup of the entire ecosystem. Different types of Change in Animals, Vegetation, Humans, Ecosystem by climate change are described below.

1. Vegetation

The vegetation is exhibiting the following changes;

1. **Migration of Vegetation Towards a Higher Altitude:** In Nainital, species such as *Berberis asiatica, Taraxacum officinale, Jasminum officinale* etc. have shifted from 1000 to 2000m height. Teak dominated forests are predicted to replace the Sal trees in central India and also the conifers may be replaced by the deciduous types. According to climatologists and palynologists, temperature change of 3°C may lead to forest movement of 250 km at a rate of 2.5 km/year which is ten times the rate of natural forest movement (Gates, 1990; Davis, 1987).
2. **Invasive Species:** Invasive species (*Lantana camara*, *Parthenium hysteron phorous, Ageratum conyzoides*) are a threat to native species being more tolerant to climatic variations (Anonymous, 2009).
3. **Changes in Phenological Behaviour:** Climate/season affects the normal life cycle (bud, leaf fall, flowering, fruiting, fertilization time and production) of the plant. The crops show early flowering and maturation which has shortened their grain fill period and yield (Anonymous, 2009).
4. **Increase in the Pest Attacks:** Due to climate change, pests (Pine wood nematode-*Bursaphelenchus xylophilus*, Pitch canker-*Gibberella circinata*, Red palm weevil-*Rhynchophorus ferrugineus,* virus, aphids, fungi) have increased in number. Variation in temperature and precipitation patterns can result in more frequent droughts and floods making indigenous plants more vulnerable to pests and diseases (rots, blights) (Tibbetts, 2007).

2. Animals

Sensitivity of the species to even a slight change in the climate leads to their extinction as in case of the golden toad. Polar bears are in danger due to reduction in Arctic ice cover. The sex of sea turtle depends on temperature and more female turtles are produced as a result of high temperature. Some threatened species (frogs, toads, amphibians, tigers and elephants) are vulnerable to the impacts of climate change like sea level changes and longer drier spells. Changes in ocean temperature and acidification may lead to loss of 95% of the living corals of Australia's Great Barrier Reef (Anonymous, 2007). Climate change, particularly global warming, may strongly affect production performance of farm animals worldwide. Among the environmental variables affecting animals, heat stress seems to be one of the intriguing factors making animal production challenging in many geographical locations in the world (Koubkova et al., 2002). Animal stress level due to temperature rise has been worked out using Temperature Humidity Index (THI) in India (Upadhyay et al., 2008). All animals have a range of ambient environmental temperatures termed the thermo neutral zone and temperature below or above this thermo neutral range of the animal create stress conditions in animals. One of the direct impacts of climate change on livestock is on the milk yield. Increase in number of stressful days and their frequency will impact yield and production of cattle and buffaloes (Upadhyay et al., 2007). India has one of the largest livestock populations in the world, and one of its notable characteristics is that almost its entire feed requirement is met from crop residues and by-products; grasses, weeds and tree leaves; and grazing on common lands and harvested fields (Dikshit et al., 2010). Climate change affects livestock production by altering the quantity and quality of feed available for animals. Climate change is expected to change the species composition (and hence biodiversity and genetic resources) of grasslands as well as affect the digestibility and nutritional quality of forage (Thornton et al., 2009). Droughts and extreme rainfall variability can trigger periods of severe feed scarcity, especially in dry land areas, with devastating effects on livestock populations (Chauhan, & Ghosh, 2014).

3. Ecosystem

1. **Marine and Coastal:** 70% of the Earth's surface is covered by oceans comprising some of the world's most diverse and unique ecosystems (mangroves, coral reefs, sea grass beds) (UNESCO, 2010). Climate change is leading to sea level rise, increased coastal erosion, flooding, higher storm surges, sea salinity ingress, increased sea-surface temperatures, ocean acidification, coral bleaching, mangroves and millions of climate change refugees. Species composition and distribution will surely be affected by such changes. Indian coastal areas vulnerable to climate change are Sundarbans, Maharashtra, Goa and Gujarat (Ran of Kutch). The distribution and composition of the species is bound to be affected (Singh, 2002).
2. **Island Ecosystem:** Islands are the most fragile with rich biodiversity and a high economic importance. 23% of island species are at present endangered. Islands have small and endemic species (corals) sensitive to the changing climate. Climate change leads to an increase in the sea level, frequency and intensity of storms, variability in rainfall and intolerably high temperatures affecting the endemic species and hence economic loss in the tourism sector (Dudgeon, 2006).
3. **Inland Water Ecosystem:** Inland water systems include the fresh water systems and are only 0.01% of the world's water source comprising 0.8% of the Earth's surface, but support 6% of the total species (FAO, 2000). They are rich source of food, income, employment and biodiversity. Changing rainfall patterns will lead to change in the course of the streams affecting breeding and food habits of many species. The ice cover is bound to decrease causing an increase in the number of flood and drought. This would further lead to changes in the phenology, physiology and migration trends of some organisms like migratory birds (Karl & Trenberth, 2006).
4. **Forest:** Forest area is about one-third of the Earth's surface and comprises two-thirds of all the known terrestrial species. They are also rich biodiversity hotspots. Half of the original forest cover has been cleared up till now. The increased level of CO_2 has led to increase in the growth of some forest. Increased temperature (even 1°C) has resulted in significant migration of tree species, increased attack of pest, invasive species and wild fires, hence modifying the composition of forest. Many animals, primates and 9% of all known tree species (woody trees, white spruce) are at risk of extinction (NASA, 2006).
5. **Agriculture:** About one-third of the world's area is under cultivation. Climate change leads to variability in rainfall patterns, heat stress, spread of pests and diseases and shortening of the crop cycle and affecting plant growth and production.
6. **Dry Lands and Grassland:** They support 35% of the world population and comprise of the arid and semi-arid areas, grasslands and savannahs. They have localized species (wild ass, Kutch etc.) and have varied crops and livestock. The desertification is expanding and so is the temperature making them drier and intolerable for the threatened species. The risk of wild fire is increasing which could change the species biodiversity (Rathore & Jasrai, 2013)

Table 2. Ecosystem: vulnerability, impacts, mitigation and adaptation with respect to climate change

Ecosystem	Polar Ice/Glaciers, Marine and Coastal, Inland water, Island, Forest, Dry lands/ Grassland, Mountain and Agriculture
Vulnerability	Climate sensitivity of flora and fauna, low resilience power.
Impacts	Rising temperature, melting ice, Sea level rise, altering stream flow Ocean acidification, increased extreme events like floods, storms Sea salinity ingress Increased pest attacks and diseases, Wildfires Invasion of invasive species Endemic species like polar bears, penguin, walruses, seals, krill are threatened Changes in phenological, physiological and migration pattern of species. Reduced agricultural yield.
Mitigation and Adaptation	Reducing pollution both industrial and vehicular, Environment impact assessment, CDM, using clean and renewable energy and biofuels Biodiversity conservation: Forest conservation, reforestation, afforestation, agro-forestry, avoiding deforestation, sustainable and efficient management of water resources, ecosystem management and restoration, preventing habitat fragmentation, over-exploitation of resources and land-use-change Agriculture: Organic farming, biological pest control, improving rice farming, no-till practices and in-situ and ex-situ gene preservation.

7. **Mountain:** One–third of the Earth's surface is covered by the mountains which supports one-third of the world population. Many species are very specific and endemic to this ecosystem and are rich natural reservoirs of goods. Climate change is leading to the glacier retreat, change in the course of rivers, migration of the tree species northward and subsequent extinction of some species (NASA, 2006).
8. **Polar Ice/Glaciers:** They are diverse ecosystem facing extremes of the cold temperature with the flora (planktons) and fauna (migratory birds, whales) and Arctic people modified to such conditions. Climate change has resulted in an increase in the temperature to about 5°C to the normal and has resulted in the melting of the ice, increase in sea level which is threatening the endemic species (polar bears, walruses, seals, emperor penguins, krill, ringed seal). Studies show a decline in the weight of the polar bears from 325 kg in 1980 to 253 kg in 2004 (IPCC, 2001). (Rathore & Jasrai, 2013). Table 2 shows impact, mitigation, vulnerability and adoption of ecosystem with respect to climate change.

4. Human

Humankind is rapidly realising the vital importance of natural ecosystems for carbon sequestration and storage. However, biodiversity loss is impairing natural ecosystems capacity to provide such mitigation benefits (Anderson et al., 2019). Climate Change leads to an increase in temperature, melting of the ice and increased extreme events. All the extreme events like floods, droughts, cyclones displace the humans from their home and lead to outbreak of water borne diseases like cholera, typhoid etc; spread of tropical and vector borne diseases like malaria, dengue etc and rodent borne diseases like plague. These diseases have shown a persistent increase in the past 50 years. The incident of heat waves has registered an increase throughout the world taking away a heavy toll of the people life every year. The increasing sea level rise has already submerged many islands and will soon leave millions of refugees for the world to provide shelter. The sea salinity ingress in the fresh water sources has made land barren and will soon be a threat to the food security (Tibbetts, 2007). The impact of climate change has been considerably enough to threaten human health both directly and indirectly through increasing temperatures, rising sea levels, water and food supply impacts, extreme weather events like floods, droughts, earthquakes, etc., susceptible shelter and population migration. (Climate Change and India, 2008) Direct effect of environmental circumstances may ease the diffusion of vector-borne diseases, water-borne diseases, cardiovascular diseases, respiratory allergies and malnutrition, etc. Indirect effects of climate change such as mental health problems and involuntary migration are also important. (Amutha & Juliet, 2017). Children, the elderly and communities are living in poverty among the most susceptible of the damaging effects due to climate change. Environmental consequences climate change, such as extreme heat wave, rising sea-levels, changes in precipitation resulting in cyclones, earthquake, flooding and droughts, intense hurricanes and degraded air quality, affect directly and indirectly the physical, social and psychological health of humans. (Amutha & Juliet, 2017). For instance, changes in precipitations are creating changes in the availability and quality of water, as well as resulting in extreme weather events such as intense hurricanes and flooding. Seeing the cumulative trend of impact of climate change on human health, implementation of alleviation measures like consolidation health systems and service delivery mechanisms through early monitoring, disease investigation, vector and disease control, and health insurance to counter the same becomes authoritative (Ministry of Environment and Forests, Government of India, 2010). Investment in research and development, health risk calculation studies, susceptibility mapping studies, formation of baseline circumstances, scenario modelling and acceptance of clean expansion mechanisms, etc. are the need of the hour. Economics would play a major role in combating the potential threat. Countries with good GDP would be able to introduce the best available tools of intervention and can fill up the lacunae in health system (Amutha & Juliet, 2017).

SOLUTIONS AND RECOMMENDATION

Climate Change mitigation involves reducing the intensity of radiative so as to reduce the effect of global warming and it can be made possible by two aspects; Geo-engineering and Carbon sequestration. Geo-engineering are the proposals to manipulate the earth's climate so as to decrease the impact of global warming from the greenhouse gas emission. It comprises of Sulphur dioxide spraying, artificial trees, cloud seeding ships, iron and limestone fertilization of the oceans and space mirrors. Another technology comprises of the various methods of carbon sequestration called Carbon Capture and Storage (CCS). According to a 2005 IPCC report major point sources of carbon dioxide include coal-fired power stations, natural gas, fossil fuel–based hydrogen, and synthetic fuel. CO_2 emissions from such sources can be captured and stored in underground geologic formations. CCS technologies are already being widely used in industries producing fertilizers, hydrogen and natural gas processing (SIAM, 2010). Environment Impact Assessment (EIA) of the industrial areas, checking vehicular pollution by the use of biofuels and using the clean technology, reducing over-exploitation of resources (over-fishing, land-use-changes); preventing poaching of rare, endangered and endemic species; preventing habitat fragmentation. The biodiversity can be conserved by management programmes including ecosystem conservation and restoration. The forest needs to be conserved with practices of reforestation and afforestation as they have 80% of the total carbon stored in terrestrial vegetation. The indigenous knowledge can also be used to prevent climate change or adapt to it (Anonymous, 2007). Strategies by the United Framework Convention on Climate Change (UNFCCC) focuses on cutting down greenhouse gas emissions to prevent climate change. Kyoto protocol has brought into existence joint implementation, emission trading and Clean Development Mechanism (CDM) to reduce greenhouse gas emission. Like all other countries

National Action Plan on Climate Change of India was released in Delhi in 2009 and involves eight missions on solar mission, enhanced energy efficiency, sustainable habitat, water mission, sustaining Himalayan ecosystem, Green India through massive tree plantation, sustainable agriculture and strategic knowledge for climate change by establishing a knowledge platform on climate change. Successful implementation of all these plans would surely help reduce Climate Change and conserve biodiversity (Rathore & Jasrai, 2013).

In order to distinguish the need and best practices for adaptation and mitigation, both global and location-specific research and evaluation activities are required, *e.g.* projecting current and future climate change impacts, assessing vulnerabilities including climate-related hazards (for effective decisions for climate risk management), evaluating current and future adaptation and mitigation activities, including possible new opportunities that may arise from climate change (Carter, 2007). Increasingly, governments, institutions and businesses are taking steps to try and achieve sustainable development, in that they are developing responses to mitigate and adapt to the threats and opportunities of climate change. However, much work remains to be done because there is a serious disconnection between the announcements and commitments made by public policy makers and the actions undertaken by companies regarding how to address the influences of climate change (Sullivan, 2010). This explains that there is a significant increase in the scope of research to study and analyse the impacts of climate change on biodiversity and ecosystem functioning. When we allow biodiversity loss, we accept losing all biodiversity's potential benefits, for example the largely unexplored toolkit biodiversity offers for building resilience to climate change. Many development projects already try to 'climate proof' investments. Development projects and private sector investments need to be 'nature-proofed' to ensure they don't contribute to, or exacerbate, biodiversity loss (Dilys et al., 2019).

CONCLUSION

Climate change affects biodiversity in many ways. Impacts on species include changes in distribution and abundance, the timing of seasonal events and habitat use and as a consequence there are likely to be changes in the composition of plant and animal communities. Strong implementation of EMP for each and every induvial industry complying national water policy, forest policy, environmental clearance guideline, CPCB, EPA. Promoting the appropriate and effective coordination among biodiversity and climate change programs in India by incorporating the eco-friendly environmental policy, bringing the biodiversity and climate change into national plans and programs. Developing policy, guidelines for biodiversity, climate change and reduce the vulnerability of local communities to climate change impacts and enhance the flexibility of local communities to the impacts of climate change. Public participation is necessary to integrate ecosystem conservation and rural development. Climate change has become the most essential environmental concern of the decade. Significant consideration is required to focus on reducing carbon and greenhouse gas emissions from energy, industrial and transport sources, through reduction in quality and quantity of fuel use, implementation of improved and advance technologies, enhances public understanding about the environment they live, sensitisation on the importance of biodiversity and climate change.

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Chapter 6
Ecological and Economic Importance of Wetlands and Their Vulnerability:
A Review

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ABSTRACT

Wetlands show a diversity of appearances like salt marshes, tidal wetlands, inland freshwater wetlands, riparian wetlands, peat lands, and many other types. Each of the types host diverse biotic communities of flora and fauna. This biodiversity changes according to the physical and chemical properties of wetlands, climate, and the geological location. This biodiversity regulates the local ecosystem, carbon sequestration, fuelwood supply, fishery-based industries, and on many other ecological and socioeconomic aspects. In addition, the wetlands have other ecological aspects like maintaining freshwater quality by sedimentation, nutrient conservation, etc. However, around the world, the wetlands are subjected to several types of threats like both anthropogenic and natural. This study is a short review work on some of the outcomes of the studies of researchers around the world to see the importance of different types of wetlands, the threats to them by anthropogenic or natural causes, and focus areas for management strategy development.

INTRODUCTION

Each of the wetlands can be an individual ecosystem. They are different by species composition, geologic location, their exposure to the different types of landscapes, climate and many other factors. Their surroundings, water sources, atmosphere etc. can regulate them as wetlands can regulate them also. Brinson (1993) pointed out that though wetness of wetlands are usually studied for understanding their function, but these functions can be potentially effected by drainage network, size of wetland, source of water,

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biogeochemical inflow and outflow etc. Hence to understand the function of wetlands, each wetland can be studied while considering these and many other factors, according to the uniqueness of the wetland. The biodiversity, climate, water and hydrological regime, ecosystem services, soil and sediments, anthropogenic dependence and activity, pollution status etc. in and around the wetlands are interdependent. So, trying to identify a particular cause of degradation of wetland ecosystem and applying a restoration strategy may or may not result into complete success depending on the other regulating factors as well as factors that were remained unstudied. The understanding of total biotic and abiotic setup is necessary for the conservation strategy development. This particular study is a review of the outcomes of the efforts of researchers to understand the ecological and economic importance of the wetlands and the major causes of their vulnerability. Separate headings and subheading are used to focus on individual factors, however interconnection of these factors are well established by the researchers and in this literature review some of those connections are mentioned. The examples mentioned here to establish the importance and role of different factors in regulation of the wetland ecosystem are only some of the vast research works that have already been done, and yet some factors may remain unmentioned here which may be of equivalent importance to develop conservation strategy for conservation and restoration of the wetlands.

IMPORTANCE OF WETLANDS

Biodiversity

Wetlands are unique ecosystems, and they host a range of diverse floral, faunal and microbial species around the world. The members of the biotic communities are dependent on each other, where the diversities are also dependent on the wetlands size, shape, location, climate, water and nutrient resources etc. Biodiversity consisting plants, animal and microbes regulate the biogeochemistry of the wetland, at the same time changes in physical and chemical nature of the wetlands are regulators of the community structure of the wetlands.

Several studies are done and being done around the world to understand the community structure and their interdependence, some of which are being discussed here. In a study by Hansson et al. (2005) it was shown that in 32 constructed wetland areas in southern Sweden, benthic invertebrate species diversity was positively related to age and surface area of the wetland. Bird species richness was positively related to surface area for up to 4-5 Ha. The high shoreline complexity and the age of the wetlands were positively related to the establishment of the high macrophytes. Small Sanjiang plain in Chaina are important habitat of red crown cranes, oriental white storks and the white-tailed sea eagle (Liu et al., 2004). In India some of the important indigenous diversity of species and migratory bird species find habitat at the wetlands of Western Ghat, Loktak lake of Manipur, Bharatpur wildlife sanctuary, Little Rann of Kutch, and the coastal wetlands of Saurastra (Bassi et al., 2014). Kantrud & Stewart (1997) in a study at natural basin wetlands of North Dakota had shown that the breeding of the waterfowls in the wetlands are dependent on several factors like water permanance, nutrient availability, wetland size, land use etc. Siwakoti (2006) mentions about 318 wetland dependent species in Terai region of Nepal (6 climbers, 287 herbs,9 shrubs and 16 trees). Banganga wetlands of Uttarakhand, India, host a rich biodiversity. There are 19 aquatic plant species, 25 in inundated shores and 27 in uplands, among which *P. barbaratum*, *I.carnea*, *P. karka*, and *T. elephantina* are common in all habitats, and the region also has animals like swamp deer, hogs and different birds.

The studies reviewed here are some of the important researches on the wetland biodiversity around the world. To understand the importance of regional biodiversity of each type of wetland is necessary to develop conservation strategies. Some of the threats to the biodiversity are discusses later in this review. The studies show a glimpse of the rich diversity found or yet to be found in the wetlands. Biodiversity not only regulates the ecosystem, but also carries economic importance. The biodiversity of wetlands can support fisheries and eco-tourism, which can help the development of regional economy. So, policy makers may consider the economic importance of some special biodiversity of particular wetlands, but ecological importance of the natural diversity of the usually neglected or the unmonitored wetlands are no less, and these should be protected in order to have a sustainable future.

Carbon Sequestration

Different studies and reviews by researchers around the world indicate that wetlands are one of the important sinks of carbon. Comparative analysis studies are also done on carbon loss from the wetland. The more in-depth studies on carbon sequestration are required to understand the formation of organic matter, release of carbon dioxide and methane, the associated microbes, role of vegetation, climate, sediment chemistry, geology, anthropogenic impact etc.

The sequestration may vary according to the types of wetland and several other factors. Stallard (1998) mentioned that fertilization by agricultural runoff, atmospheric fall out and increased CO_2 can increase the carbon sequestration, whereas the process is affected by wetland drainage, peat mining and accelerated oxidation. In a study at wetlands of northwest Florida by Choi et al. (2001) it was shown that carbon sequestration is greater in landwards expansions of coastal wetlands. In contradiction to Stallard (1998) through a study in a study on alpine wetland of Qinghai at Tibet pleateu, Bai et al. (2010) showed that wetland drainage can increase carbon loss due to increased decomposition of soil organic matter in these landscapes. Alongi et al. (2015) gave an estimation which says that approximately 17% of the total blue carbon of the world is sequestered by estuarine and marine wetlands of Indonesia which are mainly consists mangroves and mashes. In coastal wetland of Louisiana about 63% of the total carbon sequestered was dependent on vertical growth of marsh, as shown by DeLaune & White (2012). Studies by Mitsch et al. (2016) at mangroves of Southern Florida and by Loomis & Craft (2010) at tidal marshes of Georgia, USA, indicated that increase in salinity decreases the capacity of carbon sequestration by wetlands. Mitsch et al. (2016) attributed the reduction to different physiological changes in the vegetation due to increased salinity. The study also showed that the sequestration is greatest in riverine mangroves, then in fringe mangroves and lowest in basin mangroves. Bassi et al. (2014) mentions that soil of wetland can sequester 200 times more carbon than their vegetation. It was also mentioned that Indian mangroves sequester largest amount of carbon among Indian wetlands due to their greater size, diversity and complicated network of canals and tidal creeks. McCarty et al. (2009) mentioned that C sequestration in wetland can be increased by downward mixing or diffusion or leaching during sedimentation and the mechanism performs better if there is a series of smaller sedimentations or a steady state rate of sedimentation occurs.

However along with sequestration, there occurs the loss of C also by biological path ways in form of CO_2, CH_4 and dissolved organic carbon (DOC). A study in Veracruz, Mexico by Marín-Muñiz (2014) showed swamp soil sequester more carbon than marsh soil due to difference in their vegetation. Increase of water level decreases CO_2 production and favors the production of methane (Lloyd, 2006). Mitsch et al. (2013) mentioned that in most of the wetlands sequestration is usually greater than carbon loss in form of methane. Methane emission from wetland is approximately 19% of the total carbon sequestered by them (Bassi et al., 2014). Purvaja & Ramesh (2001) showed that in unpolluted coastal wetlands methane emission is inversely related to salinity and sulfate concentration, but the situation may not remain the same in polluted wetlands. Climate change may increase the loss of carbon from wetlands; drier summer can increase the CO_2 production and greater spring runoff can increase removal of dissolved organic carbon (DOC) (Clair et al., 2002).

These examples are not exhaustive and there are several researches performed and being performed on efficiency of wetlands in carbon sequestration. However, it is clear that several factors as vegetation, climate, geologic position, biogeochemistry, nutrient etc. can regulate the sequestration process, as well as the carbon loss. These shows the uniqueness of each wetlands, and hence it can be implied that, there cannot be a generalized methodology to restore and/or maintain these wetlands at the peak of their performance, but individual research effort is required around the world to cumulatively reduce carbon from atmosphere with wetlands.

Nutrient Removal

Nutrient removal is one of the important ecosystem services of the wetlands. The removal of nutrients added to water from landscapes or other resources, reduces the nutrient load in rivers and oceans, thus the natural habitats of the river and ocean are protected. Thus, the protection of their natural biodiversity, as well as, their utility for the purpose of ecology and economic services, are also preserved. The removed nutrients can follow several changes in form or stage of removal, and they can be up taken by living organisms also, or in extreme case may lead to eutrophication which may lead to death of the existing organism, and change the community structure in different ways and dimensions.

Saunders & Kalff (2001) mentions nitrogen retention capacity is highest in wetlands followed by lakes and rivers respectively. According to Hemond & Benoit (1988) Nitrogen, that usually enters the wetland as in the form of nitrate and ammonium ions, are removed effectively in three different ways. Short term removal is done by plant uptake, long term removal is done by accumulation in sediment and peat, whereas nitrogen is permanently removed from water by denitrification. Morris (1991) mentions nitrate, ammonium, and dissolved organic nitrogen are major forms of nitrogen present in North American wetlands. Phosphorus in the form of inorganic and organic phosphate enters the wetlands and plant uptake as well as accumulation in peat and sediments may play important roles in their removal (Hemond & Benoit, 1988).According to Lucassen et al. (2005) groundwater that is affected by events like dam construction, drought, water harvest for agriculture, is the major source of orthophosphate in wetland, whereas important source of nitrate is leaching from agricultural land and forest soils. In the study at the Baltic wetlands Turner et al. (1999) mentioned that Baltic wetlands are capable of removing 100000 t/year of nitrogen from water before reaching sea. The performance is better when they are nearer to the source of nitrogen. However, it was mentioned that the nitrogen removal is dependent on biogeochemical coupling of C, N, P and Si circulation. Jansson et al. (1998) showed that existing wetlands of Baltic coast can retain 5-10% of total nitrogen emission to the Baltic sea, whereas restoration of the drained wetlands can increase the potential up to 18-24%. Hydrological fluctuation can increase P concentration and export from restored wetlands (Ardón et al., 2010). Fisher & Acreman (2004) described in a study that, riparian wetlands perform better than swamps and marshes in removal of total N and total P, whereas swamps and marshes perform better during removal of ammonium-N and soluble P. It was also mentioned that the regulating factors of N and P removal in wetlands are oxygen concentration in sediment, measure of redox, degree of water logged condition, hydraulic retention and vegetation processes.

The studies indicate that wetlands around the world actively remove nitrogen, but their rate of removal and process may vary depending upon several factors. The active role is taken by plant, microbes and biogeochemical processes in sediments, whereas the permanence of water, the area, hydrology and many other factors can indirectly regulate the whole process. Further researches are required on individual types of wetlands to understand in details the nutrient removal process, so that their efficiency might be increased and preventing measures can be taken before events like eutrophication.

Water Quality

Besides nutrient removal, the wetlands have the ability to reduce the contamination of water from heavy metals, excess sediments, fecal microbes, xenobiotics etc. the they maintain the water quality in certain level that the biodiversity is unaffected, human health is conserved, and the water turns reusable for several purposes including agriculture.

Wetlands can effectively remove heavy metals from water through chemical, physical and biological mechanisms. Sheoran & Sheoran (2006) described that heavy metals can be removed by chemical processes like adsorption to clay and organic matter, hydrolysis and/or oxidation, precipitation and o-precipitation, and carbonate and sufide formation and biological processes like plant uptake, bacterial metabolism of sufate and iron reduction. All these processes are not independent, but they rely on the pH, ions, organic matter and many other factors of the wetlands. Most of the heavy metals present in the wetlands are Fe, Al, Mn, Cu, Ni, Zn, Mn, Pb, Cd etc. Similar processes can remove many of them or they may go through special removal mechanisms according to external conditions. Cu, Mn, Mo, Ni, V, Zn co-precipitates with oxides of iron, whereas Co, Fe, Ni, Pb, Zn, Co co-precipitates with oxides of manganese, and organic matter like humic, tanic and fulvic acid removes heavy metals by forming complexes (Matagi et al.,1998). Plants can effectively metal from wetland. *E. rasmosisti* is efficient for removal of Pb and Zn, and *E. ralleculosa* for Cu (Deng et al., 2004).

According to Gambrell (1994), near pH condition, mineral abundance in flooded wetland facilitates metal immobilization. But the study also mentioned of other possible ways of heavy metal removal. Soluble metals that are uptakable by the plants and metal ions bound to soil by cation exchange were described as easiest to mobilize, whereas metals bound in crystal lattice of clay are describe as most immobile. Oxidation and reduction were also mentioned to play important role. Microbial respiration was mentioned to be releasing Fe^{2-} and Mn^{2+} from oxides, making them uptakable to plants. Reduction of metal ions into sulfides are said to be immobilizing metals in coastal marshes whereas oxidation releases them, but state of oxidation is said to be non-effective on metals like Cd, Zn, Cu, Pb, Ni, but run off is said to be more effective in these cases. Matagi at al. (1998) mentioned claymineral and hydrous oxides absorbs minerals in the order Pb>Cu>Zn>Ni>Cd and peats in the order Pb>Cu>Cd=Zn>Ca. Phytostabilization by lignification and humification, phytovolatilization of highly volatile elements like mercury and selenium, and rhyzofiltraion by accumulating heavy metals on root and shoots or precipitation through plant exudates are mentioned as important mechanism of metal removal from wetland by plants, by Prasad (2003).

Hemond & Benoit (1988) described several possible ways through which wetland can change the water quality. According to them, wetlands can remove suspended solid material from water by slowing the flow of water, thus allowing more time for settle. The performance of wetlands with higher residence time is better for removal of suspended solids. Decomposition of organic matter by bacteria can decrease the Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). Wetland can reduce the pathogenic microbes in water by detaining them for long time till they fail to survive in absence of host organism. They also mentioned removal of xenobiotic organic compounds after reaching wetlands can be initiated by slowing down the flow of water. Then these compounds are removed by sorption on sediments, hydrolysis and anaerobic degradation. Yu et al. (2005) showed in their study that autochthonus microorganisms in mangrove sediment can effectively remove polycyclic aromatic hydrocarbons (PAHs).

These studies showed some examples that can explain the removal of several pollutants and contaminants from the water by the wetlands. There are also studies on the positive and negative effects of these processes. Researches around the world are being done to identify the sources of these pollutants. Reducing pollutants at the source may reduce the anthropogenic pollutant stress on the wetland, so that the natural conditions can maintained with receiving greater ecosystem services.

Economic Importance

Fisheries are one of the important use of wetlands, where there are other uses like fuel wood collection, agricultural water supply, ecotourism etc. The coastal wetland of Gulf of Mexico provides habitat to juveniles of three species of penaeid shrimps upon which the local shrimp-fishery industry is totally dependent (Engle, 2011). In India wetland dependent fisheries are prevalent in Kerala, Goa, Odisa, Jammu and Kashmir, Assam, Bihar, Andhra Pradesh, Gujarat (Bassi et al., 2014).

In India several wetlands are spot of tourist attraction. Chilka lake of Odisa, backwaters of Kerala, Small Run of Kutch, are some of the examples of many of the wetland-based attraction spots for national and international tourists, and in this place, tourism are one of the major income sources for the common people (Bassi et al., 2014).

Wetlands, besides proving resources for economic development, but also may protect life and property of the coastal communities effectively. Bassie et al. (2014) mentioned about the efficiency of Bhitarkanika mangrove of Odisa, India, against the cyclones and protecting the local communities. Through a study by Hashimet & Catherine (2013) it was shown that mangroves can reduce wave height and impact on shorelines as well as can protect the soil from washing away. Wetland can supply required freshwater for agricultural purpose. According to Greenway (2005) the artificial wetlands can effectively remove nutrient from water, and the water can be applied for irrigation purpose at agriculture, golf course and many other places.

Though there are several important studies performed around the world the world in form for actual economic services with factors like cost effective maintenance, actual income in terms of money etc., this review only tried to touch upon some of the economic fields which can be supported by the wetlands. There are several other ways by which the wetland can support the economy like maintaining soil fertility by periodic flooding, reducing human health risk from contaminations thus saving hospital expenses, conserving biodiversity, keeping the balance of the ground water table etc.

MAJOR CAUSES OF VULNERABILITY OF WETLANDS

Several factors both natural and anthropogenic are threatening the existence of the wetlands, reducing their ecosystem services, affecting their biodiversity. While climate change is slowly but continuously being an emerging factor of threat, there are existing threats like pollution, eutrophication etc. The causes and the effects can be interdependent or independent. Here some of the threats from studies of the researchers around the world have been discussed.

Climate Change

Climate change is one of the major concerns of the researchers around the world. It is already showing impact temperature fluctuation, melting of snow, increases in catastrophic events, outbreak of diseases and in many other ways. Most of the climate change are caused by anthropogenic emission of greenhouse gases (GHGs), and global warming can itself induce more global warming, for example increasing microbial decomposition of organic matter, releasing more GHGs. Wetlands are important sinks of carbon and hence has important role in regulating global climate. But they are also vulnerable to the impacts of climate changes.

Climate change can affect the biogeochemistry, ecosystem and physical properties of the wetlands in many ways. Changes in one or many of these aspects can eventually show effect on the others. In a study at Northern Prairie wetlands by Johnson et al. (2005) it was estimated due to global warming these wetlands may dry up in future, which will potentially reduce the habitat of the water fowls that were integrated part of this ecosystem. Erwin (2009) described several possible effects of climate change on the wetlands. Mangroves are to be affected by sea level rise, sea grass/marine aquatic beds will be vulnerable to increased salinity, salt marshes/intertidal marshes are to be threatened by sea level rise and coastal squeezing, Arctic/tundra wetlands by prolonged summer and higher rate of evaporation, peatlands by melting of permafrosts and desertification. Mortsch (1998) predicted that climate change can alter the seasonal cycle and mean level of water in the Great Lakes, which in turn can change the shoreline water balance and affect the productivity, wildlife, water quality etc. in these lakes. Bohn et al. (2007) mentioned that the methane emission in Vasyugan wetlands of western Siberia can increase up to 100% due to lowering of the water table under the climate change scenario. Increase in sea level can affect the sensitive biotic communities, and change in precipitation, evaporation and transpiration can alter the size of the wetlands (Brander et al., 2012).

These studies represent some of the predictions made on impact of global warming and vice-versa. It is of urgent necessity to control the global warming to save the wetlands as well as saving the wetlands to strengthen the endeavors to counter the global warming. The global warming can affect the wetlands by reducing size, permanence, increasing salinity, disturbing the biodiversity and many other ways, at the same time can increase the loss of sequestered carbon which will be a challenge to tackle the global warming.

Land Use Change and Biodiversity Loss

Land use change is one of the anthropogenic causes that threatens the existence of the wetlands, and it is common around the world. Land use changes can be performed by reclamation of wetlands for agriculture, urbanization and other economic purposes, overuse of the wetland resources, disturbing the biodiversity and in many other ways. These processes affect the wetland ecosystem services, soil fertility, hydrological balance, biodiversity; in one or multiple ways.

In a study by Liu et al. (2004), it was shown that in small Shanjiang plains of China, due to change in land use by agricultural and industrial activities caused fragmentation and land reclamation. These resulted into sharp decline in wetland and forest area and increase in paddy land, and other land use, which caused loss of nearly 73.6% of the initial wetland and decline in the rich bird communities dependent on the wetland. The flora community has changed from marshes to small leaved reed species, where remaining marshes are just associated species, and the reason was water loss due to drainage. Jenkins et al. (2003) through a study in wet prairie of Illinois, gave the hypothesis that land conversion in this region has probably reduced crustacean species from 80 to 75, and the remaining species are still vulnerable to further habitat loss. According to Froyd et al. (2014), in Santa Cruz Island giant tortoise are the most important species, they maintain the vegetation diversity in this region probably by wallowing and seed dispersal. Reducing in the number of tortoise as well as coprophilic fungi by direct and indirect human activities, have caused the conversion of freshwater wetland into Sphagnum bogs. Draining of wetlands and pollution from agricultural runoff are mentioned as most important causes of global decline of amphibians and reptile species by Gibbons et al. (2000). Prasad et al. (2002) mentioned that Indian mangroves are suffering from organic and inorganic pollutants from shrimp farms. In this paper introduction of invasive species have also been mentioned to the very harmful to local biodiversity, as introduction of *E. crassipes* and *S. moletsa* are threatening indigenous aquatic flora of India. In West Bengal excessive utilization of ground water has reduced the water supply by aquifers to the regional wetlands, which in turn is negatively affecting the existence of the wetlands (Bassie et al., 2014). Water withdrawal from the wetland as well as artificially elevating the land around wetlands can prevent the wetlands from flooding the surroundings naturally. This can eventually lead towards reduction of soil fertility and increased salinity (Prasad et al., 2002). Road infrastructure development and increased accessibility to the mangroves can increase the fragmentation in mangrove ecosystem and hence can reduce the protection they give to the coastal area (Brander et al., 2002). Disturbances, moisture and nutrient accumulation can regulate species invasion in wetland, and major invasive plants are grasses, graminoids, forbs, shrubs and trees (Zedler & Kercher, 2004). In coastal wetlands of Ghana human activities are causing increase in grass species and decrease in tree species, and events bushfire, herbivory, dispersal and rainfall can regulate the process (Wuver et al., 2003). Olubode et al. (2011) mentioned farming and fishing activities as anthropogenic disturbances in floral communities in wetlands of Ibadan in Nigeria. Water level regulation in Rainy and Namkan lakes has caused notable difference in macrophyte communities with respect to unregulated lakes (Wilcox & Meeker, 1991).

These studies are representing the concerns of the researchers to protect the wetlands. While several similar and diverse researches are also present and being performed, the situation cannot be tackled unless the policy makers make strict impositions on any activity that may affect the wetlands existence and ecosystem, and people are aware of the upcoming difficulties and losses to society in absence of the wetlands.

Pollution

Anthropogenic pollution is something that might have started from the day human learned using fire. The society relies today on intense agriculture, animal husbandry, industry, vehicles and many other factors, each of which are being responsible for pollution around the world. Wetlands are mostly polluted by untreated sewages, waste dumping, industrial waste water, run offs from agricultural field, roads, overuse of synthetic chemicals in household and industry etc. The pollution can source can be both point and non-point, though most abundant are the non-point sources. Here some of the concerns of the researchers on wetland pollution are being discussed.

According to Hemond & Benoit (1988) BOD and COD in wetlands can be changed by external flow of sewage effluent and organic matter from surface run off. This can effectively change the biogeochemistry of the wetland, and in turn can be destructive for the biotic communities thriving in the wetland. Result of this can lead to reducing the ecosystem services provided by the wetlands and its biotic communities. Bassie et al. (2014) mentioned due to eutrophication by untreated sewage water in the wetlands of Himalaya there is resulting into steep fall in dissolved oxygen (DO) and increase in BOD.

According to Hemond & Benoit (1988) aerial application of pesticide, or their volatilization, can carry them through atmosphere to the wetlands, and also the runoff from treated land can add pesticide to the wetlands. This can be extremely harmful for the invertebrates in wetland ecosystem and may disrupt the food chain. In a study by Boone & James (2003) it was shown that insecticide like carbaryl can destroy salamander larvae and also cause reproductive failure and decline in population carnivorous salamanders, whereas the herbicide atrazine decreased the chlorophyll of algal species, prolonged larval phase of small mouth larvae, and reduced the mass of toads and leopard frogs. Relyea (2009) studied impact of different insecticides and showed, carbaryl and malathion affects cladocerans, chlorpyrifos reduces the population of cladocerans and periphyton, diazinon directly affected the periphytons and indirectly reduced growth of the leopard frog tadpoles and endosufun reduces population of copepods and periphytons.

In a study by Kumar et al. (2011) at the eastern Kolkata wetlands it was seen that Mn concentration in the muscles of fishes cultivated in these wetlands were notably high than the permissible limits of FAO/WHO. Though within the limits the concentration of As, Hg (II), Ni, Cd etc., were showing varying concentration in different species. These heavy metals are probably sourced from the urban sewages, waste water from tannery, road run off and local agricultural grounds. In Nyagugogo wetlands of Rwanda, high concentration of Cr, Pb and Cd is seen in fishes, and the roots of papyrus metals are accumulated in the order Cu>Zn>Pb>Cr>Cd (Sekomo et al., 2010). Run off from roads can pollute wetlands and bring change in the biotic communities dwelling in those ecosystems (Spellerberg, 1998). In a study at South Indian coastal wetlands by Purvaja & Ramesh (2001) it was shown that pollution of coastal wetlands by human settlements can turn them into larger source of methane which can potentially alter the global carbon budget. In a study by Harikumar et al. (2009) it was seen that heavy metal pollution in Vembanad lake was moderate for Cu, moderate to high for Zn and Ni, and non-polluted to moderate for Pb. Significant contamination of Cd, Zn, and Ni has made the mangroves and mudflats of Pearl river in China unsuitable for activities like nature reserve, agriculture and reclamation (Li et al., 2007).

PAHs from industrial and domestic waste water, run off from road surface and other sources can end up in the wetlands and pollute their ecosystem (Hemond & Benoit, 1988). Xiao et al. (2014) mentions that industrial and shipping activities are causing increase of PAHs in Pearl River estuary where different types of PAHs are being found to be strongly bound to organic matter in soil. Concentration of PAHs in wetland soils of Sundarban (India) shows low to moderate level of contamination, which can be attributed to rapid urbanization and economic development in the coastal areas (Domínguez et al., 2010). Presence of PAHs facilitates growth of some plants (eg: *B. juncea*) and dcreases growth of some other (e.g. *J. subsecundus*) (Zhang et al., 2011).

These studies show pollutants can be from several sources, affecting the wetlands in several ways and results are harmful to many organisms as well as human can be potential victims of contaminations like heavy metal pollution. While climate change is a global concern, direct and indirect pollution are of regional in nature, similar to land use changes, and can be tackled by awareness and strict policies. The sources should be identified and mitigation measures must be taken according. Artificial wetlands can be effective measures for such controls.

Eutrophication

As discussed earlier it is natural for wetlands to remove nutrient from the water. Major sources of nitrogen and phosphorus in wetlands are urbanized and agricultural lands (Hemond & Benoit, 1988). Whereas internal eutrophication can occur in wetlands due to decomposition of organic matter under anaerobic condition with alkaline environment and abundance of SO_4^{2-} (Smolders et al., 2006). According to Lucassen et al. (2005) eutrophication is likely to occur in wetlands in concentration of nitrate is greater than sulfate or sulfate is mobilized by FeS_x. Houlahan et al. (2006) mentions agricultural fertilizer application as one of the important causes of eutrophication, which can decrease the plant species richness and cause shift in community structure. Increased nitrogen can alter the community structure in wetlands by supporting the nitrophilous plants and endangering the plants adapted to low nitrogen infertile soil conditions, and can also alter rates of microbial nitrogen fixation, decomposition, nitrification and nitrate reduction (Morris, 1991). Eutrophication indirectly increases the risk of *Riberioria miracidia* in snails and amphibian larvae, particularly the increase in the parasite infection increases severe limb deformity and mortality in amphibians (Johnson et al., 2007). Nyenje et al. (2010) mentioned that disposal of wastewater to wetlands is leading to eutrophication, which is resulting into extinction of fishes, depletion of dissolved oxygen and increasing the abundance of cyanobacteria and *C. Botulinum*, in sub-Saharan wetlands. Increase in P causes increase in algae and lemnids (Lucassen et al., 2005).

As the study shows the eutrophication disturbs the biodiversity of the wetlands, and this can eventually lead to extinctions of some species from a particular wetland, along with the ecosystem services provided by them. The sources of excess nutrients are mainly from agricultural, whereas other possible sources like household wastewater, horticulture, sewage etc. should not be underestimated. Controlled use of fertilizers and artificial wetlands or other dumping sites can be potential solutions. Harvesting, recycling and reusing runoff using proper channels can be a good option.

OVERVIEW OF SOME RECENT STUDIES

Some recent studies on wetlands can be considered to put light on the grave situation persisting in wetlands across the continents. Li (2017) discussed that in Sanmenxia Swan Lake Wetland Park is polluted by Pb and Cr. and the high accumulation of heavy metal is being seen in the feather and dung of the white swans, which thrives in this lake. Arefin & Mallik (2018) mentioned in their paper that from 1960 to 2008 the water bodies diminished by 32.57% and marshes by 52.58% in Bangladesh. The soil of Momoge wetlands in China showed high concentration of naphthalene in a study by Xu et al. (2017). Zou et al. (2017) addressed in their study that canalization and reclamation for agriculture are major causes for the loss of wetlands in Amur River basin, in North Eastern China. By to a study by Kaur et al. (2017), in the wetland at Harike of Punjab, it was shown that the wetland contains mutagens. The concentration of heavy metals in water was higher than permissible limits by WHO. Moreover, there was noted high growth of water hyacinth, which was mentioned to be caused due to high level of organic pollution (BOD and COD) and nutrients (NO3, SO4 and P). Sruthy & Ramasamy (2017) reported the first evidence of microplastics in Indian wetlands, that too in Vembanad Lake, which is a Ramsar site. Reynolds &

Ryan (2018) predicted through their study that microplastic contamination and ingestion can cause serious threat to the water-birds of contaminated South African Wetlands. High concentration of As, Pb, Cr, Ni, Al and Ag, were found in the soils of Hooghly River Estuary and Sundarban Mangrove Wetland areas by Mondal et al. (2018).

These studies are indicating that in every corners of the world, wherever there is any activity of social development, the events like loss of wetlands, pollution etc., are taking place. The scenario is prevalent across the globe, and if measures are not taken to mitigate such events, they are likely to be posing threat to wetlands, biodiversity etc. and may end up through bioaccumulation in plants and animals and through drinking water, and cause serious damage to human communities which rely on these wetlands for food and water resources. Moreover, the loss of biodiversity can severely affect economy, such as fisheries, agriculture, non-wood forest products, eco-tourism etc.

CONCLUSION

It can be well understood from the research outcomes from around the world, that wetlands are one of the important ecosystems with several ecological and economic benefits. The biodiversity of wetland are unique, and each of the members of the system in dependent on the other for their survival. Any reduction or extinction of a species may significantly lead of loss or overgrowth of the others resulting into collapse of the total ecosystem in the wetlands. The loss of the biodiversity by anthropogenic disturbances or overharvest can initiate such problems. The economic support like fisheries, water, soil fertility etc. can be lost in longer time. The process can also alter regional biogeochemistry and also affect human health, other water resources, agriculture etc. in several ways. Similarly, pollution by chemicals, unplanned land use, eutrophication, climate change etc. can themselves have grave the impact of each other as well as can alter the biodiversity and biogeochemistry. So, wetland biodiversity must be conserved with proper attention, policy and awareness. The alteration in biogeochemistry by excess sedimentation, eutrophication, pollution, unplanned land use, climate change etc. can affect the ecosystem as well as the water and soil quality of the region leading to similar losses.

It will be incomplete to work to protect the individual component of the wetland ecosystem like biodiversity, water quality etc., but a totalitarian approach might be more successful. Any planning to protect a wetland should consider it as a singular entity. The plan should focus on biodiversity, water quality, sources of pollution, type of pollutants, required biological, chemical or physical methodologies for restoration. Introducing any new species for such purposes should be verified for their invasiveness, and at the same time chemical or physical alterations should be done carefully so that the existing situation is not harmed in any other way. But the restoration planning is not sufficient enough for protection of wetlands, unless people are made aware of the importance of the importance of the wetlands. Both ecological and economic awareness should be developed through school education as well as adult education. Moreover, it can be very helpful to control pollution at the source. Controlled use of the agricultural chemicals, proper drainage from industries and urbanized areas, recycling and reuse of the used water can be potential solutions. Whereas the future impact of climate change can only be mitigated by global coalition to tackle greenhouse gas emission. For this moving towards green energy, reducing overuse of petroleum products and many other possible methods are needed to be studied, may be a faster pace of research is required with collaboration in economic and strategic way from across the world. Also, strict measures should be taken against filling up natural wetlands for agriculture and urbanization purpose, and also development of artificial wetlands in greater number may be necessary for harvesting rainwater as well as treatment of wastewater.

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Chapter 7
Biodiversity and Impacts of Climate Change in Home Gardens:
Evidence From a Study in West Bengal, India

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ABSTRACT

Home garden is a complex multi-functional land use system that combines multiple farming components of the homestead and provides environmental services, household needs, and employment and income generation opportunities to the households. Predicted climate changes have serious implications for crop and livestock yields particularly in tropical regions. Home garden may act as a cushion to the adverse climate shocks. There is dearth of in-depth study of home garden ecosystem in India. The authors have selected 100 households in Garhbeta-1 block, which is in the dry zone in the district of Paschim Medinipur in West Bengal, India for the study. The main objectives of the chapter include (1) identification of the key characteristics of the home garden, (2) assessing biodiversity in home gardens, (3) identifying the pattern of climate change from the household perceptions and the problems in home garden, and (4) the changes made in the home gardens.

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INTRODUCTION

Home Garden is a complex multi-functional land use system that combines multiple farming components of the homestead and provides environmental services, household needs, and employment and income diversification opportunities for farming households. Home-garden represents a kind of mixed cropping of fruits, vegetables and trees. Home garden practices attracted the international attention since 1950s, but much less than field agriculture. Home garden is important from social economic and environmental considerations. Efficient utilisation of home garden may provide food security and may supplement critical income needs. The natural resources like soil, water and sunlight may intensively be used in home garden. Home garden may improve the ecological diversity. Multiple cropping through different types of crops and plants enhances soil health. Climate changes have serious implications for crop and livestock yields particularly in tropical regions. Home garden may act as a cushion to the adverse climate shocks. One of the most important reasons for studying the home garden is that if properly planned it can improve the food security situation of the households. This is particularly important where there is low productivity in agriculture and there is lack of alternative employment opportunities.

BACKGROUND

Biodiversity can augment economic activities related to agriculture, forestry and fisheries. Globally nearly half of the human population are directly dependent on natural resources for their livelihoods, and many of the most vulnerable people depend directly on biodiversity to fulfil their daily subsistence needs. The SDG framework provides a helpful framework to demonstrate the fundamental importance of environmental issues alongside social and economic issues. Importantly, if plant conservation is not achieved, then the achievement of the SDGs is put at risk, suggesting that the integration and mainstreaming of biodiversity conservation, ecological restoration and plant protection in particular is of fundamental importance to the achievement of sustainability within the planetary boundaries. According to Okpaire (2019), Home Gardens provide the eight functions contribution to attaining eight of the Sustainable Development Goals (SDGs). These are: (i) generate small but significant stream of income, especially for woman, (ii) supply nutritive food and make food production system more productive and resilient, (iii) improve the health of women of reproductive age and young children give women more choice and control over productive resources, (iv) give women more choice and control over productive resources (iv) spur entrepreneurship, creatively and economic opportunities, particular foe woman, (v) contribute to greening of rural and urban settlements and greater resilience to disasters, (vi) have minimal food losses and help to close nutrient cycles, (vii) strengthen household-level resilience and adaptive capacity to climate-related hazards and natural disasters.

Importance of home gardens and its connection with climate change have been discussed by various authors. According to Altieri & Koohafkan (2008), a climate change impact potentially significant to small farm production is loss of soil organic matter due to soil warming. Higher air temperatures are likely to speed the natural decomposition of organic matter and to increase the rates of other soil processes that affect fertility. According to Roshetko et al. (2002), in aggregate, smallholder homegarden agroforestry systems can contribute significantly to a region's carbon budget while simultaneously enhancing smallholder livelihoods. According to Linger (2014), with insignificant garden size; homegarden agroforestry practice provides good socio-economical and agro-ecological service for farmers which have a higher implication for climate change adaptation than non-tree-based garden. According to Bardhan et al. (2012) agroforestry can serve as an important ecological tool in conserving tree species diversity, particularly on landscapes where Natural Forests fragments represent only a small fraction of the total land area. The study by Trinh et al. (2003) in Vietnam concludes that richness and stability of home gardens make them important sites for in situ conservation within ecozones, and great scope exists for the utilization of this information to improve nutritional and income-generating development projects. According to Mellisse et al. (2018), market opportunities enabled smallholders to maintain food security and dietary diversity without jeopardizing plant species richness. According to Calvet-Mir et al. (2012) home gardens provide a large set of ecosystem services, being cultural services the category most valued. According to Calvet-Mir (2012), home gardens provide a large set of ecosystem services, being cultural services the category most valued. The importance of HG in livelihood generation and food and nutrition security has also been discussed by various authors (Crowell et al., 1991; Attygalle, 1996; Hitinayake et al., 1996; Lebel et al., 2010; Weerahewa et al., 2011; Pushpakumara et al., 2012). Nguyen (1997) reported that the HGs have an important role in regulating both micro-nutrients and supply of marketed surplus. The issue of plant diversity of HG in two Peruvian Amazon communities has been reported by Ban & Coomes (2004). Blaylock & Gallow (1983) reported that the household decision to produce vegetables at home was influenced significantly by the area of household residence, homeownership, race, source of income, the number and ages of adults in the household, and the potential for saving money. A study conducted in Vietnam (URS, 2004) revealed the problem areas of home gardening with respect to lack of market information, lack of water in dry season, low plant diversity, low education, lack of technology and finance, etc. In the context of climate change, HG assumes an immense importance. Despite the large empirical evidence on adaptation, a limited number of studies have been reported in South Asia, examining the extent to which the home gardeners have adapted to climatic changes (Marambe et al., 2011; Marambe et al., 2012a, 2012b; Pushpakumara et al., 2012; Weerahewa et al., 2012). Home gardens have tremendios potentiality to food and nutrition security particularly in the backward regions (Jana et al 2015).

The home gardens can play a very crucial role in improving the food and nutrition security of the rural people. The home garden ecosystem, their biodiversity and their role in food security have a very limited number of studies particularly in India. The major objective of the study is to understand the key characteristics of the home garden in relation to biodiversity.

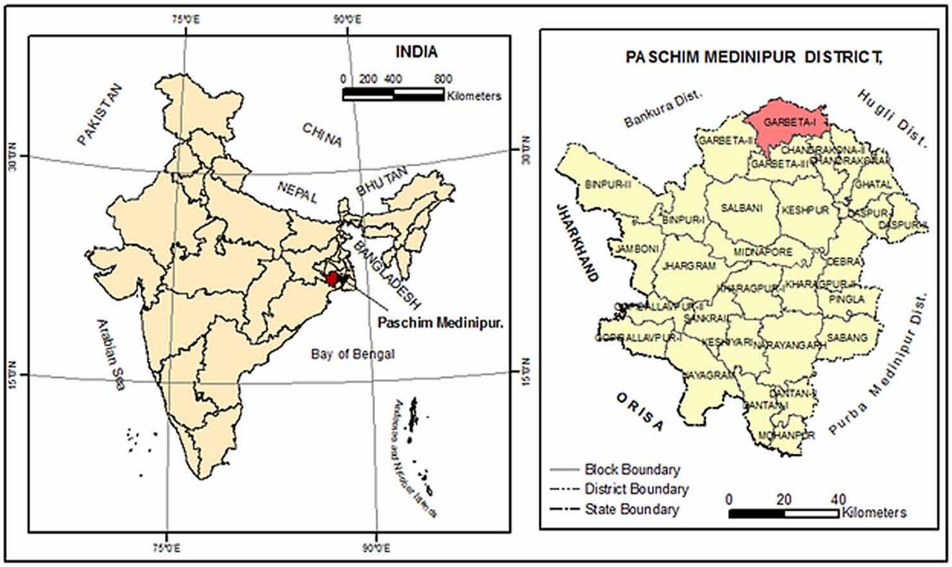
The objectives of the study include:

1. To identify the different features of home gardens.
2. Assessing biodiversity in home gardens.
3. To get insights into the peoples' perceptions about climate change.

STUDY AREA AND CHARACTERISTICS OF HOME GARDEN OWNERS

We have selected two villages namely Ledagamar and Keshia in Garhbeta – I block in the district of Paschim Medinipur in the state of West Bengal in India for our study. The study area is in the northern part of the district as shown in the following map.

Figure 1. The Map of West Bengal in India with the Study Area



We fixed some desirable criteria for choosing home garden for study. These were: (1) the extent of home garden should be within 0.5 ha, (2) composition - Trees and animals, (3) structure – at least 3 tier plant structure. The region is preferably low country (<300 m above the sea level) dry zone (<1700 mm rainfall). Applying these criteria, we selected the two villages in Garhbeta – I block as these villages suited our criteria. The villages are 5 kilometres away. The latitude and longitude of Ledagamar are 22.833 and 87.323 respectively and that of Keshia arerespectively 22.804 and 87.329 respectively. The total number of households surveyed is 100 out of which 74 households were from village Ledagamar and 26 are from village Keshia. The altitude of the place is 66 meter above the sea level. The soil is sandy loam type.

The region is in the dry zone with average rainfall of 1500 mL. The temperature in the summer season in these regions can very high up to 39 degree C. The average productivity of paddy in the region is about 2.5 tonnes per hector. Though there is sufficient vegetable production in the region, there is deficient production in pulse, oilseed. About 36% households live below the poverty line in the block. Out of the two villages selected, Keshiha is larger than Ledagamar in size. The population densities of the two villages are respectively 793 and 461 respectively. Ledagamar is dominated by Scheduled Caste Population (89.8%) and in Keshia percentage of SC and Scheduled Tribe (ST) households are respectively 35.5% and 23%.

The villages mostly depend on dug wells for the drinking water. The villages enjoy the public facilities of primary school, ICDS, SSK. More than 70% of the households are electrified as per the Government report. More than 90% of the households are seen to depend on dug wells for drinking water. The soil is sandy loam. The river Silabati being not too far away, the soil is fertile for vegetable production. The pH level of the soil shows the soil is slightly acidic in nature.

Average family size of the sample households is calculated as 6 with percentage of females and males 48% and 52% respectively. The age wise distributions of the members of all the households are as follows: Below 14 years: 22%, 15-40 Years: 53%, 41-60 Years: 19%, Above 60 Years: 6%. The occupational pattern of the household reveals that main source of livelihood is agriculture. It has been observed that the heads of households had started working in the field at an early age. Age group wise percentage distribution of household members are as follows: below 14 years: 10%, 15 -18 years: 40%, 19 – 24 years: 37%, 25-29 years – 10% and 30 years and above – 3%. The region is educationally backward. The educational level of the sample households are as follows: No Schooling – 19%, Primary – 21%, secondary – 54%, Post-secondary – 3% and university – 3%. The situation is more or less same in the two villages.

Education of the head of the household is important factor for the home garden. The average class attained by the head of the household is calculated as 4.95. The highest education level achieved for our sample is graduate. Around 23% of household members are students and 8% of housewives work outside. The families having service holder member is only 1%. Land is an important asset of the households. The average land holding of the household is 2.82 acres with maximum 7.80 acres and minimum 0.03 acres. The average land holding is slightly higher in Ledagamar than Keshia. 22% of households belong to the category of below 1 acre and 19% of households possess greater than 5 acres land. The average monthly income per home garden owner is Rs. 3,195. The main source of income is agriculture and related activities.

We have collected data about the consumption pattern of households. The average monthly per capita consumption expenditure of household was Rs. 3,735. In estimating the consumption expenditure, we have imputed cost for goods produced for self-consumption. About 82% of household consumption of milk is supplied from home garden and 79% of fruits requirement is supplied from home garden. Of the total consumption of fruits by households 78% is obtained from home garden. The main item of expenditure are food and drink (48%), clothing (12%), education (10%), fuel and light (6%).

RESEARCH FRAMEWORK AND METHODOLOGY

The primary survey was carried out during different months of 2009-10. We had structured questionnaire for our study. For noting the changes in the home garden, we carried out survey in two different seasons. The questionnaire included different aspects relating to home garden characteristics, their role in household consumption, their problem areas and also different socio-economic characteristics of home garden owners. The responses were taken from the heads of households. We have also used regression analysis to understand the variation of the contribution of home garden in consumption of the households.

The Shannon-Wiener Index (SWI) is used to evaluate the species richness and abundance of trees in the study area (Marambe et al., 2012a). The proportion of species (i) relative to the total number of species (p_i) is calculated and then multiplied by the natural logarithm of the same proportion ($\ln p_i$) (Eq 1). The resulting product is summed across species and multiplied by 1 and the SWI of individual HG is calculated.

$$SWI = - \sum p_i \, [\ln(p_i)] \tag{1}$$

We are interested here in finding the determinants of biodiversity or richness of plant species in home gardens. A high biodiversity is defined here as the value which is above the median SWI value. The median here is used instead of mean to avoid bias arising out of extremely small or large observation. Accordingly, a logit model (Equations 2, 3 and 4) (Wooldridge, 2002; Heij et al., 2004) is used to analyze the factors, which influence the biodiversity.

Latent variable y_i^* can be given by the equation below

$$y_i^* = \beta_1 + \beta_2 x_{2i} + \ldots\ldots\ldots + \beta_k x_{ki} + u_i \tag{2}$$

y_i^* is unobservable but $y_i = \begin{cases} 1, & if\, y_i^* > 1 \\ 0, & Otherwise \end{cases}$

where, $y_i = 1$, If there is high biodiversity in home garden; $y_i = 0$, otherwise.

X_{ji} 's are independent variables.

$$P(y_i = 1) = p_i = \frac{e^{\beta_1 + + \beta_2 x_{2i} + \beta_k x_{ki}}}{1 + e^{\beta_1 + + \beta_2 x_{2i} + \beta_k x_{ki}}} \tag{3}$$

Log likelihood of the logit model is given by

$$\text{Log (L}(\beta)) = \sum_{i=1}^{n} y_i \log(p_i) + \sum_{i=1}^{n} (1 - y_i) \log(1 - p_i) \tag{4}$$

We have assumed three independent variables that may affect biodiversity: if the household has changed the date of planting of crops in home gardens (plantdat), the flow value from home garden (flowdumm =1, if there is high flow from home garden), percentage of time allocated for maintenance of home garden (perctime).

RESEARCH FINDINGS

Home Garden Characteristics

A home garden is made of a house and other componentsas presented in "figure 2". The average area of the home garden is calculated as 16.8 decimal. The percentage distribution of different items per home garden for our sample is presented in the "figure 1". Crops, plants and trees occupy the major portion of the home garden. The average blank space is 17% which often is used for different household purposes including thrashing of crops, playing for the children, social purposes etc.

We have classified the home garden into three sizes – Small (0-20 decimal), Medium (11-20 decimal) and Large (Above 20 decimal). The number of different sizes of households for our sample are as follows: small – 44%, medium – 28% and large – 28%.

As for the construction of the houses, 89% of houses are mud- built and 19% of households are brick-built. The roofs of the houses were made of tin (66% of households), thatching materials, sheets etc. The types of toilets for the home gardens are as follows: septic tank – 64%, open pit – 19%, outside land – 27%. Soil conservation: 84% of the households surveyed recognize the necessity of conserving soil and 91% practice integrated farming of tree-crop-animal.

Figure 2. Components in home gardens

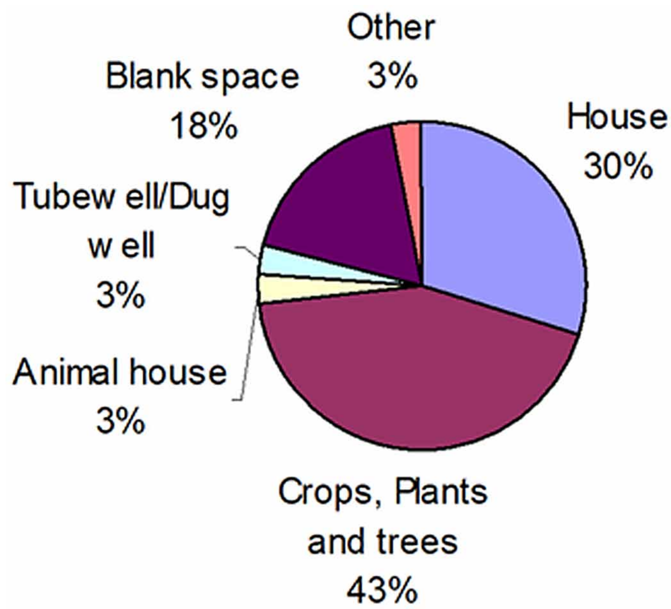


Table 1. Total types of crops, naturally grown plants, trees and domestic animals

Type	Nos.
Crops	113
Naturally Grown Plants	61
Woody Trees	72
Non-Woody Trees	15
Domestic Animals	8

(Source: Estimation Based on Primary Survey)

We have divided the vegetation in the home garden into 4 categories – crops, naturally grown plants, woody and non woody trees. Crops are basically ground strata like different vegetables. Non woody trees are mostly middle strata plants. Trees may be called high strata plants. We have observed different species of plants, trees and animals in the home garden. In our sample 100 households we have found the following types of plants and animals as shown in “table 1”.

If we look at the home gardens, we see that in the lower strata we have 66 types of crops, in the middle strata we have 44 types and in the top strata 80 types of plants. We have classified home gardens into 3 different sizes – small, medium and large. Though there is not much difference in average number of crops and plants across different sizes for lower and middle strata, the number of top strata trees is higher for larger size home garden. In “table 2”, we have presented number of plants by garden size.

In the “table 3”, we have presented average DBH (Diameter at breast height), average height, and average age of the top strata trees across different sizes of households. The average DBH and average height is not different between small and large garden. The average age of trees in small garden is 15 years in small gardens, 14 years in medium garden, and 17 years in large garden.

Table 2. Average, max & min of various types of plants of by strata and home garden size

Home Garden Size	Lower Strata			Middle Strata			Top Strata		
	Average	Max	Min	Average	Max	Min	Average	Max	Min
Small	5.1	10.0	1.0	2.6	8.0	0.0	7.5	17.0	4.0
Medium	4.7	10.0	2.0	2.6	8.0	0.0	8.6	18.0	5.0
Large	5.3	12.0	1.0	2.8	7.0	0.0	11.4	18.0	6.0
Total	5.0	12.0	1.0	2.7	8.0	0.0	8.9	18.0	4.0

Source: Based on Primary Survey

Table 3. Average DBH (cm), height (ft) and age (year) of the top strata of the households

Home Garden Size	DBH (cm)			Height(ft)			Age(year)		
	Average	Max	Min	Average	Max	Min	Average	Max	Min
Small	50	107	13	29	61	11	15	33	4
Medium	45	92	5	26	46	5	14	37	2
Large	50	82	24	29	49	17	17	38	6
Total	49	107	5	28	61	5	15	38	2

Source: Based on Primary Survey

In all the home gardens except one, the head of the household lives in the village. The annual time allocated by household to home garden varies with maximum 4015 hours and minimum 35 hours with the average of 850 hours per annum which is 1.59% of annual hours. No hired labour has been observed for the maintenance of home garden

The average number of crop species for the home gardens is observed as 7.72 with maximum of 18 and minimum of 2. Chilli is the most important crop species with 84% of households have chillii. We have reported the first 8 crop species namely chilli, papaya, brinjal, gourd, puisak, marigold and banana with percentage frequencies. Vegetables are grown mainly in the months of July to November. In “table 4”, we have presented frequency of occurrence of Crop species in home gardens.

Table 4. Frequency of occurrence of crop species per household per Year

English Name	Scientific Name	% of Home Gardens
Chilli	*Capsicum frutesena*	84
Papaya	*Carica papaya*	58
Brinjal	*Solanum melongena*	57
Gourd	*Legenariasiceraria*	45
One Kind of leafy Vegetable (puishak)	*Basella rubra*	43
Marigold	*Tagetespatula*	32
Banana	*Musa sapientum*	30

Source: Based on Primary Survey

The plants that grow naturally in an area are called naturally grown plants. The average number of naturally grown plants is calculated as 2.71 with maximum 10 and minimum 0. Frequency of first 10 naturally grown plants is presented in the "table 5".

The number of woody trees per home garden is calculated as 7.17 with maximum of 16 and minimum of 2. The percentage frequency of first 10 woody trees with average number of trees per home garden is presented in the in the "table 6". The most frequent tree is Mango with 89% of households is observed to have it.

Total number of non woody tree species per family is calculated as 1.42 with maximum 3 and minimum 1. The most frequent non woody tree is banana with 58% of households is observed to have it. Frequency of Occurrence of Non-Woody Trees is presented in "table 7".

Table 5. Frequency of occurrence of naturally grown plants species (perennial) in home gardens

English Name	Scientific Name	% of Home Gardens
Date Palm	*Phoenix sylvestris*	44
Indian Lilac	*Azadirachtaindica*	32
Elephant Apple	*Dilleniaindica*	21
Tamarind	*Tamarindusindica*	19
Golden Apple	*Angle mamelos*	12
Shirsa	*Albizialebbeck*	12
Mango	*Mangiferaindica*	11
Jamboline	*Syzygiumcumini*	09
Palm	*Borassusflaballifer*	09
One kind of timber tree (suochalta)	-	07

Source: Primary Survey

Table 6. Frequency of occurrence of woody trees (perennial) in home gardens

English Name	Family	Average Number per Home Garden	% of Home Gardens
Mango	Anacardiaceae	2.70	89
Jack fruit	-	1.97	87
Guava	Myrtaceae	0.97	57
Golden apple	Rutaceae	0.56	41
Indian lilac	Meliaceae	0.48	37
Jamboline	-	0.40	32
Coconut	Areaceae	1.25	29
Lemon	Rutaceae	0.24	22
Tamarind	Caesalpiniaceae	0.24	20
Indian Jujube	-	0.26	19

Source: Primary Survey

Table 7. Frequency of occurrence of non-woody trees (perennial) in home gardens

English	Family	Average Number per Home Garden	% of Home Gardens
Bamboo	Peaceae	0.55	32
Papaya	-	0.14	09
Banana	Musaceae	0.10	58
Hibiscus	Malvaceae	0.06	05
Clitoria	Pipilionaceae	0.02	02
Pomegranete	-	0.02	02
Kind of flower(Tagar)	Apocynaceae	0.02	02
Pine apple	Bromeliaceae	0.01	01
Kind of flower(asoueful)	Ceasalpiniaceae	0.01	01
Kind of weeds(Beragada)	-	0.01	01

Source: Primary Survey

Species Richness

The average value of SWI of the sample households in the study area is calculated as 1.436 with maximum value 2.309, minimum value 0.277 and standard deviation 0.324. The average value is slightly different for two villages in India with 1.44 for Ledagamar and 1.42 for Keshia.

Animals in Home Gardens

Almost all the households are observed to rear domestic animals. The most frequent domestic animal is cow with 84% of households are observed to have it with average number being 3.63. Frequency of occurrence of different domestic animals in home gardens is given in “table 8”.

The cost of maintenance for animals is presented in the “table 9”. The cost of maintaining cattle is higher than goat and poultry. Percentage of home garden contribution to supply of animal feeds is calculated as follows: Cattle – 19%, Poultry – 10%, Goats – 18% and Swine – 03%.

Table 8. Frequency of occurrence of different Domestic Animal species per home garden

English Name	Scientific Name	Average Number of species per Home Garden	% of Home Gardens
Cow/Cattle	*Bos indicus*	3.63	84
Goat	*Capra Sp.*	5.00	44
Poultry (Duck+ Fowl)	*Calusdomesticus, Anseranser*	8.97	49
Others (Cat, Dog, Parakeet, etc)	*Felis domesticus, Canis familiaris, Colamba livia, Cavia porcellua.*	6.43	16

Source: Primary Survey

Table 9. Cost of annual operation/maintenance of domestic animals (Rs.)

Animals	Average	Max	Min
Cattle	990	6887.7	91.8
Poultry	82.8	459	8.1
Goat	272.7	1836.9	18.45
Other (Cat, Dog, Parakeet, etc)	70.65	183.6	22.95

Source: Primary Survey

Changes Made in Home Gardens

From our field survey we have seen that planting dates have been changed for some crops like chilli (30% households), brinjal (21% households), Gourd (17% hhs) etc ("table 10"). The major reasons for changing planting dates are change onset rainfall, shortage of water and lack of timely irrigation supply etc. Other changes observed in the home garden are increasing use of new technology, like micro irrigation, sprayer machine etc. Also, the major reasons for using new technologies are obtaining higher production; prevent/overcome insect pest damages and disease etc. The other reasons are: change in onset of rainfall, to get higher production, increasing temperature etc. It is to be mentioned that 73% of households have reported that they have reduced the numbers of the animals in the home garden, whereas 13% of the households have reported that they increased the numbers of animals.

Source of irrigation: The main sources of irrigation for the sample home gardens are: Dug well (52% of households), tube well (24% of households). These are the main sources of irrigation.

Water Conservation: About 93% of households adopt different kinds of soil and water conservation measures. The main soil conservation measure adopted is mulching followed by shading and cover cropping. To improve the fertility of the soil they apply different kinds of fertilizers like – chemical (92% households), compost (22% households), cattle manures (83%).

Table 10. Type of changes made to the crops and trees in home garden during the past 20 years

<table>
<tr><th colspan="2" rowspan="2">Changes Made</th><th colspan="2">Home Gardens (HG) Making Changes</th></tr>
<tr><th>% of HGs Out of Those That Made Changes</th><th>% of Total HGs</th></tr>
<tr><td colspan="2">Changing Planting dates</td><td>60</td><td>56</td></tr>
<tr><td rowspan="4">Using new technologies</td><td>Micro-irrigation</td><td>70</td><td>66</td></tr>
<tr><td>Sprayers</td><td>07</td><td>07</td></tr>
<tr><td>Other</td><td>74</td><td>70</td></tr>
<tr><td>Varieties</td><td>19</td><td>18</td></tr>
<tr><td colspan="2">TOTAL</td><td>93</td><td>94</td></tr>
</table>

Source: Primary Survey

Estimation of the Stock Value and Flow Value from Home Garden

The returns from home garden consist of both stock value and flow value. The stock value is value of woody trees in home gardens. The flow value is the value of annual returns from crops and trees. We have also calculated the stock value per family. The stock value has been calculated after finding the volume of the tree and hen estimating at the value at the current market rate. In estimation of the value, we have taken into consideration the difference in market value of different woods. The total stock value (in Rs.) per family is calculated as 26.86 thousand of which the contribution of trees is 25.32 thousand (“table 11”).

The flow value generated per family of different types of crops is given in the “table 12”. The highest annual flow value per family is generated from tress (Rs. 4.59 thousand) followed by one-year crops and plants (Rs. 1.3 thousand).

CLIMATE CHANGE AND PROBLEMS OF HOME GARDENS

We have presented in “figure 3 and figure 4” the trend of change of temperature as per data in “table 13”. It is evident from “figure 3” that minimum temperature in the study area (Midnapore) are during 1965-2010 is rising. We have compared month-wise average daily maximum temperature between two Periods 1969-1990 & 1991-2006 for months in Table 13.

Perception of households about the different parameters of climate change is presented in “table 14”.

Table 11. Stock value of woody-non woody trees and domestic animals

Items	Average	Max	Min
Woody-non woody Trees (Rs. in ‘000)	25.32	194.86	0
Domestic Animals (Rs. in ‘000)	1.54	16.4	0
Total Stock Value (Rs. in ‘000)	26.86	196.56	0

Source: Primary Survey

Table 12. Flow Value of Crops, Naturally Plants, Woody-non woody Trees and Domestic Animals (Rs. in ‘000)

Items	Average	Max	Min
One Year Crops & Plants (Rs. in ‘000)	1.3	9.5	0.05
Naturally Plants (Rs.in ‘000)	0.19	3	0
Woody, Non-Woody Trees (Rs. in ‘000)	4.59	22.94	0
Domestic Animals (Rs. in ‘000)	2.86	19.84	0.03
Total Flow Value (Rs. in ‘000)	8.9	39.54	0.42

Source: Estimation based on Primary Survey

Figure 3. Trend of minimum temperature in home garden

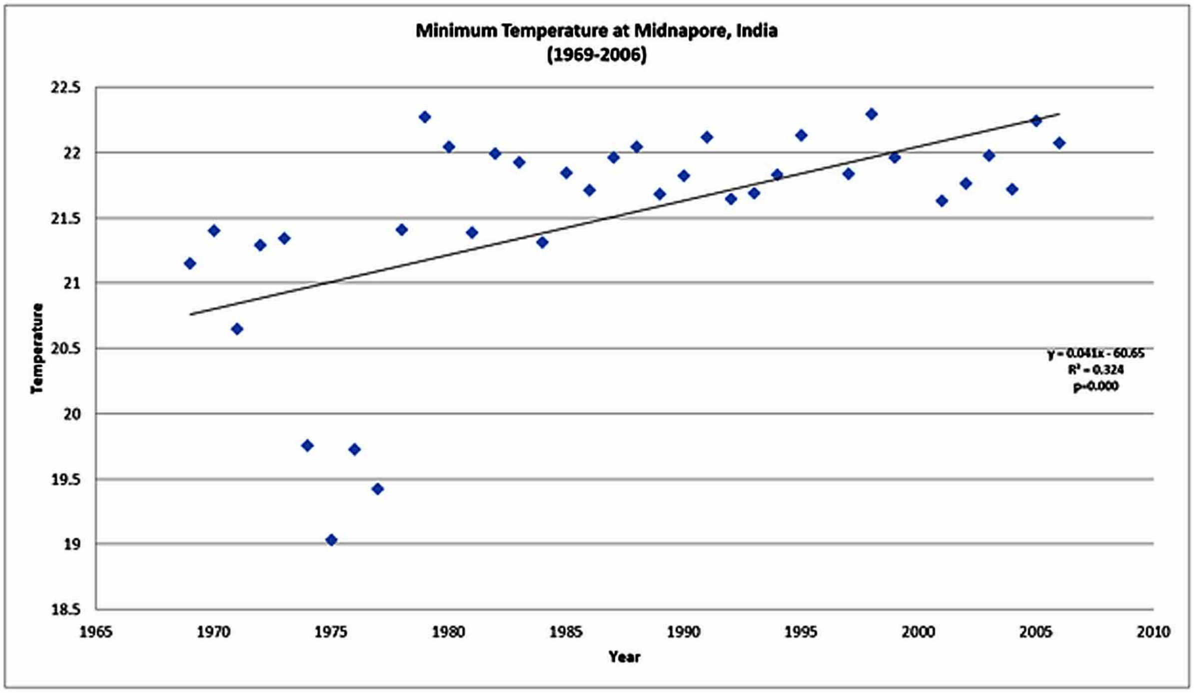


Figure 4. Trend of maximum temperature in home garden

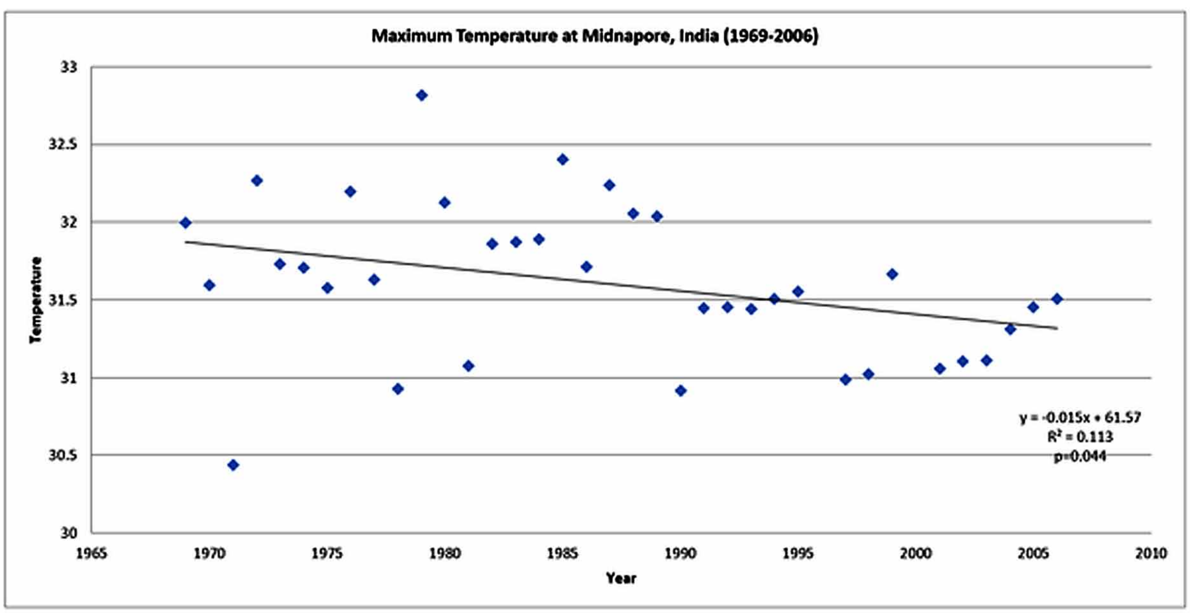


Table 13. Month wise Comparison Average Daily Maximum Temperature between two Periods 1969-1990 & 1991-2006

Month	Maximum Temperature		Minimum Temperature	
	1969-1990	1991-2006	1969-1990	1991-2006
January	26.1	24.7	13.2	13.4
February	29.1	29.2	16.3	17.3
March	34.2	33.0	20.7	21.6
April	37.6	36.5	24.1	24.7
May	37.1	36.3	25.2	25.9
June	34.8	34.3	25.8	26.4
July	32.3	32.5	25.4	26.2
August	31.8	31.9	25.4	26.1
September	32.0	31.9	25.0	25.7
October	31.7	31.3	22.8	23.6
November	29.4	28.8	18.1	18.5
December	26.3	25.7	13.5	14.1

Source: Estimation based on IMD data

Table 14. Perception of households about the events of climate change

Type of Events	Change	
	More	Less
Amount of Rainfall	0	100
Rainy Period	0	100
Temperature(Morning)	0	100
Temperature(Evening)	100	0
Wind turn	7	93
Mist	2	98
Dew	2	98
Fog	45	55
Droughts	99	1
Storms	36	64

Source: Primary survey

Problems in Home Gardens

We have discussed here different problems of home gardens which may be caused by climatic factors. Home garden owners have reported various types of pest attacks, insect and diseases in the home gardens. These are affecting the growth of plants and animals in the home gardens. We report here different kinds of attacks as reported by owners of home gardens. The most common attack on the home garden is *ledapoka* (77% of households) affecting the vegetables and trees. The other insect and pests are *jab poka, haludpoka, sadamachhi*etc ("table 15").

The crops in the home garden are vulnerable to different kinds of diseases. The common diseases in our sample home gardens are *Kutha* (41% of households), *Dhasa* (37% of households), *GaraPacha* (32% households). The common diseases with the plants they affect are given in the "table16".

It has been observed that animals from outside also trespass the home garden and make damages to the home garden ("table 17"). Twenty of the households have reported that elephants from nearby forest enter into the home garden and create damages to plants, crops and houses in the home garden. Goats and cows from other's houses also enter into the home gardens. Though most of the houses have fences, it is not well managed.

Table 15. Insect and pest attacks reported in home gardens

Local Name of the Pest Insect	English Name of the Pest	English Name of the Attacked Crop and Trees	% Home Gardens Attacked
Leda poka	Semi Looper	Brinjal,gourd,chilli,tomato,countrybean,pumpkin,yam, morunga,turner,leafy vegetable,mango,jackfruit etc.	77
Jab poka	Aphids	Brinjal,chilli,country bean,morunga,mango, jackfruit,guava,lefy vegetable etc.	33
Haludpoka	-	Gourd,Pumpkin,cucerbitaceous,terner, country bean,mango etc.	16
Sadamachi	White Fly	Chilli,snakegourd,mango,jackfruit,guava etc.	11
Maker poka	-	Chilli,brinjal,mango,jackfruit etc.	10
Machipoka	Fly	Chilli,mango,jackfruit etc.	8
Sosakpoka	Plant Hoper	Brinjal,chilli,balsamapple,mango,jackfruit,guava etc.	8

Source: Primary Survey

Table 16. Insect and diseases attacks reported in home gardens

Local Name of the Disease	English Name of the Disease	English Name of the Attracted Crop and Trees	% Home Gardens Attacked
Kutha	Mosaic	Brinjal, chilli, balsam apple, papaya, country bean, gourd, cucerbitaceous, mango, coconut, etc.	41
Dhasa	Downy mildew	Brinjal,chilli,gourd,tomato,yam, balsam apple,countrybean,morunga etc.	37
Gorhapacha	Foot rot	Chilli, brinjal, gourd, country bean etc.	32
Blight	Blight	Chilli, orange, etc.	5

Source: Primary Survey

Table 17. Animal attacks reported in home gardens based on the crop species

English Name of the Animal	Scientific Name of the Animal	% Home Gardens Attacked
Elephant	Elephas Maximus	20
Goat	Capra Sp.	07
Cow	Bos Indicus	05

Source: Primary Survey

Different kinds of weeds have been observed in the gardens. The common weeds are – cynodont (45% of households), eragostis (29% of households), evolvulus (11% of households) ("table 18").

Besides plants, animals in home gardens are affected by different diseases. The most common Pest attack on animals is *atulipoka* (ectoparasiye – 64% of households) Different diseases of animals are – *ausa*(69%), *sannipat*(35%) . The different diseases of animals with their local and English names and corresponding percentage frequencies are presented in the "table 19".

Table 18. Weeds reported in home gardens

Name of the Weeds	Name of the Attracted Crops and Plants	% Home Gardens Attacked
Croton	All type of crops	11
Cynodon	All type of crops and plants	45
Eragostis	All type of crops	29
Evolvulus	All type of crops	11
Justicia	All type of crops and plants	31
Lantana	All type of crops and plants	16
Sida	All type of crops	7
Vernonia	All type of crops	13
Vitex	All type of crops and plants	6

Source: Primary Survey

Table 19. Disease attacks reported in animals in the home garden

Local Name of the Disease	English Name of the Disease	English Name of the Attracted Animals	% Home Gardens Attacked
Ausa	Ticks	Cow, goat	69
Sannipat	H.S.	Cow, goat	35
Dairia	E.P.R.	Cow, goat, duck, fowl	24
Jar	Fiver / E.P.F.	Cow, goat	15
Jhimuni	Drousiness	Fowl, duck, parakeet	14
Thunki	R.D.	Fowl	14
Mukhegha	Mouth pox	Fowl, goat	8
Pox	Pox	Cow, fowl	7

Source: Primary Survey

The households report that some species of plants like eucalyptus, mango and jack fruit are becoming extinct in the home garden. The plants which are becoming extinct with the corresponding percentage frequencies are reported in the “table 20”. The main reasons for extinction are felling for making house, crisis of water, attack of pests, deteriorating quality of the soil.

Certain animal species are becoming extinct in recent years. Animals and the corresponding percentage frequencies who feel that the animals are becoming extinct are presented in the “table 21”. The main reasons for extinction of animals as reported by the households are shortage of food, disease, problem of rearing, bad environment, shortage of water etc.

Table 20. Plant species in extinct in home gardens

English Name	Plant Species in Extinct	% Home Gardens
Eucallyptas	*Eucalyptus/Eucalyptus sp.*	15
Mango	*Mangiferaindica*	12
Jack Fruit	*Musa paradisiacal*	11
Tamarind	*Tamarindusindica*	07
Jamboline	*Syzygiumcumini*	06
Jute	-	05
Shal	*Shorearobusta*	05
Elephant Apple	*Dilleniaindica*	04
Balsam Apple	*Momordica charantia*	04
Mahua Tree	-	04
Golden Apple	*Aegle marmelos*	03

Source: Primary Survey

Table 21. Animal species in extinct from home gardens

English Name in Extinct	Animal Species in Extinct	% Home Gardens
Crow	*Corvussplendens*	31
Fowl	*Calusdomesticus*	19
Sparrow	*Passer domesticus*	18
Cow	*Bos indicus*	13
Peacock	*Pavocristatus*	12
Goat	*Capra sp.*	11
Vulture	*Gyps bengalensis*	11
Duck	*Anseranser*	09
Tortoise	-	09
Frog	*Bufomelanostictus*	07
Snake	*Najanaja*	07

Source: Primary Survey

Unusual changes that have been observed in home gardens are leaf fall, immature fruit drops, less fruiting and flowering of trees. Unusual changes have mostly observed in the plants like mango. The reasons for unusual changes are shortage of water, insects, pests and diseases. Non-domesticated animals: Some of the non-domesticated animals are cat, sparrow, wild cat, jackal, frog and mouse. Some reasons for extinction of non- domesticated animals are presented in the “table 22”.

Water tables get higher during the months of July and August. Most of the respondents are unanimous about the fact that water level is decreasing over the years. The possible reasons for decrease in water level have been identified as decrease in rainfall and overuse of ground water. Different plants species in home gardens are found suffering different changes like unusual leaf falling, drying in summer etc. The reasons for such changes are shortage of water and higher temperature in summer in recent years. We have tried to identify the main problems faced by the home garden owners under our study. The topmost problem is crisis of water (57% of households). As the water tables are getting depleted, this is affecting the health of the trees and unusual changes are being observed in flowering and fruiting. Households are also facing the crisis of finance to maintain the home garden. Elephants are encroaching the home garden and paddy field in search of food. Another problem is increasing pests, insects and diseases in home gardens. Major problems or constraints in maintaining home gardens are reported in “table 23”.

Home garden owners have also proposed suggestions as given in “table 24” to overcome the problems faced by the home garden owners. To overcome the problem of crisis of water, home garden owners have suggested the construction of big tanks, pump, wells etc. The help from the government is required in this direction.

Table 22. Reasons for extinction

Nature of Change (Extract Information from Previous Table)	Reasons for Changes	% Home Gardens
Extinct	Increasing Habitation, Shortage of Food, Felling Plants	17
Near Extinct	Crisis of Food	68
Near Extinct	Shortage of living place	44
Near Extinct	Decreasing No. of Plants/Forest	05
Near Extinct	Unsuitable Environment/Weather	20
Increasing	Availability of Food	29

Source: Estimation Based on Primary Survey

Table 23. Main problems/constraints in maintaining home gardens

Main Problems	% Home Gardens
Crisis of Water	57
Crisis of Finance	38
Spoilage of Crops plants by Elephant	20
Increasing Pests, Insects and Diseases	10

Source: Estimation Based on Primary Survey

Table 24. Proposed suggestions to overcome the problems

Proposed Suggestions	% Home Gardens
Constructing, Big Tank, Pump, Deep Tubewell etc.	39
Credit Support from Banks	20
Financial Help by the Government	14
Essential Steps by the Govt. for Development	08

Source: Based on Primary Survey

BINARY LOGISTIC REGRESSION RESULTS

The regression results given in “table 25” show that the significant factor affecting biodiversity is planting date. The result indicates that the households who have adopted adaptation strategies have more richness of species of plants in their home gardens.

CONCLUSION

The paper highlights the different characteristics of home garden, biodiversity of home gardens, climate change and the different problems of home gardens and in a dry region in West Bengal, India. Home gardens have huge potential in improving the environment and food and nutrition security of the people in rural area. However, home gardens are facing different facing different kinds of problems. There is need of extension services on the part of the government regarding crop planning, land management, providing irrigation facilities, and training for water and soil conservation etc so that home garden owners can take different adaptation strategies. Water conservation programmes and soil and crop management programmes may be linked with government for the development of home gardens. The household should utilize the resources more efficiently and devote the leisure hours more judiciously to reap the sustainable return.

Table 25. Regression results

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	plantdat	1.035	.446	5.391	1	.020	2.814
	flowdumm	.523	.417	1.573	1	.210	1.688
	perctime	-.201	.140	2.053	1	.152	.818
	Constant	-.526	.405	1.685	1	.194	.591

a. Variable(s) entered on step 1: plantdat, flowdumm, perctime.

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KEY TERMS

Home Garden: "Home Garden" is a complex multifunctional land system that combines multiple farming components of the homestead and provides environmental services, household needs

Biodiversity: It is short form of biological diversity. It indicates the totality of genes, species and ecosystems in a region or the world.

Climate change: Any natural or induced change in climate either globally or in a particular area

DBH: Diameter at breast height. (DBH), is a standard method of expressing the diameter of the trunk or bole of a standing tree.

Woody trees: A plant with thick and tough stems

Ecosystem: A dynamic complex interaction of biotic and abiotic components of environment in a given region.

Canopy: The uppermost branches of the trees in a forest, forming a more or less continuous layer of foliage.

Chapter 8
A Short Review on *Gynocardia odorata R. Br*: A Potent Medicinal Plant of Assam

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ABSTRACT

Gynocardia odorata R. Br (Achariaceae) is an important medicinal plant. It is indigenous to Indian subcontinent and grows extensively in the tropical forests of Western Ghats and Hilly regions of North Eastern India. The plant has long been used in the traditional system of medicine to treat various cutaneous and subcutaneous diseases. The chapter deals with the different scientific studies and reports available in different aspects of this plant in the areas like morpho-taxonomy, ethnobotany, phytochemistry, and pharmacognosy.

INTRODUCTION

Commonly known as Chaulmoogra, *Gynocardia odorata* Robert Brown is one of the most important tree plants under Flacourtiaceae (currently Achariaceae) (Lemke, 1988; Santos, 2007). The generic name *Gynocardia* comes from the ancient Greek words *Gyne* means female or woman and *Kardia* means heart (directly referring to ovary), indicating the heart shaped ovary (Quattrocchi, 1999; Patil, 2007). In this context, the meaning of the genus is more or less heart shaped ovary or heart shaped fruit. The tree is commonly known under different names in different parts of the world *e.g. ma dan guo* or *ta feng tzu* in Chinese (Quattrochi, 1999), *Tulkung* in Lepcha, *Gandare*, *Koliori*, *Bandray* or *Gantay* in Nepali. In India, this tree is known in a variety of names in different dialects, such as *Salmogra*, *Lemtem* or *Bonsha* in Assamese, *Gaab*, *Deshi Gaub* or *Chaulmogra* in Bengali, *Chhalmogra* in Hindi, *Surantaeil* in

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Kannada, *Dieng-sohliang* or *Dieng sohphailing* in Khasi, *Sai-thei* in Mizo, *Alasakapaha*, *Kushthapa*, *Sagarodbhuta* or *Tuvaraka* in Sanskrit *etc*.

William Roxburgh (1815) mentioned *Gynocardia odorata,* under the name *Chaulmoogra odorata* in a catalogue of plants in the East India Company's botanical garden in Calcutta where he misidentified the plant *G. odorata* with *Hydnocarpus kurzii* which was the actual source of Chaulmoogra oil (Parascandola, 2003). The species *G. odorata* was first described by Robert Brown (1820) in the third volume of William Roxburgh's *Plants of the Coast of Coromandel*. Later on, Roxburgh (1832) again described *C. odorata* under order Dioecia Polyandria in the 3rd volume of his *Flora Indica.* Even Nathaniel Wallich (1831-32) also described the genus *Gynocardia* by its synonym as *Chaulmugra odorata* from India in the *List of Indian Woods.* Colonel Drury (1864) in his 1st volume of *Handbook of The Indian Flora* recorded the genus *Hydnocarpous* with its three species but he reported *G. odorata* as a synonym of *H. odorata*. According to Kabir (1965), *G. odorata* is endemic to Sikkim and Assam. Although the species is not assessed by IUCN yet it is Vulnerable with a limited range of distribution (Ahmedullah & Nayar, 1986), whereas Choudhury et al., (2005) reported that *G. odorata* falls under Endangered category.

BACKGROUND

G. odorata R. Br. is a crooked, moderate to large sized East Indian tree which occurs in the dense tropical and temperate forest, also in secondary forest margin (Mohan et al., 2013; Khan et al., 2014 & Sharma et al., 2016). It grows wildly throughout India and other tropical countries of the world (Roxburgh, 1820). The species is found in the moist forests of mountain valleys in South Asia- India, South- East Xizang and Yunnan in China, Bangladesh, Nepal and Myanmar (Khan, 2014 b). This monotypic genus is indigenous to the moist forests of the North East India (Parascandola 2003; Rana & Ranade, 2009; Bera et al., 2014) and is fairly common in the evergreen forests throughout Assam. It is cultivated in Nigeria, Uganda, Sri Lanka and few other South East Asian countries.

A perennial, small or middle-sized glabrous tree, 30-45m high with hard and warty bark which is gray or greenish gray in colour. Branches slender and terete, not flaking, twig tips and branchlets glabrous. Leaves bifarious, simple, oblong, abruptly acuminate, margin entire, apex rounded and contracting abruptly to a short narrow acumen, rounded or acute at base, slightly uneven, petiolate, thinly coriacious, dark green to brown in colour, 15-23cm $\times$ 4.5- 6cm; leaf blade greenish abaxially and deep green to brown adaxially, nearly concolored when dry; venation reticulate; lateral veins or secondaries 16-22 pairs, conspicuous abaxially, very arcuate; tertiaries alternate percurrent type, transverse to the midrib and often continuous to margin; quarternaries openly reticulate and alternate percurrent type, Quineries are regular polygonal reticulate type, senaries (6º) are the ultimate vein type and of thin dichotomizing type (Kalita et al., 2017); Petiole glabrous, 0.5-1.3cm. Pedicels articulate, sparsely appressed hairy or glabrous, 1.5-2.5 cm. Inflorescence axillary cyme, terminal and cauliflorous. Flowers solitary, unisexual, staminate, dioecious, pale yellow, fragrant, 1-1.25cm; Male flower and Female flowers are almost same, ovate or obtuse to rounded; Sepals 5 $\pm$ 0.5cm; Petals yellowish green, 8-10 in 2 rows, oblong or slightly obovate, each with a cuneate fleshy gland at the base $\pm$1.5 cm; Stamens 20-30; Anther elongate-cordate, filament short and villous, $\pm$ 0.5- 0.8cm long, hairy; Stigmas peltate or cordate, bifid; Style short and slender, $\pm$ 0.5cm. Fruits chocolate brown to yellowish brown in colour, globose with a hard, plain but scurfy and velvety surface; 6.5-7.6cm in diameter, fruits contains a stout beak (the remains of stigma), $\pm$ 3.5cm; Seeds numerous, variable in shape and size, usually angular-ovoid or ellipsoid about $\pm$ 2.5cm long.

ETHNOBOTANY AND TRADITIONAL BELIEF

Majority of the people belonging to tribal communities believes in traditional medicine system and use *G. odorata* in treating different types of diseases from time immemorial. The Tagin, Adi, Idu Mishimi, Digaro and Wangsu tribes of Arunachal Pradesh, uses the fruit as fodder for Himalayan civet (Hui & Das, 2004 & Hui et al., 2018) and the fruit pulp as fish poison. To poison the fishes, they used to grind the fruit pulp into fine powder and scatter it on the banks of the water bodies (Hui et al., 2005). The traditional healers of Meghalaya mix the crushed seeds with fresh butter and use it as a remedy for cutaneous diseases. The seed oil is also used both internally and externally for treating leprosy, secondary syphilis, rheumatism, scrofula and phthisis (Chopra et al., 2006). The crushed bark mixed with lime is used as fish sedative by the War Khasi community of Meghalaya (Tiwari, 2008). The Nyshi community of Papumpare District of Arunachal Pradesh uses the plant to cure diarrhea, gastric problem and for blood purification (Doley et al., 2010).The rural inhabitant of Lakhimpur District of Assam uses the leaf extract for the treatment of scabies (Phukan et al., 2011). The indigenous population of Darjeeling uses the oil extracted from different plant parts, mainly from the seeds and fruits against various skin related problems (Sharma, 2013). The seeds of *G. odorata* are also used as food by the Khasi community of Meghalaya. These people used to cut the seeds into small pieces, boil it into water and sell them in the markets to enhance the delicacy of their traditional cuisine. Even the seeds are also used to make pickles (Kayang, 2007, Seal, 2011 & Lynser, 2014). The Tagin tribe, Hill Miri tribe and Galo tribe of Upper Subansiri district of Arunachal Pradesh uses the fruit against toothache. They mix the pounded fruit with water and use it for the extraction of teeth (Chaudhry & Murtem, 2016). A majority of the inhabitants of Arunachal Pradesh do not consume the fruit but use the pounded fruits mixed with water as poison for killing insects, worms and fishes. The fruit itself considered as poisonous by these people before processing (Rai & Rai 1994; Srivastava, 2010; Shu, 2014 & Hui, et al., 2017).

From a recent interview with the local people inhabiting in Tinsukia district of Assam, it has been informed that the mature fruits are commonly used in fish poisoning.

PHYTOCHEMISTRY

Throughout the 19th century, *G. odorata* was believed to be the source of chaulmoogra oil procured from the seeds. The seeds, though once thought to be the source of chaulmoogra oil, yield Gynocardia oil contain cyanogenic glycoside gynocardine but do not contain any chaulmoogric acid or its homologue (http://efloraindia.nic.in/efloraindia/taxonList.action). The components which contribute to its curative properties like antibiotic, astringent, anti-inflammatory, anti-rheumatic, antiseptic, antibacterial, expectorant, decongestant and febrifuge properties were mainly from *Gynocardia odorata* (http://ayurvedicoils.com). In the year 1901, Sir David Prain and F.B. Power established that such compounds were extracted from Taraktogenos kurzii and then *G. odorata* was treated as false chaulmoogra. The oil which was used in the treatment of various cutaneous diseases actually came from H. kurzii (Parascandola, 2003). Later it was also confirmed that *G. odorata* neither contains Chaulmogric nor Hydnocarpus acid (Power & Barrowcliff, 1905).

Presence of three ditripenoid lactones was reported by Pradhan et al. (1995) from the root extracts of *G. odorata*. They isolated the compounds with an ent-kaurane skeleton along with odolactone, trichadenic acid-A and fi-sitosterol. Preliminary studies on diverse phytochemicals present in differnt plant parts using different solvents were carried out by scientists like Gupta et al. (2013), Mohan et al. (2013), Halder et al. (2014), Srivastava et al. (2014) & Sharma et al. (2016) recorded the presence of phytoconstituents such as alkaloids, amino acids, carbohydrates, flavonoids, fats, fixed oils, glycosides, lignins, proteins, phytosterols, phenols, saponins, steroids, tannins and triterpenoids.

Hui et al., (2018) investigated the bioactive phytochemical constitruents present in the leaf methanolic extract of *G. odorata*. They reporteds a total 50 compounds of different molecular weight. They confirmed Stigmast-5-En-3-Ol, (3. Beta.) compound with highest abundance (7.72% of peak area) in the above-mentioned extract.

PHARMACOGNOSY

Chaulmoogra plant has numerous benefits in the body through its natural healing process. It has been a part of the Traditional Chinese Medicine, Asian society of Medicine and Ayurvedic system of medicine for the treatment of leprosy and other chronic skin disorders (http://ayurvedicoils.com). The seeds of *G. odorata* are possesses majority of medicinal aspects and contains a peculiar nauseous aroma (Kurz, 1877). According to Cook (1896) Chaulmoogra oil is used both internally and externally in leprosy, secondary syphilis, rheumatism, scrofula and in phthisis. By expression, or by boiling the crushed seeds in water, fixed oil is isolated which is of a pale or golden amber colour with a faint and somewhat unpleasant smell. The oil has long been applied for stiff joints and sprains, rheumatism and neuralgia. Now a day, it has come into professional use in treating eczema, psoriasis and other inflammatory skin diseases. Chaulmoogra oil is called as Oleum Chaulmoograe in the United States and in Great Britain as Gynocardia oil. This oil was used in England in the treatment of lung tuberculosis. The oil has relieved the dyspepsia and bronchitis occurring in lepers externally whereas, it has been successfully applied in other diseases like herpes, tinea, stiffness of joints, ulcers, eczemas, psoriasis and various cutaneous eruptions. The powdered seeds are supposed to be more active than the extracted oil (Felter, 1922).

According to Roxburgh (1820), when the seed extracts are mixed with fresh butter, it can be used as a remedy for cutaneous diseases or sometimes, as a counter-irritant for bruises, sprains, etc. and sometimes applied to open wounds and sores (Selvam, 2008). Felter (1922) reported that, powdered plant parts have been advantageously used as lotion in scrofula, rheumatism and other skin related troubles (Rai & Lalramnghinglov, 2010). Chetri (2004) reported that the fruit juice of *G. odorata* can be taken one time daily for 2 weeks as an antipyretic agent. The leaf extract is used in the treatment of tooth decay (Dudam et al., 2009). The Nyieshi (Dafala) tribes of Arunachal Pradesh mix the fruit of *G. odorata* with water after pounding and apply the mixture in the extraction of teeth (Sharma et al., 2016). The young shoots are grounded and the juice obtained has been drunk to combat jaundice (Shrestha & Dhillion, 2003). Osborn (1943) reported that *G. odorata* showed a complete inhibition of 20-30 mm diameter for S. aureus whereas 30-40 mm diameter against E. coli. Again, Sharma et al (2016) investigated the antibacterial activity of the leaf sample of *G. odorata* against four bacterial strains viz. S. aureus, V. cholerare, B. subtilis, and E. coli and reported that the methanolic extract of the leaves exhibit good activity against S. aureus (10.88 $\pm$ 0.26), B. substilis (12.22 $\pm$ 0.4), V. cholerae (9.00 $\pm$ 0.33) and E. coli (10.66 $\pm$ 0.33). Many different scientists reported that *G. odorata* is rich in antioxidants. Mohan et al (2013) studied in vitro antioxidant activity of the hydroalcoholic extract of *G. odorata* leaves using DPPH scavenging assay and estimated total phenol and flavonol contents. The highest radical scavenging was observed in the hydroalcoholic leaf extract with IC50 value 28.38 ± 1.02mg. The greater number of phenolic compounds, flavonoids and flavonol content leads to more potent radical scavenging effect as shown by the hydroalcoholic extract of *G. odorata*. Haldar et al. (2014) studied the hypoglycemic effect of methanol leaf extract of *G. odorata* in streptozotocin (STZ)-induced diabetic Wistar rats substantiating its ethnomedicinal use. They used Glibenclamide (1 mg/kg, orally) as reference drug. They also studied the anti-inflammatory, analgesic, and antipyretic properties of methanolic extract of the leaf of *G. odorata* and reported reduced paw oedema into the control group at 5-hour post carrageenan injection. The methanolic extract was similar to the standard Phenylbutazone in reduction of paw oedema and cotton-pellet granuloma. The extract as well as paracetamol induced antinociception in writhing test in comparison to control. They also analysed the hepatotoxic activity in Wistar albino rats using methanol extract of leaves of *G. odorata*. The plant extract (200 and 400 mg/kg) showed remarkable hepatoprotective and antioxidant activity against acetaminophen induced hepatotoxicity. Histopathological changes of liver sample showed mild hepatocyte degeneration. Asif et al (2014) studied thrombolytic and erythrocyte membrane-stabilizing activities of the leaf and seed extract of *G. odorata* from Bangladesh using Swiss albino laboratory mice. In addition, they also studied plant's cytotoxic activity by using the nauplii of brine shrimp as in vitro model. They enumerated the basic thrombolytic activity (19.94 ± 0.53% to 10.64 ± 0.46%; $p < 0.05$), and basic cytotoxic LC50 value (23.09 ± 2.01 μg mL^{-1} to 1.18 ± 0.14 μg mL^{-1}; $p < 0.05$. They also determined the erythrocyte membrane-stabilizing activity under hypotonic solution-induced hemolysis (47.41 ± 0.46% to 18.445 ± 0.095%; $p < 0.05$) and heat-induced hemolysis (27.95 ± 0.55% to 17.84 ± 0.59%; $p < 0.05$). Srivastava et al (2014) evaluated the ulcer protective activity of ethanolic extract of *G. odorata* seeds on cold restraint and ethanol induced ulcer model. They divided five groups of which the first group serve as negative control, the second group were treated with vehicles only, the third groups were treated with Ranitidine and sucralfate (Standard) and the fourth and fifth groups were treated with ethanolic seed extract in two increasing dose (250 and 500 mg/kg body weight respectively). Both the treated fourth and fifth group showed significant ulcer protective activity in a dose dependent manner. Chauhan et al., (2017) carried out pharmacognostic studies and reported 8 different phytoconstiuents in the leaf methanolic and aqueous extract which showed significant ulcer protective activities in gastric ulcer induced rat models. Baishya et al. (2018) studied the phytochemical parameters and wound healing activities of the methanolic, ethanolic and chloroform-aqueous extract of the leaf and fruit samples and reported Flavanoid and Triterpenoid derivatives which resulted in wound healing activity.

CONCLUSION

The present review deals with the taxonomy, ethnobotany, phytochemistry and pharmacological investigation of *G. odorata* in different regions of North-East India. Different parts of this plant are claimed by the local people as having a series of potential regarding therapeutic and also other allied areas. From the available literature, it can be concluded that *G. odorata* contains high amount of secondary metabolites like flavonoid, anthocyanin, lipid, alkaloid, phenolics, saponin, tannin etc. which plays an important role in the field of ethnomedicine. It also contain high amount of nutritive compounds based on what the ethnic communities use it in their tribal cuisine. This has given credence to the use of the raw unripe fruits of *G. odorata* as an item for stimulating the taste bud. From the present survey it was found that different extracts of the plant show antibacterial, ulcer protective, cyto-toxic as well as anti-oxidant properties. So in further investigation there can be a possibility of isolation of potent bio-active molecules or molecular combinations which are solely responsible for such activities.

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Chapter 9
Wetland and Biodiversity Hotspot Conservation

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ABSTRACT

Wetland conservation is aimed at protecting and preserving areas where water exists (e.g., swamps, marshes, blogs, etc.). These wetlands make up 6% of the Earth's surface. Freshwater wetlands are utilised for cultivation of paddy, for basic water needs, for fishing, as a source of food by habitat loss, one main reason being anthropogenic activities. Wetland ecosystems are a home to birds and aquatic fauna. They are the breeding and nursing grounds for these species. They are the most productive ecosystem on Earth. Apart from this, wetlands are important as they reduce the impact of floods, control pollution, and also regulate climate. On our planet, there are regions that have large number of endemic species. Most of these are heavily threatened biodiversity hotspots. Thirty-five such regions have been identified in the world. Conservation strategies need to be framed and implemented in a very effective way and with no further wastage of time before the wetlands and hotspots disappear completely.

INTRODUCTION

Earth is the only planet where water exists. The presence of atmosphere and hydrosphere on earth made it suitable for existence of life. Though water is mainly available on earth in the form of marine, estuarine and freshwater, it provides healthy environment for growth and development for aquatic life. Due to varied climatic conditions on earth, the annual precipitation rate varies from region to region on earth. That is the reason why the distribution of freshwater uneven on earth's surface. These sharp dif-

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ferences along with some biotic and abiotic factors make freshwater ecosystems more critical, complex and diverse. Water available for human beings, animals and plants play very important role in its growth and development. People need water for mainly drinking purpose, agriculture, household purpose, for other domestic uses and also for industrial development. Though freshwater available to human beings is present as running or lotic water in rivers and streams, lentic waters in the form of wetlands, lakes, reservoirs and ground water which is present in underwater streams. The increasing population on earth needs more water to fulfil their needs and uses almost all available water resources at maximum level. Though freshwater available to human beings is very much limited, then increasing demand for it, in some areas, there is always conditions of water scarcity. The increasing human pressure on freshwater resources creates problems like water pollution and degradation of water quality in many areas, responsible for spreading of waterborne diseases in human and other animal populations. Wetland a unique ecosystem present between land and water. It is the habitat where water exists permanently or seasonally, and has a combination of aquatic and terrestrial vegetation and thus provides shelter to both aquatic and terrestrial life forms.

BACKGROUND

Wetlands may include lakes, reservoirs, rivers, mangroves, swamps, flood plains, delta, paddy fields, coral reefs, salt water lakes, etc. As per Ramsar- Global Wetland Outlook- Wetland covers almost 12.1 million km2 area, which comes under coastal and inland wetlands. They provide shelter to many aquatic plants and animals. The scientific studies between 1970 to 2015 indicate severe decline in wetlands around the world. Almost 35% of inland and marine/coastal wetlands of the world are in a degraded state and on the verge of disappearance. Though the number of man-made wetlands or artificial water bodies is increasing around the world, which is used for various purposes like agriculture, aquaculture, recreation, etc. These wetlands also play an important role such as providing protection from floods as well as droughts and other disasters. Along with natural wetlands, artificial wetlands also provide food and livelihoods, have enriched biodiversity, and they are the carbon reservoirs. Wetlands provide suitable conditions for growth and development of all forms of life. It also helps in maintaining ecological balance. Though highly productive and ecologically important, they are becoming one of the most endangered ecosystems on earth (Ramchandra, 2001).

TYPES OF WETLANDS

Depending upon the dominant vegetation in the water body, the source of water and peat presence, Wetlands are divided into four groups, as below:

1. Marshes are characterized by emergent aquatic macrophytes.
2. Acidic bogs having few higher plants and an abundance of the peat- moss Sphagnum, and low species diversity.
3. Swamps are dominated by trees.
4. Alkaline ferns that contain mosses and aquatic macrophytes.

DISTRIBUTION OF WETLANDS

Except Antarctica, wetlands are existing in all continents and every country of the world. Mostly tropical countries with humid climatic conditions support wetland development then arid or temperate countries of the world. They have covered almost 4.5 billion hectares which comes to around 9% of earth's surface. They mostly exist in between 20°N and 30°S, which represents, highly populated geographical locations and areas under tropical rain forests. A report by Global Wetland Outlook by Ramsar estimated 12.1 million km2 an area covered by coastal and inland water wetlands. However, the area under wetland cover is declining due to human activities. It was observed till 2015 that almost 35% wetlands have lost from the earth.

ECOLOGICAL AND ECONOMICAL IMPORTANCE OF WETLANDS

Wetlands are vital for human survival. Wetlands should be conserved for their countless ecological and economic benefits (Russi et al., 2013). They play a very important ecological role in following aspects such as maintenance of hydrology of the area, flood control, climate stability, carbon sequestration, shore-line stabilization, maintenance of water quality, support to aquatic and terrestrial biodiversity, provide habitat for rare, threatened and endangered wildlife. Economically they are very beneficial as they have been used for both, rural and urban water supply for many years throughout the world. They provide timber, thatch, medicines, food, fodder and fuel to the dependent population. They have been used economically viable transport services in many countries. It also supports a very rich industry like fishery and aquaculture and provide source of livelihood for billions of people throughout the globe. Their role in tourism, water sports and flood plain aquaculture is incredible. Many cultural systems and heritage have developed along the wetlands and have sustained for a long period. It also supported industrial and urban development by providing need-based environment for their growth. Though wetland provides these services to mankind and environment they are under tremendous pressure due to increasing human interference in wetland ecosystems. There is need to understand the importance of these fragile ecosystems and reach to the grass root level to know the reasons behind degradation of wetlands throughout the world. There are some increasing threats to the wetlands which are destroying their biodiversity, making them polluted and useless for man and environment. There is an ecological urgency to take the steps towards conservation and restoration of degraded wetlands. A sustainable policy should be designed for smart use of these wetlands.

The preservation of wetland is considered important by both scientist and the public. Hence the wetlands are being considered separately from other aquatic and terrestrial habitats. The wetlands are covered with vegetation that is adapted to the water logged conditions. These areas are covered with shallow waters and are saturated with soil. Though not well studies, due to heterogeneity, wetlands are of considerable economic importance. They can be highly productive and also serve as a natural buffer between land and water by acting as a sponge for sediments and nutrients, holding back in inflowing matter. Wetlands are being recognized now for their aesthetic values and as distinct ecosystems for research by limnologists and ecologists.

WETLAND BIODIVERSITY

Wetlands support large number of species as these are highly productive systems like the rainforest and coral reefs. The conditions in these ecosystems are very favourable for development of organisms, as the presence of water, high nutrient level and high level of primary production, which form the base of the food webs, which include variety of species. The plant species, mostly the hydrophytes, vary in the different wetland types, with the differing hydrology (Collins et al., 2014; Davidson and Finlayson, 2018). Wetlands support animal species which carry out most or all stages of life cycle here. Wetlands may be used as feeding, resting sites or other life activities by species.

Wetlands due to its dual support as soil and aquatic environment support rich species diversity, like coral reefs and tropical rain forests. It supports almost all taxa including chordates and non-chordates, both phytoplankton and zooplankton. It also shows seasonal variation in occurrence of various species in and around wetlands.

Coastal wetlands shelter spawning and feeding grounds for fish and shellfish. They are vital nesting grounds for birds. According to the U.S. Environmental Protection Agency (EPA), wetlands are crucial to the existence of endangered animal and plant species in the United States, most of which depend on the wetlands for part of their life cycle. Depending on the extremity of the conditions, the organisms/ species develop or adapt.

STATUS OF WETLAND BIODIVERSITY

Due to decline in area under wetlands all over the world, there is loss of biodiversity associated with wetlands. Overall global data is available for very few taxa which are regularly monitored by researchers. The information on some minor taxa is scantily available and does not give any idea about its global status. For the Taxa like fishes, reptiles, amphibians, water birds and mammals, information is available and needs to be compiled. From the available information, it can be seen that there is a loss of biodiversity in all the groups (Polidoro et al., 2010). In over half the taxa assessed, more than a quarter of species are globally threatened, rising to all species assessed in the case of marine turtles. According to the IUCN Red List, highest level of global extinction threats are for marine turtles (100% globally threatened), wetland-dependent megafauna (62%), freshwater reptiles (40%), non-marine molluscs (37%), amphibians (35%), corals (33%), and crabs and crayfish (32%).

THREATS TO WETLAND BIODIVERSITY

Number of factors has been identified as threats to biodiversity of wetlands. The main cause being humans and anthropogenic activities. Some activities are highlighted below.

Agriculture

Agriculture along with its vast benefits, also acts as a source of pollution that affects water bodies and wetlands. The excess of nutrients and chemical pesticides are two main types of agricultural pollutants. To fulfil the increasing demand for food, throughout the world, farmers started using number of chemical pesticides and fertilizers. At the beginning, they were benefited by an increase in productivity of their agriculture crops. However, due to over usage of these chemicals in agriculture, the salinity of the soil increased with a decrease in fertility and crop. As a result, more chemical fertilisers are used in an effort to increase fertility and the vicious cycle goes on. These results in accumulation of chemicals in soil and also these chemicals reach the wetlands or surrounding water bodies due to seepage and agricultural runoff. These toxic chemicals when reached to an aquatic ecosystem they have enriched the nutrients in water body leading to eutrophication. Excessive use of chemical fertilisers and pesticides in agricultural practices is common due to lack of awareness. This is the reason for the increase in the amount of nitrogen and phosphorus in water bodies including the wetlands. Ultimately, it leads to the eutrophication of the water bodies. Initially, eutrophication increases productivity of phytoplankton, but eventually, adverse effects on the composition of phytoplankton communities are seen with a shift from diatoms to non-siliceous algae (Ludwig et al., 2009). These changes lead to changes in the higher levels of food chain.

Simultaneously, the livestock animals feeding on greens, already containing chemicals, receive deposits of the chemicals leading to bioaccumulation and deposition in their tissues. Pelagic and biofilm phytoplankton communities as well are significantly affected by herbicides. Hormonal changes and related variations in the community structures are reported (Sura et al., 2012).

Industrialisation

The major cause of pollution is industrial revolution. Though the number of regulatory authorities are set up to monitor the effects on the environment, they continue to harm the health of the surroundings. Air pollution, discharge of untreated effluents in water bodies, discharge of high temperature water in the water bodies, dumping of waste in open dumpsites and landfills, large areas covered with sheds, are all the issues related to industrialisation. In this, the wetlands and illegally used as dumping sites.

Hydrologic Alterations

Changes in hydrology can change soil chemistry and wetland flora and fauna communities in (EPA, 2001). Due to the number of reasons, hydrological changes occur in the wetlands. Some of the main alterations are due to sewage, Drainage, Water extraction, Water diversion structures, Sedimentation, Invasive species, Human activities on wetlands.

CONSERVATION OF WETLANDS AND ITS BIODIVERSITY

Wetland conservation is aimed at protecting and preserving areas where water exists, such as swamps, marshes, bogs, etc. In India, work on conservation of wetlands started in 1987 and focussed on biological methods for conservation. Along with this, wetland mapping was also initiated. The conservation project is aimed at achieving the objectives of the Ramsar convention. NGOs as well as local communities are involved in this project along with the Government bodies. The mapping project is handled at Collectorate level with the help of local experts in the various fields. The National Committee on wetlands, mangroves and coral reefs have identified 93 wetlands as conservation hotspots for priority action and 19 wetlands need international assistance.

THE RAMSAR CONVENTION ON WETLANDS

It is an International treaty for conservation and sustainable use of wetlands of international importance especially as waterfowl habitat. Named after the city Ramsar of Iran, where the treaty was signed. The convention in 1990, adopted a number of criteria for identifying wetlands of international importance. These criteria have helped in defining international status of wetlands and also have provided a means of prioritising national sites. The list of wetlands includes 2331 Ramsar sites. These are not "prohibited areas" and a wise use policy is stressed for all sites. For the effective utilisation and management of these sites, guidelines have been laid down which includes an involvement of community. The 2nd of February is celebrated as World Wetlands day, the date the Ramsar Convention was adopted.

BIODIVERSITY HOTSPOTS

Life exists on earth from past billions of years, our earth is not only a home for our own species, i.e. Homo sapiens, but it has the capacity to provide shelter and living conditions for millions of species. These species are dependent on each other and their surrounding for various purposes. Earth has also experienced several mass extinctions of species and every time it has evolved with the new combinations and better adoptability amongst the species. It is difficult for scientists to understand the kind of biocomplexity that exists on earth. Though earlier mass extinctions were mostly due to natural calamities and took millions of years to occur. Unfortunately, our earth is moving towards another mass extinction, for which natural conditions and human interference are equally responsible. Human interference with natural habitats on earth has developed tremendous negative pressure on all living organisms of the earth, including human being. Biodiversity is kind of variability existing in living organisms on earth. The diversity also exist in genetic, species and ecosystem level. Biodiversity depends on agro-climatic conditions present in any habitat. On earth biodiversity is unevenly distributed, some regions are very rich in biodiversity, while some regions show merely less number of species, as these habitats provide favourable conditions for very particular species. Some regions on earth which have rich biodiversity but face continuous threat mostly due to human interference are known as biodiversity hotspots.

In the beginning 25 regions were identified as hotspots, but due to increasing knowledge about biodiversity of other geographical regions, slowly number of biodiversity hotspots is increasing. Earlier these hotspots had covered 16% of the earth's terrestrial surface, but in the present situation almost 86%

habitats of these hotspots are under pressure due to human interference or climate change and are getting severely degraded. This has increased concern about these regions throughout the conservationist. The conditions are so vest that at present status only 2% earth surface comes under these hotspots. Still these hotspots are so rich in endemism that they have 50% of the world's vascular plants and 42% of land vertebrates. Presently 36 regions in the world are recognized or demarcated as Biodiversity Hotspots. Though the hotspots make up2.3% of the global land surface, they support more than half of the world's plant species as endemics and nearly 43% of the bird, mammal, reptile and amphibian species as endemics.

In order to be included in this list of biodiversity hotspots, an area must fulfil two criteria:

- It should contain at least 1,500 species of endemic vascular plant species.
- It should have lost at least 70 percent of its primary native vegetation.

The hotspots are sites of high human population also, and hence the greater impacts on biodiversity. These impacts are not due to the density of population as much as due to human activity. According to Pereira et al. (2013), the world environmental health depends on the maintenance of biodiversity. There is a continuous loss of biodiversity which is consistent and does not seem to slowing down according to some researchers working in field of the biodiversity (Butchart et al., 2010). Conservation strategies are a crucial step towards lessening biodiversity loss, in this era of human activities, global environmental changes, habitat loss and species extinction (Marchese, 2015).

Though climate is not a static process and it is changing very slowly from beginning of the creation of earth. The combined effects of anthropogenic activities like over exploitation of habitats, pollution, invasive species and overall climate change is responsible for loss of biodiversity on earth (Barnosky et al., 2012). Overall, the biodiversity is unevenly distributed on the earth surface. Some areas are rich in biodiversity while others have poor biological diversity. Amongst biodiversity rich areas some regions are providing shelter and micro climatic conditions for some specific species, which is very unique and especially favourable for growth and development of these species. These areas are very sensitive and need to be protected from anthropogenic pressures. Because loss of these habitats may lead to extinction of species dependent on them (Myers, 1988).

The biodiversity hotspots situated in densely populated tropical countries are experiencing dynamics due to urbanization, agricultural expansion and rapid economic development. In India, mainly four global biodiversity hotspots have been demarcated based on endemic biodiversity which is under threat due to human interference- they are the Eastern Himalaya, the west coast of India-Western Ghats, Sundalands and Indo-Burma. These hotspots are under tremendous pressure due to anthropogenic activities and changing climatic conditions. Global warming, climate change, loss of habitats are the main reasons behind extinction of species in these regions. Increasing droughts in some regions while floods in other regions, are taking a toll on the plants of these diverse eco-regions. Unfortunately, lack of scientific studies on status of biodiversity creates a problem in the conservation plan of these hotspots.

Local people and most of the stakeholders are unaware of the ecological importance of biodiversity hotspots and thus are least bothered about losing natural heritage. The Western Ghats of India which are highly populated areas amongst all biodiversity hotspots, has human population density (>300 persons/ sq. km). Cincotta et al.(2006) reported a threat of growing human population in tropical regions, in general and Western Ghats of India, in particular. Due to this reason, there is an increase in the chances of human and wildlife conflict leading to entry of wild animals in human settlements and accidental deaths of animals or human beings.

The Population Census of India in 2011 reported that, in cities like Mumbai overpopulation poses direct a threat to diverse eco-regions situated in the surrounding areas due to excessive anthropogenic disturbance. Climate changes and global warming impacts can result in the shift of vegetation pole-ward thus leading to a change in the native flora of the region, for example, the Himalayas. In the Indo-Burma hotspot region, major problems exist in the form of deforestation and a higher level of forest fragmentation. The reason behind forest fragmentation is shifting cultivation practices. It was also observed in this region that natural calamities like tsunami, coastal cyclones have destroyed a lot of vegetation cover in the Andaman– Nicobar Islands, mainly mangroves and tropical rain forests. These events also affected another sensitive ecosystem of this region, i.e. coral reefs. Being part of Indo-Burma and Sundaland hotspots, there is an urgent need to take positive steps towards conservation of these hotspots. Modification in the protected area network needs to be done in order to handle the climate changes and its effects on biodiversity. Knowing the vegetation type and cover can help in the conservation and protection of the region and its biodiversity.

By now the concept of Biodiversity hotspot is well accepted all over the world, still recently due to some political pressure in these regions, some important areas with rich biodiversity and endemism have been deliberately ignored and excluded from hotspot regions. On the pretext that the biodiversity of these regions is low, they have been excluded. The importance of these areas if not obvious on a macro scale cannot be ignored at the micro level. Agriculture and industrialisation are two main factors responsible for reduction in biodiversity. Currently, scientists are involved in understanding the impact of changing climatic conditions on biodiversity hotspots. The changing pattern of rainfall, change in temperature regime has created problems in the breeding, propagation and growth pattern of plants. It has also affected pollination services provided by pollinating insects. In regards to this, it is also important to understand to what extent, conservation can maintain high biodiversity in the face of climate change. There is need to construct detailed models and by using statistical tools assess the effects of climate change on species distribution. The data received will help in planning need of conservation in these regions without disturbing any natural ecosystem.

The next step is the conservation and reconstruction of highly degraded habitats and ecosystems. Degraded lands developed in a sustainable and environmentally friendly way are called as conservation wastelands. These can be used for development of renewal energy source production such as wind farms, oil palm plantation, solar panel setups, etc. Deforestation is a major reason for biodiversity loss. Reforestation is looked upon as a solution to make up the losses incurred from the environmental view. However, this solution cannot replace the harm done to biodiversity of that area. Reforestation results in the increase in green cover but the indigenous flora and fauna are not replaced or cannot be replaced. Thus, it is a permanent loss.

CONCLUSION

Management of wetlands has to be an integrated approach in terms of planning, execution and monitoring. Trained academicians and professionals, including ecologists, hydrologists, economists, watershed management specialists, planners and decision makers must be linked with local expertise, for overall management of wetlands. This will help in the understanding of the ecology of wetlands, their status and drafting of the management and improvement strategies. Wetland biodiversity awareness programs for locals and youngsters need to be conducted. This will motivate them to get involved in the management and execution of the plans, and can be involved in protection as well as avoiding further degradation of the wetlands. The Government of India has taken up an initiative to study the wetlands of India and collect the data on the biodiversity survey, which will help to take steps in the protection and justify the jurisdictions. In Maharashtra, the work is being carried out at taluka level under the leadership of the collectorate and with the help field experts, locals, academicians, scientists.

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Chapter 10
An Insight Into the Butterflies (*Lepidoptera, Papilionoidea*) Associated With Protected Area Network of Uttarakhand, Western Himalaya

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ABSTRACT

Uttarakhand has a rich tradition to conserve its immense array of biological and cultural diversity. An annotated checklist on butterfly diversity and distribution across protected areas of state Uttarakhand is provided here which is a culmination of published literature over a period of the last 38 years (1981-2018). The list comprises 393 butterfly species under 188 genera and six families. The local status was also assigned to the compiled species of butterflies after critical review of referred literature, wherein 22.70% of the total species were found 'rare' while 41 species of butterflies are entirely lacking published record from the last many decades. A total of 51 species compiled in the present checklist, which was reported based on its presence or absence unique and rare to a particular protected area, are the species of concern as they might face extinction through slight alterations in their habitats.

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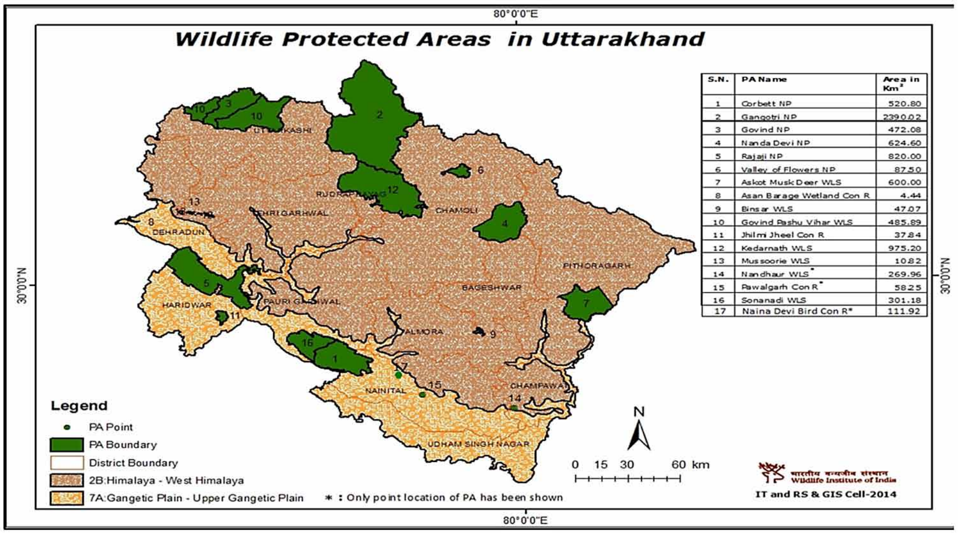
INTRODUCTION

Butterflies that belong to the super family Papilionoidea of the order Lepidoptera form vital component of terrestrial ecosystems because of their intimate associations with thehabitat. Species of butterflies exhibit extreme sensitivity towards fractional variation in climatic factors and also to disturbances in its habitats, thus rendered as indicative of general environmental attributes such as conservation value (Brown et al., 2000), disturbances (Kocher & Williams, 2000), environmental health and quality (Kunte, 2000), climate change (Hill et al., 2002) and as surrogate taxa for assessing conservation threats to other biodiversity groups (Hayes et al., 2009). Butterflies play critical roles at the nexus between environmental science and environmental action (Fleishman & Murphy, 2009) and are often used as flagship species in conservation campaigns (New, 2011).

The state of Uttarakhand nestled in the central sector of Indian Himalayan Region is bestowed with marvellous assemblage of biodiversity and is home to many endemic species of flora and fauna. From the butterfly diversity and distribution point of view, the state forms a potential zoo-geographical zone which supports more than 500 species of butterflies (Sondhi and Kunte, 2018) constituting 33.32% of the total species of butterflies known from Indian subcontinent (Kehimkar, 2014). Most pioneering assessments which dealt with the butterfly taxonomy from the state Uttarakhand, include Doherty (1886), Mackinnon and de Niceville (1899), Hannyngton (1910-11), Ollenbach (1930; 1931), Lesse (1952), Stempffer (1952), Wynter Blyth (1957), Shull (1958; 1962) etc. With the establishment of the Zoological Society of India at Kolkata, regular surveys have been carried outthrough sections on butterflies of Northern Regional Station, Dehradun at different biogeographic regions including few protected areas of Uttarakhand (Arora, 1994; 1995; 1997; Kumar et al., 2004; Kumar, 2008; Majumdar, 2010; Maulik, 2010; Sharma and Sidhu, 2010; Sidhu and Sharma, 2010).Some workers have also contributed much to our knowledge on butterflies from last few decades (Singh, 1999; 2003; 2005; 2006; 2007; 2009; 2016; Singh & Bhandari, 2003; Singh & Sondhi, 2016; Smetacek, 1992; 1993; 1995; 2002; 2004; 2010; 2011; 2012). Still, gaps exist related to many species which have not been studied adequately from the standpoints of their taxonomy and ecology and on the other hand, there are various species of butterflies with known distributions but needs recent evidence verification from the state Uttarakhand (Sondhi and Kunte, 2018). As species records often vary on spatio-temporal scale, creating checklists and updating them become crucial to understand species distribution dynamics and possible threats to them (Sawchik et al., 2005; Majumder et al., 2012; Tiple & Koparde, 2015). Moreover, despite the use of protected areas for nature conservation and maintaining ecosystem services (Vina & Liu, 2017), evidences are there for floral and faunal extinction even in protected areas either due to non-targeted conservation interventionsor increased anthropogenic pressures (Brashares, 2003; Dudley & MacKinnon, 2017). In this scenario, an attempt has been madethrough considering published literature and authentic accessible data to provide a comprehensive preliminary checklist on distribution and status of butterfly fauna highlighting unique and threatened species across different protected areas of the state Uttarakhand. It is intended that the present checklist will serve as a reliable biodiversity data forbiological recordings and conservation reviews on butterfly fauna as well as can be used for monitoring faunistic changes that are likely to occur as we move futher deeper towards Anthropocene in the 21st century.

Figure 1. Map showing in situ conservation sites of Uttarakhand
(Source: WII, 2014)



PROTECTED AREA NETWORK OF UTTARAKHAND

The hill state of Uttarakhand located in Western Himalayan region covers an area of 53,483 sq km stretched between 28° 43' and 31° 28' North Latitude and 77° 34' and 81° 03' East Longitude. The Greater Himalayas exceeding 7,000 m in elevation, the Shiwaliks (Sub-himalayan range), outermost foothills of the Himalaya (the *bhabhars*) and the *terai* region in the plains are the major physiographic zones of the state, contributing to its ecological diversity. Based on the administrative attributes, there are 13 districts covered in Garhwal and Kumaon hills. With approximately, 64.79% of its total geographical area under forests, an area of 9,885 sqkm has been clearly enmarked for *in situ* conservation of biodiversityand fragile ecosystems by the creation and management of protected area network (Rodgers and Panwar, 1988). At present there are six national parks, seven wildlife sanctuaries and four conservation reserves inthe state Uttarakhand (Figure 1 and Table 1). This protected area network covers tropical, temperate and alpine type of ecosystems. With the onset ofProject Tiger on April 1, 1973 Corbett National Park has been revived with the status of Corbett Tiger Reserve which also includes Sonanadi Wildlife Sanctuary and additional reserve forests. Furthermore, among the national parks of the state, The Nanda Devi National Park is a 'World Heritage Site' famous for its pristine and exceptionally mesmerizing landscape and it also forms the core zone of Nanda Devi Biosphere Reserve established in 1988 under the MAB programme of UNESCO (UAFPD, 2004).

Table 1. List of protected areas of Uttarakhand with information on published literature for butterfly diversity betweenthe years 1981 to 2018

S. No.	Protected Area	Year of Establishment	Area (in sq. km)	Elevation Ranges (in Meters Above Mean Sea Level)	District Coverage	Research Studies
	Wildlife Sanctuaries (WLS)					
1.	Askot WLS	1986	600.0	600-6900	Pithoragarh	Pandey et al., 2013
2.	Binsar WLS	1988	47.07	1200-2500	Almora	Arya et al., 2016; 2018
3.	Govind PashuVihar WLS	1955	485.89	1200-2700	Uttarkashi	Kumar et al., 2004; Bhardwaj et al., 2012; Uniyalet al., 2013; Singh and Sondhi, 2016
4.	Kedarnath WLS	1972	975.20	1200-4000	Chamoli&Rudraprayag	Singh, 2006; 2007; 2009; Singh and Sondhi, 2016
5.	Mussoorie (Benog) WLS	1993	10.82	1800-2300	Dehradun	Singh and Sondhi, 2016
6.	Sonanadi WLS	1987	301.18	300-850	Pauri Garhwal	Singh and Sondhi, 2016
7.	Nandhaur WLS	2012	269.96	250-350	Nainital &Champawat	Arya and Dayakrishna, 2017; Sanwalet al., 2017; Sondhi, 2017
	National Parks (NP)					
8.	Corbett NP	1936	520.82	400-1200	Nainital &Pauri Garhwal	Larsen, 1986; Kumar, 2008a; Dayakrishna, 2017
9.	Gangotri NP	1989	2390.02	1800-4500	Uttarkashi	Bhardwaj and Uniyal, 2013; Uniyalet al., 2013; Singh and Sondhi, 2016
10.	Govind NP	1990	472.08	1200-4000	Uttarkashi	Kumar et al., 2004; Bhardwaj et al., 2012; Uniyalet al., 2013
11.	Nanda Devi NP	1982	624.60	3400-3500	Chamoli	Baindur, 1993; Uniyal, 2004
12.	Rajaji NP	1983	820.0	300-1000	Dehradun, Pauri Garhwal & Haridwar	Arora, 1994; Joshi, 2007; Singh and Sondhi, 2016
13.	Valley of Flowers NP	1982	87.50	2000-3300	Chamoli	Chaturvedi, 1981; Singh and Sondhi, 2016
	Conservation Reserves (CR)					
14.	Asan Wetland CR	2005	4.44	350-500	Dehradun	Singh and Sondhi, 2016
15.	JhilmilJheel CR	2005	37.84	200-250	Haridwar	Tewari and Rawat, 2013; Singh and Sondhi, 2016
16.	Pawalgarh CR	2012	58.25	350-600	Nainital	Sondhi, 2017
17.	Naina Devi Himalayan Bird CR	2015	111.90	2200-2530	Nainital	Gariaet al., 2016
	Biosphere Reserve					
18.	Nanda Devi Biosphere Reserve	1988	5860.69	1000-3800	Chamoli, Bageshwar& Pithoragarh	Baindur, 1993; Arora, 1995; 1997; Joshi et al., 1999; Joshi et al., 2004; Uniyal, 2004; Joshi and Arya, 2007; Joshi et al., 2008, Arya, 2015; Kumar, 2015; 2017; Singh and Sondhi, 2016

DATA COMPILATION AND EVALUATION

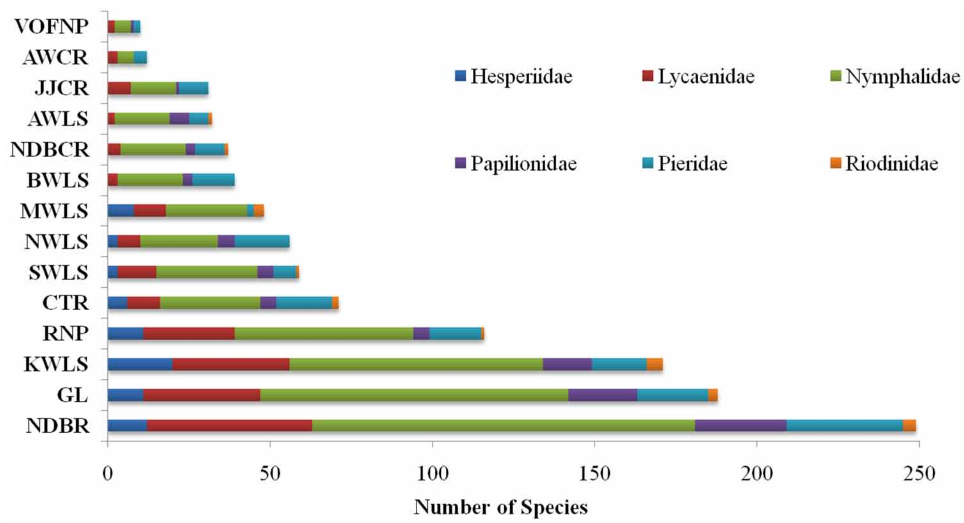
The informationon distribution records of butterflies from different protected areas was obtainedthrough author's personal observations and after gleaning through published literature, relying primarily onBaindur (1993), Arora (1994, 1995, 1997), Joshi et al. (1999), Joshi et al. (2004), Kumar et al. (2004), Uniyal (2004), Joshi (2007), Joshi and Arya (2007), Singh (2006, 2007, 2009), Joshi et al. (2008), Kumar (2008a) Bhardwaj et al. (2012), Bhardwaj and Uniyal (2013), Pandey et al. (2013), Uniyal et al. (2013),Tewari and Rawat (2013), Arya (2015), Arya et al. (2016), Garia et al. (2016), Kumar (2015, 2017), Singh and Sondhi (2016), Arya et al. (2017), Arya and Dayakrishna (2017), Dayakrishna (2017), Sanwal et al. (2017), Sondhi (2017), Arya et al. (2018) and on few earlier records (Chaturvedi, 1981; Larsen, 1986) for which information has been summarised in Table 1. In the present checklist, butterfly fauna of protected areas *viz*. Gangotri National Park, Govind National Park and Govind PashuVihar Wildlife Sanctuary has been coveredunder one category as Gangotri Landscape due to availability of overlapping data and contiguity of the regionwhich owsits unique feature as a landscape (Uniyal et al., 2013). The species of butterflies are catalogued alphabetically into families, sub-families and genera which are further numbered consecutively. An updated taxonomic classification upto family and sub-family level was adopted by using Heikkila et al. (2012). All the species in the checklist are listed with their current scientific names and authorswhile correcting any erroneous records available in the literature (Kumar, 2008; Kehimkar, 2014; Singh, 2017; Sondhi and Kunte, 2018). Local status was assigned to the butterfly species based on critical revision of literature referred to and no quantitative primary data was used. Status of species that have been missing on account of lack of evidence but have known distribution in the earliest records for nearly a century since Doherty (1886), Mackinnon and de Niceville (1899), Hannyngton (1910-11), Ollenbach (1930, 1931),Lesse (1952), Shull (1958, 1962), Stempffer (1952), WynterBlyth (1957), Arora and Mandal (1977) and hence holds no recent published records, has been assigned under needs verification category in the present checklist. The specificity of the fauna in different protected areas and the analysis of each family have also been outlined. Abbreviations for the *in situ* conservation sites of Uttarakhand covered under this list are the following:

- **NDBR**: Nanda Devi Biosphere Reserve.
- **GL**: Gangotri Landscape.
- **CTR**: Corbett Tiger Reserve.
- **RNP**: Rajaji National Park.
- **VOFNP**: Valley of Flowers National Park.
- **KWLS**: Kedarnath Wildlife Sanctuary.
- **MWLS**: Mussoorie Wildlife Sanctuary.
- **SWLS:**Sonanadi Wildlife Sanctuary.
- **BWLS**: Binsar Wildlife Sanctuary.
- **NWLS**: Nandhaur Wildlife Sanctuary.
- **AWLS**: Askot Wildlife Sanctuary.
- **NDBCR**: Naina Devi Bird Conservation Reserve.
- **JJCR**: JhilmilJheel Conservation Reserve.
- **AWCR:** Asan Wetland Conservation Reserve.

Table 2. Taxonomic overview of butterfly families showing total number of sub-families, genera and species

Family	Subfamily	Genera	Species
Hesperiidae	3 (11.53%)	29 (15.34%)	45 (11.45%)
Lycaenidae	7 (26.93%)	51 (26.98%)	100 (25.44%)
Nymphalidae	11 (42.30%)	77 (40.74%)	158 (40.20%)
Papilionidae	2 (7.70%)	9 (4.76%)	33 (8.39%)
Pieridae	2 (7.70%)	20 (10.58%)	49 (12.46%)
Riodinidae	1 (3.84%)	3 (1.58%)	8 (2.03%)
Total	26	189	393

Figure 2. Protected area wise distribution of relative composition of butterfly families showing variation in number of species

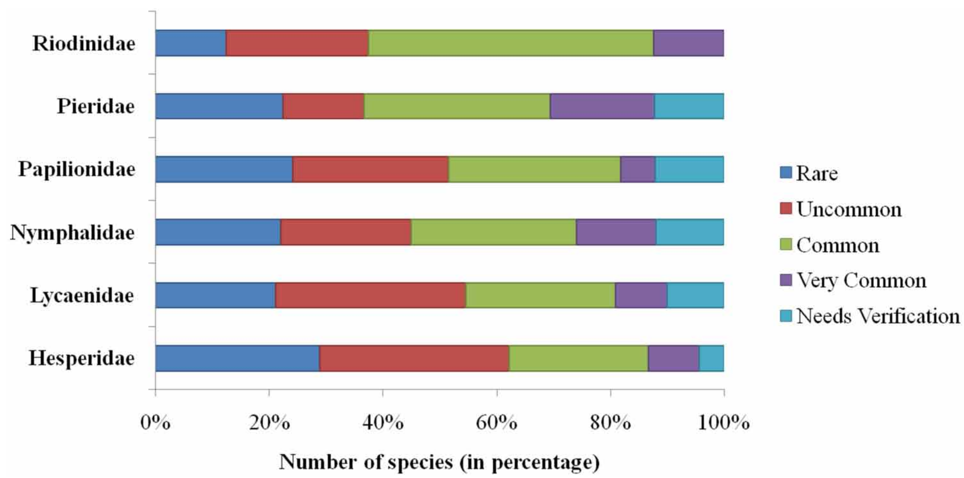


BUTTERFLY INVENTORY AND EXISTING GAPS

The compilation of data resulted ina total of 393 butterfly speciesbelonging to 188 generaandsix families fromdifferent protected areas of Uttarakhandwhich has been published in past 38 years **(Appendix I)**. Among the families, Nymphalidae was the most taxonomically diverse family with 158 species under 77 genera and 11 sub-families, followed by Lycaenidae (100 species under 51genera and seven sub-families) and others. The family with least taxonomic diversity was Riodinidae with eight species under three genera belonging to single sub-family Riodininae (Table 2).

A general pattern of differences emerges from the literature review on recorded fauna of butterflies across protected areas of Uttarakhand. From Figure 2 it was concluded that as several surveys and studies had been conducted in NDBR, it stood themost hyper diverse protected area in relation to butterfly fauna comprising 249 species under six families.This was followed by GL (188 species), KWLS (171

Figure 3. Local status of species under different families of butterflies compiled from protected areas of the Uttarakhand



species) and RNP (116 species), respectively. The tallies for other protected areas are as follows:CTR (71 species), SWLS (59 species), NWLS (56 species), MWLS (48 species), BWLS (39 species), NDBCR (37 species), AWLS (32 species),JJCR (31 species), AWCR (12 species) and VOFNP (10 species).The notable addition to the present checklist is *Antheneemolusemolus* (Godart) of family Lycaenidae reported for the first time in the Kumaun hills which is also the only published informationfrom Pawalgarh Conservation Reserve (Sondhi, 2017).

Many species show specialized ecological requirements, which make them truly specific and sensitive to changes in habitat and its management. Thus, such species with specificity to particular habitat are of prime importance asthese taxa can be used as a proxy for monitoring habitat quality changes which is quick, easy and inexpensive way(Lien, 2007).In the present checklist, based on presence or absence of each compiled species, 37.15% of the total species have been reported from a particular protected areaand hence can be considered as unique species. Most of thesespecies were confined to NDBR (59 species), followed by KWLS (22 species), GL (21 species), RNP (14 species), MWLS (nine species),JJCR (seven species), NWLS, AWCR (four species each),CTR, SWLS (two species each) andAWLS, NDBCR (one species each), respectively. However, merely based on presence or absence of species in the present checklist, none of them should be considered truly specific as discrepancies in the existing data and inconsistency in the exploration might also be attributed for such results, therefore appropriate qualitative and quantitative data is required to make further comparisonson butterfly fauna pertaining to these regions.

As per the IUCN Red List of the total species of butterflies, none of the species in the present checklist are threatened globally. However, based on evaluation of local status of butterflies in Uttarakhand, 89 species were found as ‘rare’ most of which belonging to family Nymphalidae (35 species), Lycaenidae (21 species) and Hesperiidae (13 species) (Figure 3). The total numbers of 103 species were found uncommon, while 113 and 47 species of butterflies were addressed as common and very common, respectively. The majority number of species under families Nymphalidae, Pieridae, Papilionidae and Riodinidae were commonin terms of their local status excerpted from the literature. A total number of 41 species of butterflies, majorily belonging from NDBR and GL needs verification which means that these species are either doubtful records or lacks authentic evidences from many years. Such species need urgent assessment as they probably might be facing danger of local extinction in these regionsdeveloped for ensuring protection of biological repository.

13.01% of the total butterfly species in the present checklist reported as unique and rareto a protected area have been suggested as 'species of conservation priority' which includes 23 species from NDBR such as *Celaenorrhinuspatula*, *Spalgisepius*, *Nacadubaaluta*, *Cheritrafreja*, *Tajuriamelastigma*, *Paranticamelaneus*, *Libytheaceltis*, *Neptisradha*, *Tanaeciajulii*, *Lasiommatamaerula*, *Papilioarcturusarius*, *Coliasladakensis*, *Appiaslibythea*, *Baltiabutleri*, and few others. Similarly, 10 species namely *Bibasisjaina*, *Polytremisdiscreta*, *Soviagrahami*, *Udara albocaeruleus*, *Apaturaambica*, *Dichorrhagianesimachus*, *Polyuradolon*, *Mycalesisnicotia*, *Mycalesissuaveolens*, and *Meandrusalachinus* from KWLS and *Hasorachromus*, *Tagiadesjapetus*, *Argynnisjainadeva*, *Neptisnarayana*, *Meandrusagyas*, *Papilioalcmenor*, *Papiliohelenus*, *Coliasmyrnmidone* from GWLS are species of conservation priority. The other species of butterflies include *Baorisfarri*, *Polyura agrarian* from SWLS, *Thoressaaina*, *Dodona ouida* from MWLS, *Udaspesfolus*, *Paridesphiloxinus* from RNP, *Neptiszaida* from BWLS, *Amblypodiaselhetensis* from CTR, *Vindulaerota* from JJCR and *Gandacaharrinaassamica* from NWLS. Furthermore, of the total species compiled in the list, 93species of butterflies are legally protected under Indian Wildlife (Protection) Act, 1972. However, inspite of being protected legally, the effectiveness of Wildlife (Protection) Act, 1972 in the conservation of butterflies is still doubted and unclear (Kunte, 2008).

CONCLUSION

Quantification of butterfly diversity and species richness is of prime importance for evaluating the status of protected areas (Majumder et al., 2012). Perusal of literature on butterfly fauna from protected areas of Uttarakhand suggests that there exist gap areasin studiesnot only at the macro level but also at the micro level with some species devoiding evidences from last many decades. It is important to highlight here that presently, *in situ* conservation sites, namely Pawalgarh Conservation Reserve,Valley of Flowers National Park,Asan Wetland Conservation Reserve, JhilmilJheel Conservation Reserve, Askot Wildlife Sanctuary, Corbett Tiger Reserve and few others are among the least explored protected areas of Uttarakhand, thus there is an urgent need to bridge the existing gaps on butterfly fauna in these regions. Research and re-documentation of butterflies targeted at determining ecology of butterflies in these protected areas have to be initiated in order to conserve any dwindling population of butterflies. It is also recommended that the present checklist is highly likely to get updated in near future based on new publication records for butterfly fauna.

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APPENDIX

Table 3. Systematic checklist on distribution of butterfly species across different protected areas of state Uttarakhand as per the survey of published literature between the years 1981-2018.

Sl. No.	Species name	Distribution at Different Protected Areas														Local Status
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
I	**Family: Hesperiidae**															
A	**Sub-family: Coeliadinae**															
1.	*Badamia exclamationis* Fabricius	-	-	-	-	-	-	+	-	-	-	-	-	-	-	UC
2.	*Bibasis jaina* (Moore)	-	-	-	-	-	+	-	-	-	-	-	-	-	-	R
3.	*Burara oedipodea belesis* Mabille	-	-	-	+	-	-	-	-	-	-	-	-	-	-	UC
4.	*Choaspes benjaminii* (Guerin & Meneville)	+	+	-	-	-	+	+	-	-	-	-	-	-	-	UC
5.	*Choaspes xanthopogon* (Kollar)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
6.	*Hasora chromus* (Cramer)	-	+	-	-	-	-	-	-	-	-	-	-	-	-	R
B	**Sub-family: Hesperiinae**															
7.	*Aeromachus dubius* Elwes & Edwards	-	-	-	-	-	+	-	-	-	-	-	-	-	-	UC
8.	*Aeromachus stigmata* Moore	-	-	-	-	-	-	+	-	-	-	-	-	-	-	VC
9.	*Baoris farri* Moore*	-	-	-	-	-	-	-	+	-	-	-	-	-	-	R
10.	*Borbo bevani* (Moore)	-	-	+	-	-	-	-	+	-	-	-	-	-	-	C
11.	*Gegenes nostrodamus* (Fabricius)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
12.	*Matapia aria* Moore	-	-	-	+	-	-	-	-	-	-	-	-	-	-	C
13.	*Notocrypta feisthamelii* (Moore)	+	-	-	-	-	+	-	-	-	-	-	-	-	-	C
14.	*Notocrypta curvifascia* Felder & Felder	-	-	-	+	-	-	-	-	-	-	-	-	-	-	C
15.	*Oriens gola* (Moore)	+	-	-	+	-	-	-	-	-	-	-	-	-	-	C
16.	*Parnara guttata* (Bremer & Grey)	+	-	+	+	-	+	-	-	-	+	-	-	-	-	UC
17.	*Pedesta masuriensis* (Moore)	-	-	-	-	-	+	+	-	-	-	-	-	-	-	R
18.	*Pelopidas assamensis* de Niceville*	-	-	-	+	-	+	-	-	-	-	-	-	-	-	VC
19.	*Pelopidas mathias* (Fabricius)	-	+	-	+	-	+	-	-	-	-	-	-	-	-	UC
20.	*Pelopidas sinensis* Mabille*	-	-	-	-	-	-	+	-	-	-	-	-	-	-	C
21.	*Polytremis discreta* (Elwes & Edwards)*	-	-	-	-	-	+	-	-	-	-	-	-	-	-	R
22.	*Polytremis eltola* (Hewitson)	+	+	-	-	-	+	-	-	-	-	-	-	-	-	C
23.	*Potanthus dara* (Kollar)	+	+	-	-	-	+	-	-	-	-	-	-	-	-	R
24.	*Potanthus pseudomaesa clio* (Evans)	-	-	-	-	-	+	-	-	-	-	-	-	-	-	C
25.	*Sovia grahami* (Evans)	-	-	-	-	-	+	-	-	-	-	-	-	-	-	R
26.	*Taractrocera maevius* Fabricius	-	-	-	-	-	+	-	-	-	-	-	-	-	-	C
27.	*Telicota aneilla bambusae* (Herrich-Schaffer)	-	-	+	-	-	-	-	-	-	+	-	-	-	-	UC
28.	*Telicota colon* Fabricius	-	-	-	-	-	-	-	-	-	-	-	-	-	+	VC
29.	*Thoressa aina* de Niceville	-	-	-	-	-	-	+	-	-	-	-	-	-	-	R
30.	*Udaspes folus* (Cramer)	-	-	-	+	-	-	-	-	-	-	-	-	-	-	R

continued on following page

Table 3. Continued

Sl. No.	Species name	Distribution at Different Protected Areas														Local Status
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
C	**Sub-family: Pyrginae**															
31.	*Caprona ransonnetti* Felder & Felder	+	-	-	+	-	-	-	-	-	-	-	-	-	-	UC
32.	*Celaenorrhinus dhananda* Moore	-	+	-	-	-	+	-	-	-	-	-	-	-	-	R
33.	*Celaenorrhinus leucocera* (Kollar)	-	+	-	-	-	+	-	-	-	-	-	-	-	-	UC
34.	*Celaenorrhinus munda* Moore	-	-	-	-	-	-	+	-	-	-	-	-	-	-	UC
35.	*Celaenorrhinus patula* de Niceville	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
36.	*Celaenorrhinus pero* de Niceville	-	-	-	-	-	+	-	-	-	-	-	-	-	-	VC
37.	*Lobocla liliana* Plotz	-	-	-	-	-	+	+	-	-	-	-	-	-	-	UC
38.	*Pseudocoladenia dana* (Fabricius)	-	+	-	-	+	+	-	-	-	-	-	-	-	-	C
39.	*Sarangessa dasahara* Moore	-	-	+	+	-	-	-	+	-	-	-	-	-	-	C
40.	*Sarangessa purendra* Moore	+	+	+	-	-	-	-	-	-	-	-	-	-	-	UC
41.	*Spialia galba* (Fabricius)	-	-	+	+	-	-	-	-	-	+	-	-	-	-	UC
42.	*Tagiades atticus* (Fabricius)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
43.	*Tagiades japetus* (Stoll)	-	+	-	-	-	-	-	-	-	-	-	-	-	-	R
44.	*Tagiades litigiosa* Moschler	-	+	-	-	-	-	-	-	-	-	-	-	-	-	UC
45.	*Tagiades menaka* (Moore)	-	-	-	-	-	+	-	-	-	-	-	-	-	-	UC
II	**Family: Lycaenidae**															
A	**Sub-family: Aphnaeinae**															
46.	*Spindasis elwesi* Riley*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
47.	*Spindasis lohita himalayanus* Moore*	-	-	-	+	-	-	-	-	-	-	-	-	-	-	UC
48.	*Spindasis nipalicus* (Moore)*	-	-	-	-	-	+	-	-	-	-	-	-	-	-	UC
49.	*Spindasis vulcanus* (Fabricius)	-	+	-	+	-	-	-	+	-	-	-	-	-	-	C
B	**Sub-family: Curetinae**															
50.	*Curetis bulis* (Westwood)	-	+	-	-	-	+	-	-	-	-	-	-	-	-	UC
51.	*Curetis dentata* Moore	+	-	+	+	-	+	-	-	-	-	-	-	-	-	C
C	**Sub-family: Lycaeninae**															
52.	*Heliophorus androcles* (Doubleday & Hewitson)*	+	+	-	+	-	-	-	-	-	-	-	-	-	-	UC
53.	*Heliophorus brahma* (Moore)	+	+	-	-	-	-	-	-	-	-	-	-	-	-	NV
54.	*Heliophorus epicles indicus* Fruhstorfer	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
55.	*Heliophorus moorei coruscans* (Moore)	-	+	-	-	-	-	-	-	-	-	-	-	-	-	C
56.	*Heliophorus oda* (Hewitson)	-	-	-	-	-	-	-	-	-	-	-	+	-	-	UC
57.	*Heliophorus sena* (Kollar)	+	+	+	+	-	+	-	+	+	+	+	+	-	-	VC
58.	*Heliophorus tamu* (Kollar)	+	+	-	-	-	+	-	-	-	-	-	-	-	-	C
59.	*Lycaena kasyapa* (Moore)	-	+	-	-	-	-	-	-	-	-	-	-	-	-	NV
60.	*Lycaena panava* (Westwood)	+	+	-	-	-	+	-	-	+	-	-	-	-	-	C
61.	*Lycaena phlaeas* (Linnaeus)	+	+	-	-	-	+	-	-	-	-	-	+	-	-	C
62.	*Lycaena thersamon* Esper	-	-	-	-	-	-	-	-	-	-	+	-	-	-	R
D	**Sub-family: Miletinae**															
63.	*Allotinus multistrigatus* de Niceville	+	-	-	-	-	-	-	-	-	-	-	-	-	-	UC

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Table 3. Continued

Sl. No.	Species name	Distribution at Different Protected Areas														Local Status
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
64.	*Spalgis epius* (Westwood)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
E	**Sub-family: Polyommatinae**															
65.	*Acytolepis puspa* (Horsfield)*	-	+	-	+	-	+	+	-	+	-	-	-	+	-	VC
66.	*Albulina galathea* Blanchard	+	+	-	-	-	-	-	-	-	-	-	-	-	-	NV
67.	*Albulina pheretus lehanus* (Moore)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
68.	*Aricia agestis* Denis & Schiffermueller	-	-	-	-	-	+	-	-	-	-	-	-	-	+	UC
69.	*Aricia astrarche* Bergs	+	+	-	-	-	-	-	-	-	-	-	-	-	-	UC
70.	*Castalius caleta* (Hewitson)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
71.	*Castalius ethion* (Doubleday & Hewitson)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
72.	*Castalius rosimon* (Fabricius)*	+	+	+	+	-	-	-	+	-	+	-	-	+	-	VC
73.	*Catochrysops strabo* Fabricius	-	-	-	+	-	-	-	+	-	-	-	-	-	-	UC
74.	*Celastrina argiolus* Linnaeus	+	+	-	-	-	+	-	-	-	-	-	-	-	-	C
75.	*Celastrina gigas* (Hemming)	+	-	-	-	-	+	-	-	-	-	-	-	-	-	VC
76.	*Celastrina huegelii* (Moore)	+	+	-	-	+	+	-	-	-	-	-	-	-	-	VC
77.	*Celatoxia marginata* (de Niceville)	+	-	-	-	-	+	-	-	-	-	-	-	-	-	C
78.	*Chilades lajus* (Stoll)	-	-	-	+	-	-	-	+	-	-	-	-	-	-	C
79.	*Chilades pandava* (Horsfield)	-	+	-	-	-	-	-	+	-	-	-	-	-	-	C
80.	*Everes argiades diporides* Chapman*	+	+	-	-	-	+	+	-	-	-	-	-	-	-	UC
81.	*Everes huegelii Moore*	-	-	-	-	-	-	+	-	-	-	-	-	-	-	UC
82.	*Everes indica* Evans	-	-	-	-	-	-	+	-	-	-	-	-	-	-	C
83.	*Freyeria putli* Kollar	-	-	-	+	-	-	-	-	-	-	-	-	-	-	C
84.	*Freyeria trochylus* (Freyer)	-	-	+	+	-	-	-	-	-	+	-	-	-	-	UC
85.	*Jamides alecto* (Felder & Felder)*	-	-	-	-	-	-	-	-	-	-	-	-	+	-	C
86.	*Jamides celeno* (Cramer)	-	+	-	-	-	-	-	+	-	+	-	-	-	-	C
87.	*Lampides boeticus* (Linnaeus)*	+	+	-	+	-	+	-	-	-	+	-	-	-	-	C
88.	*Megisba malaya* (Horsfield)*	+	-	+	+	-	-	-	-	-	-	-	-	-	-	UC
89.	*Nacaduba aluta coelestis* de Niceville*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
90.	*Nacaduba dana* de Niceville	+	-	-	-	-	-	-	-	-	-	-	-	-	-	UC
91.	*Neopithecops zalmora* (Butler)	-	-	-	+	-	-	-	+	-	+	-	-	-	-	UC
92.	*Polyommatus eros* Riley	+	+	-	-	-	-	-	-	-	-	-	-	-	-	NV
93.	*Polyommatus icarus chitralensis* Swinhoe	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
94.	*Prosotas nora* Moore	-	-	-	+	-	-	-	+	-	-	-	-	-	-	VC
95.	*Pseudozizeeria maha* (Kollar)	+	+	+	+	-	+	-	+	-	-	-	-	-	-	VC
96.	*Talicada nyseus* (Guerin- Meneville)	+	-	-	+	-	-	-	-	-	-	-	-	-	-	C
97.	*Tarucus extricatus* Butler	-	-	-	+	-	-	-	-	-	-	-	-	-	-	UC
98.	*Tarucus indica* Evans	-	-	+	-	-	-	-	-	-	+	-	-	-	-	C
99.	*Tarucus venosus Moore*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	UC
101.	*Udara albocaeruleus* (Moore)	-	-	-	-	-	+	-	-	-	-	-	-	-	-	R
102.	*Udara dilecta* (Moore)	-	-	-	-	-	+	-	-	-	-	-	-	-	-	C

continued on following page

Table 3. Continued

Sl. No.	Species name	Distribution at Different Protected Areas														Local Status
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
103.	*Zizeeria karsandra* (Moore)	-	+	+	+	-	+	-	-	-	-	-	+	-	-	VC
104.	*Zizeeria otis* Fabricius	-	-	+	-	-	+	-	-	-	-	-	-	-	-	C
105.	*Zizina labradus* (Godart)	-	-	-	-	-	-	-	-	-	-	-	-	+	-	UC
F	**Sub-family: Poritiinae**															
106.	*Poritia hewitsoni* Moore*	+	+	-	+	-	-	-	-	-	-	-	-	-	-	UC
G	**Sub-family: Theclinae**															
107.	*Amblypodia selhetensis* Hewitson*	-	-	+	-	-	-	-	-	-	-	-	-	-	-	R
108.	*Ancema ctesia* (Hewitson)	+	-	-	-	-	+	-	-	-	-	-	-	-	-	UC
109.	*Arhopala amantes* (Hewitson)	+	-	-	+	-	-	-	-	-	-	-	-	-	-	UC
110.	*Arhopala atrax* (Hewitson)	-	-	-	+	-	-	+	-	-	-	-	-	-	-	C
111.	*Arhopala dodonea* Moore	+	-	-	-	-	+	-	-	-	-	-	-	-	-	R
112.	*Arhopala ganesa* Moore	+	-	-	-	-	-	+	+	-	-	-	-	-	-	UC
113.	*Arhopala paraganesa* (de Niceville)	-	-	-	-	-	+	-	-	-	-	-	-	-	-	UC
114.	*Arhopala rama* (Kollar)	-	-	-	-	-	+	-	-	-	-	-	-	-	-	UC
115.	*Chaetoprocta odata* (Hewitson)	+	-	-	-	-	+	-	-	-	-	-	-	-	-	UC
116.	*Cheritra freja* (Fabricius)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
117.	*Chilaria kina* (Hewitson)*	+	+	-	-	-	+	-	-	-	-	-	-	-	-	R
118.	*Chrysozephyrus birupa* (Moore)	+	-	-	-	-	+	+	+	-	-	-	-	-	-	C
119.	*Chrysozephyrus syla* (Kollar)	+	+	-	-	-	+	-	-	-	-	-	-	-	-	R
120.	*Deudorix epijarbus* Fruhstorfer*	-	+	-	+	-	+	-	-	-	-	-	-	-	-	R
121.	*Deudorix perse* Hewitson	-	+	-	-	-	-	-	-	-	-	-	-	-	-	NV
122.	*Esakiozephyrus bieti* Oberthur*	+	+	-	-	-	-	-	-	-	-	-	-	-	-	R
123.	*Esakiozephyrus icana* Moore	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
124.	*Esakiozephyrus mandara* (Doherty)*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	NV
125.	*Euaspa ziha* (Hewitson)*	+	-	-	-	-	+	+	-	-	-	-	-	-	-	R
126.	*Euaspa milionia* (Hewitson)	-	-	-	-	-	-	+	-	-	-	-	-	-	-	UC
127.	*Flos asoka* (de Niceville)*	-	-	+	-	-	-	-	-	-	-	-	-	-	-	UC
128.	*Horaga onyx* Moore	-	-	-	-	-	-	-	-	-	-	-	-	-	+	UC
129.	*Hypolycaena othona* (Hewitson)	-	-	-	+	-	-	-	-	-	-	-	-	-	-	C
130.	*Loxura atymnus* (Stoll)	+	+	-	+	+	-	-	-	-	-	-	-	+	-	C
131.	*Pratapa icetas icetas* (Hewitson)*	-	+	-	-	-	+	-	-	-	-	-	-	-	-	R
132.	*Rapala iarbus* (Fabricius)	-	+	-	+	-	-	-	-	-	-	-	-	-	-	UC
133.	*Rapala jarbas* Kollar	+	+	-	-	-	-	-	-	-	-	-	-	-	-	UC
134.	*Rapala manea* Moore	-	-	-	+	-	-	-	-	-	-	-	-	-	-	C
135.	*Rapala nissa* Kollar	-	+	-	-	-	+	-	-	-	-	-	-	-	-	C
136.	*Rapala selira* (Moore)	+	-	-	-	-	+	+	-	-	-	-	-	-	-	VC
137.	*Rapala varuna* (Hewitson)*	-	+	-	+	-	-	-	-	-	-	-	-	-	-	R
138.	*Sinthusa chandrana* Moore*	-	-	-	-	-	+	-	-	-	-	-	-	-	-	UC
139.	*Tajuria cippus* (Fabricius)*	-	-	-	-	-	-	-	-	-	-	-	-	+	-	UC
140.	*Tajuria diaeus* (Hewitson)*	-	-	-	-	-	+	-	-	-	-	-	-	-	-	UC
141.	*Tajuria melastigma* de Niceville*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R

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Table 3. Continued

Sl. No.	Species name	Distribution at Different Protected Areas														Local Status
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
142.	*Tajuria yajna* (Doherty)*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
143.	*Thermozephyrus ataxus* (Doubleday & Hewitson)*	+	-	-	-	-	+	-	-	-	-	-	-	-	-	R
144.	*Ticherra acte* (Moore)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
145.	*Virachola isocrates* (Fabricius)	+	-	-	-	-	-	-	-	-	-	-	-	+	-	C
III	**Family: Nymphalidae**															
A	**Sub-family: Acraeinae**															
146.	*Acraea issoria* (Hubner)	+	-	-	-	-	+	+	-	+	-	-	-	+	-	C
147.	*Acraea violae* (Fabricius)	+	+	-	+	-	-	-	-	-	-	-	+	-	-	C
148.	*Cethosia cyane* (Drury)	-	+	-	-	-	-	-	-	-	-	-	-	-	-	NV
B	**Sub-family: Apaturinae**															
149.	*Apatura ambica* Kollar*	-	-	-	-	-	+	-	-	-	-	-	-	-	-	R
150.	*Dichorrhagia nesimachus* Boisduval	-	-	-	-	-	+	-	-	-	-	-	-	-	-	R
151.	*Dilipa morgiana* (Westwood)*	-	+	-	-	-	+	-	-	-	-	-	-	-	-	R
152.	*Hestina nama* (Doubleday)	-	+	+	-	-	-	-	-	-	-	-	-	-	-	UC
153.	*Mimathyma ambica* (Kollar)	-	+	-	-	-	+	-	-	-	-	-	-	-	-	R
154.	*Rohana parisatis* Westwood	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
155.	*Sephisa dichroa* (Kollar)	+	+	-	-	-	+	+	-	+	-	+	-	-	-	C
156.	*Stibochiona nicea* (Gray)	+	+	-	-	-	+	+	-	-	-	-	-	-	-	UC
C	**Sub-family: Biblidinae**															
157.	*Ariadne merione* (Cramer)	+	+	+	+	-	-	-	+	-	+	-	+	+	-	VC
D	**Sub-family: Charaxinae**															
158.	*Charaxes bernardus hierax* (Felder & Felder)	-	-	-	-	-	-	+	+	-	-	-	-	+	-	R
159.	*Charaxes eudamippus* (Doubleday)	+	-	-	-	-	-	+	+	-	-	-	-	-	-	UC
160.	*Charaxes marmax* (Westwood)*	+	-	-	-	-	-	+	+	-	-	-	-	-	-	R
161.	*Charaxes solon* Fabricius	-	-	-	-	-	-	-	-	-	-	-	-	-	+	UC
162.	*Polyura agraria* (Swinhoe)	-	-	+	-	-	-	-	+	-	-	-	-	-	-	R
163.	*Polyura athamas* (Drury)	+	-	+	+	-	-	-	+	-	-	-	-	-	-	UC
164.	*Polyura dolon* (Westwood)	-	-	-	-	-	+	-	-	-	-	-	-	-	-	R
E	**Sub-family: Cyrestinae**															
165.	*Cyrestis thyodamas* Kollar	+	+	+	+	-	+	-	-	-	+	-	-	-	-	C
166.	*Pseudoergolis wedah* (Kollar)	+	+	-	-	-	+	-	-	+	-	-	-	-	-	C
F	**Sub-family: Danainae**															
167.	*Danaus chrysippus* (Linnaeus)	+	+	+	+	-	-	+	+	+	+	+	+	+	+	VC
168.	*Danaus genutia* (Cramer)	+	+	+	+	-	+	-	-	-	+	+	-	-	-	VC
169.	*Euploea core* (Cramer)*	+	+	+	+	-	+	-	-	+	+	+	+	+	-	C
170.	*Euploea mulciber* (Cramer)*	+	+	+	+	-	+	-	-	-	+	+	-	+	-	C
171.	*Parantica aglea* (Stoll)	+	+	+	+	-	-	-	-	-	+	+	-	-	-	VC
172.	*Parantica melaneus* (Cramer)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
173.	*Parantica sita* (Kollar)	+	+	-	+	-	+	-	-	-	-	+	-	-	+	C
174.	*Tirumala limniace* (Cramer)	+	+	+	+	-	-	-	-	-	+	-	-	-	-	VC

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Table 3. Continued

Sl. No.	Species name	Distribution at Different Protected Areas														Local Status
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
175.	*Tirumala septentrionis* (Butler)	+	+	-	-	-	-	-	-	-	-	-	-	-	-	UC
G	**Sub-family: Heliconiinae**															
176.	*Argynnis childreni* Gray	+	+	-	-	-	+	-	-	+	-	-	-	-	-	UC
177.	*Argynnis clara* Blanchard*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
178.	*Argynnis jainadeva* Moore	-	+	-	-	-	-	-	-	-	-	-	-	-	-	R
179.	*Argynnis kamala* (Moore)	+	+	-	-	-	-	-	-	-	-	-	-	-	-	UC
180.	*Argynnis pandora* Denis & Schiffermueller	-	+	-	-	-	-	-	-	-	-	-	-	-	-	NV
181.	*Argyreus hyperbius* (Linnaeus)	+	+	-	+	-	+	-	-	+	-	-	-	-	-	VC
182.	*Cupha erymanthis* (Drury)	+	+	-	-	-	+	-	+	-	+	-	-	-	-	C
183.	*Fabriciana adippe* Denis & Schiffermueller*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	UC
184.	*Issoria isaeea* Doubleday	+	+	-	-	+	+	-	-	-	-	-	-	-	-	C
185.	*Phalanta phalantha* (Drury)	+	+	+	+	-	+	-	+	+	+	+	+	-	-	C
186.	*Vagrans egista* (Cramer)	-	-	-	+	-	-	-	+	-	-	-	-	-	-	C
187.	*Vindula erota* (Fabricius)	-	-	-	-	-	-	-	-	-	-	-	-	+	-	R
H	**Sub-family: Libytheinae**															
188.	*Libythea celtis* Fuessly	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
189.	*Libythea lepita* (Moore)*	+	+	+	+	-	+	-	-	-	-	-	-	-	-	C
190.	*Libythea myrrha* Fruhstorfer	+	+	-	+	-	-	-	+	-	-	-	-	-	-	UC
I	**Sub-family: Limenitinae**															
191.	*Athyma asura* Moore	+	-	-	-	-	+	-	-	-	-	-	-	-	-	R
192.	*Athyma opalina* (Kollar)	+	+	-	-	-	+	+	-	-	-	-	-	-	-	VC
193.	*Athyma perius* (Linnaeus)	+	+	-	+	-	-	-	+	-	-	-	-	-	-	C
194.	*Athyma selenophora* (Kollar)	-	-	-	+	-	+	-	-	-	-	-	-	-	-	R
195.	*Athyma zeroca* (Moore)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
196.	*Auzakia danava* (Moore)	+	-	-	-	-	+	+	-	-	-	-	-	-	-	UC
197.	*Cynitia lepidea* (Butler)*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	UC
198.	*Euthalia aconthea* (Cramer)	-	+	+	+	-	-	-	+	-	+	-	-	-	-	C
199.	*Euthalia lubentina* (Cramer)*	-	-	-	+	-	-	-	-	-	-	-	+	-	-	R
200.	*Euthalia patala* (Kollar)*	-	-	-	-	-	+	-	-	-	-	-	+	-	-	C
201.	*Limenitis trivena* (Moore)	+	+	-	-	-	-	-	-	-	-	-	-	-	-	NV
202.	*Moduza procris* (Cramer)	-	-	-	+	-	-	-	-	-	-	-	-	-	-	UC
203.	*Neptis ananta* Moore*	+	+	-	-	-	+	+	-	-	-	-	-	-	-	C
204.	*Neptis clinia praedicta* Smetacek	-	+	-	+	-	+	-	-	-	-	-	-	-	-	C
205.	*Neptis hylas* (Linnaeus)	+	+	+	+	-	-	-	+	-	-	-	-	-	-	C
206.	*Neptis mahendra* Moore	+	+	-	+	-	+	-	-	-	-	-	+	-	-	VC
207.	*Neptis narayana**	-	+	-	-	-	-	-	-	-	-	-	-	-	-	R
208.	*Neptis radha* Moore*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
209.	*Neptis sankara* (Kollar)*	+	+	+	+	-	+	-	-	-	+	-	-	-	-	C
210.	*Neptis sappho astola* Moore	-	+	-	-	-	+	-	-	-	-	-	-	-	-	C
211.	*Neptis soma* Eliot*	+	-	-	-	-	+	-	-	-	-	-	-	-	-	VC

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Table 3. Continued

Sl. No.	Species name	Distribution at Different Protected Areas														Local Status
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
212.	*Neptis vikasi pseudovikasi* (Moore)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
213.	*Neptis yerburyi* (Butler)	+	+	-	+	-	+	-	-	-	-	+	+	-	-	C
214.	*Neptis zaida* Westwood*	-	-	-	-	-	-	-	-	+	-	-	-	-	-	R
215.	*Pantoporia hardonia* (Stoll)	+	+	-	+	-	-	-	+	-	-	+	-	-	-	C
216.	*Phaedyma columella* (Cramer)*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	UC
217.	*Sumalia daraxea* Doubleday	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
218.	*Symphaedra nais* (Forster)	+	+	-	+	-	-	-	-	-	-	-	-	-	-	UC
219.	*Tanaecia julii* (Bougainville)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
J	**Sub-family: Nymphalinae**															
220.	*Aglais cashmiriensis* (Kollar)	+	+	-	+	-	+	-	-	+	-	+	+	-	-	VC
221.	*Aglais ladakensis* Moore	-	+	-	-	-	-	-	-	-	-	-	-	-	-	NV
222.	*Hypolimnas bolina* (Linnaeus)	+	+	+	+	-	-	-	+	-	+	-	-	+	-	C
223.	*Hypolimnas misippus* (Linnaeus)*	+	+	-	+	-	+	-	+	-	+	-	-	-	+	C
224.	*Junonia almana* (Linnaeus)	+	+	+	+	-	-	-	+	-	+	-	-	+	-	C
225.	*Junonia atlites* (Linnaeus)	+	+	+	+	-	-	-	-	-	+	-	-	+	-	C
226.	*Junonia hierta* (Fabricius)	+	+	+	+	-	-	-	+	-	-	-	+	-	-	C
227.	*Junonia iphita* (Cramer)	+	+	+	+	-	+	-	+	+	+	+	-	-	-	VC
228.	*Junonia lemonias* (Linnaeus)	+	+	+	+	-	-	-	+	-	+	-	+	-	-	VC
229.	*Junonia orithiya* (Linnaeus)	+	+	+	+	-	-	-	+	-	+	-	+	+	-	C
230.	*Kallima inachus* (Boisduval)	+	+	-	+	-	+	-	+	+	-	-	-	+	-	C
231.	*Kaniska canace* (Linnaeus)	+	+	-	+	-	+	+	-	+	-	-	-	-	-	C
232.	*Nymphalis xanthomelas* (Stichel)	+	+	-	-	-	+	+	-	-	-	-	-	-	-	UC
233.	*Polygonia c-album* (Linnaeus)*	+	+	-	-	+	+	-	-	-	-	-	-	-	-	R
234.	*Polygonia egea* (Cramer)	+	+	-	-	-	-	-	-	-	-	-	-	-	-	UC
235.	*Symbrenthia brabira* Moore	+	-	-	-	-	+	-	-	-	-	-	-	-	-	UC
236.	*Symbrenthia hippoclus* (Cramer)	+	+	+	+	-	-	-	-	-	-	-	-	-	-	C
237.	*Symbrenthia hypselis* (Moore)	-	+	-	-	-	+	-	-	-	+	-	-	-	-	UC
238.	*Symbrenthia lilaea khasiana* Moore	-	+	-	+	-	+	-	-	-	-	-	-	-	-	C
239.	*Symbrenthia niphanda* Moore*	+	+	-	-	-	-	-	-	-	-	-	-	-	-	R
240.	*Vanessa cardui* (Linnaeus)	+	+	-	+	-	+	-	-	+	+	+	+	-	-	C
241.	*Vanessa indica* (Herbst)	+	+	+	+	-	+	-	+	+	-	+	+	-	-	C
K	**Sub-family: Satyrinae**															
242.	*Aulocera brahminus dokwana* Evans*	+	-	-	-	+	+	-	-	-	-	-	-	-	-	R
243.	*Aulocera loha* Doherty	+	-	-	-	-	+	-	-	-	-	-	-	-	-	C
244.	*Aulocera padama* Kollar	+	+	-	-	-	+	-	-	+	-	-	-	-	-	UC
245.	*Aulocera saraswati* (Kollar)	+	+	-	-	-	-	-	-	-	-	-	-	-	-	UC
246.	*Aulocera swaha* (Kollar)	+	+	-	-	+	+	-	-	+	-	-	+	-	-	VC
247.	*Callerebia ananda caeca* Walkins*	+	+	-	-	-	+	+	-	-	-	-	-	-	-	C
248.	*Callerebia hyagriva* (Moore)*	+	+	-	+	-	+	-	-	-	-	-	-	-	-	R
249.	*Callerebia hybrida* Butler	+	-	-	-	-	+	+	-	-	-	-	-	-	-	VC

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Table 3. Continued

Sl. No.	Species name	Distribution at Different Protected Areas														Local Status
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
250.	*Callerebia kalinda* Moore*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
251.	*Callerebia nirmala* (Moore)	+	+	-	-	-	+	-	-	-	-	-	+	-	-	VC
252.	*Callerebia scanda* (Kollar)	+	+	-	-	-	+	+	-	-	-	-	-	-	-	UC
253.	*Callerebia shallada* Marshall & de Niceville	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
254.	*Elymnias hypermenestra undularis* (Drury)	+	+	-	+	-	-	-	-	-	-	-	-	-	-	UC
255.	*Elymnias patna* (Westwood)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
256.	*Hipparchia parisatis shiva* (LeCerf)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
257.	*Hyponephele davendra* (Moore)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
258.	*Hyponephele lupina* Costa	-	+	-	-	-	-	-	-	-	-	-	-	-	-	NV
259.	*Hyponephele pulchra* (Felder & Felder)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
260.	*Lasiommata maerula* (Felder)*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
261.	*Lasiommata schakra* (Kollar)	+	+	-	-	-	+	+	-	+	-	+	+	-	-	VC
262.	*Lethe baladeva aisa* Fruhstorfer*	+	-	-	-	-	+	-	-	-	-	-	-	-	-	R
263.	*Lethe confusa* Aurivillius	+	+	-	-	-	+	+	+	-	-	+	-	-	-	C
264.	*Lethe dakwania* Tytler	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
265.	*Lethe europa**	-	+	-	+	-	-	-	-	-	-	-	-	-	-	R
266.	*Lethe goalpara* (Moore)*	+	+	-	-	-	+	-	-	-	-	-	-	-	-	R
267.	*Lethe insana* (Kollar)*	+	+	-	-	-	+	+	-	-	-	-	-	-	-	UC
268.	*Lethe jalaurida* (de Niceville)*	+	+	-	-	-	-	-	-	-	-	-	-	-	-	NV
269.	*Lethe kansa* (Moore)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	UC
270.	*Lethe maitrya* de Niceville	+	-	-	-	-	+	-	-	-	-	-	-	-	-	C
271.	*Lethe rohria* (Fabricius)	+	+	-	-	-	-	-	-	-	-	-	+	-	-	C
272.	*Lethe siderea* Marshall*	+	-	-	-	-	+	-	-	-	-	-	-	-	-	UC
273.	*Lethe sidonis sidonis* (Hewitson)	+	+	-	-	-	-	+	-	-	-	-	-	-	-	UC
274.	*Lethe sidonis vaivarta* Doherty	-	-	-	-	-	+	-	-	-	-	-	-	-	-	VC
275.	*Lethe verma* (Kollar)	+	+	-	-	-	+	+	+	+	-	-	+	-	-	VC
276.	*Melanitis leda ismene* Cramer	+	-	+	+	-	-	-	-	-	-	-	-	-	-	C
277.	*Melanitis leda leda* (Linnaeus)	+	+	+	+	-	-	-	+	-	+	+	-	-	-	C
278.	*Melanitis phedima galkissa* Fruhstorfer	+	-	-	-	-	+	-	-	-	-	-	-	-	-	R
279.	*Melanitis phedima bela* (Cramer)	-	-	-	+	-	-	-	-	-	-	-	-	-	-	UC
280.	*Melanitis zitenius* (Herbst)*	+	+	-	-	-	-	-	-	-	-	-	-	-	-	NV
281.	*Mycalesis francisca sanatana* Moore	+	+	-	-	-	+	+	-	-	-	-	-	-	-	UC
282.	*Mycalesis heri* Moore*	+	-	-	-	-	+	-	-	-	-	-	-	-	-	R
283.	*Mycalesis lepcha* (Moore)*	+	-	-	-	-	+	+	-	-	-	-	-	-	-	R
284.	*Mycalesis mineus* (Linnaeus)*	+	+	-	+	-	-	-	+	-	-	-	-	-	-	UC
285.	*Mycalesis nicotia* Westwood	-	-	-	-	-	+	-	-	-	-	-	-	-	-	R
286.	*Mycalesis perseus* (Fabricius)	+	+	+	+	-	+	-	+	-	+	-	-	+	-	C
287.	*Mycalesis suaveolens* Wood-Mason & de Niceville*	-	-	-	-	-	+	-	-	-	-	-	-	-	-	R

continued on following page

Table 3. Continued

Sl. No.	Species name	Distribution at Different Protected Areas														Local Status
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
288.	*Neope pulaha* Moore	-	+	-	-	-	+	-	-	-	-	-	-	-	-	UC
289.	*Neope yama* Moore	-	-	-	-	-	+	+	-	-	-	-	-	-	-	R
290.	*Oeneis buddha garhwalica* Tytler*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
291.	*Orinoma damaris* Gray	+	-	-	-	-	+	-	-	-	-	-	-	-	-	C
292.	*Paralasa mani* de Niceville*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	NV
293.	*Rhaphicera moorei* (Butler)	+	+	-	-	-	+	-	-	-	-	-	-	-	-	UC
294.	*Ypthima asterope* (Klug)	+	+	-	-	-	-	-	-	-	-	-	-	-	-	UC
295.	*Ypthima baldus* (Fabricius)	+	+	+	+	-	+	-	+	+	-	-	-	+	-	VC
296.	*Ypthima huebneri* Kirby	-	-	+	+	-	-	-	+	-	+	-	-	-	-	VC
297.	*Ypthima indecora* Moore	+	+	-	-	-	+	-	-	-	-	-	-	-	-	C
298.	*Ypthima kasmira* (Moore)	+	-	-	+	-	-	-	-	-	-	-	-	-	-	UC
299.	*Ypthima kedarnathensis* Singh	-	-	-	-	-	+	+	-	-	-	-	-	-	-	C
300.	*Ypthima lisandra avanta* (Moore)	-	-	-	+	-	-	-	-	-	-	-	-	-	-	UC
301.	*Ypthima nareda* (Kollar)	+	-	-	-	-	+	-	-	-	-	-	-	-	-	UC
302.	*Ypthima nikaea* Moore	-	+	-	-	-	-	+	-	-	-	-	-	-	-	VC
303.	*Ypthima sakra* Moore	+	+	+	-	-	+	-	-	-	-	-	-	-	-	VC
IV	**Family: Papilionidae**															
A	**Sub-family: Papilioninae**															
304.	*Atrophaneura aidoneus* (Doubleday)	+	-	-	-	-	+	-	-	-	-	+	-	-	-	R
305.	*Atrophaneura varuna astorian* (Westwood)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	UC
306.	*Byasa dasarada ravana* (Moore)	+	+	-	-	-	+	-	-	-	-	-	-	-	-	C
307.	*Byasa latreillei* (Donovan)	+	-	-	-	-	+	-	-	-	-	-	-	-	-	R
308.	*Byasa polyeuctes* (Fruhstorfer)	+	+	-	-	-	+	-	-	+	-	-	+	-	-	C
309.	*Graphium agamemnon* (Linnaeus)	-	+	-	-	-	-	-	-	-	-	-	+	-	-	C
310.	*Graphium cloanthus* (Westwood)	+	+	-	-	-	+	-	+	-	-	+	-	-	-	C
311.	*Graphium doson* (Felder & Felder)	+	+	-	-	-	-	-	-	-	+	-	-	-	-	C
312.	*Graphium erous* (Rothschild)	+	+	-	-	-	+	-	-	-	-	-	-	-	-	UC
313.	*Graphium nomius* (Esper)	+	-	+	+	-	-	-	+	-	+	-	-	-	-	UC
314.	*Graphium sarpedon* (Linnaeus)	+	+	+	-	-	-	-	-	-	-	+	-	-	-	C
315.	*Meandrusa gyas* Westwood*	-	+	-	-	-	-	-	-	-	-	-	-	-	-	R
316.	*Meandrusa lachinus* (Fruhstorfer)*	-	-	-	-	-	+	-	-	-	-	-	-	-	-	R
317.	*Pachliopta aristolochiae* (Fabricius)	+	+	-	+	-	+	-	+	-	+	-	-	-	-	C
318.	*Papilio agestor* Moore	+	+	-	-	-	-	-	-	-	-	-	-	-	-	UC
319.	*Papilio alcmenor* Felder & Felder	-	+	-	-	-	-	-	-	-	-	-	-	-	-	R
320.	*Papilio arcturus arius* Rothschild	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
321.	*Papilio bianor* polyctor (Boisduval)	+	+	-	-	-	+	-	-	+	-	-	-	-	-	UC
322.	*Papilio bootes janaka* Moore*	+	-	-	-	-	+	-	-	-	-	-	-	-	-	R
323.	*Papilio clytia* Linnaeus*	+	+	+	-	-	-	-	-	-	-	-	-	-	-	C
324.	*Papilio demoleus* Linnaeus	+	+	+	+	-	-	-	+	-	+	-	-	-	-	VC
325.	*Papilio helenus* Linnaeus	-	+	-	-	-	-	-	-	-	-	-	-	-	-	R

continued on following page

Table 3. Continued

Sl. No.	Species name	Distribution at Different Protected Areas														Local Status
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
326.	*Papilio paris* Linnaeus	+	-	-	-	-	-	-	-	-	-	-	-	-	-	UC
327.	*Papilio polytes* Linnaeus	+	+	+	+	-	+	-	+	+	+	+	+	+	-	VC
328.	*Papilio protenor* Cramer	+	+	-	-	-	+	-	-	-	-	+	-	-	-	C
329.	*Papilio rhetenor* Westwood	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
330.	*Papilo machaon* Menetries*	+	+	-	-	+	+	-	-	-	-	+	-	-	-	UC
331.	*Parides philoxinus* Gray	-	-	-	+	-	-	-	-	-	-	-	-	-	-	R
331.	*Troides aeacus* (Felder & Felder)	+	+	-	-	-	+	-	-	-	-	-	-	-	-	UC
B	**Sub-family: Parnassinae**															
332.	*Parnassius charltonius* Gray*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
333.	*Parnassius epaphus* Oberthur*	+	+	-	-	-	-	-	-	-	-	-	-	-	-	UC
334.	*Parnassius hardwickii* Gray	+	+	-	-	-	+	-	-	-	-	-	-	-	-	C
335.	*Parnassius jacquemonti* Boisduval*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
336.	*Parnassius stoliczkanus* Felder & Felder*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
V	**Family: Pieridae**															
A	**Sub-family: Coliadinae**															
337.	*Catopsilia florella* Fabricius	-	-	-	+	-	-	-	-	-	+	-	-	-	-	C
338.	*Catopsilia pomona* (Fabricius)	+	+	+	+	-	+	-	+	+	+	-	-	-	-	VC
339.	*Catopsilia pyranthe* (Linnaeus)	+	+	+	+	-	+	-	-	-	+	-	+	-	-	C
340.	*Colias eogene* Felder*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
341.	*Colias erate* (Esper)	+	+	+	+	-	+	-	-	+	-	-	-	-	+	C
342.	*Colias fieldii* Menetries	+	+	+	+	-	+	-	-	+	+	+	+	-	+	VC
343.	*Colias ladakensis* Felder*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
344.	*Colias myrnmidone* Danube	-	+	-	-	-	-	-	-	-	-	-	-	-	-	R
345.	*Eurema andersoni* (Moore)*	-	-	+	-	-	-	-	-	-	+	-	-	-	-	UC
346.	*Eurema blanda silhetana* (Wallace)	-	+	+	-	-	+	-	-	-	+	-	-	-	-	VC
347.	*Eurema brigitta rubella* (Wallace)	+	+	+	+	-	+	-	+	+	-	-	-	-	-	C
348.	*Eurema hecabe* (Linnaeus)	+	+	+	+	-	-	-	+	+	+	+	+	+	-	VC
349.	*Eurema laeta* (Boisduval)	+	+	+	+	-	-	+	+	+	+	-	+	-	-	C
350.	*Gandaca harina assamica* Moore	-	-	-	-	-	-	-	-	-	+	-	-	-	-	R
351.	*Gonepteryx mahaguru* (Gistel)	+	-	-	-	-	+	-	-	-	-	-	-	-	-	R
352.	*Gonepteryx rhamni nepalensis* (Doubleday)	+	+	-	-	+	+	-	-	+	-	+	+	-	+	VC
B	**Sub-family: Pierinae**															
353.	*Aporia agathon ariaca* (Moore)*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
354.	*Aporia agathon caphusa* (Moore)*	+	+	-	+	-	+	-	-	+	-	+	+	-	-	VC
355.	*Aporia agathon phryxe* (Boisduval)	+	-	-	-	-	+	-	-	-	-	-	-	-	-	C
356.	*Aporia leucodice soracta* Moore	+	+	-	-	-	+	+	-	-	-	-	-	-	-	C
357.	*Aporia nabellica* (Boisduval)*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
358.	*Appias lalage* (Doubleday)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	UC
359.	*Appias libythea* (Fabricius)*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
360.	*Baltia butleri* (Moore)*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R

continued on following page

Table 3. Continued

Sl. No.	Species name	Distribution at Different Protected Areas														Local Status
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
361.	*Belenois aurota* (Fabricius)	+	+	+	+	-	-	-	-	+	+	-	-	+	-	C
362.	*Ceporia nerrissa phryne* (Fabricius)*	+	-	+	+	-	-	-	-	-	+	-	+	-	-	C
363.	*Colotis danae* (Fabricius)	-	-	-	-	-	-	-	-	-	+	-	-	+	-	R
364.	*Colotis etrida* (Boisduval)	-	-	-	-	-	-	-	-	-	-	-	-	+	-	UC
365.	*Delias belladonna* (Gray)*	+	+	-	-	+	+	-	-	+	-	-	-	-	-	C
366.	*Delias eucharis* (Drury)	+	-	+	+	-	-	-	+	-	+	-	-	-	-	C
367.	*Delias hyparete indica* (Wallace)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
368.	*Delias sanaca* (Moore)*	+	+	-	-	-	-	-	-	-	-	-	-	-	-	R
369.	*Euchloe ausonia daphalis* (Moore)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
370.	*Hebomoia glaucippe* (Linnaeus)	-	-	-	-	-	-	-	-	-	-	-	-	+	-	C
371.	*Ixias marianne* (Cramer)	+	-	-	-	-	-	-	-	-	+	-	-	+	-	UC
372.	*Ixias pyrene* (Linnaeus)	-	-	-	-	-	-	-	-	-	-	-	-	+	-	UC
373.	*Leptosia nina* (Fabricius)	+	-	+	+	-	+	-	+	-	-	-	-	+	-	C
374.	*Mesapia peloria* (Hewitson)	-	-	-	-	-	-	-	-	-	+	-	-	+	-	R
375.	*Pareronia hippia* (Fabricius)	-	-	-	+	-	-	-	-	-	+	-	-	-	-	C
376.	*Pareronia valeria* (Cramer)	+	+	+	+	-	-	-	+	-	-	-	-	-	-	C
377.	*Pieris brassicae* (Linnaeus)	+	+	+	-	-	+	-	-	+	-	+	-	-	-	VC
378.	*Pieris callidice kallora* (Moore)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	UC
379.	*Pieris canidia indica* Evans	+	+	+	+	-	+	-	-	+	+	+	+	-	-	VC
380.	*Pieris montana ajaka* Moore	-	+	-	-	-	+	-	-	-	-	-	-	-	-	VC
381.	*Pieris napi* Moore	+	+	-	-	-	-	-	-	-	-	-	-	-	-	UC
382.	*Pieris rapae* (Linnaeus)	-	+	-	-	-	-	-	-	-	-	-	-	-	-	NV
383.	*Pontia callidice kalora* Moore	+	-	-	-	-	-	-	-	-	-	-	-	-	-	R
384.	*Pontia chloridice alpina* (Verity)*	+	-	-	-	-	-	-	-	-	-	-	-	-	-	NV
385.	*Pontia daplidice* (Rober)*	+	+	+	-	-	+	-	-	+	-	-	+	-	+	C
VI	**Family: Riodinidae**															
A	**Sub-family: Riodininae**															
386.	*Abisara bifasciata* Moore	-	-	-	+	-	-	-	-	-	-	-	-	-	-	VC
387.	*Abisara echerius* (Stoll)	-	+	+	-	-	-	-	-	-	-	-	-	-	-	C
388.	*Abisara fylla* (Westwood)	-	-	-	-	-	+	-	-	-	-	+	-	-	-	C
389.	*Dodona dipoea nostia* Fruhstorfer*	+	-	-	-	-	+	+	-	-	-	-	-	-	-	C
390.	*Dodona durga* (Kollar)	+	+	-	-	-	+	-	-	-	-	-	+	-	-	C
391.	*Dodona eugenes* Bates	+	+	-	-	-	+	+	-	-	-	-	-	-	-	UC
392.	*Dodona ouida* Fruhstorfer	-	-	-	-	-	-	+	-	-	-	-	-	-	-	R
393.	*Zemeros flegyas* Fruhstorfer	+	-	+	-	-	+	-	+	-	-	-	-	-	-	UC

Chapter 11
Biodiversity Assessment for Asian Highway 48 (Near Jaldapara National Park) From Bhutan to Bangladesh Passing Through India:
Case Study

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ABSTRACT

In the present study, the authors have elaborated a case study for the biodiversity assessment for Asian Highway 48 (Chainage 84.775 km to 87.690 km) passing through Jaldapara National Park located in Alipurdwar District of West Bengal state of India. The objectives of the study were to assess the biological diversity within the specified area (1.65 km^2) to establish the baseline status of floral and faunal species. Here, we have covered flora and fauna for the assessment as well as quantitative study covering frequency, density, dominance, IVI, Shannon Wiener Index, variance, etc. The area is ecologically sensitive as endangered species were observed; animals like elephants used to cross the road very frequently. Therefore, it is strongly recommended to prepare the conservation plan for elephants and other REET species in the Jaldapara National Park to conserve the endangered species in situ.

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INTRODUCTION

'Biodiversity' refers broadly to all species and habitats in an ecosystem, rather than simply the number of taxa (McQuatters-Gollop et al., 2019). Quantification of biodiversity is crucial for many biological and societal applications, including biogeography and ecosystem services, understanding biological interactions, and for designing conservation and management strategies. But quantifying biodiversity is a big challenge as it requires taxonomic expertise, significant funding and substantial time (Ritter et al., 2019). The objective of economic activities is the process of satisfying the requirements of any commodity, whether production - distribution of products or fulfilling the commodity demand. Roads and Highways make a crucial contribution to economic development and growth and bring important social benefits. For growth and development of a nation, they are very essential. In addition, providing access to employment, social, health and education services makes a road network crucial in fighting against poverty. Since it is also critical for generating substantial employment, India had taken major steps towards development of this critical infrastructure all across the country. India has one of the largest road networks in the world, spanning over a total of 5.6 million km. Over 64.50% of all goods in the country are transported through roads, while 90% of the total passenger traffic uses road network to commute. During FY 2017-2018, Government of India allocated US$ 10.13 billion for national highway development across the country. Public Private Partnership Appraisal Committee (PPPAC) recommended development of 312 projects, as on September 2017.

BACKGROUND

The Government of India had applied for financial assistance from the Asian Development Bank (ADB) towards the cost of SASEC road connectivity investment program (SRCIP). The SRCIP is a multi-tranche Financing facility (MFF) that aims to improve about 500 km of priority road sections in the North Bengal and Northeast of India, through an investment program set out in phases (tranches). Asian highway (AH) 48 from Jaigaon to Changrabandha (about 91 km) was existing road of 2 lane standards and had flexible pavements and was a part of the existing National Highway Network. The realignments and bypasses had been proposed in the project road. The Government of India had applied a portion of financial assistance to engage consultant firms to provide services related to Authority Engineer, Implementation Support Consultant and External Monitoring for Wildlife Conservation Activities. The Authority's Engineer has been engaged for EPC contracts at the contract level. In addition, the Implementation Support Consultant (ISC) is engaged to support EAs in external monitoring of safeguard implementation, third-party maintenance quality, road safety audit, financial management and subsequent submission to ADB. ADB has a regional cooperation program in four South Asian countries: Bangladesh, Bhutan, India and Nepal, called South Asia Economic Cooperation (SASEC1), which has been supporting regional cooperation in the transport sector through SAARC2 and BIMSTEC3 over a decade. The transport division of the United Nations Economic and Social Commission for Asia and Pacific (ESCAP) has initiated the Asian Highway Network with the aim of promoting the development of international road transport in the region. The regional road connector between Bhutan and Bangladesh through India is designated as Asian Highway No.48 (AH-48). Trade and people movement is gradually increasing through the selected corridor.

The regional road connector between Bhutan and Bangladesh through India is designated as Asian Highway No.48 (AH-48). Rehabilitation and Upgrading to 2-lane with paved shoulder configuration and strengthening of Bhutan Border (at Pasakha) to Bangladesh Border (at Changrabandha) comprising of Jaigaon-Hasimara-Dhupguri section and Mainaguri –Changrabandha section (totalling 90.568 km) including Pasakha access road of AH-48 corridor comprised of: Widening and strengthening of road with 10m carriageway including paved shoulder and 1 m of earthen shoulder covered with 150mm thick compacted layer of granular material on either side of road in rural area, and 11.5m carriageway in urban locations.

Jaldapara National Park at Glance

The Jaldapara National Park located in Alipurduar district; West Bengal is spread over an area of 234.51 sq. km. The flora and fauna represent rich biological significance of this area. The National Park is surrounded by dense human population. The park extends from Bhutan Hills to the Terai bordering Cooch Behar district. The area is eco fragile and eco sensitive. The activities/industries outside the park influence the habitat and water regime of the park. The remaining grassland and species dependent upon them have a better chance of survival if some regulation is exercised on the activities in the vicinity of Jaldapara National Park. The Jaldapara National Park contains a total 585 Nos. of identified plants species which belongs to 429 genus, 111 families including 91 grass species and 19 orchid species. The flora species include Sal (*Shorea robusta*), Chilauni (*Schima wallichi*), Chikrasi (*Chukrasia tabularis*), Champ (*Michelia champaca*), Bahera (*Terminalia belerica*), Sidha (*Lagerstroemia parviflora*), Panisaj (*Terminalia myriocarpa*), Lampati *(Duabanga sonneratioides*), Lali *(Amoora wallichi*), Lahasune (*Amoora rohituka*), Kainjal (*Bischofia javanica*), Simul (*Bombax ciba*), Khair (*Acacia catechu*), Sissoo (*Dalbergia sissoo*) Siris (*Albizzia spp*).The Jaldapara Wildlife Sanctuary has great ecological significance as it forms the gene pool reserve for the great Indian one horned Rhinoceros outside Nepal and Assam. Jaldapara has 33 species of carnivores and herbivores, approximately 246 species of birds, 29 species of reptiles, 8 species of turtles, 54 species of fishes and a host of other micro fauna including Rhinoceros (*Rhinoceros unicornis*), Elephant (*Elephas maximus*), Leopard (*Panthera pardus*) Gaur (*Bos gaurus*), Hog badger (*Arctonyx collaris*), Sloth Bear (*Melursus ursinus*), Hispid hare (*Caprolagus hispidus*), Bengal florican (*Eupodotis bengalensis*), Python (*Python reticulatus*), Indian Pangolin (*Manis crassicaudata).*

OBJECTIVE OF THE STUDY

The objectives of the study were to assess the biological diversity within the specified area (1.65 km^2) to establish the Baseline status of floral and faunal species. Following were the clear objective of this study:

1. Collection of secondary data on forests, trees, shrubs, etc.
2. Assessment of flora and fauna present within the anticipated impact zone of the road (AH48) upto 2.915 km stretch.
3. To describe the floristic and faunal communities along the road /AH48 up to 2.91 km stretch.
4. To identify species and ecosystem/habitat of conservation significance within study area.
5. To identify representative spectrum of threatened species, population and ecological communities as listed by IUCN, WCMC, ZSI, BSI and Indian Wildlife Protection Act, 1972 and to assess the status of individual species using the revised IUCN/SSC category system.

6. Assessment of plant species with respect to frequency, abundance, Importance Value Index etc. within study area.
7. Assessment/calculation of Shanon Wiener Index (H) for birds, herpetofauna and butterfly.
8. Prediction of biological stresses within the anticipated impact zone of the proposed highway, if any.

STUDY AREA AND STUDY PERIOD

Study Area

A study area is geographical area for which data is analysed in a report and/or map. There are two ways to define study area:

- Site-based study area.
- Geographical unit-based study area.

For the current study, we considered the site-based study area. Here, the site was the Asian Highway road of 2.915 km (Chainage 84.775 km to 87.690 km). As per Indian Road Congress (IRC), the cross-road locations and the cross sections of cross road shall be taken at 25 m intervals upto 50 m from centre line or upto ROW of cross road, whichever is more. The study on cross-sections was carried with minimum length of 200 m either side of the project road centre line.

Considering various construction activities of the road and transportation over the proposed road during post construction phase, the anticipated impact zone considered was 300m (200m as per IRC + 100m buffer zone considering the transportation noise) for assessment from centre point on both sides of the road passing through Jaldapara National Park. Then, the area considered for study was 600m x 2915m or 1.749 km^2. However, there was 165m road which falls under agricultural revenue but the land was recorded under forest while there was no forest tree except road side plantation; hence actual forest area of 1.65 km^2 had been considered for quadrant study. The study period for the study considered was winter season Oct. to Dec. 2018. Coordinates for Quadrant Study are given in Table 1.

METHODOLOGY

The sampling plots for floral inventory were selected randomly in the suitable habitats (Anderson, 1867; Jain & Rao, 1983; Dixit, 1984; Wilson & Reeder, 2005; Kumar, 2013; Kumar et al., 2013).

The methodology adopted for faunal survey involve random survey, opportunistic observations, diurnal bird observation, active search for reptiles, faunal habitat assessment, active search for scats and foot prints, animal call, and review of previous studies. Emphasis had been placed on presence of endemic species, threatened species, if any, present in the study area.

Desktop literature review was conducted to identify the representative spectrum of threatened species, population and ecological communities listed by IUCN, WCMC, ZSI, BSI and Indian Wild life Protection Act, 1972 (Bentham & Hooker, 1862-1883; Hunter, 1879; Dixit, 1984; Ghosh et al., 2004; Lushington, 1915; Wilson & Reeder, 1993; BirdLife International, 2000; BirdLife International, 2004a,

Table 1. Coordinates for Quadrant Study – Biodiversity Assessment

Point	Latitude	Longitude
Road Starting Point	26°43’44.60”N	89°17’40.60”E
300 m left wrt Road	26°43’54.00”N	89°17’40.38”E
300 m right wrt Road	26°43’34.96”N	89°17’41.18”E
1st Quadrats starting point	26°43’45.25”N	89°17’46.85”E
Left 300 m wrt Road	26°43’54.82”N	89°17’44.11”E
Right 300 m wrt Road	26°43’35.98”N	89°17’49.08”E
2nd Quadrats starting point	26°43’46.78”N	89°17’59.57”E
Left 300 m wrt Road	26°43’56.52”N	89°17’58.15”E
Right 300 m wrt Road	26°43’37.22”N	89°18’0.60”E
3rd Quadrats starting point	26°43’48.24”N	89°18’12.03”E
Left 300 m wrt Road	26°43’57.51”N	89°18’11.90”E
Right 300 m wrt Road	26°43’38.60”N	89°18’12.73”E
4th Quadrats starting point	26°43’47.20”N	89°18’28.14”E
Left 300 m wrt Road	26°43’56.83”N	89°18’28.95”E
Right 300 m wrt Road	26°43’37.47”N	89°18’28.92”E
5th Quadrats starting point	26°43’46.39”N	89°18’44.51”E
Left 300 m wrt Road	26°43’56.21”N	89°18’44.68”E
Right 300 m wrt Road	26°43’36.88”N	89°18’44.36”E
6th Quadrats starting point	26°43’45.04”N	89°19’10.15”E
Left 300 m wrt Road	26°43’54.41”N	89°19’10.76”E
Right 300 m wrt Road	26°43’35.38”N	89°19’9.48”E
6th Quadrats starting point	26°43’44.96”N	89°19’16.92”E
Left 300 m wrt Road	26°43’54.56”N	89°19’17.31”E
Right 300 m wrt Road	26°43’35.34”N	89°19’12.96”E

b; Wilson and Reeder, 2005; BirdLife International, 2010; Kumar & Srivastava, 2012; Kumar, 2013; Kumar et al., 2013; Kumar & Aggarwal, 2013a,b). The status of individual species was assessed using the revised IUCN/SSC category system (WCMC, 1988; IUCN, 1994; WCMC, 2000; IUCN, 2001, 2003, 2008, 2010).

Parameters

The following parameters had been selected for the primary survey of ecology and biodiversity:

1. Flora in the study area
    a. Trees.
    b. Shrubs.
    c. Herbs.

   d. Climbers.
   e. Floristic composition of study area.
   f. Medicinal plants of study area.
   g. Status of forest, their category in study area.
   h. Rare and endangered flora in study area.
   i. Endemic plants in study area.
2. Fauna in the study area
   a. Reptiles.
   b. Amphibians.
   c. Birds.
   d. Mammals.
   e. Butterflies.
   f. Rare and endangered fauna in study area.
   g. Endemic fauna in study area.
   h. Wild life and their conservation importance in study area.

Sampling Location/Area

To conduct sampling of floral and faunal elements, randomly selected quadrates along the road and other habitats had been selected in the study area (anticipated impact zone).

Field Data Collection

The field data collection includes biodiversity inventorization of different life forms of floral and faunal groups of study area. Among flora, elements such as trees, shrubs, herbs and grasses should be enlisted while among faunal elements; major taxa like herpetofauna, birds and mammals had been recorded from different major ecosystems/habitats. During the reconnaissance survey, evidences of all mammals in form of tracks, dung and sightings were looked. For documentation of faunal diversity, species list method had been followed, list of animals observed was directly recorded on site so that faunal resources of area are catalogued correctly.

Following is the categorization of methodology for specific study:

1. Odonate (predators), coleoptera and hymenoptera (pollinators):
   a. Net sweeps.
   b. Light traps.
   c. Scented traps.
   d. Opportunistic sightings also recorded along with information on species and host plant visited.
2. Herpetofauna:
   a. It was sampled using circular plots and belt transects.
   b. Intensive search (is) had been done within a circular plot of 10m radius placed at every 100m along the transect, while transect of 80m long and 6m wide was used in space between two circular plots.

    c. All the microhabitats (rock and boulders, dead and fallen logs, flushing and beating of dense bushes and grass patches, checking of rock and tree crevices and leaf litters) within the transects was checked for herpetofauna. Opportunistic survey was done using plots of 5m x5m.

3. Avifauna*:* It was estimated using variable width transects, point count and area search (perambulation technique) in different vegetation. Bird counts are best done within ½ hour after sunrise and completed in four hours after sunrise. The species and mode of detection (song, call, visual, other) was recorded. Below is the flow of methodology followed for bird count and Shanon Wiener Index calculation:
    a. List of all bird species observed.
    b. The total number of different species observed represents the observed bird species composition.
    c. Add the number of birds of each species to get species abundances observed during any one sampling period.
    d. Total abundances of birds estimated by adding all species abundances together.
    e. The bird species in all microhabitat is recorded along with their numbers seen.
    f. For each sighting tree species used, substrate used, vertical strata used, activity, how and what its feeding was recorded.
    g. Riverine area was also surveyed for the aquatic bird species.
    h. Information of nesting habitats or breeding sites also recorded.
4. Mammals:
    a. **Direct Count:** For each sighting species, abundance, age and sex, sighting distance, sighting angle, distance on transect and activity of animal with habitat features had been documented.
    b. **Indirect Count:** Presence and relative abundance of most of small and large mammals had been undertaken using methods that rely on indirect evidence such as animal burrows/holes, dung, pellets, feeding signs, tracks etc. This had been done using transects and plots. The passive track counts scat counts helped in determining abundance.
5. Floristic Density: For floristic density, PCQ (Point Centred Quarter) (Cottam & Curtis, 1950) method had been followed. In the point-centred quarter method, a set of points (usually positioned along the transect to traverse the area) is initially selected. The area around each point is divided into four 90° quadrants, and the plant closest to the point in each quadrant is identified. The distance between the central point and selected plant in each quadrant is measured, and then averaged across the four to represent the distance (d) at each sample point. At the conclusion of data collection, the average distance for all sample points is calculated. Vegetation measurements had been determined from points rather than being determined in an area with boundaries. The quantitative assessment like frequency, abundance, diversity indices etc. had been followed of standard method. The vegetation growth at different locations with progressing age of restoration had been studied. Tree plot (10 m radius), shrub plot (5m radius) and herbs plot (1m radius) were selected according to terrain and requirements for the quantitative study. The following three type of plot had been selected for the present study:
    a. Herbs: 1m x 1m quadrants.
    b. Shrubs: 5m x 5m quadrants.
    c. Trees: 10m x 10m quadrants.
6. Ecological Sensitivity of the area: Ecological sensitivity of study area had been analysed based on the following criteria:
    a. Wild life importance.

b. Floral endemicity.
c. Faunal endemicity,
d. State of terrestrial vegetation.
e. State of wet land vegetation.
f. Mangrove vegetation.
g. Conservation importance.
h. Legal status (national park, wild life sanctuary, reserve forest, wetlands agricultural lands).
i. Lakes /reservoirs/dam.
j. Natural lakes and swamps.
k. Breeding ground of migratory and residential birds.

DATA ANALYSIS

The data of primary assessment of floral and faunal species had been analysed by using standard methods. Following standard methods of calculation were used.

Floral Species

1. Frequency:

$$Frequency\left(\%\right) = \frac{No. of\, Quadrants\, in\, which\, species\, occurred}{Total\, no. of\, Sampling\, units\, studied} \times 100$$

2. Density:

$$Density\left(\%\right) = \frac{Number\, of\, individuals\, of\, the\, species}{Total\, area\, studied} \times 100$$

3. Abundance: This is the number of individuals of any species per unit area of occurrence.

$$Abundance = \frac{Total\, no. of\, individuals\, of\, species\, in\, all\, quadrants}{No. of\, quadrants\, in\, which\, species\, occurred} \times 100$$

4. Dominance: Dominance is the area occupied by stems of a species in any given area.

$$Basal\, area\, of\, a\, species = Sum\, of\, basal\, areas\, of\, all\, the\, stems$$

$$Basal\, area\, of\, individual\, stem = \pi D^2\, /\, 4$$

Where, D=Diameter of stem

5. Relative Density:

$$Relative\,Density = \frac{Density\,of\,the\,species}{Total\,density\,of\,all\,the\,species} \times 100$$

6. Relative Frequency:

$$Relative\,Frequency = \frac{Frequency\,of\,the\,species}{Total\,Frequency\,of\,all\,the\,species} \times 100$$

7. Relative Dominance:

$$Relative\,Dominance = \frac{Dominance\left(cover\right)of\,the\,species}{Total\,dominance\,of\,all\,the\,species} \times 100$$

8. Importance Value Index (IVI): The value reflecting the relative importance of individual species in study area.

$$IVI = Relative\,Density + Relative\,Dominance + Relative\,Frequency$$

Faunal Species

For quantitative study of faunal species, the Shanon Wiener Index (H) for birds, herpetofauna and butterfly were considered. Shannon wiener diversity index is also known as concentration of dominance.

Given a vector of frequencies (counts), f_i the Shannon diversity index is computed as:

$$H' = -\sum_{i=1}^{S} p_i (\ln p_i)$$

The Shannon equitability index is simply the Shannon diversity index divided by the maximum diversity -

$$E = H / H_{\max}$$

p_i = Number of individuals of species i/total number of samples.
S = Number of species or species richness.
H_{max} = Maximum diversity possible.
E = Evenness = H/$H_{max.}$

Table 2 indicates sensitivity of the study area. Mode of data collection and parameters considered during the Biodiversity Assessment is depicted in Table 3.

RESULTS AND DISCUSSION

Floral Diversity of the Study Area

The objective of floral inventory of the study area was to provide necessary information on floristic structure in the study area for formulating effective management and conservation measures. The climatic, edaphic and biotic variations with their complex interrelationship and composition of species (adapted to these variations), had resulted in different vegetation cover, characteristic of each region (Ohasi, 1975). The tree species, herbs, shrubs, climbers and major crops, were documented during this survey (Jain, 1968; 1991).

Trees and Shrubs

Total 107 species of trees belong to 42 families are enumerated from study area in Table 4.

Herbs

Total 22 herbaceous species belongs to 21 family (agricultural crops not included) were recorded from the study area enlisted in Table 5.

Grasses and Parasitic Plant

Total 9 grass species belong to Gramineae family (agricultural crops not included) were recorded from the study area enlisted in Table 6.

Table 2. Sensitivity of the study area

<table>
<tr><th>S. No.</th><th>Area/Track/Zone</th><th>Name of Forest/HotSpots</th><th>Remarks</th></tr>
<tr><td>1.</td><td>Road</td><td>Passing Through Jaldapara National Park; Forest area</td><td>2.915 km stretch of AH-48 passing through Jaldapara National Park</td></tr>
<tr><td>2.</td><td>Rail track</td><td>Parallel Rail track to AH-48 at a distance of 300m to 500m</td><td rowspan="4">The Jaldapara National Park contains a total 585 Nos. of identified plants species which belongs to 429 genus, 111 families including 91 grass species and 19 orchid species. It has 33 species of carnivores and herbivores, approximately 246 species of birds, 29 species of reptiles, 8 species of turtles, 54 species of fishes and a host of other micro-fauna.</td></tr>
<tr><td>3.</td><td>River</td><td>Torsa River on the other side</td></tr>
<tr><td>4.</td><td>National Park/Wildlife Sanctuary</td><td>Jaldapara National Park Notified SO 2733(E) dtd. 22nd August 2017, previously it was notified as Jaldapra Wildlife Sanctuary vide Notification no. 2890-For.11B-13/98 dtd 27th August 1998 by Governor of West Bengal</td></tr>
<tr><td>5.</td><td>Agricultural Field</td><td>Cropping field near the Road</td></tr>
</table>

Table 3. Mode of data collection and parameters considered during the biodiversity assessment

S. No.	Aspect	Data	Mode of Data Collection	Parameters Monitored	Remarks
1.	Terrestrial Ecology	Primary data collection	By Field Survey (Hutto et al., 1986; Welsh, 1987; F. Thommpson et al., 1989; Welsh et al., 1991; Allen et al., 1996; Misra, 2013).	For Floral diversity, Vegetation measurements: Tree, Shrub, Herbs, Grasses, Climbers, Cultivated plants in the study area, Floristic composition of the study area, Medicinal plants of the study area, Status of the forest, their category in the study area, Rare and endangered flora in the study area. Endemic plants in the study area. For Fauna in the study area: Reptiles, Amphibians, Birds, Fresh water fishes Mammals, Butterflies. Rare and Endangered fauna in the study area, Endemic fauna in the study area, Wild life and their conservation importance in the study area.	Random survey, opportunistic observations, diurnal bird observation, active search for reptiles, faunal habitat assessment, active search for microhabitat, scats, foot prints, animal call, pug marks, debarking sign, Nesting, Claws, Dung, etc. and information from local villagers.
2.		Secondary data collection	Jaldapara National Park Forest Data Data of Fisheries department. Literature like research papers, books published by research/ academic Institutions. Reports	Interpretation of secondary data for Ecological Sensitive Areas such as national forests, wild life sanctuaries, lakes, ravines, hills, hillocks and reserve forest, vegetation, type, importance etc.	Bentham & Hooker, 1862-1883; Hunter, 1879; Dixit, 1984; Ghosh *et al.,* 2004; Lushington, 1915; Wilson & Reeder, 1993; BirdLife International, 2000; BirdLife International, 2004a, b; Wilson & Reeder, 2005; BirdLife International, 2010; Kumar & Srivastava, 2012; Kumar, 2013; Kumar *et al.,* 2013; Kumar & Aggarwal, 2013. The status of individual species was assessed using the revised IUCN/SSC category system (WCMC, 1988; IUCN, 1994; WCMC, 2000; IUCN, 2001, 2003, 2008, 2010.
3.	Evaluation of Ecological sensitivity	Secondary	Review and Discussion	Wild life importance, Floral Endemicity, Faunal Endemicity, State of Terrestrial vegetation, State of wet land vegetation, Conservation importance, Legal status (National park, Wild life sanctuary, Reserve forest, Wetlands, Agricultural lands) Lakes /reservoirs/ dam, Natural lakes and Swamps, Breeding ground of Migratory and Residential birds.	-

Table 4. Trees in the study area (natural vegetation)

S. No.	Family	Common/Hindi Name	Botanical Name
1.	Anacardiaceae	Aam	*Mangifera indica*
2.		Jhingan	*Lannea coromendelica*
3.	Annonaceae	Ashok	*Polyalthia longifolia*
4.		Kari	*Sarcopetalum tomentosum*
5.	Apocynaceae	Dudhi/Karayja	*Wrightia tinctoria*
6.		Satiana	*Alstonia scholaris*
7.	Arecaceae	Supari	*Areca catechu*
8.		Chaur	*Caryota urens*
9.		Khajur	*Phoenix dactylifera*
10.		Tal	*Borassus flabelliformis*
11.	Bignoniaceae	Padar	*Sterospermum suaveolens*
12.	Bixaceae	Kakai	*Flacourtia ramontchi*
13.	Bombacaceae	Semul	*Bombax ceiba*
14.	Boraginaceae	Chamror	*Ehretia laevis*
15.	Burseraceae	Kharpat	*Garuga pinnata*
16.	Capparidaceae	Barna	*Crataeva unilocularis*
17.	Celastraceae	Jamrasi	*Elaeodendron glaucum*
18.	Combreteceae	Arjun	*Terminalia arjuna*
19.		Dhavada	*Anogeissus latifolia*
20.		Bahera	*Terminalia belerica*
21.		Kardhai	*Anogeissus pendula*
22.		Saaj	*Terminalia tomentosa,*
23.	Cornaceae	Ankol	*Alangium lamarckii*
24.	Ebenaceae	Tendu	*Diospyros melanoxylon*
25.		Bhaktendu	*Diospyros cordifolia*
26.	Elaeocarpaceae	Jalpai	*Eleocarpus floribundus*
27.	Euphorbiaceae	Aanvla	*Emblica officinalis*
28.		Thuar	*Euphorbia neriifolia*
29.		Ratanjot	*Jatropha curcas*
30.		Roli	*Mallotus philippinensis*
31.		Katathohar	*Euphorbia nivulia*
32.		Belker	*Trewia nudiflora*
33.		PataBahar	*Codiaeum variegatum*
34.	Fabaceae	Acacia	*Acacia auriculiformis*
35.		Kanchan	*Bauhinia purpurea*
36.		Luhasiris	*Albizia lucidor*
37.		Madar	*Erythrina indica*
38.		Siris/Beladuba	*Samanea saman*

continued on following page

Table 4. Continued

S. No.	Family	Common/Hindi Name	Botanical Name
39.	Lauraceae	Maida lakdi	*Litsea glutinosa*
40.	Lecythidaceae	Kumbhi/Kalindi	*Careya arborea*
41.	Leguminosae	Anjan	*Hardwickja binata*
42.		Asta	*Bauhinia racemosa*
43.		Imli	*Tamarindus indica*
44.		Karanj	*Pongamia glabra*
45.		Kachnar	*Bauhinia variegata*
46.		Koroi	*Albizia lebbek*
47.		Keyolar	*Bauhinia spp.*
48.		Kheir	*Acacia catechu*
49.		Khejra	*Prosopis juliflora*
50.		Gulmohar	*Delonix regia*
51.		Chhekur	*Prosopis spicigera*
52.		Tinsa	*Ougeinia dalbergiodes*
53.		Dhovin	*Dalbergia paniculata*
54.		Palas	*Butea monosperma*
55.		Babool	*Acacia nilotica*
56.		Bijasaal	*Pterocarpus marsupium*
57.		Reonjha	*Acacia leucophloea*
58.		Safed khair	*Acacia ferruginea*
59.		Sehra	*Bauhinia retusa*
60.		Sheesham	*Delbergia latifolia*
61.		Sissu	*Delbergia sissoo*
62.	Lythraceae	Seja	*Lagerstroemia parviflora*
63.		Ajar	*Largerstoemia speciosa*
64.	Malvaceae	Kullu	*Sterculia lanceolata*
65.		Jabaphul	*Hibiscus rosasinensis*
66.	Meliaceae	Neem	*Azadirecta indica*
67.		Bakain	*Melia azedarach*
68.		Rohan	*Soymida febrifuga*
69.	Mimosaceae	Khori	*Pithecellobium angulatum*
70.	Moraceae	Gular	*Ficus glomerata*
71.		Pakar	*Ficus infectoria*
72.		Peepal	*Ficus religiosa*
73.		Bargad/vad/Bot	*Ficus bengalensis*
74.		Dumur	*Ficus lepidosa*
75.		Bhahtoot	*Morus laevigates*
76.		Kathal	*Artocarpus heterophyllus*

continued on following page

Table 4. Continued

S. No.	Family	Common/Hindi Name	Botanical Name
77.	Moringaceae	Sahjana	*Moringa pterygosperma*
78.		Sajna	*Moringa oleifera*
79.	Musaceae	Kola/Kela	*Musa sps*
80.	Myrtaceae	Jamun	*Syzygium cuminii*
81.		Gum tree	*Eucalyptus sp.*
82.		Piyara	*Psidium guajava*
83.	Oleaceae	Banpalas	*Schrebera swietenioides*
84.	Oxalidaceae	Kamranga	*Averrhoa carambola*
85.	Pinaceae	Eucalyptus	*Eucalyptus maculata*
86.	Poaceae	Bijali bans	*Bambusa pallida*
87.		Kako Bans	*Bamboosa hamiltonii*
88.		Makal ban	*Bambusa nutans*
89.		Barua Bans	*Bambusa arundinacea*
90.	Provenance	Gameri	*Gamelina arborea*
91.	Phyllanthaceae	Amla	*Phyllanthus emblica*
92.	Rhamnaceae	Kul	*Ziziphus jujuba*
93.	Rubiaceae	Morinda tree	*Morinda tinctoria*
94.		Kem	*Mitragyna parvifolia*
95.		Tilaki	*Wendlandia exserta*
96.		Papra	*Gardenia latifolia*
97.		Bharangi	*Gardenia turgida*
98.		Lokhandi	*Ixora parviflora*
99.	Rutaceae	Keth	*Feronia limonia*
100.		Kaitha	*Limonia crenulata*
101.		Meethneem	*Murrasya koenigii*
102.	Salicaceae	Bher	*Salix tetrasperma*
103.	Simaroubaceae	Maharukh	*Ailanthus excelsa*
104.	Tiliaceae	Dhaman	*Grewia tiliaefolia*
105.	Ulmaceae	Chirol	*Holoptelea integrifolia*
106.	Verbenaceae	Thiurgorwa	*Vitex peduncularis*
107.		Sagaun/Teak	*Tectona grandis*

Table 5. List of herbaceous species observed in the study area

S. No.	Family	Hindi Name	Scientific Name
1.	Acanthaceae	Maruadona	*Strobilanthes callosus*
2.	Amaranthaceae	Chirchita	*Achyranthes aspera*
3.	Apocynaceae	Karonda	*Carissa spinarum*
4.	Asciepiadaceae	Oak	*Calotropdis gigantea*
5.	Berberidaceae	Sarkata	*Argemone mexicana*
6.	Capparidanceae	Aradanda	*Capparis horrida*
7.		Kareel	*Capparis aphylla*
8.	Compositae	Gokhuru	*Xanthium aspera*
9.	Leguminosae	Nirgud	*Indigolera pulchella*
10.	Liabiatae	Kala Bansa	*Colebrookea oppositifolia*
11.	Lythraceae	Dhawai	*Woodfordia floribunda*
12.	Malyaceae	Banakpas	*Thespesia lampas*
13.	Myrsinaceae	Babrang	*Embelia robusta*
14.	Myrtaceae	Jamun	*Eugenia heyncana*
15.	Rhamnaceae	Jharberi	*Zityphtis rotundifolia*
16.	Rutaceace	Ratanjot	*Clausena pentaphylla*
17.	Salicaceae	Bansa	*Salix tetrasperma*
18.	Sterculiaceae	Marorfali	*Helicteres isora*
19.	Tamaricacene	Jhau	*Tamarix dioica*
20.	Tiliaceae	Kukurbicha	*Grewia hirsuta*
21.	Verbenaceae	Harsingar	*Nyctanthes arbortristis*
22.	Vitaceae	Hathi kand	*Leea macrophylla*

Table 6. List of grasses plant observed in the study area

S. No.	Family	Hindi Name	Scientific Name
1.	Gramineae	Kus	*Eragrostis nees*
2.		Kaus	*Saccharum spontaneum*
3.		Gararu	*Coix gigentea*
4.		Gadela	*Coix lacrymajobi*
5.		Guner	*Themeda quadrivalvis*
6.		Dub	*Cynodon dactylon*
7.		Poniya	*Sehima sulcatum*
8.		Phooli	*Apluda mutica*
9.		Basu	*Sorghum halepense*

Cultivated Plants in the Study Area

The prevalent cropping systems of the area were the cumulative results of past and present decisions by individuals; these decisions were usually based on experience, tradition, expected profit, personal preferences and resources, and so on. The crop occupying the highest percentage of the sown area of the region was taken as the major crop and all other possible alternative crops were considered as minor crop. It was observed that, the different parts of the study area were practicing different crop pattern based on the season and availability of irrigation facility.

- **Major Horticultural Crops:** Plantation of Mango trees (*Mangifera indica*) was observed at some places in the study area, but no other horticultural crops were observed.
- **Major Vegetable Crops:** None
- **Minor:** None
- **Pulses:** None

Rare and Endangered Flora in the Study Area

Out of 17000 species of higher plants known to occur in India, nearly 614 higher plant species were evaluated by IUCN. Among them 247 species are under threatened category (IUCN, 2008).

As per list of 2012; plants seemed to be the most threatened life form with 60 species being listed as Critically Endangered and 141 as Endangered in India. Among the enumerated flora in the study area, none of them were assigned any threat category by Red data book of Indian Plants (Jain & Sastry, 1984; Nayar & Sastry, 1987; 1988; 1990; Oldfield et al., 1998; Kholia & Bhakuni, 2009) and Red list of threatened Vascular plants (IUCN, 2010).

Endemic Plants of the Study Area

De Candolle (1855), Swiss botanist, first used the concept of Endemic, which is defined as an area of a taxonomic unit, especially a species which has a restricted distribution or habitat, isolated from its surrounding region through geographical, ecological or temporal barriers. Out of 17000 species of known flowering plants of India, nearly 5000 species are said to be endemic. Nearly 58 genera and 1932 taxa are found to be endemic to peninsular India (Nayar, 1980; Ahmedullah & Nayar, 1986; 1987; Jain 1992; Nayar, 1996; Vijaya Shankar et al., 2005; Nautiyal et al., 2009a,b; Shendage & Yadav, 2010).

Status of the Forest, Their Category in Study Area

The study area was in the Jaldapara National Park as the AH-48 passes through this National Park.

Extent and Boundaries of Eco-sensitive Zone

The extent of Eco-sensitive Zone was 1 km in the revenue area and 2 km in the surrounding forest area from the boundary of Jaldapara National Park.

Activities Prohibited or to be Regulated within the Eco-sensitive Zone

All activities in the Eco-sensitive Zone shall be governed by the provisions of the Environment (Protection) Act,1986 (29 of 1986) and the rules made there under including the Coastal Regulation Zone (CRZ), 2011 and the Environmental Impact Assessment Notification, 2006 and other applicable laws including the Forest (Conservation) Act,1980 (69 of 1980), the Indian Forest Act, 1927 (16 of 1927), the Wildlife (Protection) Act 1972 (53 of 1972), and amendments made there to.

Prohibited Activities in Eco Sensitive Zone

- **Commercial Mining:** All new and existing (minor and major minerals), stone quarrying and crushing units are prohibited with immediate effect except for meeting the domestic needs of bonafide local residents including digging of earth for construction or repair of houses and for manufacture of country tiles or bricks for housing and for other activities. The mining operations shall be carried out in accordance with the order of the Hon'ble Supreme Court dated 04.08.2006 in the matter of T.N. Godavarman Thirumulpad vs. UOI in W.P.(C) No.202 of 1995 and dated 21.04.2014 in the matter of Goa Foundation Vs. UOI in W.P.(C) No.435 of 2012.
- **Setting of Industries Causing Pollution (Water, Air, Soil, Noise, etc.):** No new industries and expansion of existing polluting industries in the Eco-sensitive zone shall be permitted. Only non-polluting industries shall be allowed within ESZ as per classification of Industries in the Guidelines issued by Central Pollution Control Board in February 2016, unless so specified in this notification. In addition, non-polluting cottage industries shall be promoted.
- **Establishment of Major Hydroelectric Project:** Prohibited (except as otherwise provided) as per applicable laws.
- **Use or Production or Processing of any Hazardous Substances:** Prohibited (except as otherwise provided) as per applicable laws.
- **Discharge of Untreated Effluents in Natural Water Bodies or Land Area:** Prohibited (except as otherwise provided) as per applicable laws.
- **Setting of New Saw Mills:** No new or expansion of existing saw mills shall be permitted within the Eco-sensitive Zone.
- **Setting up of Brick Kilns***:* Prohibited as per applicable laws.
- **Use of Polythene Bags:** Prohibited as per applicable laws.
- **Commercial use of Firewood:** Prohibited as per applicable laws.
- **New Wood-based Industry:** Prohibited as per applicable laws.

Faunal Biodiversity of Study Area

For the documentation of the faunal biodiversity of the study area with respect to birds, reptiles, amphibians, and butterfly species, a baseline survey had been conducted.

Birds

The sighting of bird species was very less during the study period. The birds observed in the study area are listed as schedule IV as per IWPA, 1972. A taxon is near Threatened, when it had been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable categories, but is close to qualifying or is likely to qualify for threatened category in the future. The list of birds observed from the study area is provided in Table 7.

Butterflies

Butterflies from three families observed during the present study are documented in Table 8.

Herpetofauna

In amphibian group, the toads were sighted during the study period. The reptiles Common Garden Lizard, House Gecko, Fan-Throated Lizard, Common rat Snake, etc. were observed in the region and are listed in Table 9.

Mammals

Very few mammals were observed in the study area and are listed in Table 10.

Domestic Animals

The domestic animals *viz.* dog, cow, buffalo and chicken (only at one spot) were observed in the study area.

Insects like Wasps, Honeybees and Signature spider were also recorded.

Fisheries

Torsa River was the major natural drain in the study area located outskirts of Jaldapara National Park. The fishes observed in study area are listed in Table 11.

- *Migratory Route of Aquatic Fauna (Fish):* In AH-48, fish species like Tor showed migratory behaviour in river Torsa and usually migrated upstream for spawning.
- *Spawning and Breeding Grounds Along Sub-project Roads:* Along proposed AH-48 sub-project alignment spawning and breeding ground were recorded for major and minor carps in the Torsa River.
- *Identification of Endemic/ Threatened and Endangered Species:* Along sub-project roads, *Tor putitora* was found to be the only fish species which is an endangered category according to National Bureau of Fish and Genertic Resources (NBFGR) found in rivers Mahananda and Torsa.
- *Rare and Endangered Fauna of Study Area:* The IUCN Red List is the world's most comprehensive inventory of the global conservation status of plant and animal species. It uses a set of criteria to evaluate risk of extinction of thousands of species and subspecies. These criteria are relevant to all the species and all regions of the world. The IUCN Red List, with its strong scientific base, is recognized as the most authoritative guide to the status of biological diversity. IUCN (2008) has evaluated 1976 animal species from India. Among them, 313 are recognized as threatened species. Among them one species is considered as extinct, while 44 species are in critically endangered (CR) category, 88 is in endangered category (EN), while 181 is considered as vulnerable (VU).

Table 7. Systematic lists of birds in the study area with status

S. No.	Family	Vernacular Name	Scientific Name	Status
1.	Accipitridae	Black-winged kite	*Elanus caeruleus*	R
2.		Black kite	*Milvus migrans*	R
3.		Shikra	*Accipiter badius*	V
4.		Changeable hawk-eagle	*Nisaetus cirrhatus*	O
5.		Tawny eagle	*Aquila rapax*	E
6.		Crested serpent eagle	*Spilornis cheela*	E
7.	Alcedinidae	Pied kingfisher	*Ceryle rudis*	R
8.		Common kingfisher	*Alcedo atthis*	R
9.		White-throated kingfisher	*Halcyon smyrnensis*	V
10.	Anatidae	Eurasian teal	*Anas crecca*	O
11.	Apodidae	Alpine swift	*Tachymarptis melba*	R
12.		Little swift	*Apus affinis*	R
13.	Ardeidae	Grey Heron	*Ardea cinerea*	R
14.		Cattle egret	*Bubulcus ibis*	R
15.		Little egret	*Egretta garzetta*	R
16.	Campephagidae	Small minivet	*Pericrocotus cinnamomeus*	W
17.		Scarlet minivet	*Pericrocotus speciosus*	V
18.	Caprimulgidae	Indian nightjar	*Caprimulgus asiaticus*	R
19.	Charadriidae	Red-wattled lapwing	*Vanellus indicus*	R
20.	Columbidae	Rock pigeon	*Columba livia*	R
21.		Eurasian collared dove	*Streptopelia decaocto*	R
22.		Spotted dove	*Spilopelia chinensis*	R
23.	Coraciidae	Indian roller	*Coracias benghalensis*	R
24.	Corvidae	Jungle crow	*Corvus macrorhynchos*	R
25.	Cuculidae	Common hawk-cuckoo	*Hierococcyx varius*	R
26.		Koel	*Eudynamys scolopaceus*	R
27.	Dicruridae	Fork-tailed drongo	*Dicrurus adsimilis*	R
28.		White-bellied drongo	*Dicrurus caerulescens*	R
29.	Estrildidae	Red avadavat	*Amandava amandava*	V
30.		Tricoloured munia	*Lonchura malacca*	O
31.	Gruidae	Sarus crane	*Grus antigone*	R
32.	Hirundinidae	Wire-tailed swallow	*Hirundo smithii*	S
33.	Laniidae	Long-tailed shrike	*Lanius schach*	R
34.	Leiothrichidae	Jungle babbler	*Turdoides striata*	R
35.	Meropidae	Green bee-eater	*Merops orientalis*	R
36.		Blue-tailed bee-eater	*Merops philippinus*	R
37.	Motacillidae	Grey wagtail	*Motacilla cinerea*	R
38.		White wagtail	*Motacilla alba*	R

continued on following page

Table 7. Continued

S. No.	Family	Vernacular Name	Scientific Name	Status
39.	Muscicapidae	Tickell's blue flycatcher	*Cyornis tickelliae*	R
40.		Black redstart	*Phoenicurus ochruros*	S
41.		African stonechat	*Saxicola torquatus*	W
42.		Blue-capped rock thrush	*Monticola cinclorhyncha*	R
43.		Oriental magpie-robin	*Copsychus saularis*	R
44.		Indian robin	*Saxicoloides fulicatus*	R
45.	Nectariniidae	Purple sunbird	*Cinnyris asiaticus*	R
46.	Oriolidae	Eurasian golden oriole	*Oriolus oriolus*	O
47.	Phalacrocoracidae	Little Cormorant	*Phalacrocorax niger*	V
48.		Large Cormorant	*Phalacrocorax carbo*	V
49.	Phasianidae	Black Partridge	*Francolinus francolinus*	R
50.		Grey francolin	*Francolinus pondicerianus*	V
51.		Jungle bush quail	*Perdicula asiatica*	R
52.		Indian peafowl	*Pavo cristatus*	R
53.	Picidae	Yellow fronted pied woodpecker	*Leiopicus mahrattensis*	R
54.	Pittidae	Indian pitta	*Pitta brachyura*	R
55.	Ploceidae	Baya weaver	*Ploceus philippinus*	R
56.	Psittacidae	Alexandrine parakeet	*Psittacula eupatria*	R
57.		Rose-ringed parakeet	*Psittacula krameri*	R
58.	Pycnonotidae	Red-vented bulbul	*Pycnonotus cafer*	R
59.	Recurvirostridae	Black-winged stilt	*Himantopus himantopus*	R
60.	Scolopacidae	Common redshank	*Tringa totanus*	R
61.		Common snipe	*Gallinago gallinago*	W
62.	Sittidae	Indian nuthatch	*Sitta castanea*	S
63.	Strigidae	Eurasian eagle-owl	*Bubo bubo*	O
64.		Jungle owlet	*Glaucidium radiatum*	O
65.	Sturnidae	Chestnut-tailed starling	*Sturnia malabarica*	V
66.		Brahminy starling	*Sturnia pagodarum*	V
67.		Jungle myna	*Acridotheres fuscus*	R
68.	Upupidae	Hoopoe	*Upupa epops*	R

Note: Key to Status
R: Resident
V: Vagrant
S: Summer only
W: Winter only
O: Occurs most years
E: Escape

Table 8. Butterflies in the Study Area

Scientific Name and Family	Common Name	Relative Abundance
Family: Asclepiadaceae		
Danaus genutia Cramer	Striped Tiger	Common
Family: Papilionidae		
Papilio polytes	Common Mormon	Common
Family:Pieridae		
Eurema hecabe	Common Grass yellow	Very Common
Ixias Marianne	White orange tip	Common
Family: Nymphalidae		
Danaus chrysippus	Plain Tiger	Common
Hypolimanasmisippus	Danaid egg fly	Common
Mycalesisperseus	Common bush brown	Uncommon
Cynthia cardui Linnaeus	Painted Lady	Uncommon
Junoniahierta Fabricius	Yellow pansy	Common
Junonia orithya Linnaeus	Blue pansy	Fairy Common

Table 9. Reptiles and amphibian in the study area

S. No.	Common Name	Scientific Name	Schedule as IWPA, 1972
1.	Toad	*Bufo bufo*	Not listed
2.	Indian Chameleon	*Chameleon calcaratus*	Schedule II
3.	Common Garden Lizard	*Calotes versicolor*	Not listed
4.	Fan-Throated Lizard	*Sitana ponticeriana*	Not listed
5.	House Gecko	*Hemidactylus flaviviridis*	Not listed
6.	Brahminy Skink*	*Mabuya carinata*	Not listed
7.	Common Rat Snake	*Ptyas mucosus*	Schedule II
8.	Kekula/Nag/Cobra*	*Naja naja*	Schedule II

*Not sighted but included as per the secondary information from villagers.

Table 10. List of mammals observed in the study area

S. No.	Family	Common Name	Scientific Name	Schedule
1.	Cervidae	Indian hog deer	*Axis porcinus*	Schedule -I
2.	Elephantidae	Indian Elephant	*Elephas maximus indicus*	Schedule -I
3.	Leporidae	Hispid hare	*Caprolagus hispidus*	Schedule -I
4.	Muridae	Indian bush rat	*Golunda ellioti*	Schedule -V
5.	Mustelidae	Hog badger	*Arctonyx collaris*	Schedule -I
6.	Pteropodidae	Shot nosed fruit bat	*Cynopterus sphinx*	Schedule -V
7.	Sciuridae	Common 5 Striped Squirrel	*Funambulus pennantii*	Schedule -IV

Table 11. List of fishes reported from the study area

S. No.	Family	Common Name	Scientific Name
1.	Bagridae	Gengra*	*Rita rita*
2.		Tengara*	*Mystus bleekeri*
3.	Channidae	Katla	*Chana gachua*
4.		Samval (Saul)	*Chana marulius*
5.		Samval*	*Chana striatus*
6.	Cyprinidae	Tor	*Tor putitora*
7.		Katla (Komal, Bhakhar)	*Catla catla*

*not seen directly.

WildLife (Protection) Act, 1972, amended on 17th January 2003, is an Act for the protection of wild animals, birds and plants and for matters connected therewith or ancillary or incidental thereto with a view for ensuring ecological and environmental security of the country.

QUANTITATIVE ASSESSMENT OF FLORAL DIVERSITY

1. **Frequency:** Frequency, as given by Raunkiaer (1934), indicates the number of sampling units in which a given species occur. Frequency of mangrove vegetation refers to the degree of dispersion of individual species in an area and is usually expressed in terms of percentage of occurrence. The values of relative frequency are calibrated on a 10-point scale to assign a status to the species in each region. From this 10-point scale and each group in each region, four distinct groups are derived as follows:
    a. 10 Very Frequent.
    b. 5– 7 Frequent.
    c. 3– 5 Less Frequent.
    d. < 3 Rare.
2. **Abundance:** The density and abundance represent numerical strength of species in the community. Abundance is described as the number of individuals occurring per sampling unit and density as the number of individuals per sampling unit. The abundances are grouped to assign abundance categories, as suggested by Dagar et al. (1991) and are detailed below:
    a. 25 d –Dominant.
    b. 15 – 25 Va-Very Abundant.
    c. 10-15 a –Abundant.
    d. 6-10 f –Frequent.
    e. 3- 6 o –Occasional.
    f. 1 - 3 r –Rare.
3. **Importance Value Index (IVI):** The concept of Important Value Index (IVI) has been developed for expressing the dominance and ecological success of any species, with a single value. This index utilizes three characteristics, *viz*. relative frequency (Rf), relative density (Rd) and relative abundance (Ra). The three characteristics are computed using frequency, density and abundance for all the species falling in all the transects by using the following formula.

IVI = Relative frequency + Relative abundance + Relative density

The area in question had good floral diversity as it was the part of National Park. The relative frequency (Rf), relative abundance (Ra), relative density (Rd) and Importance Value Index (IVI) has been listed in Table 12 for the study area. Trees within Right of Way of Project Road AH-48 are given in Table 13.

QUANTITATIVE ASSESSMENT OF FAUNAL DIVERSITY

The quantitative assessment of faunal biodiversity assessment was done using Shannon Wiener Index (H) for mammals, birds, herpatofauna, butterfly, etc. The Shannon Wiener Index (H) and its variance is presented in Table 14.

BIOLOGICAL STRESS IN THE IMPACT ZONE

The Asian Highway 48 near Jaldapara is passing through Jaldapara National Park. Jaldapara National Park is situated at an altitude of 61 m and is spread across 216.51 km^2 of vast grassland with patches of riverine forests. Jaldapara received the wildlife sanctuary status in the British Era in 1941 when the area was 141 sq. km. Now, Jaldapara is spread over an area of 216.51 sq. km with a Rhino population of more than 160. Other important species includes Deers, Bisons, Leopards and numerous birds including the famous Great Hornbill. It consists a great diversity of flora and fauna of mixed deciduous forest, grasslands and river banks. Also, the Malangi River flows nearby from east to west. Drained by rivers Torsa, Malangi, Hollong, Chirakhawa, Kalijhora, Sissamara, Bhaluka and Buri Torsa, the Sanctuary provides extensive grassland which is last refuge to a wide variety of mammals, amphibians, reptiles and birds. The grass wetland, ideal for Rhinos provide them natural habitat for their strong survival. The forest is mainly savannah covered with tall elephant grasses. Some rare species like hog-badger and hispid hare are also found here. The birds to be found here are the Pallas's Fishing Eagle, Crested Eagle and Shikra, besides peafowl, Jungle fowl, patridges, lesser Pied Hornbill and Bengal Florican. Python, monitor lizards, kraits, cobras, geckos and about 8 species of fresh water turtles were also found in National Park. Many animals are endangered like – the Asiatic one-horned rhino and elephants in Jaldapara National Park. The elephant habitat in North Bengal is characterized by a high degree of habitat fragmentation and severe human-elephant conflict resulting to loss of agricultural crops, property, and several human lives every year.

Due to the depredation, some retaliatory killing of elephant occurs in India and Nepal by electrocution, poisoning, bullet injury, or through arrow. In the year 2007, 3 elephants died, then during the months of June-July of 2008 another one died through electrocution. In 2009 alone, gun shots accounted for 10 elephant injuries.

- **Accidental Death of Mammals Along Proposed AH-48 Sub-projects**: As per data available from West Bengal Forest Department, most of the accidental deaths to elephant and spotted deer were caused by train collision.
- **Rhinoceros in Jaldapara National Park:** The Rhinoceros unicorn is the flagship species for the Jaldapara National Park. As per the recent census in the park, there are around 184 rhinos which

Table 12. Species Importance Index Values for the studied plots

S. No.	Family	Botanical Name	Rf	Ra	Rd	IVI
1.	Anacardiaceae	*Mangifera indica*	0.5	0.6	0.4	1.5
2.		*Lanneacoro mendelica*	0.3	0.2	0.2	0.7
3.	Annonaceae	*Polyalthia longifolia*	0.25	0.3	0.2	0.75
4.		*Saccopetalum tomentosum*	1.5	1.4	1.6	4.5
5.	Apocynaceae	*Wrightia tinctoria*	1.1	1.2	1	3.3
6.		*Alstonia scholaris*	1.3	1.1	1.4	3.8
7.	Arecaceae	*Areca catechu*	1.2	1	1.2	3.4
8.		*Caryota urens*	0.4	0.5	0.6	1.5
9.		*Phoenix dactylifera*	0.5	0.6	0.5	1.6
10.		*Borassus flabelliformis*	0.6	0.2	0.6	1.4
11.	Bignoniaceae	*Sterospermum suaveolens*	1.2	1.1	1.3	3.6
12.	Bixaceae	*Flacourtia ramontchi*	0.6	0.4	0.6	1.6
13.	Bombacaceae	*Bombax ceiba*	0.5	0.6	0.6	1.7
14.	Boraginaceae	*Ehretia laevis*	0.3	0.2	0.3	0.8
15.	Burseraceae	*Garuga pinnata*	1	0.9	1	2.9
16.	Capparidaceae	*Crataeva unilocularis*	1.1	1.2	1	3.3
17.	Celastraceae	*Elaeodendron glaucum*	1.8	1.5	1.8	5.1
18.	Combreteceae	*Terminalia arjuna*	0.5	0.8	0.5	1.8
19.		*Anogeissus latifolia*	0.9	0.9	1.1	2.9
20.		*Terminalia belerica*	0.4	0.1	0.4	0.9
21.		*Anogeissus pendula*	0.5	0.6	0.5	1.6
22.		*Terminalia tomentosa*	0.4	0.9	0.6	1.9
23.	Cornaceae	*Alangium lamarckii*	0.6	0.5	0.6	1.7
24.	Ebenaceae	*Diospyros melanoxylon*	2.1	1.5	1.6	5.2
25.		*Diospyros cordifolia*	1	1.3	1	3.3
26.	Elaeocarpaceae	*Eleocarpus floribundus*	1.3	1.1	1.3	3.7
27.	Euphorbiaceae	*Emblica officinalis*	1.1	1.2	1.1	3.4
28.		*Euphorbia neriifolia*	1.2	1	1.2	3.4
29.		*Jatropha curcus*	0.4	0.4	0.4	1.2
30.		*Mallotus philippinensis*	0.5	0.4	0.5	1.4
31.		*Euphorbia nivulia*	0.9	0.9	0.9	2.7
32.		*Trewia nodiflora*	0.5	0.6	0.5	1.6
33.		*Codiaeum variegatum*	1.2	1.3	1.2	3.7
34.	Fabaceae	*Acacia auriculiformis*	1.2	1.2	1.2	3.6
35.		*Bauhinia purpurea*	0.9	0.6	0.9	2.4
36.		*Albizzia lucidor*	0.5	0.5	0.5	1.5
37.		*Erythrina indica*	0.8	0.4	0.8	2
38.		*Samanea saman*	0.6	0.9	0.6	2.1

continued on following page

Table 12. Continued

S. No.	Family	Botanical Name	Rf	Ra	Rd	IVI
39.	Lauraceae	*Litseag lutinosa*	1	0.9	0.8	2.7
40.	Lecythidaceae	*Careya arborea*	1.5	1.2	1.5	4.2
41.	Leguminosae	*Hardwickja binata*	0.9	0.8	0.9	2.6
42.		*Bauhinia racemose*	0.8	0.8	0.8	2.4
43.		*Tamarindus indica*	1.6	1.5	1.6	4.7
44.		*Pongamia glabra*	0.8	0.8	0.8	2.4
45.		*Bauhinia variegata*	0.5	0.6	0.5	1.6
46.		*Albizzia lebbek*	0.6	0.8	0.6	2
47.		*Bauhinia spp.*	1.1	1.3	1.1	3.5
48.		*Acacia catechu*	1.3	1.1	1.3	3.7
49.		*Prosopis juliflora*	1.5	1.4	1.5	4.4
50.		*Delonix regia*	1.2	1	1.2	3.4
51.		*Prosopis spicigera*	0.6	0.8	0.6	2
52.		*Ougeinia dalbergiodes*	1.2	1.6	1.2	4
53.		*Dalbergia paniculata*	1.2	1.5	1.2	3.9
54.		*Butea monosperma*	1.5	1.6	1.5	4.6
55.		*Acacia nilotica*	1.6	1.5	1.6	4.7
56.		*Pterocarpus marsupium*	1.6	1.1	1.6	4.3
57.		*Acacia leucophloea*	1.8	1.9	1.8	5.5
58.		*Acacia ferruginae*	1.5	1.6	1.5	4.6
59.		*Bauhinia retus*	1.6	1.8	1.6	5
60.		*Delbergia latifolia*	1.5	1.4	1.5	4.4
61.		*Delbergia sissoo*	0.6	0.6	0.6	1.8
62.	Lythraceae	*Lagerstroemia parviflora*	0.4	1	0.4	1.8
63.		*Largerstoemia speciosa*	1.2	1.5	1.2	3.9
64.	Malvaceae	*Sterculialan ceolata*	1.3	1	1.3	3.6
65.		*Hibiscus rosasinensis*	0.5	0.9	0.5	1.9
66.	Meliaceae	*Azadirecta indica*	0.9	0.9	0.9	2.7
67.		*Melia azedarach*	1.2	1.2	1.2	3.6
68.		*Soymida febrifuga*	1.6	1.7	1.6	4.9
69.	Mimosaceae	*Pithecellobiuman gulatum*	0.6	0.4	0.6	1.6
70.	Moraceae	*Ficus glomerate*	1.5	1.6	1.5	4.6
71.		*Ficusi nfectoria*	0.5	0.6	0.5	1.6
72.		*Ficus religiosa*	0.5	0.8	0.5	1.8
73.		*Ficus bengalensis*	1.6	1.6	1.6	4.8
74.		*Ficus lepidosa*	0.6	0.4	0.6	1.6
75.		*Morus Iaevigates*	0.9	1.1	0.9	2.9
76.		*Artocarpus heterophyllus*	0.4	0.5	0.4	1.3

continued on following page

Table 12. Continued

S. No.	Family	Botanical Name	Rf	Ra	Rd	IVI
77.	Moringaceae	*Moringa pterygosperma*	0.6	0.6	0.6	1.8
78.		*Moringa oleifera*	1.3	1.2	1.3	3.8
79.	Musaceae	*Musa sps*	0.8	0.9	0.8	2.5
80.	Myrtaceae	*Syzygium cuminii*	0.5	0.9	0.5	1.9
81.		*Eucalyptus sp.*	0.9	0.5	0.9	2.3
82.		*Psidium guajava*	0.9	1.1	0.9	2.9
83.	Oleaceae	*Schreberas wietenioides*	1.1	1	1.1	3.2
84.	Oxalidaceae	*Averrhoa carambola*	1.2	1.2	1.2	3.6
85.	Pinaceae	*Eucalyptus maculata*	1.8	1.2	1.8	4.8
86.	Poaceae	*Bambusa pallida*	0.6	0.6	0.6	1.8
87.		*Bamboosa hamiltonii*	1.2	1.2	1.2	3.6
88.		*Bambusa nutans*	0.9	0.9	0.9	2.7
89.		*Bambusa arundinacea*	1.2	1.2	1.2	3.6
90.	Provenance	*Gamelina arborea*	0.9	0.9	0.9	2.7
91.	Phyllanthaceae	*Phyllanthus emblica*	1.6	1.6	1.6	4.8
92.	Rhamnaceae	*Ziziphus jujuba*	1.5	1.5	1.3	4.3
93.	Rubiaceae	*Morinda tinctoria*	1	1.5	1.2	3.7
94.		*Mitragyana parvifolia*	0.5	0.3	0.5	1.3
95.		*Wendlandia exserta*	1	0.9	0.8	2.7
96.		*Gardenia latifolia*	1.2	1.2	1.2	3.6
97.		*Gardenia turgida*	1.2	1.1	1.3	3.6
98.		*Ixora parviflors*	0.23	0.5	0.2	0.93
99.	Rutaceae	*Feronia limonia*	0.9	0.9	0.9	2.7
100.		*Limonia crenulata*	0.2	0.2	0.3	0.7
101.		*Murrasya koenigii*	1.2	0.3	1.2	2.7
102.	Salicaceae	*Salix tetrasperma*	0.6	0.6	0.6	1.8
103.	Simaroubaceae	*Ailanthus excelsa*	0.26	0.3	0.6	1.16
104.	Tiliaceae	*Grewia tiliaefolia*	0.26	0.3	0.2	0.76
105.	Ulmaceae	*Holoptelea integrifolia*	0.45	0.4	0.5	1.35
106.	Verbenaceae	*Vitex peduncularis*	0.25	0.5	0.2	0.95
107.		*Tectona grandis*	0.9	1.6	0.8	3.3
Total			100	100	100	300

Table 13. Trees within right of way of project road AH-48

Chainage	Length	No of Trees on Left Side	No of Trees on Right Side
0-300 m	300 m	13	16
300-600 m	300 m	25	29
600-900 m	300 m	62	69
900-1200 m	300 m	78	95
1200-1500 m	300 m	86	64
1500-1800 m	300 m	68	98
1800-2100 m	300 m	92	88
2100-2400 m	300 m	101	86
2400-2700 m	300 m	62	76
2700-2915 m	215 m	21	27
Total	2915 m	608	648

Table 14. Shannon Wiener Index (H) and its variance for Faunal Species spotted in the study area. (Significant at P <0.005)

Faunal Species	Shannon Wiener Index (H) and Its Variance	Distance from AH-48		
		100 m	200 m	300 m
Mammals	H	1.124	1.966	2.128
	Variance H	0.005653	0.001985	0.001630
Birds	H	2.581	4.015	6.155
	Variance H	0.0009896	0.002389	0.008217
Butterfly	H	1.032	3.125	5.925
	Variance H	0.000301	0.000365	0.006897
Herpetofauna	H	2.102	4.259	5.125
	Variance H	0.003184	0.000977	0.001013

Shannon Wiener Index increased inside the dense forest.

include males, females and calves in suitable proportion as compared to 149 rhinos in 2011. According to forest sources, maximum number of rhinos were spotted in Jaldapara east range (97 individuals). Fifteen rhinos were spotted in Kodalbusty range and two in Chilapata range. Rhinos are voracious consumers and need at least 50 kg of vegetable every day. Again, their food habit is very selective. They forage only on the young twigs of edible plants and explains their need for wider areas for their foraging. Rhinoceros reportedly does not cross the sub-project road section as they mostly prefer to stay in deeper part of the Jaldapara National Park. In AH-48 sub-project road alignment, no endemic wildlife species was found.

- **Wetlands Along Proposed Alignments AH-48 Sub-project:** No prominent wetlands found along AH-48 sub-projects were found.
- **Dependence of People on Flora and Fauna along proposed alignments AH-48 Sub-projects:** Very few people were found dependent on selling fuel woods from neighbouring protected forest or naturally growing tree species.

The biological stress due to road passing through Jaldapara National Park was negligible due to small stretch at one end, however, four species of the study area were protected under Schedule –I. Out of which Indian Elephant was frequent visitor of the area and commonly found crossing the road. Hence, there is an urgent need of conservation plan implementation. Local people should be aware about the importance of wildlife and no poaching or hunting should be allowed by any means. The floral species were also common in nature and were protected at their site. No tree cutting was observed and all sign boards were sighted at their place.

RECOMMENDATION

It is strongly recommended to prepare the conservation plan for elephant as elephant movement was observed in the area. The study area where the road is passing has no REET species (flora and fauna) observed. The maintenance of road side plants/tree is recommended along with proper signage on turns and movement of wildlife. Moreover, there is an urgent need of public awareness for the importance of wildlife, as illegal hunting, killing or capturing of wild animals was recorded from locals living in the forest and nearby villagers.

CONCLUSION

The study area had 107 trees and shrub species; 22 species of herbs and 9 species of grasses to represent the floral diversity of the region. While in faunal diversity, 68 species of birds, 10 species of butterfly, 8 species of herpetofauna, 7 species of mammals and 7 species of fishes were recorded during study period. The study area had no endemic or endangered floral species while 4 mammal species (Indian Elephant, Indian hog deer, Hispid hare, Hog badger) recorded from study area were protected under Schedule – I of Indian Wildlife Protection Act, 1972. Elephant was the frequent visitor of the area. The biological stress of the area was not critical but required conservation plan for schedule – I species. The railway line was passing parallel to road at a distance of 300m – 500m. Due to this, no major animal other than elephant comes in that area. The biodiversity of that area was maintained from pre-construction to post construction. Conservation plan for wildlife should be prepared and implemented to save the wildlife of the area.

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Chapter 12
Sand Mining and Biodiversity Decline With Reference to Rajasthan Area:
Mining and Biodiversity

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ABSTRACT

Biodiversity sustains human livelihoods and life itself. An estimated 40% of the global economy is based on biological products and processes. As the biodiversity harbours a great amount of diversity with respect to species diversity, crop diversity, etc., which provides a rich amount of a well-evolved systems over time and background support for rich resources, the mining is a destructive activity generated by human beings for providing strength and security to their living standards. The mining in the concerned zones provides raw materials in the form of crusher, gravels and stones, etc. for construction of roads, railway lines, and other infrastructure. It results in the loss of biodiversity of both flora and fauna and physiographic features of the concerned region. After the mining operation in any area is over, the sign of same lie for decades and maybe forever. It results in creation of so many environment-related problems and health hazards. Mining poses serious and highly specific threats to biodiversity.

INTRODUCTION

Biodiversity is a term applied all the biological capital occurring within a particular area. It captures both variety, in terms of genes and species and processes, the complex and diverse interactions between different species and between living organisms and the non-living environment. Biodiversity is not static;

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climate, soil chemistry and genetic constantly change, altering the balance between species. Competition for resources forces the evolution of new species as well as co-evolution between those already present. Species that are less well adapted to the environment or unable to compete with others, may disappear, while others may take their place (MMSD, 2001). The mining is that a process in which the materials (stones) are removed from the sites by boring and blasting and then send for further processes like crushing, grinding, *etc.* Both types of mining either open cast or underground, cause destruction of natural scene. This activity has led to development in all the sectors *viz.* social, economic, transport, educational and industrial *etc.* in one hand and so many serious concerns related with physical, chemical and biological environment in another. There is no doubt as to make our society healthy and prosperous; environment which lay developmental foundation of a nation, must be healthy and prosperous (Musa & Jiya, 2011). Minerals are non-renewable limited natural resources and constitute vital raw materials in a number of basic and important industries. The extraction of minerals from nature often cause imbalances, which adversely affect the environment. The environment impacts of mining are on wildlife and fishery habitats, the local climates, water balance and the pattern of rainfall, the depletion of forest, sedimentation and the disruption of the ecology. Therefore, management of the country's mineral resources must be closely associated with her overall economic development and environmental protection and preservation strategy. India has huge mineral resources. Thus, the mining industry is a very important industry in India (Mehta, 2002).

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. It is the most widely used product for different purpose with majority in construction industry. Sand and gravel are mined world-wide and account for the largest volume of solid material extracted globally. It is used in construction of buildings, house and other infrastructure projects (*e.g.* roads, bridges, airports *etc.*) thereby provides economic and social benefits to the country. Based on a rough estimation, it is estimated by MoM that the total consumption of sand in India is 700 million tonnes in 2016-17, which has been derived from the cement consumption (MoM, 2018b). Sand is mainly found in the oceans, coastal areas, rivers, lakes, streams, reservoirs, flood plains, deserts, agricultural fields, mountains and hills. Sand and gravel have long been used as aggregate for construction of building and roads. The demand for these materials continues to rise. The main source of sand is from in-stream mining. (MNREDIDM, 2009). Among all the sources, river bed is the most common and prevalent source of sand in the country. Sand is mined from these areas either manually or mechanically using machineries (MoM, 2018b). Industrial sand and gravel are produced, processed and used in construction and industry all over the world. As less expensive and readily accessible resource many companies are involved in its mining both legally and illegally without considering the damage they are causing to the environment (Tariro, 2013).

BACKGROUND

The mining in India has a respectable antiquity of pre-Harappa period. This is evident from the extensive workings for gold and base metals in Hutti Gold Mines in Raichur and at Rajpura – Dariba. The task of tracing the status of technology or for that matter the chronological evolution of mining in India between 1400-1800 Anno Domini (A.D.) is beset with formidable difficulties. There is much evidence that diamond mining activity was pre-eminent during this period. The French jeweler, Jean Baptiste Tavernier, in his account of travels (1665-69) gave details of three diamondiferous region of India (Bagchi & Ghose, 1980). India developed strong technology of mining and smelting, which is rather older than Harrapan civilization. Zinc technology was first started 2000 years ago. However, mining for most of the other minerals is of recent origin and some minerals like rock phosphates were discovered after independence (Chauhan, 2010).

As per the MMSD (2001) in recent times the impetus to the mineral development was imparted in the country only after the political independence came in the year 1947 when the significance of role of minerals was realized in nation building. On the eve of Independence, the annual value of mineral production was merely Rs. 0.58 billion and only a few minerals were mined and the country largely depended on imports of commodities such as copper, lead, zinc, sulphur, graphite, petroleum and their products. The inventory details were available only in respect of coal, iron ore, chromite, bauxite, manganese ore and magnesite. The Indian Bureau of Mines (IBM) was established to look after the scientific development and conservation of mineral resources. IBM was also assigned the responsibility of conducting exploration with more of emphasis on coal, iron ore, limestone, dolomite and manganese ore keeping in view the requirement of the proposed steel plants. Later, in 1972 when the Mineral Exploration Corporation was established, this function was transferred to it.

INDIAN SCENARIO OF MINING INDUSTRY

As per MoM (2018a) Indian mining industry is characterized by a large number of small operational mines. Reporting mine is defined as A mine reporting production or reporting nil production during a year but engaged in developmental work, such as, overburden removal, underground driving, sinking work, exploration by pitting, trenching or drilling as evident from the MCDR returns. The number of mines which reported mineral production (excluding minor minerals, petroleum (crude), natural gas and atomic minerals) in India was 1531 in 2017-18 as against 1508 in the previous year. Out of 1531 reporting mines, 230 were located in Tamil Nadu, followed by Madhya Pradesh (197) Gujarat (191), Karnataka (142), Odisha (132), Andhra Pradesh (129), Chhattisgarh (112), Goa (87), Rajasthan (85), Maharashtra (75) and Jharkhand (58). These 10 States together accounted for 94% of total number of mines in the country in 2017-18.

India continued to be wholly or largely self-sufficient in minerals which constitute primary mineral raw materials to industries, such as, thermal power generation, iron and steel, ferro-alloys, aluminium, cement, various types of refractories, china clay-based ceramics, glass, chemicals like caustic soda, soda ash, calcium carbide, Titania white pigment etc. India is, by and large, self-sufficient in coal (with the exception of very low ash coking coal required by the steel plants) and lignite among mineral fuels; bauxite, chromite, iron and manganese ores, ilmenite and rutile among metallic minerals; and almost all the industrial minerals with the exception of chroysotile asbestos, borax, fluorite, kyanite, potash, rock phosphate and elemental sulphur. Despite high degree of self-sufficiency, some quantities of flaky and amorphous graphite of high fixed carbon, kaolin and ballclay for special applications, very low silica limestone, dead-burnt magnesite and sea water magnesia, battery grade manganese dioxide, etc. were imported to meet the demand for either blending with locally available mineral raw materials and /or for manufacturing special qualities of mineral-based products. To meet the increasing demand of uncut diamonds, emerald and other precious and semiprecious stones by the domestic cutting and polishing industry, India continued to depend on imports of raw uncut stones for their value-added re-exports (MoM, 2019).

MINING IN RAJASTHAN

As per GoR (2015) the Rajasthan State is located in the north western part of India. It is the largest State in the country with an area of 3,42,239 sq. km., encompassing about 11% of the total geographical area of the country. The State is bounded between Latitude 230 03'- 300 12' N and Longitude 690 29'-780 17'E. Rajasthan's geographical area is marked with diversity of land type and is characterized by sand dunes, fertile plains, rocky undulating land and some forested regions. The Aravalli hill range, considered as the oldest in the world, bisects the State almost diagonally. Almost two third State is enveloped by the Thar Desert having arid and semi-arid climatic conditions. Only 9.36% of the State is under forest cover. The Population of Rajasthan is 72,307,157. Every facet of Rajasthan is unique and fascinating so as its geology. Its rocks range in age from one of the oldest feature (more than 3,500 million years' age) to recent, displaying a wide range of rocks and mineral deposits. Mining and smelting of its base metal deposits are also one of the oldest in world dating back to more than 2,500 years before present (500 Before Crisis) Rajasthan is considered as a museum of minerals both metallic and non-metallic including renowned building stones and is also resources of Radioactive minerals, Lignite, Petroleum and Natural Gas. Rajasthan is the richest State in terms of availability and variety of minerals in the country. The State is fortunate to have 79 varieties of minerals, out of which 57 are being produced. Its share is 9% in the country's total mineral production. The State is a leading producer of Lead, Zinc, Gypsum, Soapstone, Ball Clay, Calcite, Rock Phosphate, Feldspar, Kaolin, Copper, Jasper, Garnet, Wollastonite, Emerald, Silver, etc. It is renowned world over for its deposits of Marble, Sand Stone and other decorative stones.

As per the RSBB (2019) though a large percentage of the total area is desert and even though there is little forest cover, Rajasthan has a rich and varied flora and fauna. The natural vegetation is classed as Northern Desert Thorn Forest. These occur in small clumps scattered in a more or less open forms. Density and size of patches increase from west to east following the increase in rainfall. The North-western thorn scrub forests lie in a band around the Thar Desert, between the desert and the Aravallis. The Aravalli and the south-eastern region is home to the dry deciduous forests, with tropical dry broadleaf forests that include teak, Acacia, and other trees. The hilly Vagad region lies in southernmost Rajasthan, on the border with Gujarat. With the exception of Mount Abu, Vagad is the wettest region in Rajasthan, and the most heavily forested. North of Vagad lies the Mewar region, home to the cities of Udaipur and Chittaurgarh. The Hadoti region lies to the southeast, on the border with Madhya Pradesh. North of Hadoti and Mewar lies the Dhundhar region, home to the state capital of Jaipur. Mewat, the easternmost region of Rajasthan, borders Haryana and Uttar Pradesh. All these regions have varied flora and fauna distinct to the region.

India is rich in mineral deposits and Rajasthan ranks second only to Bihar. Some minerals like Wollastonite and Jespar are found only in Rajasthan. It has 97% of Zinc, 93% of Gypsum, 96% of fluorite, 70% of sandstone and limestone, 89% of asbestos, 90% of marble, 70% of calcite, 80% of lead, 56% of tungsten, 75% of soapstone deposits of India. In order to evaluate scientifically the effect of mining on environment, a study sponsored by Department of Environment and forest, Government of Rajasthan, was carried out in Bijolia Mining area (Chauhan, 2010). The findings were sensational and revealing. Bijolia is one of the largest mining areas of Rajasthan where mining on large scale commenced nearly three decades ago. Mining activity in Bijolia area is spread over an area of about 61.7 km^2 and covers parts of Bhilwara, Bundi and Chittorgarh districts of Rajasthan and Mandsaur district of Madhya Pradesh (Prasad, 1984). In Rajasthan Ajmer, Bhilwara, Bikaner, Dungarpur, Jaipur, Pali, Rajsamand and Udaipur are its main mining districts. But major minerals do not reflect the true picture of mining in Rajasthan, minor minerals and stone quarries do. This sector provides employment to more about three million workers throughout the state. Rajasthan has thousands of unorganised mines, which can be as small as one twentieth of a hectare. They fall out of the purview of government control and there are no accounts of these mines and the State Government has failed to regulate illegal mining in forest areas because many unauthorised small illegal mines are also there and these mines located in remote areas, including in forest area are very difficult to monitor and another reason is the lack of assessment of Rajasthan's natural resources (Gahlot, 2014).

BIODIVERSITY OF RAJASTHAN

The Rajasthan state have a various type of floral and faunal diversity, some of biodiversity species are given in table 1.

IMPACT OF MINING ACTIVITY ON BIODIVERSITY

Mining affects biodiversity at multiple spatial scales (site, landscape, regional and global) through direct (*i.e.* mineral extraction) and indirect processes (via industries supporting mining operations and external stakeholders who gain access to biodiversity-rich areas as the result of mining) (Sonter et al., 2018).

Impact of Mining

Wildlife fauna includes the non-domesticated animals (or other organisms). Mining heavily impacts the wild fauna through the removal of vegetation and topsoil, ecosystem destruction, the release of pollutants, and the generation of noise. Wildlife fauna includes the non-domesticated animals (or other organisms). Mining heavily impacts the wild fauna through the removal of vegetation and topsoil, ecosystem destruction, the release of pollutants and the generation of noise. Wildlife fauna includes the non-domesticated animals (or other organisms). Mining heavily impacts the wild fauna through the removal of vegetation and topsoil, ecosystem destruction, the release of pollutants, and the generation of noise. Wildlife fauna includes the non-domesticated animals (or other organisms). Mining heavily impacts the wild fauna through the removal of vegetation and topsoil, ecosystem destruction, the release of pollutants and the generation of noise.

An accepted part of pre-mining investigations is a survey of existing flora and fauna. Cataloguing individual species and grouping these into floral habitats are the first tasks. However, apart from identifying rare and endangered plants and animals, planners must consider the ecological integrity of an area and what role it plays as a part of a regional environment. Relevant questions include how well species and habitats are protected in parks and conservation areas and the role of the site as a part of a habitat corridor. The species selected for establishment will depend on the future land use of the area, soil conditions and climate. If the objective is to restore the native vegetation and fauna, then the species are pre-determined. Some indigenous species may not thrive in, areas where soil conditions are substantially different after mining: Climate, soils and the rehabilitation strategy are important considerations in minimizing impacts on native flora and fauna (Saviour, 2012).

Table 1. Biodiversity in Rajasthan

S. No.	Biodiversity of Rajasthan	Numbers
	Plant Biodiversity	
a)	**Angiosperms**	
	Wild Species	1714
	Agro-horticultural Species	320
b)	**Gymnosperms**	
	Wild Species	01
c)	**Cryptogams**	
	Liverworts and Hornworts	37
	Mosses	42
	Ferns	60
d)	**Plants of Special Interest**	
	Red data Species	02
	Orchids	14
	Terrestrial	08
	Epiphytic	06
	Parasitic Species	10
	Carnivorous Species	05
	Endemic Species	19
	Medicinal Plants Species	157^{+}
	Animal Biodiversity	
a)	**Fish**	114
b)	**Amphibians**	14
c)	**Reptiles**	14
d)	**Mammals**	87
e)	**Birds**	510
f)	**Some Interesting Aspects of Fauna**	
	Endangered-mammals	16
	Endangered-Reptiles	08
	Crt. Endangered-Birds	03
	Endangered	02
	Vulnerable	13
	Conservation dependent	01
	Threatened	14
	Red data Bird Species	14
	Animals: Schedule I	
	Mammals	15
	Reptiles	05
	Birds	6(+ Accipitridae)

(RSBB, 2019)

AS per Singh & Singh (2016) wildlife fauna includes the non-domesticated animals (or other organisms). Mining heavily impacts the wild fauna through the removal of vegetation and topsoil, ecosystem destruction, the release of pollutants and the generation of noise.

- **Habitat Loss:** Mining activities mainly disturb, remove or redistribute the land surface with some impacts being short-term and some long-term. During the excavation or mine spoil piling, the wild life species along with the sedentary species such as invertebrates, reptiles, burrowing rodents and small mammals are destructed or displaced.
- **Habitat Fragmentation:** Habitat fragmentation is a serious ecological impact that occurs due to breaking of a large land area into smaller patches. It affects the migratory routes of the wildlife by making the dispersal of native species from one patch to the other difficult or impossible. The species requiring large forest patches mostly disappear due to habitat fragmentation.

Due to mining activity the land has lost viability for agricultural purposes, as well as loss of habitat for birds and other animals, in addition to erosion. This has culminated in the destruction of the luxuriant vegetation, biodiversity, cultural sites and water bodies (Albert, 2015). Mining causes massive damage to landscape and biological community as plant communities get disturbed and subsequently become impoverished thus presenting a very rigorous condition for its growth. Dumping of mine products will result into destruction of surrounding vegetation, soil and water pollution. Soil Nutrients play a vital role in enhancing the growth of forest because plants require essential soil nutrients such as nitrogen, calcium, potassium, phosphorus, among others which are assimilated from the soil to complete their vegetative and reproductive life circles (Unanaonwi & Amonum, 2017).

Impacts on biodiversity may occur at any of the following levels as per Naturenomics (2011):

- **Ecosystem Level**: If a potential project changes the size, diversity or spatial variation of the ecosystem. An impact to an ecosystem can occur if its ability to provide long-term function or services is changed.
- **Species Level**: Loss of species in certain area can reduce its area of occupancy and fragment populations changing distributional range.
- **Genetic Level:** Diversity within an ecosystem is also associated with genetic diversity of populations. Ecosystem level and species level changes can lead to genetic level changes which are difficult to measure.

Cumulative Impacts

In situations where multiple mining projects (or other projects, such as industrial or infrastructure projects) are being implemented within a broad geographic area (such as a watershed or valley area), it is important to consider the cumulative impacts on biodiversity (that is, the additive effects of other projects, such as multiple coal mines in a coal basin, together with any associated infrastructure). Good Practice Guidance for Mining and biodiversity, (ICMM) suggests that while assessing cumulative impacts, attention should be given to:

- Existing or proposed activities in the area and the likely effect on biodiversity of those proposals in conjunction with the proposed mining activity.

- Synergistic effects of individual project impacts when considered in combination.
- Known biodiversity threats in the area and the likely contribution of the proposed mining activity to increasing or decreasing those stresses.

Loss of Ecosystem Services

Mining may result in the removal of ecosystems or habitats. Permanent habitat loss may occur due to extensive clearing for the mine location, while temporary habitat loss may occur due to limited clearing for exploration access. Changes in ecosystem affect the ecosystem services. E.g. clean water for the local communities, fuel wood and fodder availability, loss of non-timber forest produce like bamboo, edible fruits and vegetables etc. It is very complicated to assess the loss of some ecosystem services like pollinator services. Loss of habitat may affect the pollinator populations which in turn will have a negative impact on the fruit and grain crops owing to the non-availability of appropriate pollinators.

Habitat Fragmentation Impacts

The isolation or fragmentation of ecological habitats can have significant impact on biodiversity. Fragmentation may disrupt ecological processes critical to the maintenance of biodiversity especially if over long periods. Hence, rehabilitation of areas within short period and maintaining ecological corridors become necessary mitigation measure.

Alteration of Ecological Processes

The alteration of ecological processes like hydrological regime, changes in structural diversity, vegetation, disruption of predator-prey relationships, disruption of soil structure, introduction of burning as weed control can disrupt natural ecosystem recovery processes, making recovery difficult or impossible.

Pollution Impacts

Pollution of air, water and soils at or around a mine will directly and indirectly affect biodiversity by altering the optimal environmental conditions required by the organisms.

Disturbance Impacts

Disturbance provides competitive advantage to invasive species of plants and animals. Mining activities like digging, soil removal, noise, artificial lighting and vibrations may also disturb wildlife by creating difficulties in roosting, nesting, dispersal *etc.*

Concerns over impact on biodiversity in the mining areas have led to formulation of various precautionary measures, regulations and laws. These have been modified and amended at times. It is necessary under the current laws to carry out biodiversity assessment and impact analysis as part of an Environmental Impact Assessment (EIA) of the mining project, to obtain environmental clearance, define an environmental management plan (EMP), including biodiversity management and mitigation measures and mine closure plan.

BIOLOGICAL ENVIRONMENT NEAR MINING AREA IN KOLAYAT TEHSIL, BIKANER DISTRICT OF RAJASTHAN

The biological study of the area is conducted to understand the ecological status of the existing flora and fauna to generate baseline information and evaluate the probable impacts on the biological environment.

Flora

The flora is basically the plant life that is present in a particular region or habitat or at a particular time. The natural floral species found in the whole of the area are given in Table 2.

Fauna

Fauna is the animal life that is present in a particular region or habitat or at a particular time. Irrespective of its unfriendly terrain, Rajasthan gives shelter to a variety of animals and birds. This area is relatively calm and there is no source of high noise level. The natural fauna found in the whole of the area are given in Table 3.

IMPACT OF MINING ACTIVITY ON BIODIVERSITY OF KOLAYAT AREA

The impact on biodiversity is difficult to quantify because of its diverse and dynamic characteristics.

Impact of Sand Mining on Flora and Fauna of Kolayat Tehsil

Mining activities leads to a dusty environment which is responsible for deposition of dust on foliage of all green plants in the area. It not only impairs with the process of photosynthesis but also destruction of natural habitat leads to extinction of a number of plant species of medicinal importance and aesthetic value. The dust pollution of the fugitive dust and borne dust cause due to excavation. The effect of particulate matter on vegetation is in the form of incrustation, plugging of stomata and loss of chlorophyll and reduction of photosynthesis process. Disturbance in plant metabolism due to deposition of dust particles on foliar surfaces leads to reduction in plant growth. The activities such as operation of machinery as excavator and movement of dumpers/trucks can have impact in terms of disturbance due to noise; interference in movement *etc.* Due to uncontrolled mining and pollution in this area flora and fauna is facing a stressed condition and interference of human activities in their natural habitat leads to entry of some of the wild animals in human habitat and they are either killed by poachers or even other animals like dogs *etc*.

CONCLUSION

Minerals are the basic raw material for all industries other than those which are based on agricultural produce. Rajasthan has basic raw material in the form of minerals for ceramic refractories, abrasives, chemical and fertilizer, glassware, fire proof and grinding material etc. It has base metals like lead,

Table 2. Flora of Kolayat Tehsil

S. No.	Botanical Name	Common Name	Family
Trees			
1.	*Acacia nilotica*	Babool, Kikar	Mimosaceae
2.	*Ziziphus nummularia*	Ber	Rhamnaceae
3.	*Prosopis cineraria*	Khejri	Mimosaceae
4.	*Capparis decidua*	Ker	Capparidaceae
5.	*Calotropis procera*	Aak	Asclepidaceae
6.	*Prosopis juliflora*	Vilayti Babool	Fabaceae
7.	*Salvadora oleiodes*	Jhal	Salvadoraceae
8.	*Azadirachta indica*	Neem	Meliaceae
9.	*Acacia senegal*	Kumbhat	Mimosaceae
10.	*Ficus religiosa*	Peepal	Moraceae
11.	*Salvadora persica*	Saltbush/ Pilu	Salvadoraceae
12.	*Dalbergia sissoo*	Shisham	Fabaceae
13.	*Acacia senegal*	Kumttha, Khair	Mimosaceae
14.	*Cordia gharaf*	Gondhi	Boraginaceae
15.	*Eucalyptus camaldulensis*	Safeda	Myrtaceae
16.	*Ficus benghalensis*	Bargad	Moraceae
17.	*Ficus religiosa*	Pipal	Moraceae
18.	*Boswellia serrata*	Luban	Burseraceae
19.	*Moringa oleifera*	Senjana	Moraceae
20.	*Butea monosperma*	Dhak	Fabaceae
21.	*Tamarindus indica*	Imli	Caesalpiniaceae
22.	*Phoenix sylvestris*	Khajur	Arecaceae
23.	*Crotalaria burhea*	Senia	Fabaceae
Shrubs and Herbs			
1.	*Aerva persica*	Bui	Amaranthaceae
2.	*Argemone mexicana*	Satyanasi	Papaveraceae
3.	*Crotalaria burhia*	Sinia	Fabaceae
4.	*Datura innoxia*	Dhatura	Solanaceae
5.	*Echinops echinatus*	Oont-Kateli	Asteraceae
6.	*Tribulus terrestris*	Gokhru	Zygophyllaceae
7.	*Leptadenia pyrotechnica*	Khimp	Asclepidaceae
8.	*Calotropis procera*	Akra	Asclepidaceae
9.	*Capparis decidua*	*Capparis decidua*	Capparidaceae
10.	*Ziziphus nummularia*	Jhar Ber	Rhamnaceae
11.	*Calotropis gigantea*	Safed Aak	Asclepiadaceae
12.	*Calotropis procera*	Aak	Asclepiadaceae
13.	*Capparis sepiaria*	Kanthari	Capparaceae

continued on following page

Table 2. Continued

S. No.	Botanical Name	Common Name	Family
14.	*Cassia auriculata*	Tarwar	Caesalpiniaceae
15.	*Clerodendrum phlomidis*	Arna	Verbenaceae
16.	*Commiphora wightii*	Gugul, Gugal	Burseraceae
17.	*Cordia gharaf*	Gondhi	Boraginaceae
18.	*Dendrocalamus strictus*	Lathi Baans	Bamboosoideae
19.	*Euphorbia caducifolia*	Thor	Euphorbiaceae
20.	*Justicia adhatoda*	Arusa	Acanthaceae
21.	*Lantana camara*	Raimuniya	Verbenaceae
22.	*Ricinus communis*	Arandi	Euphorbiaceae
23.	*Vortex negundo*	Nirgundi	Verbenaceae
24.	*Achyranthes aspera*	Chirchita	Amaranthaceae
25.	*Boerhavia diffusa*	Punarnava	Nyctaginaceae
26.	*Cassia occidentalis*	Kasunda	Caesalpiniaceae
27.	*Cassia tora*	Panwar	Caesalpiniaceae
28.	*Commelina benghalensis*	Kankawa	Commelinaceae
29.	*Convolvulus microphyllus*	Sankh Pushpi	Convonvulaceae
30.	*Crotalaria medicaginea*	Rattlepod	Fabaceae
31.	*Cyperus rotundus*	Motha	Cyperaceae
32.	*Launaea procumbens*	Jangli gobhi	Asteraceae
33.	*Lepidagathis trinervis*	Prather phod buti	Acanthaceae
34.	*Ocimum americanum*	Kali tulsi	Lamiaceae
35	*Peristrophe paniculata*	Atrilal	Acanthaceae
36.	*Pulicaria undulata*	Sontikli	Asteraceae
37.	*Sida acuta*	Baraira	Malvaceae
38.	*Sida cordata*	Bhuini	Malvaceae
39.	*Sida cordifolia*	Kharinta	Malvaceae
40.	*Sida ovata*	Bal	Malvaceae
41.	*Solanum viarum*	Jungle Bengun	Solanaceae
42.	*Tephrosia purpurea*	Sharpunkha	Fabaceae
43.	*Tridax procumbens*	Khal-Muriya	Asteraceae
44.	*Triumfetta rhomboidea*	Chikti	Tiliaceae
45.	*Xanthium strumonium*	Chota Gokhru	Asteraceae
Grasses			
1.	*Cynodon dactylon*	Doob	Poaceae
2.	*Cenchrus ciliaris*	Dhaman	Poaceae
3.	*Eragrostis*	Candy grass	Poaceae
4.	*Sorghum halepense*	Johnson grass	Poaceae
5.	*Aristida funniculata*	Aristida	Poaceae

continued on following page

Table 2. Continued

S. No.	Botanical Name	Common Name	Family
6.	*Brachiaria ramosa*	Brown top millet	Poaceae
7.	*Brachiaria reptans*	Running grass	Poaceae
8.	*Cenchrus biflorus*	Indian Sandbur	Poaceae
9.	*Digitaria ciliaris*	Crab grass	Poaceae
10.	*Paspalum distichum*	Knot grass	Poaceae
11.	*Saccharum munja*	Sarkanda	Poaceae
12.	*Spoonbills helvolus*	Sakaton grasses	Poaceae
13.	*Imperata cylindrica*	Dabh, Khans	Poaceae

Table 3. Fauna of Kolayat Tehsil

S. No.	Botanical Name	Common Name	Family
1.	*Calotes versicolor*	Indian Garden Lizard	Agamidae
2.	*Hemiacetals' flaviviridis*	House Gecko	Gekkonidae
3.	*Lepus nigricollis*	Indian Hare (Rabbit)	Leporidae
4.	*Meriones hurrianae*	Desert Gerbil	Muridae
5.	*Mus musculus*	House Mouse	Muridae
6.	*Rattus rattus*	Black Rat	Muridae
7.	*Hemiechinus auritus*	Long-eared hedgehog	Hesperlidae
8.	*Vulpes bengalensis*	Indian Fox	Amathusildae
9.	*Merops orientalis*	Green Bee-eater	Meropidae
10.	*Eudynamys scolopacea*	Common Koel	Cuculidae
11.	*Corvus splendens*	House crow	Corvidae
12.	*Passer domesticus indicus*	Indian House-Sparrow	Passeridae
13.	*Columba livia*	Rock Pigeon	Columbidae
14.	*Sturnia pagodarum*	Brahminy Starling	Sturnidae
15.	*Bubulcus ibis*	Cattle Egret	Ardeidae
16.	*Acridotheres tristis*	Common Myna	Sturnidae
17.	*Centropus sinensis*	Greater Coucal	Cuculidae
18.	*Francolinus pondicerianus*	Grey Francolin	Phasianidae
19.	*Upupa epops*	Hoopoe	Upupidae
20.	*Streptopelia decaocto*	Collared Dove	Columbidae
21.	*Coracias benghalensis*	Indian Roller	Coraciidae
22.	*Vanellus indicus*	Red-wattled Lapwing	Charadriidae
23.	*Psittacula krameri*	Rose-ringed Parakeet	Psittacidae
24.	*Athene brama*	Spotted Owlet	Strigidae
25.	*Ardeola grayii*	Paddy bird	Ardeidae

continued on following page

Table 3. Continued

S. No.	Botanical Name	Common Name	Family
Avifauna			
26.	*Pycnonotus leucogenys*	White-eared Bulbul	Pycnonotidae
27.	*Bubo bubo*	Owl	Strigidae
28.	*Aegypius monachus*	Vulture	Accipitridae
29.	*Pycnonotus cafer*	Red-vented bulbul	Pycnonotidae
30.	*Turdoides malcolmi*	Large grey babbler	Timaliinae
31.	*Orthotomus sutorius*	Tailor Bird	Cisticolidae
32.	*Pavo crisatus*	Peafowl	Phasianidae
33.	*Anas platyrhynchos*	Domestic Duck	Anatidae
34.	*Grus antigone*	Saras	Gruidae
Mammals			
35.	*Funambulus pennanti*	Striped squirrels	Sciuridae
36.	*Felis chaus*	The Jungle cat	Felidae
37.	*Hemiechinus collaris*	Hedge hog	Erinaceidae
38.	*Boselaphus tragocamelus*	Nil gai	Bovidae
39.	*Hystrix indica*	The Indian Porcupine	Hystricidae
40.	*Herpestes edwardsii*	The common mangoose	Herpestidae
41.	*Golunda ellioti*	Indian bush rat	Muridae
42.	*Gazella benettii*	Chinkara	Bovidae
43.	*Canis aureus*	Jackal	Canidae
44.	*Histricus Indica*	Sehi	Canidae
45.	*Pteropus sp*	Bats	Pteropodidae
Reptiles			
46.	*Chamaeleo zeylanicus*	Indian chemeleon	Chamaeleonidae
47.	*Uromastyx hardwickii*	Indian spiny tailedlizard	Agamidae
48.	*Eryx johnii*	Indian Sand Boa	Boidae
49.	*Bungarus cacrulcus*	Indian Krait	Elapidae
Amphibians			
50.	*Rana hexadactyla*	Indian Pond Frog	Dicroglossidae

zinc and copper which can form foundation of many industries. Uncontrolled mining and blasting in Rajasthan, affects other country also like if uncontrolled mining happens in Rajasthan than its effects on all those country where the Aravalli range situated. In order to reduce environmental risks and vulnerability, sand miners need to first remove vegetation properly and store it somewhere for further use during rehabilitation. Sand miners should properly fence their sites so as to prevent accidents such as animals falling into the mine pits. Sand miners should also consider proper methods of mining that will reduce or mitigate soil erosion. Rehabilitation after mining is highly recommended and should be one of the conditions for issuing sand mining certificates. Alternative sources of livelihood such as farming should be encouraged for these rural communities. To protect our earth from excessive mining and for the immediate remedy there is an urgent need of a well-defined specific mining law, based on conservation and Environment Management Plan with special reference to the site of mining activity, removal and disposal of surficial materials.

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Chapter 13
Survey Methodology for Biodiversity Assessment:
An Overview

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ABSTRACT

Rapid urbanization, population explosion, and developing technology have degraded natural habitat of flora and fauna. They can't get proper natural habitat and environment. Because of these reasons, they can't survive. They are in danger. We have to save them. If we can't save them, our whole ecological cycle will be disturbed, and it will create problems for us. So, we have to find reasons for extinction of flora and fauna. For that, it is necessary to do biological survey/assessment. From biological survey/assessment we can find/assess what type of impact are harmful for flora-fauna, how it will affect flora-fauna, what is the reason behind extinction of flora-fauna. From biodiversity survey we can provide and create natural habitat for flora-fauna. So, impact assessment is very important consideration. Every industry/plant or any type of activity should do biodiversity survey. This chapter explores a survey methodology for biodiversity assessment.

INTRODUCTION

Biodiversity is the basis of ecosystem services to which human well-being is intimately linked. No feature of earth is a lot of complicated, lively, and varied than living organisms that occupy its surfaces and its seas, and no feature is experiencing more dramatic change at the hands of humans than this extraordinary, singularly exceptional feature of Earth. Breathable air, potable water, fertile soils, productive lands, bountiful seas, the equitable climate of Earth's recent history, and other ecosystem services are manifestations of the workings of life. It follows that large-scale human influences over this biota have tremendous impacts on human well-being. It also follows that the nature of these impacts, good or bad, is within the power of humans to influence (Carrington, 2018). Biodiversity is well-defined as the

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changeability among all living organisms from all sources together with, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part of. It includes variety within species, between species and of ecosystems. Biodiversity includes all ecosystems—managed or unmanaged. Biodiversity is difficult to quantify precisely. But precise answers are rarely needed to develop an effective understanding of where biodiversity is, how it is changing over space and time, the drivers responsible for such change, the significances of such change for ecosystem services and human well-being, and the response options available. There are several measures of biodiversity like species richness (the number of species in a given area). The multidimensionality of biodiversity poses difficult challenges to its measurement. So, a variety of proxy measures are frequently used. These include the species richness of specific taxa, the number of distinct plant functional types, or the multiplicity of different gene sequences in a sample of microbial DNA taken from the soil.

Biodiversity is important for ecosystem amenities and hence for all human well-being. At the same time, however, these losses in biodiversity and associated changes in ecosystem services have caused other people to experience declining well-being, with some social groups being pushed into poverty. Across the series of biodiversity measures, current rates of loss exceed those of the historical past by several orders of magnitude and show no indication of deceleration. Biodiversity is deteriorating quickly because of change in land use, climate change, offensive species, overexploitation, and pollution. These result from demographic, economic, socio-political, cultural, technological, and other indirect drivers. While these drivers vary in their importance among ecosystems and regions, current trends indicate an ongoing loss of biodiversity. So, biodiversity assessment is necessary (Millennium Ecosystem Assessment, 2005).

BACKGROUND

The Earth's biological resources are vigorous to humanity's economic and social development. As a result, there is an increasing recognition that biological diversity is a global asset of marvellous value to present and future generations. At the equivalent time, the threat to species and ecosystems has never been so great as it is today. Species extinction caused by human activities continues at associate awful rate. In response, the United Nations Environment Programme (UNEP) convened the Ad Hoc working group of experts on biological diversity in November, 1988 to reconnoitre the need for an international convention on biological diversity. Soon after, in May 1989, it established the Ad Hoc working group of technical and legal experts to prepare an international legal tool for the conservation and sustainable use of biodiversity. Through February 1991, the Ad Hoc Working group had become known as the Intergovernmental Negotiating Committee. Its work culminated on 22 May 1992 with the Nairobi Conference for the Adoption of the Agreed Text of the Convention on Biological Diversity. The Convention was opened for signature on 5 June 1992 at the United Nations conference on environment and development. The Convention entered into force on 29 December 1993, which was 90 days after the 30th confirmation. The Convention on Biological Diversity was inspired by the world community's increasing commitment to sustainable development. It represents a dramatic step within the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising from the use of genetic resources (CBD, 2016). After CBD came into force, it is mandatory for all its signatory countries to implement the provisions in the Convention (UNEP, 1992).

Extensive anthropogenic interventions in natural ecosystems in recent times have been resulting in loss of biodiversity. There is a need to develop and implement a suitable national action plan for promoting biodiversity conservation, sustainable use of its components and equitable sharing of benefits arising from such use. Biodiversity, encompassing variety and variability of all life on earth, is the product of over 3.5 billion years of evolutionary history. Biodiversity is that the degree of variation of life forms inside a given species, ecosystem, community or a complete planet. Biodiversity monitoring is a process of assessment of existing status and change in the condition of biodiversity, as measured against a set of criteria and indicators. Several indicators are developed to trace changes in species populations across the nation (van Strien et al., 2016) and globally (Butchart et al., 2010; Brummitt et al., 2017). Some of them are adopted as official "environmental health" statistics (Gregory & van Strien, 2010), whereas others report on progress against international targets like those within the Convention on Biological Diversity (Collen et al., 2009; Tittensor et al., 2014). Biodiversity indicators, environmental management, and questions around which conservation interventions to prioritize have a common need for knowledge generated by high-quality data from consistent long-term monitoring. At present, vast datasets are being accumulated from a range of sources such as earth observation networks (*e.g*., National Ecological Observatory Network (NEON)] (Lindenmayer et al., 2018) and citizen science initiatives (Isaac et al., 2014) with an assumption that they can detect changes in species populations. However, to date, these have not been sufficiently benchmarked against traditional ways of measuring changes in populations of species (e.g., repeat measure animal tracking data) to understand their utility (Bayraktarov et al., 2019).

BIODIVERSITY ASSESSMENT

Biodiversity Assessment encompasses all the taxons which are present in the subjective study area. Determination of the Biodiversity of that place needs separate methodological applications for different taxons. Now, in the respective study of assessing Biodiversity at different chainages following methodology is used.

1. Biodiversity/Ecosystem and Goals

The system consists of the people and ecosystem of the area to be assessed. The goals encapsulate a vision of sustainable development and provide the basis for deciding what the assessment will measure. Monitor horizontal transact within 3 km along both side of road especially nearby wildlife crossing zone.

2. Identify Elements/Issues and Objectives

Elements are key concerns, issues or features of human society and the ecosystem that will be considered to get an adequate sense of their condition. They are grouped by dimensions. Car patrolling will be done for seven days at a particular time interval through the entire horizontal road. In this, communication to local community and concern forest rangers regarding the scenario on man and wildlife conflicts and their moment/frequency will have considered.

3. Indicators and Performance Criteria selection (On-Site)

Some special Indicators will select which have measurable and representative aspects of an issue. Performance criteria will be planned for standards achievement of each indicator. Spatial distribution and belt transact will be carried out with time scale to enumerate the encounter rate at different part of the day to identify hotspot for animal crossing. Random parameters will be collected from Indian meteorological department.

4. Measure and Map the Indicators

Indicators results are recorded in their original measurements, given scores on the basis of the performance criteria, and mapped. Mapping will be done using google earth and GPS coordinates. Ad Libitum scanning will be done for the entire study area.

5. *C*ombine the Indicators and Map the Indices

Indicators scores are combined up the hierarchy: indicators into sub issue indices; sub-issue indices into indices; issue indices into dimension indices; and dimension indices into subsystem indices (separate indices for people and the ecosystem). Indices are mapped to reveal visually overall findings and specific patterns of performance. Data collected will be analysed using PAST 3 software.

6. Review Results and Propose Policies

The review links the assessment to action by Analysing the patterns and the data behind them to suggest what actions are needed and where. Other than photography no sample will be collected during the study.

Basic Steps for Biodiversity Assessment are listed in Table 1.

CONVENTIONS ON BIOLOGICAL DIVERSITY (CBD)

The Convention on Biological Diversity (CBD) entered into force on 29 December 1993. It is a multilateral treaty. It has 3 main objectives:

- The conservation of biological diversity.
- The sustainable use of the components of biological diversity.
- The fair and equitable sharing of the benefits arising out of the utilization of genetic resources.
- In other words, its objective is to develop national strategies for the conservation and sustainable use of biological diversity. It is often seen as the key document regarding sustainable development. The Convention on Biological Diversity was inspired by the world community's growing commitment to sustainable development. It represents a dramatic step forward in the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising from the use of genetic resources.

IMPACT ASSESSMENT

Impact assessment is the process of identifying the future significances of a current or proposed action. It is used to ensure that projects, programmes and policies are economically viable, socially equitable and

Table 1. Basic steps for biodiversity assessment

S. No.	Environment Study	Type of Data	Methodology
1.	Collection of secondary data for familiarization of study area	Secondary	Desktop Study
2.	Habitat mapping	Secondary	Desktop Study
3.	Interpretation of secondary data from available sources for Ecological Sensitive Areas such as national forests, wild life sanctuaries, lakes, ravines, hills, hillocks and reserve forest, etc.	Secondary	Discussion
4.	Analysis of data as per aspect and impact analysis and identify the probable impacts	Secondary	Review and discussion
5.	Interpretation of aspect/impact on ecology and biodiversity	Secondary	Review and discussion
6.	Determining suitable methods of primary data collection for floristic survey	Secondary	Point quarter plot less/ point centred quadrate sampling method followed. Vegetation measurements will be determined from points rather than being determined in an area with boundaries.
7.	Selection of suitable methodology for documentation of faunal diversity	Secondary	Opportunistic observation/Species list method/Direct sighting/ Intensive Search/bird calls/Micro-habitat search/pugmarks and footprint observation/ debarking observation and indirect sighting etc.
8.	Check list Preparation as per sensitivity and biodiversity.	Secondary	Review and discussion
9.	Field Data Collection Survey of flora and fauna clearly delineating season and duration. Parameters Flora in the study area: (Trees, Shrubs, Herbs, Climbers) Cultivated plants in the study area, Floristic composition of the study area, Medicinal plants of the study area, Status of the forest, their category in the study area, Rare and endangered flora in the study area. Endemic plants in the study area,	Primary	Field visit and site survey
	Fauna in the study area: (Reptiles, Amphibians, Birds, Fresh water fishes, Mammals, Butterflies) Rare and Endangered fauna in the study area, Endemic fauna in the study area, Wild life and their conservation importance in the study area.	Primary	Field visit and site survey

continued on following page

Table 1. Continued

S. No.	Environment Study	Type of Data	Methodology
	Aquatic Environment Fresh Water Life: (Algae, Anthozoa, Cephalopod, Fishes, Gastropod, Invertebrates, Molluscs, Reptiles, Snails, Water birds) Marine Life: (Anthozoa, Arthropods, Cephalopod, Cetaceans, Cnidarians, Coral reef, Echinoderms, Gastropod, Hemichordates, Lophophorates, Molluscs, Reptiles, Sea Turtles, Seabirds, Seawater Fishes, Shellfishes, Sponges, Worms, Planktonic Life [Phyto/Zoo]) Total genera Major genera Taxonomy Nanoplanktonic Flagellates Cnidarians Rotifera, Chaetognatha, Polychaeta Copepods Cladocerans, Krill Insect Larvae Tunicates	Primary	Guidelines of APHA for sample collection By using Lackey's drops method and light microscope
10.	Evaluation of Ecological sensitivity Ecological sensitivity of study area will be analysed based on the following criteria: Wild life importance, Floral Endemicity, Faunal Endemicity, State of Terrestrial vegetation, State of wet land vegetation, Mangrove vegetation, Conservation importance, Legal status (National park, Wild life sanctuary, Reserve forest, Wetlands, Agricultural lands) Lakes /reservoirs/dam, Natural lakes and Swamps, Breeding ground of Migratory and Residential birds.	Secondary	Review and Discussion
11.	Data Analysis	Secondary	Desktop study
12.	Assessment of potential damage to flora and fauna due to project activity, if any.	Secondary	Desktop study and discussion
13.	Ecological Impact Assessment	Primary	Review and Discussion
14.	Delineation of mitigation measures, preparation of Green belt development plan and Conservation plan, if required.	Primary	Review and Discussion
15.	Report Preparation.	-	-

environmentally sustainable. Guidance developed under the Convention helps to decide which aspects of biodiversity may need to be monitored and how to carry this out in a cost-effective way.

Impact Assessment is an important tool for plateful ensure that development is planned and implemented with biodiversity in mind. Biodiversity is acceptable to all or any varieties of impact assessment and maybe addressed at all levels, from environmental impact assessment (EIA) carried out for individual projects to the strategic environmental assessment of policies, plans and programmes. Its values ought to be addressed in social impact assessment and health impact assessment might essential to consider the role of biodiversity in disease transmission or biological control. Finally, biodiversity provides commodities for international trade which will be the topic of study in impact assessment (CBD, 2019).

Need for Impact Assessment:

- Survey of flora and fauna clearly explaining season and duration.
- Assessment of flora and fauna present within the impact zone of the project.
- Assessment of potential damage to terrestrial and aquatic flora and fauna due to tree felling, construction activities, transportation, etc.
- Assessment of damage to terrestrial flora and fauna due to fugitive emission and land use and landscape changes.
- Assessment of damage to aquatic and terrestrial flora and fauna due to physical disturbances and alterations.
- Prediction of biological stresses within the impact zone of the proposed highway.
- Delineation of mitigation measures to prevent and reduce the damage.

TREE ENUMERATION

Enumeration describes a category of combinatorial enumeration issues during which one should count undirected or directed graphs of certain types, generally as a function of the quantity of vertices of the graph. Tree enumeration is widely practised in combinatorics and in the analysis of algorithms. Many different tools and tricks have been used in approaching this problem in the various classes of trees. The problem of estimating the size of a backpedal tree is a significant but tough problem in the computational sciences. An effective solution of this problem can have a major impact on the hierarchy of complexity classes. The authors showed numerically that this simple algorithm can be very efficient for handling different counting problems, such as counting the number of satisfiability assignments and enumerating the number of perfect matchings in bipartite graphs. Trees diameter and height of rooted trees will be considered in tree enumeration. There is basic 3 considerations for tree enumeration, which are listed below:

- Length of path is total number of lines shown in diagram.
- Diameter of tree is length of longest path joining two of points in diagram and
- Height of rooted tree is length of longest path joining root and another end point.

SURVEY METHODOLOGIES FOR BIODIVERSITY ASSESSMENT

Biodiversity surveys are undertaken to find out what organisms exist in a given area. The data that is gathered from these surveys is used for numerous purposes such as:

1. Monitoring endangered populations.
2. Evaluating conservation priorities of an area.
3. Bioprospecting.

Table 2. Sources for data collection

S. No.	Ecology and Biodiversity	Sources
1.	List of Plants (Floral Diversity)	Botanical Survey of India (BSI), Kolkata and regional offices, Regional Forest Department, Environmental Information System (ENVIS), India, Government of India Directory.
2.	List of Animals (Faunal Diversity)	Zoological Survey of India (ZSI), Kolkata and regional offices, Chief Wildlife Warden, Environmental Information System (ENVIS), India, Government of India Directory,
3.	Taxonomic studies	International Association for Plant Taxonomy (IAPT), International Plant Name Index (IPNI), Royal Botanic Garden, Kew, UK, Zoological Survey of India (ZSI), Kolkata Botanical Survey of India (BSI), Kolkata
4.	Forest and its type (Forest Diversity)	Forest Survey of India (FSI), Dehradun Indian Council of Forestry Research & Education (ICFRE), Dehradun, French Institute Pondicherry, Indian Institute of Remote Sensing (IIRS), Dehradun National Remote Sensing Centre (NRSC), Ministry of Environment and Forests (MoEF), New Delhi
5.	Diversity of Western/ Eastern Ghats	Salim Ali, Institute of Ornithology and Natural History Coimbatore, Tropical Botanical garden & research Institute Coimbatore, Kerala Forest Research Institute Peechi, Kerala, Indian Institute of Science Bangalore, Centre for Ecological Science Bangalore
6.	Mountain Diversity/ Himalayan Diversity/North Eastern Diversity	G.B. Pant Institute of Himalayan Environment & Development, Regional centres of ZSI Dehradun, Wild Life Institute of India Dehradun, Institute of Bio resource Shillong.
7.	Desert Biodiversity	Central Arid Zone Research Institute Jodhpur, Bombay Natural History Society (BHNS), Mumbai, Salim Ali Institute of Ornithology and Natural History Coimbatore, Wild Life Institute of India Dehradun (WII), World Wildlife Fund India (WWF) Zoological Survey of India (ZSI),
8.	Wild Animals	Wildlife Institute of India (WII), Dehradun, Environmental Information System (ENVIS), India Ministry of Environment, Forests and Climate Change (MoEFCC), Department of Environment and Forests (DoEF),
9.	List of Mangroves	Conservation and Management of Mangroves (CMM), New Delhi, Global Environment Facility (GEF). Ministry of Environment and Forests (MoEF), New Delhi
10.	List of Avifauna	Bombay Natural History Society (BHNS), Mumbai Environmental Information System (ENVIS), India Salim Ali Centre for Ornithology and Natural History, Coimbatore Nature Club Surat (Gujarat) Bird Life International (UK) and its Regional Offices(www.birdlife.org)
11.	List of Medicinal Plants	Central Institute of Medical and Aromatic Plants (CIMAP), Lucknow, Environmental Information System (ENVIS), India

continued on following page

Table 2. Continued

S. No.	Ecology and Biodiversity	Sources
12.	Coastal and Marine diversity	Central Marine Fisheries Research Institute (CMFRI), New Delhi National instate of Oceanography Goa, Botanical Survey of India Portable air, M.S. Swaminathan research Foundation Chennai, Madras Science Foundation Chennai, Coastal Zone Management Authority (CZMA), New Delhi, Environmental Information System (ENVIS), India Ministry of Environment and Forests (MoEF), New Delhi, Central Board of Irrigation and Power (CBIP)
13.	Wetland Diversity	Bombay Natural History Society (BHNS), Mumbai Salim Ali Institute of Ornithology and Natural History Coimbatore, Wild Life Institute of India Dehradun, World Wild life Fund, Zoological Survey of India (ZSI), Kolkata, Wetland of India (MoEF) new Delhi, Environmental Information System (ENVIS), India Ministry of Environment and Forests (MoEF), New Delhi
14.	Agricultural information	Indian Agricultural Research Institute (IARI), New Delhi, Ministry of Environment and Forests (MoEF), New Delhi
15.	Endemicity Rare Endangered	International Union for Conservation of Nature (IUCN), Wildlife Institute of India (WII), Dehradun, World Conservation Monitoring Centre (WCMC), UK, National Biodiversity Authority (NBA), National Biodiversity Data Bank (NBDB)
16.	Conservation plan	International Union for Conservation of Nature (IUCN), World Conservation Monitoring Centre (WCMC), UK Wildlife Institute of India (WII), Dehradun National Bureau of Plant Genetic Resources (NBPGR), New Delhi National Tiger Conservation Authority (NTCA), National Botanic Research Institute (NBRI), Lucknow National Dairy Research Institute (NDRI), Haryana
17.	Offences/Crimes	Tiger and Other Endangered Species, Crime Control Bureau (TOESCCB), Wildlife Crime Control Bureau (WCCB)
18.	Heritage	National Museum of Natural History (NMNH), New Delhi Natural History Museum, London, UK
19.	Island Diversity	Zoological Survey of India (ZSI), National Institute of Oceanography, Goa Central Marine Fisheries Research Institute (CMRI), New Delhi
20.	Effect of pollutants on biodiversity	Central Pollution Control Board (CPCB), New Delhi State Pollution Control Board (SPCB), States American Public Health Association (APHA)

The actual methodology of the survey of biodiversity depends the goal of the project, the unit of biodiversity being measured, and how the data will be analysed. Data collected can be either qualitative (presence/absence, also known as binary) or quantitative data, in which the number of individuals for each species are counted. Small mobile animals such as insects are usually captured using traps or nets, while plants are usually visually identified in the field. Steps for biodiversity assessment are listed below.

1. Data Collection (Desktop Review)

Desktop review of existing mapping and supplementary information should be used to target important areas for field survey and to ensure that field survey work is undertaken efficiently. Prior to the commencement of any habitat surveys in the field, a review of existing habitat and species information should be undertaken. Desktop analysis should include information in a variety of different formats. In addition, consulting with individuals and organisations that may have information on the study area may prove useful. Gathering this information may be time-consuming, but the result will be a more efficient field survey targeted at habitats and locations of potential importance. Desktop data may be used to prepare a preliminary habitat map to be used in the field to guide survey efforts. For desktop review different sources are listed in table 2 for different data collection.

2. Habitat Mapping

In order to create a map, it is necessary to use some sort of mathematical formula to transform spherical geographic coordinates on the earth's surface so they can be represented in two dimensions. This process results in a map projection that approximates the true shape of the earth. A map projection is a special configuration used to fit a portion of the globe onto a flat view (Davis, 1996). This process introduces errors into spatial data, the character of which will vary depending on the projection used (Heywood et al., 2006). Each projection has its specific areas of distortion and its own set of advantages and disadvantages. The main areas of distortion are shape, area, distance and direction. A cartographer will attempt to eliminate distortion by choosing the most suitable projection, depending on the map's purpose and the area covered. After deciding on a suitable map projection, a suitable coordinate reference system must be chosen. A coordinate reference system consists of a set of assigned points on a flat surface, which originate from a set of predefined rules. These points – often referred to as latitude and longitude, or eastings and northings – define the position of the geometry relative to a false origin on the earth's surface.

3. Field Work

Identifying habitat types according to the guide to habitats and habitats directive habitats classification schemes and mapping their extent is the most important goal of the field survey. The field survey may also require gathering more detailed information on the species composition and structure of habitats, conservation value, threats, and other data. The types of data to be collected in the field will vary according to the survey objectives and the resources available to the project. The survey rates of fieldworkers undertaking habitat surveys depend on a number of factors, including topography, weather on the day, complexity of habitat types, accessibility throughout the study area, the experience of the survey personnel, and the scale at which the habitat mapping is to be carried out. Survey rates will also be lower where more detailed information than habitat identity and location is collected.

4. Sampling

Samples are taken from sites of floristic and faunal importance likes, lakes, ravines, hills, hillocks and forest, if any present in study area surveyed to document its floral and faunal diversity. For floristic density, PCQ (point centered quarter) (Cottam & Curtis, 1956) plot less sampling method should be followed. In the point-centered quarter method, a set of points (usually positioned along a transect to traverse the area) is initially selected. The area around each point is divided into four 90° quadrants, and the plant closest to the point in each quadrant is identified. The distance between the central point and selected plant in each quadrant is measured, and then averaged across the four to represent the distance (d) at each sample point and vegetation measurements should be determined from points rather than being determined in an area with boundaries.

5. Laboratory Analysis

In laboratory analysis/study, sample taken from different areas/locations are identified in microscope with Lackey Drop Method.

6. Ecological Sensitivity

Ecological sensitivity of study area has been analyzed based on the following criteria:

1. Wild life importance
2. Floral endemicity
3. Faunal endemicity
4. State of terrestrial vegetation
5. State of wet land vegetation
6. Mangrove vegetation
7. Conservation importance
8. Legal status (national park, wild life sanctuary, reserve forest, wetlands, agricultural lands)
9. Lakes /reservoirs/dam
10. Natural lakes and swamps
11. Breeding ground of migratory and residential birds.

7. Authentication

It includes cross review with published documents.

TOOLS FOR BIODIVERSITY MONITORING

We require Binocular, Compound microscope, Slides, Cover slips, High resolution with at least 40X zooming camera, Safety Shoos, Plankton net, 1 litter Sample collector bottle (Polypropylene), Sample preservation bottle (500 mL), Formalin, Tape (measuring), Scissors, File, Bag (for fragile material), Gloves, and Goggles to field work for biodiversity assessment.

SOLUTIONS AND RECOMMENDATIONS

Assessing areas of high biodiversity plays a vital role in determining key areas for conservation and establishing conservation priorities. Biodiversity implication is a ranking of an area according to specified values such as fewness, diversity, fragmentation, habitat condition, resilience, threats, and ecosystem processes. The more critical role an area or system plays for ecosystems, the more value it has in positively influencing biodiversity. The value of an area is assessed on an extensive set of attributes such as relative size or condition, whether it is habitat for threatened species, or if it provides connectivity across the landscape.

Recommendations

1. Interfering as little as possible on their habitat can best mitigate the impact of activities on animals. If such animals use area where activity will take place, activity should be concentrated to maximum extent possible in those parts of area that they least frequent.
2. During the planning phase of road, an attempt should be made to avoid extending into home range wild animals. If this is not feasible, activity should be completed, as quickly as possible and regular and sustained use of area over time should be minimized.
3. Regular or sustained intrusions of men or equipment into nesting areas of birds should be avoided to the maximum possible extent, especially while eggs are being incubated by the adults and until the young have left the nest.
4. Restricting input of polluting substances into watercourses, estuaries and open sea can mitigate impacts upon fish and aquatic populations.
5. Additionally, when a part of activity involves water level control, changes in such levels should be programmed to extent it is possible to do so in a way that will minimally disturb nesting and feeding habitat.

CONCLUSION

Biodiversity is an essential part of ecology. It requires major attention because day by day, due to increase in urbanization; assessment is necessary. From assessment of Biodiversity we can get proper information of biodiversity and ecology. It helps us to find how many species/flora/faunas are degrading, what was the reason behind that and from impact assessment we can say that how many species will remain in future and because of what effects, species will become extinct, etc. So, biodiversity impact assessment is necessary.

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Chapter 14
Techniques to Assess Animal Diversity:
Faunal Diversity Assessment

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ABSTRACT

Methods for surveying and monitoring fauna will depend on the types of fauna that the study is looking for. Animal diversity assessment goal is the conservation of animals and their interaction between biodiversity. Assessment also includes their habitat and taking actions to conserve the faunal species. Animal diversity includes vertebrate animals and invertebrate animals. Faunal diversity includes odonate (predators), coleoptera, hymenoptera (pollinators), herpetofauna, avifauna, fish, mammals, and butterflies. Animal diversity assessment describes their food, habitat, ecology, and their population. Animal diversity assessment technique describes impact of pollution on their environment. In this chapter, the authors have elaborated about the techniques of faunal biodiversity in the field.

INTRODUCTION

Biodiversity is the variety of different forms of life on earth, including the different plants, animals, micro-organisms, the genes they contain and the ecosystem they form. Assessment method is the implementation of the management plan for the interaction between biodiversity, the different human activities and the physical environment. It is identified and implement actions to conserve faunal species and habitats. It refers to genetic variation, ecosystem variation, species variation (number of species) within an area, biome or planet (Rawat & Agarwal, 2015). Fauna resources are the entire wild animal of any

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particular region or ecosystem. These wild animals can be found in all ecosystems including forests, grasslands, plains, wetlands and deserts. Fauna species assessment has more concentration to national parks or wildlife parks. Many local rangeland communities support unique flora and fauna species making them important in terms of conservation and scientific interest (Yager et al., 2018). Biodiversity assessment is the first stage in the process of defining the biodiversity management objectives for an area. Its purpose is to gather and assess the information required to make decisions and recommendations for the future. The diversity of animal forms and highlights their distribution, life cycle, structure, and economic significance. Animal diversity include vertebrates and invertebrates. Vertebrates are those animals that have vertebrae and invertebrates are those animals that lack vertebrae. The main characteristics of vertebrate's animal is their backbone. Backbone is start from head and along to the tail. Backbone is the core of the endoskeleton it allows vertebrates to hold its shape. The vertebrate column is made up of repeating units of vertebrae. Classification of vertebrate's animals are fish, amphibians, reptiles and mammals. Methods for surveying and monitoring fauna will depend on the types of fauna and study. During the reconnaissance survey, it may be that the researcher would be looking for evidences of all mammals in the form of tracks, dung, and sightings. The methods for carrying out faunal studies will vary depending on the researcher, but such studies may involve establishing various forms of transects, using PCQ (point centered quadrates) and quadrat methods, laying traps for insects or small mammals, or simply walking and counting in the case of certain bird surveys.

Diversity and distribution of vertebrates are clearly better documented than for other groups and even though it can be seen that new species of freshwater fish or even amphibians are still being described regularly, experts of all vertebrate groups are able to supply a fairly reliable estimate of the true number of extant species.

BACKGROUND

At the beginning of the present century, was an expressive study of nature, a sort of natural history, which drew inspiration from the works of explorers and naturalists. Biodiversity is well-defined as the variability among living organisms from all sources, including, terrestrial, marine, other aquatic ecosystems, the ecological complexes of which they are part this contains diversity within species, between species and ecosystems (OECD, 2014). Biodiversity has evolved over the last 3.8 billion years or so of the planet's approximately 5 billion-year history. Although five major extinction events have been recorded over this period, the large number, variety of genes, species and ecosystems in existence today are the ones with which human societies have developed, and on which people depend. As the basis for all ecosystem services, and the foundation for truly sustainable development, biodiversity plays fundamental roles in maintaining and enhancing the well-being of the world's more than 6.7 billion people, rich, poor, rural and urban alike. Biodiversity comprises much of the renewable natural capital on which livelihoods and development are grounded biodiversity, encompassing variety and variability of all life on earth, is the product of over 3.5 billion years of evolutionary history. A process of assessment of existing status and change in the condition of biodiversity, as measured against a set of criteria and indicators. The faunal biodiversity to be assessed at species level, ecosystem level and genetic level. The oldest method to assess faunal diversity were direct count and indirect count.

ODONATE (PREDATORS), COLEOPTERA AND HYMENOPTERA (POLLINATORS)

Odonate

The odonates are one of the magnificent and colourful groups of flying insects distributed worldwide in three sub orders *i.e.* anisoptera (dragonflies), zygoptera (damselflies) and anisozygoptera. Odonates are one of the beneficial group of insects through insect pest control and acting as an indicator species of habitat disturbance (Palita, 2016). Adult dragonflies and damselflies are collected with a sweep net with 150cm long handle and orifice 25 cm in diameter. Collection of odonate for assessment is based on monthly wise. Each specimen has their wings folded together above their body for further process and preservation of odonate in laboratory they are placed in a triangular envelope. Pairs of mating males and females are placed together in the same envelope. Data on collection and information such as locality, date, time and the collector's name are recorded for each specimen (Adu et al., 2015).

Coleoptera

For every sampling point the micro habitat features is to be registered. Further opportunistic sightings can also be recorded along with the information on species and the host plant visited. For the observation of adult odonates the method is direct search techniques. For this purpose, choose search point randomly. In the result of observation of odonates is based on their family wise species with number, their habitat and distribution and their local occurrence (Majumder, 2014). Pitfall trapping is the old method for sampling carabid insects and other ground-dwelling invertebrates. Pitfall traps were less efficient compared to manual searching methods, both in terms of relative abundance and species richness of carabid beetles. The reason for the wide use of pitfall traps in invertebrate sampling is their simplicity of setting and using, and their low cost in terms of manpower. Despite their usefulness, the interpretation of pitfall trap data is subject to many problems because they rarely reflect the true abundance of the target organisms being sampled. The biodiversity crisis facing tropical habitats make quick low-cost collecting methods necessary for species inventorying (Bruno & Jacob, 2009).

Hymenoptera

Bees are sampled using malaise traps, ground-level pan traps, elevated pan traps, and vane traps. Between the pan traps and vane traps, blue-colored traps collected the greatest wealth and species richness, and yellow traps the least. Elevated pan traps and vane traps collected quite similar species composition. Different colored pan traps at the same height collected more similar species composition than did those at different heights, but species composition of blue ground-level pan traps was relatively similar to elevated pan traps, regardless of color. Elevated traps can increase the effectiveness of bee surveys in tallgrass prairie, and that a grouping of trap types gives a more complete picture of the bee fauna than does a single survey method (Geroff et al., 2014).

HERPETOFAUNA

Herpetofauna and humans have interacted since earliest time in many aspects. These animals face many problems to survive with the urbanizing world. This becomes a great challenge for the protection of the herpetofauna. While many studies are being carried out on herpetofauna, very few studies have examined the herpetofaunal interaction with humans (Boruah et al., 2017). Amphibians and Reptiles can be sampled using circular plots and belt transects. Intensive search (IS) can be done within a circular plot of 10m radius placed at every 100m along the transect, while the belt transects of 80 m long and 6m wide is used in the space between the two circular plots. All the microhabitats (rock and boulders, dead and fallen logs, flushing and beating of dense bushes and grass patches, checking of rock and tree crevices and leaf litters etc.) within the transects is thoroughly checked for herpetofauna. In all cases relative abundance can only be estimated for species where adequate data is available. In addition, the microhabitat features can also be recorded along with its availability and extent. Reptiles have very general habitat necessities, while others have specific ones. Reptiles can live in terrestrial, aquatic, or riparian habitats. Those that inhabit riparian habitats are not considered aquatic, but they are strongly associated with riparian-upland transitional zones. Reptile populations are negatively affected by environmental pollutants, such as heavy metals, pesticides, and radioactive waste (Natural Resources Conservation Services, 2006). Following Table 1 shows details of foraging habitat, food, group and breeding habitat of reptiles.

Amphibians have highly permeable skin that rapidly absorbs toxic substances in the air, water, and soil. Amphibians have complex life cycles and need appropriate habitat for egg, larval, and adult stages. Amphibians and reptiles can be found in almost all habitat types that is forests to deserts to grasslands. Many species use different habitats during different times of the year (Natural Resources Conservation Services, 2006). Following Table 2 shows details of foraging habitat, food, group and breeding habitat of amphibians.

Table 1. Habitat, food and breeding habitat of reptiles

Group	Foraging Habitat	Food	Breeding Habitat
Crocodiles and alligators	In and around water (lakes, ponds, swamps, rivers)	Insects, snails, crustaceans, reptiles, frogs, fish, birds, mammals	In ground or in heaped vegetation and soil
Lizards	In cracks and crevices, in rock or brush piles, in tree trunks or foliage, under rocks and logs, among leaf litter or vegetation, underground	Leaves, fruit, flowers, insects, snails, scorpions, crabs, other invertebrates, eggs, small mice, lizards	In soil, under fallen leaves, in crevices, in rotting logs
Snakes	On the ground, in crevices or burrows, in rock or brush piles, in trees, in water	Insects, spiders, snails, slugs, crayfish, crabs, fish, salamanders, frogs, lizards, turtles, birds, eggs, small mammals	Upland, riparian, or wetland areas, burrows, rotting logs
Turtles and tortoises	In salt or fresh water, on land (forests, deserts, grasslands)	Aquatic plants, grasses, berries, fruit, flowers, leaves, insects, worms, slugs, snails, crustaceans, other invertebrates, frogs, snakes, turtles, fish, jellyfish	Well-drained sandy or loose soil; sometimes associated with burrows

Table 2. Habitat, food and breeding habitat of amphibians

Group	Foraging Habitat	Food	Breeding Habitat
Frogs and toads	Under logs, in leaf litter, in damp rock crevices, in soft soil or mud, in shrubs and trees, in water, beneath the soil surface.	Tadpoles – algae, plant detritus, leaves, other tadpoles Adults – Insects, worms, other invertebrates, frogs, snakes, lizards, small turtles, small birds, mammals	Fresh water or moist areas
News and salamander	Cool, damp, shady places; in caves or burrows, in trees, under rocks and logs, on ground, in water; underground	Larvae – insects and other invertebrates, small crustaceans, tadpoles, zooplankton, other salamander larvae Adults – insects, worms, and other invertebrates, fish, other salamanders, small mice	Fresh water or moist areas

AVIFAUNA

Birds are good indicators as it responds fast to threats and changing environmental conditions. Bird counts are best done within half an hour after sunrise and should be completed no later than four hours after sunrise. Observers should record the species, sex, and mode of detection (song, call, visual, other) of all birds seen or heard within a 150 feet radius of the point on the transect. Line transect, point count and mist netting method are used to survey the birds in the study area. For 2-km transect lines are established in each site (two 2-km transects within study area and another two 2-km transects outside the study area with at least 5 km distance). Diversity indices are calculated to determine the diversity of birds in the two sampling sites (Cordulo et al., 2016). The method to estimate the bird diversity in this type of habitat is belt transects. Transects of the size 1000m x 1000m, is laid in the cover of each wetlands. All birds species including ducks, cranes, waders and storks which are present in the transect are identified to the species level and their number (Kumar & Kanaujia, 2017).

Methodology

Make a list of all the bird species observed in the entire sampling site. The total number of different species observed represents the observed bird species composition. Add the number of birds of each species to get species abundances observed during any one sampling period. Total abundances of birds can be estimated by adding all species abundances together. The bird species in all microhabitat is recorded along with their numbers seen. Further, for each sighting tree species used, substrate used, vertical strata used, activity, if feeding, details on where, how and what its feeding is recorded. In addition, the number of water bodies in the study area is also surveyed for the aquatic bird species and individuals enumerated using total count. In case of larger water bodies having numerous individuals, flock or block count method can be adopted. Information of nesting habitats or breeding sites can also be recorded whenever encountered.

MAMMALS

Among the group of animals that serve as indicators are mammals, including primates. Mammals are vertebrates that have the characteristics of homoitherm (warm-blooded) with typical breastfeeding, giving birth and have fur (Septiani & Sidabutar, 2015). These characteristics separate them from reptiles and birds, from which they diverged in the late Triassic (Kumar, 2018). Mammals within the transect range, additional data from accidental encounter, dung, footmarks and calls are also used to record the presence of mammals (Abprez et al., 2018). For the collection of the mammalian specimens, arrangement of collection, preservation, and labelling equipment's, such as traps, mist nets, firearms, forceps, axe, knife, hammer, plaster of Paris, hand lens, scissors, trays, aluminium poles, ropes, scales, chemicals (ethyl alcohol, formaldehyde, chloroform, alum, arsenic soap etc.) pencil, scale, labelling paper, silk thread, collection vials, plastic bags, head lights, torches, battery, haversacks, hunting shoes, camera, compass, altimeter, field note book etc. should be made in the laboratory (IUCN, 1994).

Direct Count

Both terrestrial and arboreal (small and large) mammals are counted during monitoring of line transect that can be walked in the early and late hours of the day and during the night using spotlight or headlights. In addition, road strip count using vehicle during day may also be carried out. For each sighting, species, abundance, age and sex, sighting distance, sighting angle, distance on transect and activity of the animal with the habitat features are documented.

Indirect Count

Presence and relative abundance of most of the small and large mammals can be undertaken using methods that rely on indirect evidence such as animal burrows/holes, dung, pellets, feeding signs, tracks etc. this would be done using transects and plots. The passive track counts, scat counts can help in determining the abundance. The camera traps can be used to distinguish the species, its sex and also establish its presence in the area. Scats of leopard, sloth bear, hyena, jackal, wolf and other cats, evidences of digging by sloth bears, scarps of leopards recorded along paths, trails and roads with distance covered can also be used to estimate the relative abundance of these species. The rodents are sampled using Sherman traps. The Sherman trap is a box-style animal trap designed for the live capture of small mammals. It was invented by Dr. H.B. Sherman in the 1920s and became commercially available in 1955. The Sherman trap consists of eight hinged pieces of sheet metal that allow the trap to be collapsed for storage or transport.

FISH

Correlation between fish species richness with the hydrological attributes showed good relationship and water depth, dissolved oxygen and pH were found the most important variables in shaping fish assemblage. In the present communication habitat ecology, species diversity, distribution and different indices of fish biodiversity management were studied (Singh et al., 2010). High rates of water consumption relative to water supply led to three distinct long-term periods of gradual decrease in water level and to a general increase in the amplitude of water-level fluctuations. These changes affect the availability of spawning habitats in the littoral. At high water levels, the proportion of hard substrates (gravel, boulders, and rocks) in the littoral zone is much higher than at low water levels, when sand and silt become the dominant substrate. Hard-substrate habitats are favourable for the development of diverse periphytic and invertebrate communities, and provide good feeding conditions for herbivore, planktivore, and benthivore fishes and their fingerlings (Ostrovsky et al., 2014). Tools and materials for fish identification includes nets, trawl, specimen boxes, caliper, plastic bags, camera, Global Positioning System (GPS), identification book, tools for measuring the physical and chemical composition of water, and stationery. Species identification can be done with the help of the species identification book and for each species the length should measure and the total number counted per species. The identification of species, diversity, and conservation status should be studied for any area in question (Septiani & Sidabutar, 2015).

BUTTERFLIES

Insects are one of the good indicators of environmental quality of any ecosystem. Butterflies have specific habitat requirement depending upon their feeding and reproduction requirements, loss of which may cause local extinction. Thus, the conservation value of a habitat could be assessed by the presence of various species of Butterflies in an area (Chorge et al., 2008). Butterflies have exhibited increased sensitivity and responses to climatic fluctuations, which demonstrate a strong and direct influence on their development, reproduction and survival (Ashraf et al., 2018). They have different requirements for different habitat types for mating, breeding and nectaring are thus in sync with the diversity and quality of their habitats (Sprih, 2014). The counts are conducted along fixed transects of about 1 km consisting of smaller sections, each with a homogeneous habitat type. The fieldworkers record all butterflies in an imaginary box 2.5 meters to their right, 2.5 meters to their left, 5 meters ahead of them and 5 meters above them (Swaay et al., 2008). Butterfly counts are conducted between March-April and September- October. Visits are only conducted when weather conditions meet specified criteria. Most of the transects are recorded by skilled volunteers, but their results are usually checked by butterfly expert (Swaay et al., 2002). This migration of pollens makes genetic difference in plants type and give a better chance at survival against different disease. These insects also provide food for further organisms, for example; birds, reptiles amphibians and also acts as biological pest control. But the population of these insects decline quickly due to human activities, habitat destruction, uses of pesticides and unawareness of people about the importance of flying flowers (Mobeen et al., 2016).

SOLUTION

The mitigation of the problems needs to be addressed with tangible solutions for conserving species in the wild. Assessing the animal diversity in future research automatic recognition of all species producing sound in a recording will be possible in all environments and conditions. There is a need to develop and implement a suitable national action plan for promoting biodiversity conservation, sustainable use of its components and equitable sharing of benefits arising from such use. This relatively small community would benefit greatly from an increased presence of ornithologists, and such collaboration would present mutual opportunities for advancing study designs and analytic approaches. The opportunities for integration are broad and exciting, and the proposed linkages can form useful collaborations to build a more knowledgeable scientific community. Development of methodology rigorous indicator of genetic diversity might require for instance a global estimate of an effective number of breeds in each species weighted by their within-breed diversity. Domestication of animal species should be advocated both for poverty alleviation in the communal lands of the area, and for a balance to be maintained in the ecosystem (Balian et al., 2008) (Yager et al., 2018).

CONCLUSION

The faunal diversity assessment aim is the compiling an overview of genus and species level diversity of animals in the continental, aquatic ecosystem of the world. Faunal diversity assessment is the ecological information on the species of reptiles, terrestrial birds and mammals known to occur. Assessment method is describing the community structure, distribution and abundance of the different taxa. Different levels of disturbance have different effects on animal diversity in the study sites. Reliable information on the status and trends of forest fauna resources help give decision makers the prospective necessary for orienting wildlife policies and programs. Diversity and distribution of vertebrates are clearly better documented than for other groups and even through it can be seen that new species of freshwater fish or even amphibians are still being described regularly, experts of all vertebrate groups are able to supply a fairly reliable estimate of the true number of extant species.

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Chapter 15
Techniques to Assess Plant Diversity:
Floral Biodiversity Assessment

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ABSTRACT

Understanding the unequal distribution of species diversity is one of the greatest challenges in ecology. Standardized sampling protocol for diversity assessment are there for essential to reflect diversity patterns across spatial scales and to compare the diversities of different ecosystems. Measurements of biodiversity at the level of species or inhabitants are directed towards the fulfillment of an index of the number of species and their relative abundances in a given landscape. Massive loss of valuable plant species in the past centuries and its adverse impact on environmental and socioeconomic values has caused the conservation of plant resources. Appropriate identification and characterization of plant materials is important for the successful conservation of plant resources and to ensure their sustainable use. This review presents a basic description of different techniques that may be used for analysis of plant species. This chapter also includes an overview of the diverse, predominantly molecular techniques used in assessing plant genetic diversity.

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INTRODUCTION

Floral diversity states to the variety of plants taking place during a specific region and particular era. It generally refers to the diversity of naturally occurring indigenous/native plants. The word Flora comes from the Latin, Flora – the goddess of plants (floris means flower). A total of 215,644 species of plants out of 298,000 predicted have been catalogued on earth till-date. Apart, 8,600 flora species have been recorded from ocean out of estimated 16,600 as per Environmental Information System (ENVIS) on Floral (Plant) Diversity. Plants are important part of the environment. Plants (Flora diversity) are the base of the food chain and biogeochemical cycling of nutrients between terrestrial and aquatic ecosystems. They must constantly fight against the environmental modifications, however, that threaten to cause global species extinction and habitat destruction (Ansari et al., 2016). Plants are a large group of living components in nature. As biodiversity is an association of all living components of the nature from different possible natural habitats. Plants are also known as producers. They are important for reduction of pollution level and also a source of energy by trapping solar radiations to convert in to chemical energy (Sources of energy) in their photosynthesis activities. Animals are referred as consumers (Herbivores) which are dependent for energy in green plants, carnivore's dependent on herbivores. This dependency of organisms forms a food chain. It is important and remarkable relationship among the varied group of organisms in nature (Patel, 2015). Assessment of plant diversity is fast and non-destructive approaches of measuring plant species diversity have been a subject of excessive scientific curiosity and disquiet to environmentalists and field ecologists worldwide (Peng, 2018) and quantify the population of floral diversity at study area. Knowledge of the spatial distribution of floral species is essential to conservation and forest managers in order to identify high priority areas like vulnerable species and habitats, and designate areas for reserves, refuges and other protected areas. A reliable map of the diversity of plant species over the landscape is an invaluable tool for such purposes (Hernandez-Stefanoni & Ponce-Hernandez, 2006).

BACKGROUND

The idea of biodiversity has been known to man ever since he started to minutely observe the living being around him. The term biological diversity was used by Robert E. Jenkins and Thomas Lovejoy in 1980. The word biodiversity itself may have been coined by W.G. Rosen in 1985. The term biodiversity was used as the title for a symposium organized by national research council in Washington in (1986). At that time, as people became more aware of the extinction crisis, biodiversity emerged as a significant issue. Before the development of population and community ecology in the 1960's, global patterns of species diversity, particularly the increase in diversity towards the equator, were explain by the greater age and more stable environment of the tropics or by a combination of age and area. Large-scale patterns of plant diversity have been known in general terms since early natural history explorations of the earth in the 18^{th} and 19^{th} centuries (Ricklefs, 2005). Massive loss of valuable plant species within the past centuries and its adverse impact on environmental and socioeconomic values has triggered the conservation of plant resources. Appropriate identification and characterization of plant materials is necessary for the successful conservation of plant resources and to confirm their sustainable use (Khan et al., 2010). The practice of molecular makers in agriculture has been introduction from the 1980s broaden and simplified both for commercial and scientific uses to acknowledge new information such as large number of agronomic and disease resistance traits are available in major crop species (Phillips & Vasil 2001; Gupta & Varshney, 2004), the concept of genetic markers is not a new one; within the 90th century, Gregor Mendel employed phenotype-based genetic markers in his experiments. Later, phenotype-based genetic markers for Drosophila melanogaster conduct to the founding of the theory of genetic linkage, occurring when particular genetic loci or alleles for genes are inherited jointly. The limitations of phenotype-based genetic markers conduct to the development of DNA-based markers, i.e., molecular markers (Barcaccia et al., 2000) and Molecular tools developed in the past few years provide simple, less laborious means for assigning known and unknown plant taxa. These techniques answer many new evolutionary and taxonomic queries, which were not previously possible with only phenotypic methods. Molecular techniques such as DNA barcoding, random amplified polymorphic DNA (RAPD), amplified fragment length polymorphism (AFLP), microsatellites and single nucleotide polymorphisms (SNP) have recently been used for plant diversity studies (Khan et al., 2010).

INDIAN SCENARIO ON FLORAL DIVERSITY

As per Roy & Roy (2016) India is one of the twelve-mega-biodiversity countries of the world. With only 2.4% of the land area, India already accounts for 7% to 8% of the recorded species of the world. Over 47,000 species of plants and 81,000 species of animals have been recorded by the Botanical Survey of India and the Zoological Survey of India, respectively. As per Environmental Information System (2016), India being one of the tropical countries harbours 46,824 species including species of virus/bacteria and fungi. In India, the floral diversity is focused in 4 phytogeographically unique regions, viz., Himalayas, Western Ghats, Northeast India and Andaman and Nicobar Islands. 11.4% of Indian Flora accounts in the total recorded plant species of the world and about 28% of the floral species are endemic to India. In India, a total of 17,817 species of Angiosperms exist which are the largest plant group in India and constitute 38.15% of plant diversity of the entire country, followed by fungi comprised of 14,698 species, representing 31.38%. The country also has high level of cryptogam diversity. Till date, total numbers of 2,479 species of Pteridophytes and around 1,265 of Bryophytes have been recorded in India. The bryophytes are also significantly rich in the Himalayas, Western Ghats, Eastern Ghats, Nilgiris and Andaman and Nicobar Islands. India also contains widespread distribution of algae and fungi. The diversity of marine algae in Mandappam-Pamban region of Tamil Nadu coast and Okha-Dwarka region of Gujarat coast appear to be the richest species. Lichens, consist of symbiotic algae and fungi, are composite organisms found very rich in the Eastern and Western Himalayas, Western Ghats and Andaman and Nicobar Islands. Most of the ferns and gymnosperms (including cycads, pines, firs, junipers, etc.) grow in cool temperate zones of the Himalayas, and in the mountainous regions of southern India, especially in the Western Ghats. According to current estimates, the Indian flora represents nearly 12% of the global floral diversity (excluding viruses). The significance of the Indian plant is further evidenced by the number of species of wild relatives of crop plants in different regions of the country. Rice, sugarcane, tree cotton, jute, yams, cucurbits, brassicas, various millets, cumin seeds, citrus fruits, banana, tamarind, mango, jackfruit, turmeric, ginger, cardamom, cinnamons, black pepper, betel nut and numerous aromatic and medicinal plants are the important plant resources of the Indian region. India is also one of the 12 primary centers of origin of cultivated plants and is rich in agricultural biodiversity. India is equally rich in traditional and indigenous knowledge, both coded and informal on the use and importance of the biodiversity in the country (Roy & Roy, 2016).

ASSESSMENT OF PLANT DIVERSITY

Understanding biological diversity in terms of the processes by that ecosystems and their components function, be it at community, species, population or genetic levels, is critical to informing its sustainable use and safeguarding it for the benefit of future generations. Provided that biological diversity is dynamic, continually evolving and changing in response to biotic and abiotic fluctuations and other environmental pressures, it is necessary to record in time and area (*i.e.* benchmark) its status quo and, subsequently, monitor that status quo in order to find changes and assess their impacts. Such impacts may require intervention or mitigation measures to safeguard the future conservation, including sustainable use, of biological diversity. Crucially important is the need to identify species present in areas of natural habitat ahead of any changes in land use so to assess what diversity could also be lost from a region. This is particularly pertinent to tropical ecosystems, where levels of endemism tend to be higher than in more temperate regions and, consequently, the risks of species turning into globally extinct could also be greater (Green et al., 2009). Plant diversity assessment and documentation is the first step ahead before the next step of conservation of these biological resources. As per Heywood (1995) plant diversity documentation requires surveying, sorting, cataloguing and quantifying. Without documenting of this biodiversity there is a no means of conservation. Good biodiversity is always making the good environments which are helpful for people for many purposes. Biodiversity balance the food chain, food web, CO_2 sequestration, nutrient cycling and livelihood of human being (Raj, 2014).

Sampling Frequency

The seasonal sampling is recommended for the continuous study. The rainy, winter and summer seasons are the preferred times of the sampling. However, frequency of the sampling can vary on the case-to-case basis.

Phyto-sociological Studies

The vegetation is studied in the selected sites by laying nested quadrants of 1m x 1m, 5m x 5m and 20m x 20m sizes. Herbs are studied in 1m x 1m quadrants, shrubs in 5m x 5m quadrants and trees in 20m x 20m quadrants (shape and size of quadrants can herb/grass/litter sample plots (1m radius), Tree plot (10 m radius), Shrub plot (3m radius), vary according to terrain and requirements). Following quantitative characters are calculated using the standard formulae:

1. **Frequency:** Frequency refers to the degree of dispersion of individual species in an area and usually expressed in terms of percentage (Sarkar, 2016). It is calculated by the equation:

$$Frequency\left(\%\right) = \frac{No.\,of\ Quadrants\ in\ which\ species\ occurred}{Total\ no.\,of\ Sampling\ units\ studied} \times 100$$

2. **Density:** The number of individuals of the species in a unit area is its density. It is calculated as follows:

$$Density\left(\%\right) = \frac{Number\ of\ individuals\ of\ the\ species}{Total\ area\ studied} \times 100$$

3. **Abundance:** This is the number of individuals of any species per unit area of occurrence. It is calculated as follows:

$$Abundance = \frac{Total\ no.\ of\ individuals\ of\ species\ in\ all\ quadrants}{No.\ of\ quadrants\ in\ which\ species\ occurred} \times 100$$

4. **Dominance:** Dominance is the area occupied by stems of a species in any given area. It is calculated by measuring the diameter of the individual stems and adding the areas of the stems in a given area for the species.

$$Basal\ area\ of\ a\ species = Sum\ of\ basal\ areas\ of\ all\ the\ stems$$

$$Basal\ area\ of\ individual\ stem = \pi D^2\ /\ 4$$

where D=Diameter of stem

5. **Relative Density:** Relative Density is the measure of numerical strength of a species in respect to the total number of individuals of all the species (Sarkar, 2016). This is calculated by following formula:

$$Relative\ Density = \frac{Density\ of\ the\ species}{Total\ density\ of\ all\ the\ species} \times 100$$

6. **Relative Frequency:** Relative dispersion of individual species in an area in relation to the number of all the species occurred (Sarkar, 2016). Relative Frequency of the species is calculated by following formula:

$$Relative\ Frequency = \frac{Frequency\ of\ the\ species}{Total\ Frequency\ of\ all\ the\ species} \times 100$$

7. **Relative Dominance:** Dominance is the parameter which is determined by the value of basal area. For the comparative analysis Relative dominance is determined. It is the coverage value of a species with respect to the sum of coverage of the rest of the species in the area (Sarkar, 2016). This is calculated by the following formula:

$$Relative\ Dominance = \frac{Dominance\left(cover\right)\ of\ the\ species}{Total\ dominance\ of\ all\ the\ species} \times 100$$

$$Basel\,Area = \frac{\left(Circumference\,at\,breast\,height\right)^2}{12.56}$$

8. **Importance Value Index (IVI):** Importance Value Index is used to determine the overall impact of each species in the community structure. It is calculated by the addition of the percentage values of the relative frequency, relative density and relative dominance (Relative Basala Area) (Sarkar, 2016).

$$IVI = Relative\,Density + Relative\,Dominance + Relative\,Frequency$$

9. **Abundance/Frequency Ratio (A/F):** This is the ratio of the abundance and frequency of the given species. This is used to describe the distribution pattern of the species in the area.

Diversity Indices

Diversity indices are values propounded by various ecologists, which incorporate several parameters into single values.

1. Hill's diversity indices:

$$No = S$$

Where, S is the total number of species and represents the effective number of species present.

$$N_1 = eH'$$

Where, H' is Shannon's index and represents abundant species.

$$= eH'N_2$$

$$= \frac{1}{\lambda}$$

Where, λ is Simpson's index and represents very abundant species.

2. Shannon-Wiener Index: It is a measure of general diversity determined with the information function.

$$H' = -\sum_{i=1}^{S} p_i(\ln p_i)$$

Where
H' is the Shannon index of general diversity,
p_i is the proportion of ith species in that community.

The Shannon index is a measure for diversity. Values smaller than 2 indicate low diversity, while values greater than 2 point to a high diverse stand.

3. Concentration of Dominance (Cd): which is the inverse of diversity is measured by Simpson's Index as:

$$H' = -\sum_{i=1}^{S}\left(pi\right)^2$$

where, pi is the same as for Shannon-Weiner information function.

Dominance tendency was assumed when Simpson's Index > 0.25

4. Quotient of Similarity (Q_S), on the basis of the number of species under each community is measured as:

$$Q_s = \frac{2_c \times 100}{a+b}$$

Where, a and b are the number of species in A and B communities, and c is the number of species common in both the communities.

5. Evenness index (E):

$$E = \frac{1/\lambda - 1}{eH' - 1}$$

Where, λ and H' are same as given earlier.

6. β-Diversity index: β-Diversity is calculated to measure the rate of species change across the stands. The expression is as follows:

$$E = \frac{S_c}{S}$$

Where, Sc is the total number of species encountered in all the stands and S is average number of species per stand. ($\beta = \gamma/\alpha$**:** relationship between α, β and γ diversity)

7. Equitability index:

$$J = \frac{H'}{Ln\left(S\right)}$$

Where,

J = Pielou's Equitability index.

H' = Shannon Wiener diversity index.

S = number of species, ln is logarithm to the base e.

Dominance-Diversity Curves

Dominance/diversity curves, displaying the relative abundances of the species within a community, have often been constructed from field data. Several ecological and statistical models of dominance/diversity have been proposed, to explain the curves. Yet, rarely have curves of different models been fitted to field data (Wilson, 1991). To ascertain the resource apportionment among the various species at various sites, Dominance-Diversity (D-D) curves are drawn. A perusal of the D-D curves indicates that for sites undergoing succession, the curve is a geometric series at first but tends to proceed towards a series. This indicates that competition among species is increasing for available resources. Log normal distribution would give the best distribution of species-abundance pattern. If curve is a series, this indicates that competition among species is increasing for available resources. The log series indicates that moderately common species reflect most closely the nature and environment and fluctuate violently from time to time than the most abundant species. The curves, which represent the geometric series confirm niche preemption hypothesis. Dominance-diversity curves plotted between importance value index and species sequences of plants indicate a relationship between different species (Kumar et al., 2006).

Molecular Tools for Assessing Plant Diversity

Genetic diversity can be defined as any quantitative measure of the variability of a population, which reflects the equilibrium between mutation and the loss of genetic variation. The development of molecular markers for plants, initially isoenzymes, provided access to the genetic variability found in the accessions, which was useful for characterizing the germplasm and for genetic improvement, based on specific markers. Given their genetic link, DNA markers can be used to detect allelic variation in the genes underlying the target characteristics (Carvalho, 2019). The assessment of genetic diversity within and between inhabitants is often performed at the molecular level using various laboratory based techniques such as allozyme or DNA analysis, that measure levels of variation directly. Molecular techniques are applied in the analysis of specific genes, as well as to increase understanding of gene action, generate genetic maps and assist in the development of gene transfer technologies. Molecular tools have also had critical roles in studies of phylogeny and species evolution, and have been applied to increase our understanding of the distribution and extent of genetic variation within and between species (Mondini et al., 2009). As per Mondini (2009) genetic diversity is also gauged by molecular, morphological and biochemical characterization and evaluation:

- Molecular*:* Molecular analyses comprise a large variety of DNA molecular markers, which might use for analysis of variation. Different markers have different genetic qualities (they can be dominant or co-dominant, can amplify anonymous or characterized loci, can contain expressed or non-expressed sequences, etc.).
- Morphological: Morphological characterization doesn't require costly technology but large areas of land are often required for these experiments, making it possibly costlier than molecular assessment. These traits are often susceptible to phenotypic plasticity; conversely, this allows assessment of diversity within the presence of environmental variation.
- Biochemical: Biochemical analysis is carried out by separation of proteins into specific banding patterns. It is a fast methodology, that requires only small amounts of biological material.

However, only a few amount numbers of enzymes are available and thus, the determination of diversity is limited.

- Genetic or DNA based marker techniques are Restriction Fragment Length Polymorphism (RFLP), Random Amplified Polymorphic DNA (RAPD), Simple Sequence Repeats (SSR) and Amplified Fragment Length Polymorphism (AFLP). These are now in common use for ecological, evolutionary, taxonomical, phylogenic and genetic studies of plant sciences. Analyses of genetic diversity are usually based on assessing the diversity of an individual using either allozymesor molecular markers, that tend to be selectively neutral Mondini et al. (2009).

As per Mondini et al. (2009) genetic variability within a population can be accessed through:

1. The number (and percentage) of polymorphic genes in the population.
2. The number of alleles for each polymorphic gene.
3. The proportion of heterozygous loci per individual.

Given below is an overview of the different types of markers used for assessing genetic diversity.

Molecular Markers

In traditional plant breeding, genetic diversity was usually diagnosed through observational selection. But now, with the development of molecular biology this work is determined at molecular level biology this work is determined at molecular level based on DNA changes and their effects on the phenotype. Once DNA was extracted from plant, changes in the samples are determined using PCR or hybridization and subsequent agarose or acrylamide gel electrophoresis (to recognize different molecules based on their size, chemical composition or charges). Genetic markers are used for labelling and tracking the genetic variations in DNA samples. Genetic markers are biological compounds which can be determined by allelic variations and can be determined by allelic variations and can be used as experimental probes or labels to track an individual, tissue, cell, nucleus, chromosomes genes. In classical genetics, genetic represents allele diversity. In modern genetics, genetic polymorphism is the relative difference in genetic locus of the genome. Genetic markers can be used to facilitate the study of heredity and variation. DNA markers are accepted widely as potentially valuable tools for crop breeding such as rice, wheat and forage species. The use of DNA markers in plant and animal breeding has opened new territory in agriculture which is called molecular breeding. These markers widely used because of their high prevalence and expression in different stages of the organisms. These markers come from different classes of DNA mutations such as substitution mutations (point mutations), replication errors and DNA tandem repeats. DNA markers involve several sets of markers and divide into two main categories: PCR-based molecular markers and hybridization-based molecular markers. Restriction Fragment Length Polymorphism (RFLP) is a hybridization-based molecular marker. More ever, Random Amplified Polymorphic DNAs (RAPD), Amplification Length Polymorphism (ALP), Simple Sequence Repeat (SSRs), Amplified Fragment Length Polymorphism (AFLP) Sequence Characterized Amplified Regions (SCARs), Sequence Tagged Sites (STS), Single Polymorphic Amplification Test (SPLAT), Variable Number of Tendom Repeats (VNTRs), DNA Amplification Fingerprinting (DAF), Single Nucleotide Polymorphism (SNPs), Microsatellites or Short Tandem Repeats (STRs) and Single Strand Conformation Polymorphism (SSCP) are PCR-based molecular markers (Kordrostami & Rahimi, 2015). Characterization of plant with the use of molecular markers is an ideal way to conserve plant genetic resources. Molecular characterization helps to determine the breeding behaviour of species, individual reproductive success and the existence of gene flow, the movement of alleles within and between populations of the same or related species, and its consequences (Prasad, 2014).

Advantage (Mondini et al., 2009; Kordrostami & Rahimi, 2015)

- It consists in assessing co-dominance, absence of epistatic and pleiotrophic effects, simple use, and low costs.
- Time saving.
- Biosafety.
- Stability and Reliability.

Disadvantages (Mondini et al., 2009)

- The number of polymorphic enzymatic systems available is limited and the enzymatic loci present only a small and not random part of the genome - therefore, the observed variability may be not representative of the whole genome.
- There are only limited isozyme systems per species (no more than 30) with correspondingly few markers.
- Although these markers allow large numbers of samples to be analysed, comparisons of samples from different species, loci, and laboratories are problematic, since they're affected by extraction methodology, plant tissue, and plant stage.

Biochemical Markers

The use of biochemical markers includes the analysis of seed storage proteins and isozymes. This technique utilizes enzymatic functions and may a comparatively inexpensive yet powerful method of measuring allele frequencies for specific genes (Mondini et al., 2009). Isozymes had a long history in genetic variability studies in forestry, to assess the genetic diversity present within natural forest stands (Ritland et al., 2005, Doligez & Joly, 1997) or to determine whether domestication practices had led to a reduction in diversity. However, the problem of these biochemical marker assays is that they are affected by plant phenological stage and their limited availability, and therefore, they would never allow for a genome-wide scan of variability (only 0.1% of the total variation is detectable by this technique) (Porth & El-Kassaby, 2014). Biochemical markers can be categorized in two types:

Phytochemical Markers

Phytochemicals are non-nutritive chemical constituents of plants which occur naturally in it, or the chemicals which is derived from plants are called Phytochemicals. The discovery of novel compounds (phyto-chemicals) from wild plant species is an achievement toward the enhancement of the eradication of the human diseases. With the advancement of modern techniques such as mass spectrometry (MS) and nuclear magnetic resonance spectrometry (NMR) combined with separation techniques facilitated the identification and structural elucidation of molecules. These phyto-chemical analyses are valuable tools for taxonomic differentiation within species or for evaluating the effect of environmental factors (Kumar et al., 2018b).

Protein Markers

Polymorphisms in protein profile as detected by electrophoresis followed by specific staining of a discrete protein sub-class have been used successfully as biochemical markers in plant breeding and genetics. Much of the detectable protein variations identify allelic variability in Structural genes encoding the proteins. Alternatively, some protein variation may appear due to post translational modification. Two classes of proteins isoenzymes/isozymes and alloenzymes /allozymes, are used as markers (Kumar et al., 2018a). Isozymes analysis is used for various research purposes in biology, viz. to delineate phylogenetic relationships, for estimation of genetic variability and taxonomy, to study population genetics and developmental biology, to characterization in plant genetic resources management and plant breeding. Isozymes were defined as structurally different molecular forms of an enzyme with, qualitatively, the same catalytic function. Isozymes originate through amino acid alterations, that cause changes in net charge, or the spatial structure of the enzyme molecules and also, therefore, their electrophoretic mobility. After specific staining the isozyme profile of individual samples may be observed (Kumar et al., 2009). Allozymes are variants of enzymes which differ in one or few amino acids because of allelic differences of the encoding orthologous genes. For allozyme analyses, proteins are extracted from plant tissues and separated by electrophoresis by their net charge, conformation and size. Mutations in the DNA may result in replacement of an amino acid, hence in modification of net electric charge and the overall shape of the protein. These protein modifications affect the migration rate of the proteins in an electric field allowing allelic variation detection by gel electrophoresis and subsequent enzyme-specific stains. These stains contain the respective sub-strate for the enzyme, co-factors and an oxidized salt. Thus, the allozymes become visible as bands in the gel, and their numbers reflects the number of loci and alleles (homozygous or heterozygous), as well as in some cases the number of subunits of the protein that can be separated (Omondi et al., 2016).

Morphological Markers

Morphological markers are based on visually accessible traits like flower colour, seed shape, growth habits, and pigmentation, and it doesn’t need expensive technology but large tracts of land area are often required for these field experiments, making it possibly costlier than molecular assessment in developed countries and equally expensive in developing countries considering the labour cost and availability. These markers traits are often susceptible to phenotypic plasticity; conversely, this allows assessment of diversity in the presence of environmental variation that can’t be ignored from the genotypic variation. These types of markers are still having advantage and they are mandatory for distinguishing the adult plants from their genetic contamination within the field, for example, spiny seeds, bristled panicle, and flower/leaf colour variants (Govindaraj et al., 2015).

SOLUTION

Biological diversity may be preserved for posterity in 2 ways – in situ and ex situ. Ex situ maintenance of species is provided by botanical gardens, Zoos and aquaria and of gene pools by germplasm banks (seed stores, in vitro collections and field gene banks) and grass-root collections of plant cultivars and animal breeds. Botanical gardens probably have a greater capacity with respect to plant species. But clearly it's possible to maintain ex-situ only a small fraction of the world's species. In-situ conservation is done by protecting areas rich in biodiversity. These include biosphere reserves, national parks, sanctuaries, etc. The concept of biosphere reserves is the brainchild of Man and Biosphere Programme of UNESCO. The primary objective of this concept is to save, for the current and future use, the diversity and integrity of biotic communities of plants and animals within natural ecosystems and to safeguard the genetic diversity of species on which their continuing evolution depends. Such reserves area unit to comprise of terrestrial and marine ecosystems and to coincide with national parks and sanctuaries (Bahadur et al., 2015). Another best solution to protect the floral diversity is awareness of humans about plant diversity and reduction of pollution potential in environment.

CONCLUSION

Finally, it's concluded that the diversity of the plants is a key component of nature not only important for their value as a source of energy but they are also having wide potential to protect the environment in multifold directions. A plant provides better environment and platform to all the living beings in healthy development of the nature. Assessment of plant diversity is very important step for conservation of that resource. Without assessment and documentation there is a no means of conserving the biological resources including flora and fauna. Due to increasing population with increasing need of food and shelter are necessitates the deforestation. It's time to conserve this forest treasure through assessment of unknown flora, that is an important part of humankind by giving all tangible and intangible products. Further, information of plant diversity is required for the study of dynamic nature of vegetation under specific eco-environment situation.

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