सत्यमेव जयते

ENVIRONMENTAL SUSTAINABILITY, GREEN GROWTH AND DISASTER RESILIENCE

A Knowledge Compendium under the project CAP-RES supported by DST (GoI)

nidm
Resilient India - Disaster Free India

National Institute of Disaster Management
(Ministry of Home Affairs, Government of India)

सत्यमेव जयते

ENVIRONMENTAL SUSTAINABILITY, GREEN GROWTH AND DISASTER RESILIENCE

KNOWLEDGE COMPENDIUM

Under the project
Climate Adaptive Planning for Resilience and Sustainable Development in Multi-hazard Environment (CAP-RES)
Supported by Department of Science and Technology, Government of India

2021

National Institute of Disaster Management (NIDM)
(Ministry of Home Affairs, Government of India)

Plot No.15, Pocket 3, Block-B, Sector-29, Rohini, Delhi-110042
Website: www.nidm.gov.in

ENVIRONMENTAL SUSTAINABILITY, GREEN GROWTH AND DISASTER RESILIENCE
KNOWLEDGE COMPENDIUM

ISBN No.: 978-93-82571-63-6

Edition: 2021

Editors

Major General Manoj Kumar Bindal, VSM
Executive Director, NIDM

Prof. Anil K Gupta, Head, ECDRM Division,
NIDM, Delhi
(Project Director-CAP-RES, DST Project)

Dr. Sweta Baidya, Research Associate,
CAP-RES, NIDM, Delhi

Associate Editors

Ms. Pritha Acharya, Research Scholar,
CAP-RES, NIDM, Delhi

Ms. Shweta Bhardwaj, Research Scholar,
CAP-RES, NIDM, Delhi

Published by

National Institute of Disaster Management (NIDM), Ministry of Home Affairs, Government of India, New Delhi-110042

Citation:

Bindal, M.K., Gupta, A.K., Baidya, S., Acharya, P. and Bhardwaj, S., 2021. Environmental Sustainability, Green Growth and Disaster Resilience. National Institute of Disaster Management, New Delhi, Pages 264

Disclaimer:

This publication is based on the collective case studies and best practices invited and edited under the project "Climate Adaptive Planning for Resilience and Sustainable Development in Multi-Hazard Environment (CAP-RES)" under the National Mission on Strategic Knowledge on Climate Change (NMSKCC). This knowledge compendium includes a range of information from research work undertaken by several institutes and various published, unpublished literature, reports, documents, and web-resources. Editors gratefully acknowledge the authors and other original sources. This compendium full or in parts, can be freely referred, cited, translated and reproduced for any academic and non-commercial purpose, with appropriate citation.

Dr. Akhilesh Gupta
Senior Advisor
DST
Head
Strategic Programmes, Large Initiatives and Coordinated Action Enabler (SPLICE) &
Climate Change Programme

Department of Science and Technology (DST)
Government of India
Technology Bhavan, New Mehrauli Road,
New Delhi-110016

MESSAGE

Climate Change and disasters are going to be the key issues for country like India as it is one of the most important factors influencing our day to day life. Over the last few decades, global temperatures have been rising. The causes of climate change can be attributed to increase human activities as most anthropogenic activities ranging from fossil fuel combustion, biomass burning, changes in land cover and land use etc. release of Greenhouse Gases into the atmosphere. The IPCC messages are that the climate change is going to impact at least some key areas, like for example, the temperature, sea level and natural hazards are going to rise.

But with increasing knowledge and awareness regarding various disasters, now clearly there is a paradigm shift from relief and rescue approach to create awareness, infrastructure and building resilience approach, which in future will help to achieve the sustainable goals.

In this regard, the Green Growth approach is the best solution for building disaster and climate resilience. The pathways of Green Growth approach can help in achieving the goals of Paris Climate Agreement and Sendai Framework. Several pathways of Green Growth includes urban green growth, circular economy, green industry, carbon neutral energy sources, waste management, Resilient agriculture, Disaster resilient green infrastructure, ecosystem management through Nature Based Solution etc.

This knowledge compendium has brought up existing pathways and innovative ideas for Green Growth implementation. It has also emphasized upon the policy intervention which can support the green growth. Therefore, this document is most relevant in the present time.

(Akhilesh Gupta)

Maj Gen Manoj Kumar Bindal
VSM
Executive Director

राष्ट्रीय आपदा प्रबंधन संस्थान
(गृह मंत्रालय, भारत सरकार)
National Institute of Disaster Management
Ministry of Home Affairs, Govt. of India
Plot No.15, Pocket 3, Block-B, Sector-29,
Rohini, Delhi-110042

FOREWORD

Climate Change, unplanned developmental work, changing land use and environmental degradation are the major drivers of disaster risk and vulnerability. For past few decades, hydro-meteorological disasters are rising unprecedentedly. All recent climate projections are indicating continuous rise in the frequency and intensity of all natural disasters.

The DST funded CAP-RES project focuses on five thematic areas, Resilient Agriculture, Resilient Health, Green Growth and DRR, Climate proofing during disaster relief and recovery and Policy Instruments in DRR. The present compendium is on the importance of Green Growth in DRR and sustainable management of life and resources.

The purpose of this Knowledge Compendium on Environmental Sustainability, Green Growth and Disaster Resilience is a document for dissemination of knowledge, experiences and expertise through case studies and best practices by the experts from different institutes. This compendium has enabled us to add value to the present understanding of different approaches for DRR including science, policy planning and practices and facilitate to prepare a roadmap for addressing climate change induced risks and vulnerability through Green Growth approach.

This document is much relevant as along with the increasing climate change and uncontrolled developmental activities are giving rise to global temperature and sea level. The Green Growth approach is the only way which can help us live a better and sustainable future.

(Manoj Kumar Bindal)

ACKNOWLEDGEMENT

The Compendium on Green Growth has been supported by Department of Science and Technology (DST), Government of India, through the Climate Adaptive Planning for Resilience and Sustainability in Multi-Hazard Environment (CAP-RES). A special note of thanks to Dr. Akhilesh Gupta, Senior Advisor & Head, SPLICE and Climate Change, DST, GoI for entrusting NIDM with the opportunity to take up and work on the CAP-RES project. The project team is thankful to Major General Manoj Kumar Bindal, Executive Director NIDM for his constant support and encouragement for undertaking the study and ensuring the smooth functioning of the project.

The project team is also thankful to all the authors who have shared their researches and experiences and helped the project team to compile this compendium. Their valuable strategy recommendation will help to achieve the sustainable goals through green growth.

From CAP-RES team, Dr. Sweta Baidya (Research Associate) coordinated and compiled the case studies. Thanks are also due to the CAP-RES team including Ms. Pritha Acharya (Research Fellow) and Ms. Shweta Bhardwaj (Research Fellow). The project team also extend thanks to Shri SK Tiwari (Librarian, NIDM) and the entire publication cell of NIDM including Ms. Karanpreet Kaur and Ms. Sonali Jain for helping in printing and publication of this report.

Prof. Anil K Gupta
Project Director
CAP-RES Project &
Head ECDRM Div., NIDM

CONTENTS

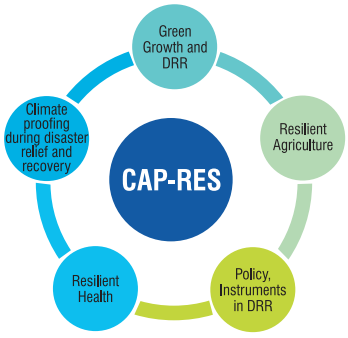
CONTEXT

Centre for Excellence on Climate Resilience (CECR at NIDM)

National Institute of Disaster Management (NIDM) has a dedicated Division on Environment, Climate change and Disaster Risk Management (ECDRM) which has been designated as a Centre of Excellence on Climate Resilience (CECR) under the National Action Plan for Climate Change and Human Health (NAPCCHH). The CECR is implementing five research projects namely Climate Adaptive Planning for Resilience and Sustainable Development in Multi-hazard Environment (CAP-RES) with support of DST-Govt of India, National Agriculture Disaster Management Plan (NADMP) funded by the Ministry of Agriculture & Farmers Welfare, Health Resilience and Capacity Building (HER-CAP) with WHO, Crisis Management Plan for Dealing with Contamination of Water Bodies (CMP-WB) funded by CPCB, Disaster Management Plan for Ministry of Environment, Forest and Climate Change (NEFC-DMP) with MOEFCC, National Disaster Management Plan of Dept. of Chemicals and Petrochemicals (NCP-DMP) supported by MOC&F. It also collaborates with a number of international and national organizations working in the areas of climate change adaptation and resilience with reference to disaster risk reduction

About CAP-RES

Climate Adaptive Planning for Resilience and Sustainable Development in Multi-Hazard Environment (CAP-RES) is an umbrella project which tries to address the gap areas in capacity building to curb the challenges of climate change. The project encompasses five thematic areas: a) Green Growth and DRR; b) Resilient Agriculture; c) Resilient Health; d) Climate proofing during disaster relief and recovery; and d) Policy, Instruments in DRR. CAP-RES focuses across three specific regional contexts, i.e. Indian Himalaya Region (special reference to North East), Coastal region and Central western region. Region specific climate related hazard complex, including flood, drought, water scarcity, forest fire, cyclone/storm surge, coastal erosion, slope erosion/ landslide, windstorms, heat wave, disease epidemics, industrial/chemical risks, etc.



Introduction

INTRODUCTION

Introduction to the Knowledge Compendium

Anil K Gupta, Sweta Baidya, Pritha Acharya and Shweta Bhardwaj

Climate Change is increasingly posing risk to human life and resources and maintaining sustainable future is becoming a challenge especially in the developing country like India whose larger percentage of economy depends on the agriculture and unorganized sector. The technological development and globalization has given rise to unprecedented developmental activities which ultimately leads to increased human induced disasters and resource and environmental degradation. Development is inevitable in today's technology oriented world. But sustainable development is the most desired way of development to safeguard our society, economy and environment. An inclusive development strategy is thus the key. Green Growth is the only pathway to come out of this issues. Green Growth has gained a lot of momentum as an effective strategy as well as an important tool for ensuring that the future development is sustainable as well as greener.

Green growth encourages environment friendly economic growth while ensuring the uninterrupted environmental services and resources to continue human well-being in future. To achieve this we must catalyze the green investment and green innovation to underpin the goals of Sustainable Development Goals (SDGs). Green Growth provides a realistic and nature based approach to gain measurable progress across social, economic and environmental pillars.

Green growth enhances the productivity by increasing the efficiency in production and energy consumption and reducing waste generation. The success of Green Growth approach depends on innovation that leads to new sustainable way of utilizing existing resources and economically viable environment friendly resource generation. To successfully implement green growth tools, the demand for green goods, services and technologies have to be boosted. To bring in the Green Growth practices in the system, we need to mobilize the revenues through green taxes etc. The subsidies those are harmful to the environment should be minimized or eliminated.

The "one-size-fits-all" approach does not work in the implementation of green growth. The green growth strategies have to be tailored to fit specific areas or regions. The Strategies have to be problem specific. New innovative green growth policies can bring efficient

infrastructure to ensure resilient health and poverty eradication. This type of innovation will also support national schemes like "Per Drop More Crop" by saving water and "Skill India" by creating in-situ resources etc.

Many of the countries in the world have indeed embedded and continue to embed the concept of green growth into their systems. Imperative evidences are there to prove that the green growth is inevitable for sustainable development and it is possible to ingrain the green growth approaches in Indian systems. But policy approach will be able to provide the organizational underpinnings towards green growth transition. There are many pathways of green growth like Green Economy, Green energy, Green Industry, Urban Green Growth, Nature Based Solution etc. But for successful implementation of all green growth pathways, revamping our various national and regional policies and practices is inevitable.

Scope of the Compendium:

This Knowledge Compendium is a part of the CAP-RES project funded by DST-GOI. The CAP-RES focuses across five thematic areas such as Green Growth and DRR, Resilient Agriculture, Resilient Health, Climate proofing during disaster relief and recovery and Policy Instruments in DRRT. Experts from various state-level and national level institutions have shared their research work multi-disciplinary methodologies and experiences through the case studies and best practices.

NIDM's Knowledge Compendium on Green Growth demonstrates that, there are many pathways of sustainable development including green growth. The Compendium presents a compilation of some promising pathways through which the goals of environmental sustainability and green growth can be achieved. Authors have found out several ways from around the world, that have been found innovative and creatively promoting green growth in various sectors. This compendium has highlighted many innovative provisions, which promote resource efficiency and sustainable production and consumption through resilient agriculture, waste management, disaster resilient construction etc. and other practices towards a transition to green economy.

The Compendium contains a compilation of case studies and best practices that significantly deviates from the usual practice of resource generation or utilization. This is an example of already existing pathways which calls for driving development agenda along with new policy approaches, regulatory methods, and legislative provisions for future promotion of green growth. This knowledge compendium is divided into seven sections and the first section gives a brief introduction about the compendium. Section two to six presents Case studies and Best Practices documented by various authors.

Section two represents six case studies and best practices related to Sustainability. In this section the first Case study is "Mapping Land Use Cover, Community Perceptions For Ecosystem Services With Context To Disaster Risk Reduction: A Case Study From Tampara Lake". This case study is designed around the Tampara Lake in Odisha. The paper examines the land cover changes using Landsat data and tries to understand the landscape dynamics, indicating a significant loss in wetland extent. The study also tries to understand the human-nature interactions through an ecosystem services assessments. The second study is "Assessment of Flood Disaster Vulnerability And Mapping Using HEC-RAS- A Case Study of Neerasagar Reservoir, Karnataka" which has aimed at preparing flood risk maps of the Neerasagar Reservoir in Karnataka. Dam hydraulics and history of floods are assessed and the estimates of flood and their vulnerability has been presented. This study is first of its kind in the North Karnataka region, which are mostly drier regions, where flood risks are comparatively low and would help in sustainable drought mitigation strategies for future floods of similar and higher magnitudes. The third paper of this section, "Analysis of Knowledge, Attitude and Practice (KAP) with Reference to Drinking Water in Alleppy District Kerala and Evolve Effective Management Practices" discusses the knowledge, attitude, and practices (KAP) of rural and impoverished communities in the Kuttanad region of Alleppy which is severely water stressed amongst plentiful water sources. This paper comes up with the idea that for the Kuttanad region, small scale rainwater harvesting and simple purification technologies at household level could be the most appropriate and sustainable technological interventions till large scale interventions by the governing agencies are sought. The fourth paper "Protection of Mangroves as core component for implementing the Nature based Solutions" represents the importance of Nature based solution (NbS) in saving the resources of earth for the survival of humans. It also shows NbS as an important tool in in the climate change strategies, regulations, investment in infrastructure and funding mechanisms. While discussing about the benefits of NbS it suggests that NbS should be implemented at the landscape scale and, in order to tackle social problems, NbS should be the part of the overall strategy, plan and intervention design. The fifth case of this section is "Impact of Peri-Urban Issues on the Environment and People: A Review on Indian Scenario" which highlights the challenges of Peri-Urban areas and environment in Indian context depicting the transformation in physical properties and surfacing of the issues pertaining to environmental degradation and public health. The paper also highlights the future perspectives to enable the proper management of these areas. The sixth case study, "Scenario of Solid Waste Management - Case Study From Vadodara City" brings forth the problem of non availability of proper management of biodegradable solid waste including the restaurant generated waste and domestic waste. The domestic waste itself counts as high as 754 tonnes per day with additional concrete waste of 100 tonnes per day. The paper deals with simple solutions that need to be addressed through people participation and generation of revenue from the waste.

The third section deals with the options of making the agriculture system resilient. This section has two studies. One is "Plant growth promoting rhizobacteria Pseudomonas putida RA for climate resilience and agricultural sustainability" which presents A comparative analysis of the effects of RA-inoculation on various morphological, physiological and biochemical parameters in two contrasting chickpea cultivars of 'desi' and 'kabuli' types during drought stress and subsequent recovery conditions suggested utility of RA in drought stress amelioration. This particular chickpea variant will help in climate adaptation agricultural sustainability development programmes. And the other is about "The Potential of Wild Edible Plants in the Economy of Indigenous People A Case Study from Male Mahadeshwara Betta (MM Hills), Karnataka". This study has brought out 94 wild edible plants which are locally available in Male Mahadeshwara Betta (MM Hills), Karnataka. This plants have high nutritional value and could be a very economically viable source of income source for the local people. It can also reduce the pressure on biotic resources and has potential in contributing the ecosystem sustainability and mitigating the threats due to disasters that are driven by variety of factors and aggravated by ecosystem degradation.

Section four discusses regarding the different ways of making disaster resilient construction. In this section we have four case studies. The first one is “Green Buildings: A Sustainable Green Growth approach towards Disaster Resilience”. The chapter talks about need for green growth approaches for fostering resilient and sustainable development. The chapter through case study analyses highlights various sustainable tools and techniques adopted globally for building resilience towards disasters using green infrastructures. The next chapter “Climate Change Resilience Solutions for Built Structures” highlights the need for promoting sustainable infrastructural solutions for building climate resilience. The chapter highlights some climate resilient structural solutions that can be easily sourced, planned and implemented by communities to improve life cycle of built infrastructure and help mitigate and adapt to changing present and future climatic risk patterns. The third chapter in this section is “A Framework for Resilient and Sustainable Post-Disaster Housing Strategies” The chapter provide a framework for India's post-disaster shelter strategies by synthesizing evidence from secondary research and following a case study approach highlighting some of the best practices from around the world. The framework considers land, institutional and legislative settings, knowledge and capital, and capability as key attributes for sustainable post-disaster housing strategy. The last case study of this section is “Eco-friendly Approach for Construction: A Case Study from Uttarkashi, Uttarakhand”. The case study is designed around Kamad Village in Uttarakhand, Uttarkashi and introduces a system for building construction promoting environment-friendly, disaster-safe construction while generating economic gains for local community. The model promotes

use of locally available building material and setting up of sustainable delivery model for these materials through community-based production and supply systems. The model creates opportunities to strengthening local economy while improving the environmental outcomes of construction practices.

Section five brings out some strategic issues about disaster risk management, environmental sustainability and circular economy. The first paper in this section provides ‘‘Insights into Embankment safety assessment using life cycle approach. This paper discusses the embankments as a case study which play a role in flood control. Embankment breaches have led to devastating floods, owing to inadequate maintenance. With the documentation since the colonial era, it is argued in this paper that a comprehensive safety assessment of embankments based on the Life Cycle approach is needed to minimise their overall economic and environmental costs. This is an attempt to suggest a dynamic LCA approach based assessment of embankments to reduce the impact of floods in India. The second chapter "Analysing the Integrated Paper and Pulp Industry through a Circular Economy Lens" highlights the need for promoting circular economy across paper and pulp industry. The chapter analyses interventions taken various paper and pulp industries and explores key gap, challenges and opportunities for incorporating concept of circular economy within this particular sector. The last study of this section is "Disaster Risk Management and Role of Education: Examining Teachers' Understanding" which presents the knowledge and classroom behaviour of teachers regarding sustainability and disaster risk (DR) awareness through Interview and observation schedules. Results revealed that teachers have narrow understanding of sustainability through 'saving the environment' by reducing pollution and conserving water. This study provide insight into the required modification in teachers' education and curriculum to achieve education for sustainable development and DRR.

The penultimate section of this compendium talks regarding the pathways of green growth and carbon management. It contains three subsections which deals with the carbon management strategies and green growth approaches for disaster management. The first case study in this section is "Green Growth and Flood Proofing: A Case of Land Use Change in Hyderabad". This case study is designed around the city of Hyderabad, Telangana. The study analyses land use changes as one of the key instruments in assessing green growth and flood resilience in the cities. It further identifies the instrumental role of green growth and flood proofing in mainstreaming Sendai Framework and Sustainable Development Goals at the local level. The second study is about "Carbon Management and Greenhouse Gas Extenuation". The case study uses an article based approach to identify and the suitable approaches to reduce and mitigate carbon and green-house gas emissions. The study touches upon additional strategies including green revolving fund, renewable energy credits, power purchase agreements etc. which will allow revenues

accumulation and enable carbon neutrality. The last study talks about "Carbon Sequestration for Clean Energy and Green India"which aims at discussing the processes by which carbon management takes place in the energy sector. Important themes covered in this paper including perspectives in carbon capture and sequestration technology, advancements in the pre-combustion, combustion and post-combustion capture, terrestrial sequestration and CO_2 storage in the oceans.

The compendium has arrived at strategy & policy pointers based on the research outcomes which are very much relevant for the changing landscape and climate change. This report is based on findings from different approaches undertaken to study several green growth pathways and entry points which has either been successfully implemented or can be implemented in future for achieving sustainability. The outcomes provide insights to an imperative entity of climate resilient ecosystems which was not accounted and acknowledged separately prior to this research in India.

A
Sustainability

Chapter-1

Mapping Land Use Land Cover and Community Perceptions for Ecosystem Services with Context to Disaster Risk Reduction: A Case Study from Tampara Lake

Dushyant Mohil[1*], Louise Schreyer[1] and Santosh S. Palmate[1]

Abstract

The landscape in Tampara basin is undergoing transformative changes. The lakes, ponds, marshes and floodplains those that were previously absorbing excess floods flows from abundant rains have been drained to make rice fields, or have been built over. Analysing changes in land use and land cover, provides a good understanding of changing landscape dynamics.

Ecosystem Services Shared Value Assessment (ESSVA) tool is further used to assess community perceptions, preferences and attitudes for ecosystem services. Data from 650 structured questionnaire survey of basin communities and eight focal group discussions (FGDs) indicated preferences for 18 ecosystem services identified as being derived from the wetland and the heterogeneities within these communities. The land use land cover changes and FGDs further indicate increasing water stresses which can exacerbate communities' vulnerability levels. The results of the survey would be mapped with DRR plans as risk reduction measures and to build resilience.

Keywords: NbS, Ecosystem-based DRR, Wetland-wise use, Ecosystem services, Perceptions, Lake basin management, ESSVA

I. Introduction

Water related risks are those that are direct results of hydro climatic inferences like, floods, droughts and extreme storms such as cyclones, hailstorms and snowstorms. In India a majority of events are related to water. Water-related risks damage ecosystems leading to loss of lives and productive assets. In India alone, water-related disasters have

---

The paper is an outcome of the results from Partners for Resilience programme implementation in Odisha.

Dushyant Mohil*(✉), Louise Schreyer and Santosh S. Palmate
Wetland International, New Delhi, 110024, India
*Email: dushyant.mohil@wi-sa.org

accounted for 98% damage in the last five years (2016-2019) and this is predicted to increase in frequency due to climate change (Guha-CRED 2016).

Recent water related disaster events such as the floods in Kashmir 2014 Chennai in 2015 and Kerala in 2018 have shown that environmental degradation is one of the most critical underlying causes of risk, integrated approaches which work with nature have the potential to make communities more resilient as well as helping adapt to a changing climate (Kumar et al., 2020).

Ecosystems provide nature-based solutions (NbS) to address a multitude of risk factors. NbS approaches can be effective tools to assist district planners, in reducing risk in tandem with the disaster management cycle i.e. buffering and mitigating hazard impacts, reducing vulnerability by providing ecosystem services and reducing exposure when natural infrastructure is established in highly exposed areas (Cohen et al., 2016, Sudmeier-Rieux et al., 2019).

India's commitment to the Sendai Framework targets and coherence with the Paris Agreement and the 2030 Sustainable Development Goals has seen a comprehensive revision and redrafting of the National Disaster Management Plan. The NbS to reducing disaster and climate risks, especially Ecosystem-based Disaster Risk Reduction (Eco-DRR) and Ecosystem-based Adaptation (EbA) are now integral part of the policy agenda to reduce disaster risks (NDMP 2016).

II. Methodology

The approach for the study involves three sequential steps (Figure 1):

- The first step is setting the scope: demarcating landscape boundary and physical settings of the wetland
- The second step involved developing landscape maps and undertaking vulnerability assessments
- The third step involves mapping ecosystem services

Figure 1: Assessment Approach

Mapping approach

Tampara, a freshwater lake on the east coast of Odisha State (Map 1) was selected as a demonstration site, wherein Wetlands International South Asia is formulating a community based wetland management plan. The wetland spanning 409 ha within a basin of 2,200 ha is the primary source of water for over 25,000 households living in Chhatarpur Municipality, and irrigation in and around Tampara wetland. The lake is also an important source of fish, and aquatic aromatic Pandanus, sustaining livelihoods of over 700 households.

A region of interest was defined based on interactions with community members. The area of interest considers the catchment and other influences to the catchment which is larger than wetland. The larger region of interest enables for a landscape analysis and not merely looking at the immediate surroundings of the intervention site. Land use and land cover changes in the sub-catchment needs thus to be analysed. The region of interest is comprised of the lower basin of the Rishikuliya River, as well as the area situated east of Tampara Lake and west of the city of Brahmapur. The total surface of this region of interest amounts to approximately 111100 hectares. Land cover classification was performed with QGIS Semi-Automatic Classification Plugin (developed by Luca Congedo) on two satellite imageries. Two Landsat imagery scenes were selected for the area of interest from 5 October 1988 using the Landsat 5 TM satellite and from 10 October 2018 from the Landsat 8 OLI satellite.

Satellite imagery scenes were selected for early October, as the fall is the season of maximum growth of marshes in the area. These datasets were downloaded for free from the US Global Survey (USGS) Global Visualization Viewer (GloVis) website (https://glovis.usgs.gov/).

Pre-processing was performed on the satellite imagery through Digital Object Identifiers (DOI) atmospheric correction before the classification. Six land use land cover classes were defined in accordance with the identified region of interest.

The Normalized Difference Water Index (NDWI) is the most commonly used index for mapping water bodies through remote sensing. The formula used for NDWI computation was the following:

NDWI = (Green - NIR)/ (Green+NIR). The NDWI product is dimensionless and varies from-1 to +1. Looking at NDWI values and their geographical distribution over area of interest, we were able to define a threshold for water content and then extract total area of water.

A Google Earth Engine script was developed to first select the least cloudy imagery from Landsat satellites between beginning of September and end of November. The three months of September, October and November correspond to the season of maximal water

extent. Landsat satellites were chosen for this analysis due to good spatial resolution (30 m at nadir point), returning period, and availability of historical data- from 1988 to 2018 for our scene. Landsat 5 imagery scenes were selected for the period from 1988 to 2013 and from 2013 to 2018, Landsat 8 was selected. Not all years could be uses due to: a) high cloud cover for certain years, which led to the discarding of certain scenes b) data missing. A major gap is noticeable between 1993 and 2003.

Ecosystem services shared value assessment approach

The perceptions, attitudes and preferences humans hold for ecosystem services are important elements for engendering changes in the way's stakeholders engage with management of wetlands. In an attempt to understand behavioural dimensions of ecosystem services for integration in wetland management planning and decision making, ESSVA tool developed by International Lake Environment Committee (ILEC) was piloted during the year under Partners for Resilience (PfR) programme for assessing stakeholder perceptions, attitudes and preferences for wetland ecosystem services (Kumar et al., 2018).

The ESSVA tool uses a structured questionnaire to engage with stakeholders in discussion regarding management of ecosystem services. Behavioural data is elicited through a structured questionnaire having seven sections. The first two sections contain questions on the demographic and socio-economic data aspects of the household, and relationship with the wetland. The third section has questions on identification and ranking of various ecosystem services, considered relevant by the responding households. The causes and impacts of impairment of ecosystem functions are assessed next, both in terms of human health, cultural values and economic consequences. Questions on responsibilities and ownership are included in the fifth section, followed by section on role in basin governance and possible improvement. The questionnaire uses pictures depicting various options, thus enabling the respondent to relate each choice to a visual state. A primary purpose of the questionnaire is to engage the stakeholder in discussions regarding management of ecosystem services, from the respondent's frame of reference (Kumar et al., 2018).

The tool was first piloted in the form of survey in March 2018 and covered 278 households. The survey was conducted by a group of trained surveyors employed by Netcoast

After the pilot survey, a further detailed assessment was conducted in March-October 2018 covering 3% of the total population within the basin a total of 650 individuals responded to the questionnaire. Respondents were identified using stratified random sampling (based on location of houses in the landscape in either lower or upper catchment areas). The communities identified a total of 18 ecosystem services (6 provisioning services, 5 regulatory services, 7 cultural services).

III. Results and Discussion

Landscape Settings

Tampara is vulnerable to multiple disasters such as floods, drought, tropical cyclones, storm surges and tsunamis. As part of the Rushikulya river basin Tampara is highly susceptible to h floods lieng close to estuary where flood waters intermingle with high tide. The floods usually occur during monsoon season due to heavy rainfall. Besides, the basin is prone to storm surges. The storms produce tidal surges that are usually accompanied with heavy rainfall making the coastal belt vulnerable to both floods and storm surges. People lose their houses, lives, livestock, crop and property worth millions is damaged. Additionally, these currents majorly affect the livelihood of coastal residents as they are exposed to coastal disasters. The residents are not only at the risk of losing their lives but they constantly strive to regain their normal routine post extreme events. The atmospheric temperature in summer is increasing along with regular low pressures along with an unpredictable rain pattern. In recent years Cyclone Titli and Phailin have all made landfalls in close proximity to Tampara, leading to extensive losses.

Tampara's proximity to Rishikuliya and the coast makes it physiographically an important flood buffer for the villages along the coastal plains. While the coastal plains and floodplains are flat the western parts of the basin along Chattarpur are at a higher elevation so the natural flow of water is towards Tampara and in cases of extreme rainfall when Tampara's connectivity to Rishikuliya helps maintain the water levels in the area.

Wetlands in the basin act as natural defence against water-related risks. Their role in regulating water flow, especially around river floodplains and seasonal streams is crucial in buffering the communities against the risk of floods and droughts. A regulated hydrological regime in turn also enhances access to freshwater, reduces salinity ingress and is crucial to all forms of economic activities. The degradation and transformation of wetlands make communities and their resource systems vulnerable. The district has experienced major floods in 2003, 2006 and 2009 and recently in 2018 post cyclone Titli. The mean annual rainfall of the region is nearly 1250 mm with an average of 92.75 rainy days during the study years. The rainfall pattern however started showing a declining trend over the last 20 years with a reduction in number of rainy days. With extensive exploitation of groundwater, the water scarcity in the region has been further aggravated (DDMP Ganjam).

Landscape transformation and water related risks

The preliminary results show massive wetlands depletion over the area, with an estimated loss of marsh surface of approximately 73%. Marshes total coverage dropped from over 95 km^2 to 25.5 km^2. Half of the marsh's conversion is attributed to the expansion

of agricultural areas. Built-up areas increased considerably, due to urban expansion of Chatrapur and Brahmapur. The major transformation observed in water extent took place over 1 year, between 1992 and 1993. Overall, a loss of 23% of water bodies was estimated with the NDWI analysis over the region of interest between 1988 and 2018. This is consistent with the land cover analysis, which estimated the loss in water bodies to 16.2%.

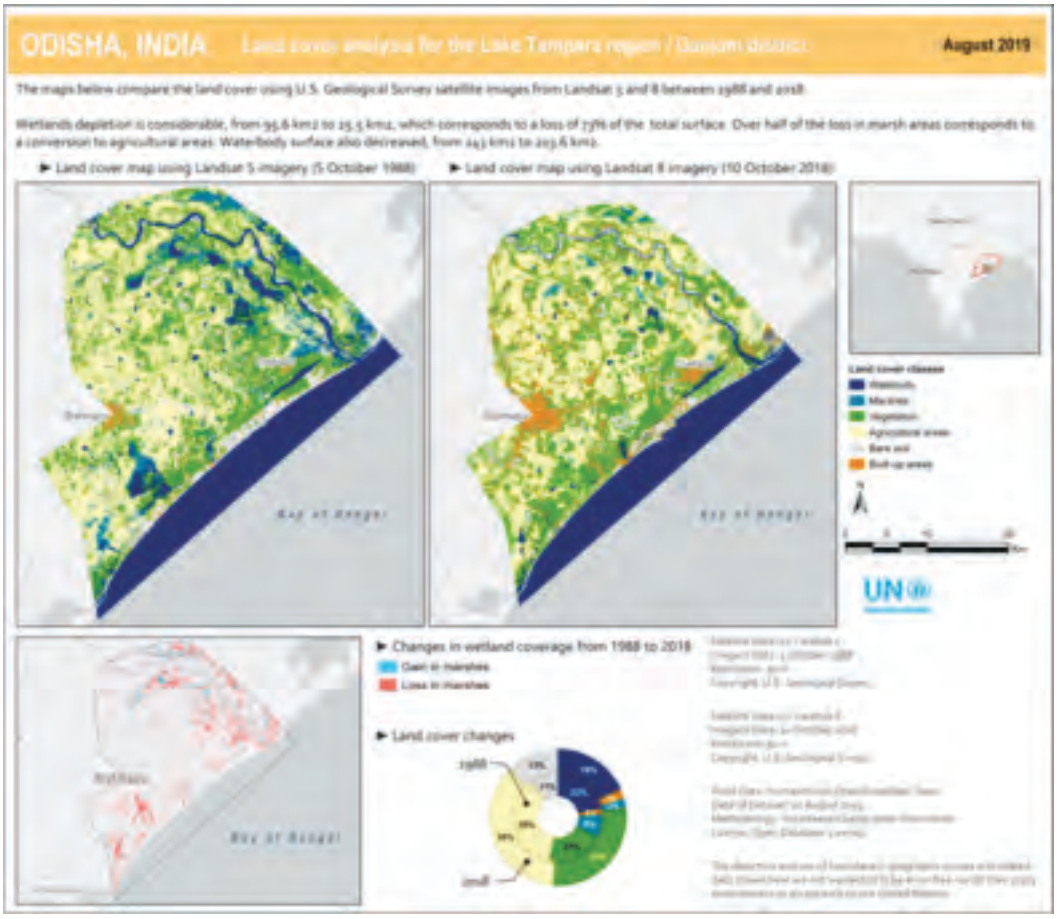


Figure 2: Map 1 Tampara Lake Basin (Source: UN Environment)

The river floodplains and streams, which aid absorption of peak monsoon flows and overall water conveyance in the landscape have been choked and encroached upon. The connectivity between wetland regimes, particularly between Haripur Lake (South of

Tampara) and Tampara have been fragmented by extensive constructions, impeding connectivity within the landscape, Alternations in the landscape have led to change in key hydrological processes that shape up the coast and estuary region. Proximity to the coast with the loss of wetlands also creates a risk of salinization of groundwater and soil. Wetlands play a crucial role in storing rainfall, recharging shallow aquifers and maintaining a freshwater wedge.

Map 2

Map 3

Figure 3: Map 2, 3 Showing Flooding after Cyclone Titli is much more extensive in wetland areas that have undergone rapid transformation (Bhuvan ISRO GEO portal)

Adverse transformations in the landscape, from wetland to non-wetland use have accentuated water-related risks in the landscape. Inundation maps (Map 2, 3) post cyclone Titli, show maximum inundation North of Tampara wetland. The area where inundation has taken place is also where maximum land use change from wetlands to agriculture over a 30-year period is observed (Map 1).

Land cover changes might trigger feedbacks from the ecosystems to the risk component, from prolonged water stresses to exacerbating communities' vulnerability levels and is thus needed for an analysis on ecosystem-based disaster risk reduction interventions to floods and water logging, enhances water insecurity and ultimately reduces resilience. Restoration and sustainable management of wetlands is a significant pathway for reducing water-related risks through use of ecosystem-based approaches (Kumar et al., 2017).

Wetland ecosystem services

Communities living in the Tampara basin have high levels of economic, social, physical and environmental vulnerability and limited risk reduction behaviour, which when combined with the high hazard multiplicity and hazard frequency takes the overall vulnerability of the communities higher (DDMP 2017). There is a high dependency on ecosystem services, with water for domestic use and irrigation the highest. The area inherently has poor quality infrastructure and low levels of technical skills and knowledge. The area has seen a rapid transformation in agriculture, with land use patterns indicating the increase in agriculture and fallow lands. Agriculture expansion along the outlet of the wetland has also impeded the outflow to river. High rates of unemployment and limitations for occupational diversity results in a large proportion of unproductive and dependent population, lowering the per capita income levels.

Inundation on October 12
Inundation October 16

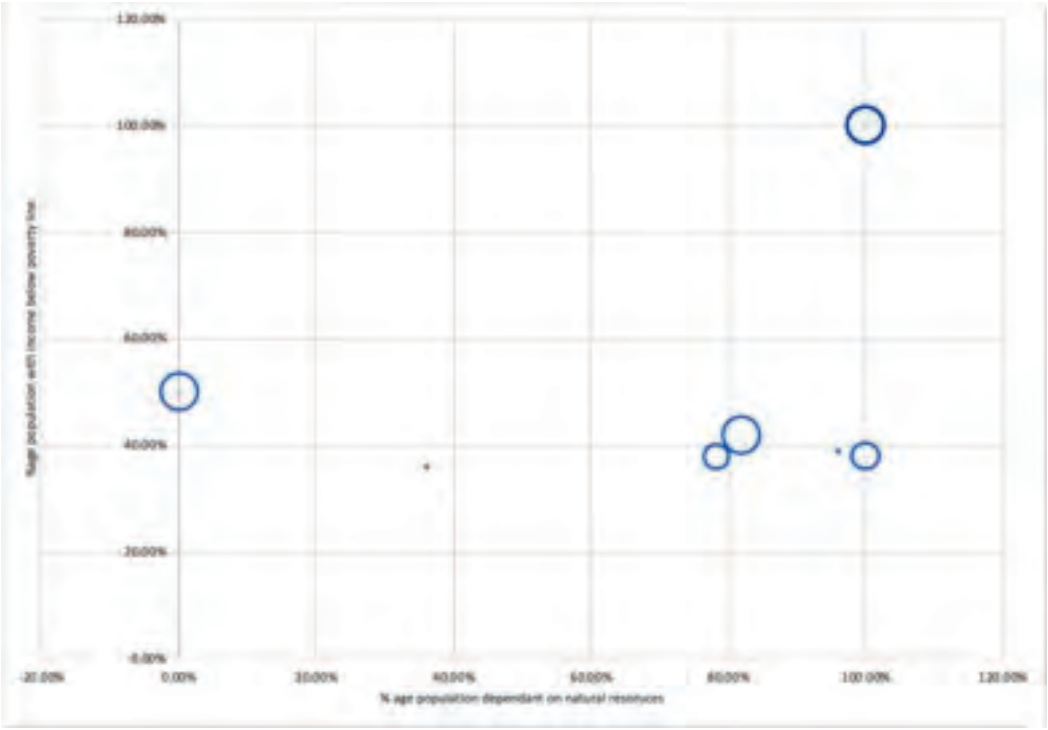


Figure 4: Distribution of villages on the basis of dependence on natural resources (X-axis), population under poverty line (Y-axis), and ownership of agricultural land (size of the bubble). Villages placed on the higher quadrant (with smaller bubble size) (Source: author)

Despite high economic, social, physical and environmental vulnerability and the inherent hazard risks that exist in region, communities do not actively engage in risk reduction activities, either individually or as a group. The community's mind-sets are still focused on relief centric approaches.

The communities identified 18 ecosystem services (6 provisioning 5 regulating and 7 cultural services) as being derived from the wetland (see Table 1 and Figure 3). Direct use of wetland and location within basin accounted for 19% of variance, occupation and distance from the wetland accounted for 18% of the variance, gender and ecosystem awareness 17% of the variance and age and income explained 14% of the variance.

Table 1: Identified Wetland Ecosystem Services along with Standard Deviations

Provisioning Services	Water for domestic	Water for industrial	For irrigation	For livestock	Transport	Fishing
Mean	0.76	0.75	0.47	0.37	0.32	0.39
Deviation	0.14	0.15	0.29	0.20	0.24	0.37

Regulating services	Climate moderation	Pollution abatement	Drought mitigation	Flood mitigation	Habitat for plants and animals
Mean	0.79	0.77	0.75	0.73	0.79
Deviation	0.21	0.19	0.20	0.20	0.24

Cultural services	Aesthetic	Natural	Tradition	Educational	Historical	Religious	Tourism
Mean	0.75	0.73	0.70	0.70	0.71	0.67	0.49
Deviation	0.24	0.24	0.24	0.27	0.25	0.26	0.27

The rankings ascribed to provisioning services mapped with the occupation categories (a fisher ranked fishing as the highest and a farmer to the provision of water for irrigation). However, communities which had a lesser direct dependence on the wetlands for livelihoods (such as business owners, wage labourers and private sector employees) ranked the regulating and cultural services higher. Scores for disaster risk reduction functions and select cultural services (religious values, aesthetic values, and education values) were rated high.

Gender specific analysis highlighted distinct perception regarding wetland ecosystem services (Figure 4). Men scored provisioning services higher than the women (95% significance), whereas women scored cultural services higher than the men. Meaning that the role of ecosystems in regulating hazards is well recognised by communities, and gender has a bearing on the perception of ecosystems in reducing disaster risk. Similarly, the male respondents felt that the impact of wetland ecosystem degradation on economy and health are higher than the females (95% significance).

Regarding roles in the management of wetland, communities having a direct dependence on the wetland raked their role as an individual to be higher as compared to that of the municipality or the state and central government. Communities with lesser direct dependence on wetlands (those engaged in businesses and private service) felt that the state government had a major role to play in ensuring that wetland ecosystem services are sustained.

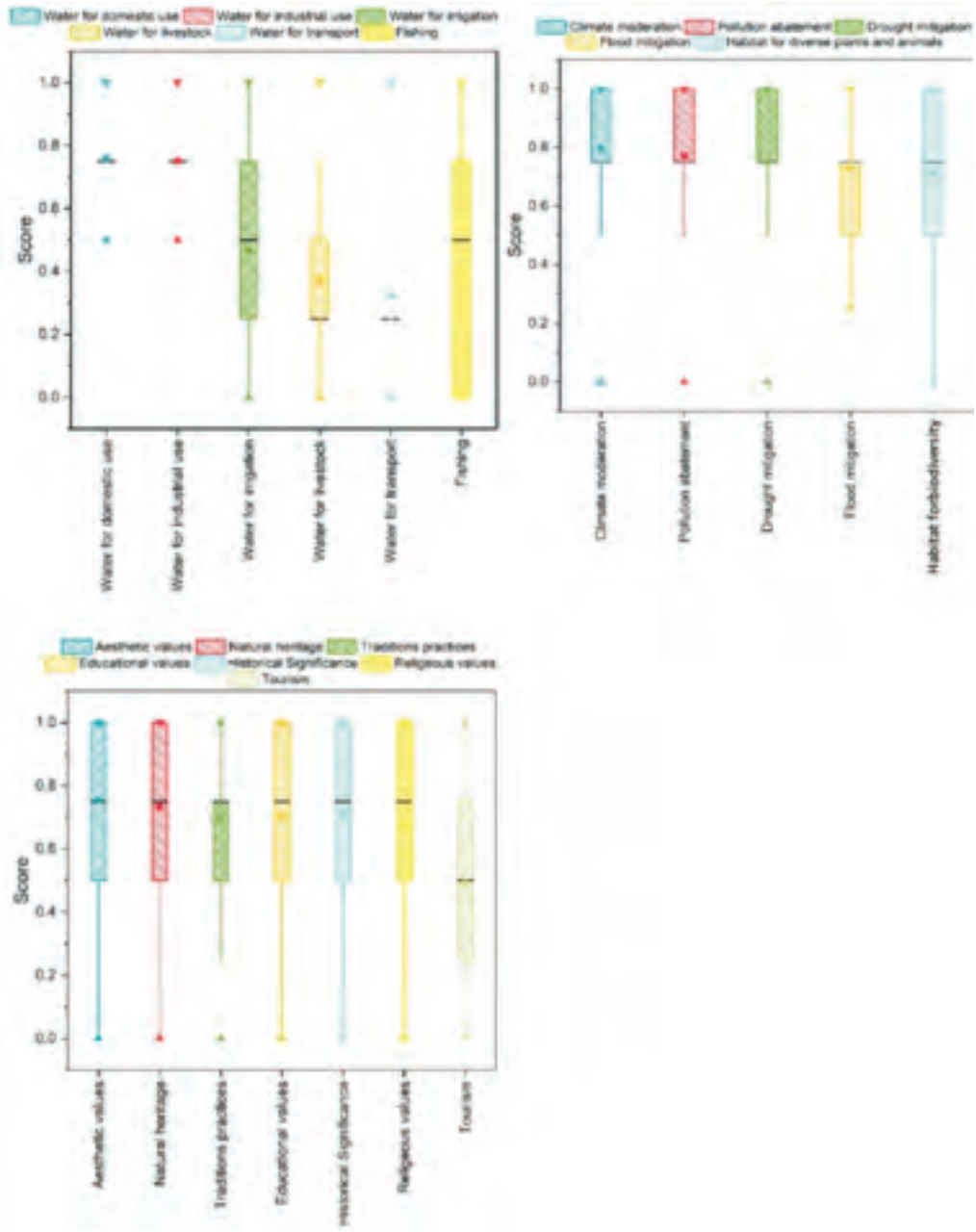


Figure 5: Ranking of preferences for ecosystem services: provisioning, regulating and cultural services
(Source: author)

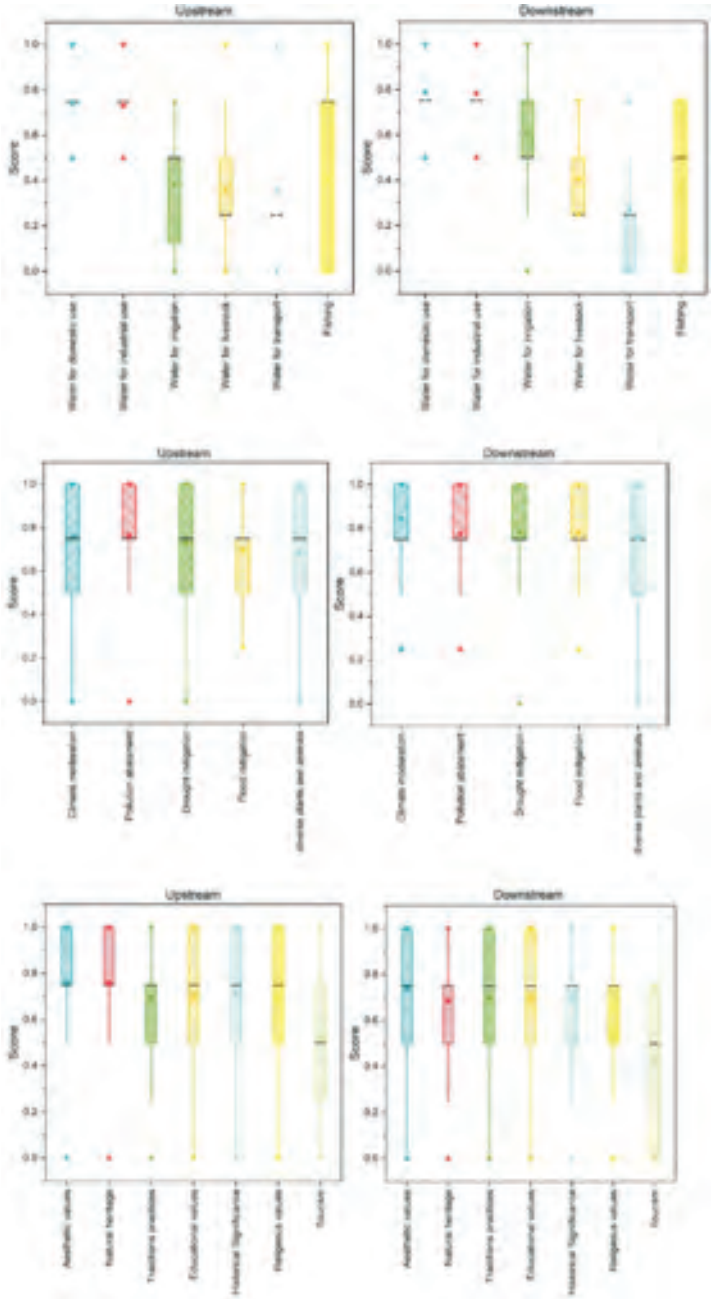


Figure 6: Differences in perceived significance of ecosystem services by communities in upstream and downstream area of the wetland
(Source: author)

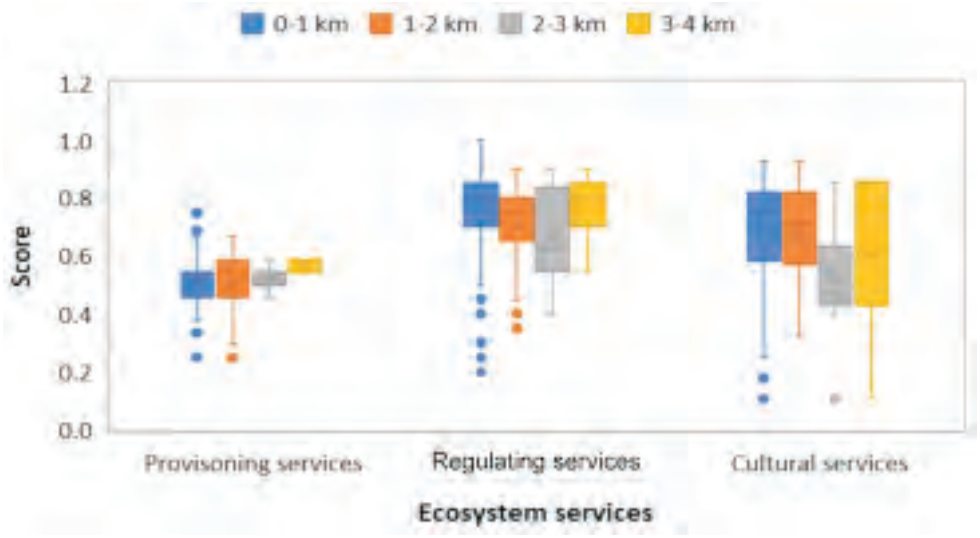


Figure 7: Perceived significance of wetland ecosystem services by communities with respect to proximity to the wetland
(Source: author)

Results of ecosystem services assessment indicate a high level of awareness and appreciation of wide-ranging ecosystem services of wetlands. The assessments also indicate the differences in perception between upstream and downstream communities, distance from the wetland (Figure 4). Communities living close to the wetland rank provisioning services and regulation service higher when compared with communities living far from the wetland rank cultural services higher (Figure 5). gender and other physical, social and economic variables. Understanding such differences can be the basis of a socially nuanced intervention strategy for engaging communities in management and stewardship of ecosystem services.

The results from the survey are key step towards adopting a community driven wetland management plan. Planners can effectively develop messages for different community groups for the different role ecosystem services play and especially for risk reduction. Provisioning services and cultural services can be used as resilient building measure. Regulating services as DRR mitigation measures.

IV. Conclusion

Single point approaches to disaster risk reduction have been ineffective up until now, Eco-DRR is a comprehensive approach which covers multi disciplines and looks at ways to increase resilience by addressing one of the main drivers of risk (environmental degradation). The approach considers both spatial and temporal scales in the context of

risk reduction (Cohen et al., 2016, Estrella 2013). It also attempts to create synergies between different government departments and empowering grassroot institutions.

Ecosystems support communities by providing essential ecosystem services such as food, fuel, shelter and can strengthen human resilience and security against disasters and reduce socio-economic vulnerability. For example, the establishment of coastal nurseries provide seedlings for fruit, forest or mangrove. Planting these forests can provide food, increase aesthetical effects and provide shelter, which can support tourism activities (MEA 2005).

By using tools such as ESSVA ecosystem services can be mapped to help planners understand the relationship communities have with their ecosystems, providing essential support before, during and after disaster events. Planners can also use the approach to assessing and responding to risk of upstream and downstream development around ecosystems. Further it will help communities understand the hidden regulating values that can be taken for granted, help develop a common view of ecosystem services and explore restoration options.

While in the short run, infrastructure centric approaches may reduce vulnerability of the communities to this risk, the cost burden of such interventions are rarely factored in decision-making. While the interlinkages of ecosystem services management and disaster management are highlighted, there are limitations to how much protection nature-based solutions can provide depending on the magnitude of the hazard.

Exactly how much protection an ecosystem can provide is limited to local conditions. Also, ecosystem-based approaches are often more cost-effective over time and in some cases, grey-green infrastructure combinations may be more ideal (Kumar et al., 2017).

References

- Bhuvan ISRO's Geo-portal (www.bhuvan.nrsc.gov.in). Accessed on December 5, 2020
- Cohen-Shacham, E., Walters, G., Janzen, C. and Maginnis, S. (eds.) (2016). Nature-based Solutions to address global societal challenges. Gland, Switzerland: IUCN. xiii + 97pp.
- Estrella, M. and N. Saalismaa. 2013. Ecosystem-based Disaster Risk Reduction (Eco-DRR): An Overview, In: Renaud, F., Sudmeier-Rieux, K. and M. Estrella (eds.) The role of ecosystem management in disaster risk reduction. Tokyo: UNU Press
- Government of Odisha, District Disaster Management Plan Ganjam (2017). DDMP Ganjam

- Government of India, National Disaster Management Authority (2016). National Disaster Management Plan (NDMP). Government of India, National Disaster Management Authority.
- Guha-Sapir D. and Hoyois Ph. (2016). Annual Disaster Statistical Review 2016: The Numbers and Trends. Brussels: CRED.
- Kumar, R., Saluja, R. and Mohil, D., 2020. Wetlands as Buffers for Water-Mediated Disaster Risks: Policy and Programming Opportunities in India. In Nature-based Solutions for Resilient Ecosystems and Societies (pp. 83-98). Springer, Singapore.
- Kumar R., Mohil S. D., Pattnaik A. and Sikka R. (2018).Perceptions, attitudes and preferences for wetland ecosystem services: a case study of Tampara, Odisha (ILEC)
- Kumar, R., Tol, S., McInnes, R. J., Everard, M. and Kulindwa, A.A. (2017). Wetlands for disaster risk reduction: Effective choices for resilient communities. Ramsar Policy Brief No. 1. Gland, Switzerland: Ramsar Convention Secretariat.
- Mohanta, R., Behera, S. K., Mishra, S. S., Sethy, J., Swain, K. K. and Sahu, A. K. (2017). Status, distribution, habitat type of threatened bird diversity, potential eco-tourism site and conservation strategy for wetland in Tamapara Lake Southern Odisha. India. Spring, 6(7), 14-21.
- Millennium Ecosystem Assessment (MEA 2005). Ecosystems and Human Well-being: Synthesis. Washington, DC.: Island Press
- Sudmeier-Rieux, K., Nehren, U., Sandholz, S. and Doswald, N. (2019). Disasters and Ecosystems, Resilience in a Changing Climate - Source Book. Geneva: UNEP and Cologne: TH Köln - University of Applied Sciences.
- UNDRR, 2018. Words into action guidelines. (http://www.rrcap.ait.asia/Publications/ECE_MP.WAT_56_E_web.pdf)

Chapter-2
Assessment of Flood Disaster Vulnerability and Mapping Using HEC-RAS - A Case Study of Neerasagar Reservoir, Karnataka

Jayasree Vaidyanathan[1] and Basappa Venkatesh[2]

Abstract

Floods are one of the most devastating natural calamities to mankind. While flood disrupts the normal life of people, damage infrastructure, road network, and basic services in urban areas, there are other reparations are in terms of crop loss, death to livestock, and isolation of people etc., affecting the economy of the nation. Assessing the vulnerability and mapping the extent of flood-prone areas provides key solutions for mitigation of floods.

The present study aims at preparing flood risk maps of the Neerasagar Reservoir in Karnataka. Dam hydraulics and history of floods were assessed and the estimates of flood and their vulnerability were carried out. The HEC-RAS model was used with the dam break option which represents the extreme condition and which cause maximum damage. The result obtained was analyzed and maps of maximum depth, the extent of water, and vulnerability were prepared. Results show that a considerable area (>12 sq.km) would be under flood risk and two or more villages downstream of the dam would be affected due to floods. The flood generated by the dam breach would not only damage the property, it damage considerable Kharif crop area. This study would be first of its kind in the North Karnataka region, which are mostly drier regions, where flood risks are comparatively low and would help in sustainable drought mitigation strategies for future floods of similar and higher magnitudes.

Keywords: Flood mapping, Vulnerability, Neerasagar, HEC-RAS, Mitigation

Jayasree V[1] (✉) And Venkatesh. B2.

[1]Principal Investigator and Scientist, School of Natural Sciences and Engineering, National Institute of Advance Studies (NIAS), IISc Campus, Bangalore, Karnataka, India -560012. Email: jayasree_nias@yahoo.in

[2]Scientist and Head, National Institute of Hydrology, Visvesvaraya Nagar, Belagavi, Karnataka, India 560 019. Email:bvenki20@gmail.com

I. Introduction

Floods, may be defined as the overflow of rivers banks, which inundate and causes considerable damage to life and property. Its impacts are highly variable across space and time. While it damages infrastructure, road and other networks in urban areas, the damages are in terms of crop loss, death to livestock, isolation of people, lack of communication etc. in both cases affecting the Country's economy. Identification of flood prone areas and assessment of their vulnerability are vital for deriving mitigation plans.

One of the ways through which impacts of floods can be reduced is construction of dam to store water. Dams built across rivers are not only for storing water, but also for flood control, drinking water, irrigation and many other purposes. In case of eventualities such as the failure of dams or the dam breaching, the resultant impacts would be in terms of loss of lift, property and damages to infrastructure and many others. Therefore, dam breaks analysis also is to be included for any disaster management programme. Such information used in conjunction with demography and details of resources/infrastructure and various others would help in deriving planning emergency action plans and mitigation measures.

The dam break analysis, the process of studying a dam failure phenomenon and analyzing the resultant consequences in the downstream, deals with simulation of assumed dam failure for existing dams (Pandya and Jitaji, 2013). Similarly, breach modeling is the process of understanding and simulating the breach development in the dam. With the advancement of various computing technologies, simulation models were widely used in dam break analysis flood process (Xia et al., 2010) and overview of various such models has been discussed by Wahl (2010). Some of the models for dam break failures are the DAMBRK, SMPDBK, FLDWAV, BREACH, HEC-RAS and many others. US Army corps of Engineers developed the latest version of HEC-RAS model for flood studies. Some advanced models were also cited in literature for break analysis and breach modeling (Pillai et al., 2012, Bergman et al., 2014, Lariyah et al., 2013 Shi et al., 2016), which are able to generate inundation map also that would be extremely useful in crisis management.

The HEC-RAS is one such model that allows to analyse the flood as well as the damage casued by such floods (USCAE, 2016), applicability of which in many Indian river basins have been already established. A study by Agnihotri et al., (2011) used the HEC-RAS model to prepare a flood mitigation plan for Tapi River in Surat, Gujrat India. The analysis aimed at identifying the locations where the floodwater is exceeding the river cross-section of river to suggest the modification for the river cross-section. Another experiment by Timbadiya et al., (2014) validated the model using the observed rain and flow data on the upper reaches to forecast the flood on the lower reached of Tapi River. Sravani and Balaji (2013) derived flood inundation map for Thamiraparaniriver in Tamilnadu considering the land use changes in the basin over a period of time. Updated versions HEC-RAS-1D and 2D and GDMS tools were used to map the flood extends of Yamuna river in Allahabad and the

Ganga river in Sangam area, Prayagraj by Kumar et al., 2017 and 2019 respectively. This model has progressed well and the integrated EC-RAS/HECHMS and GIS model the HEC-GeoRAS (USACE, 2009) which were proven successful in flood simulation of upper Godavari River in India (Chavan and Shetkar, 2019). The Flood inundation maps, the most important outcome from the models accurately envisage arrival time at critical locations and also the dam breach flood depths

The present study has been carried out to assess the flood disaster vulnerability for the Neerasagar reservoir in Bedtinala catchment of Dharwad city in Karnataka. The Govt. of India, recommending the dam operator to review the hydrological parameters of the dam along with the preparation of Emergency Action Plan (EAP) for dams under their jurisdiction. This is important to develop the evacuation plans in the worst possible eventualities, such as dam breach (break). In view of this, the dam break analysis of Neerasagar dam was carried out using the HEC-RAS model to develop the flood risk mapping downstream of Neerasagar reservoir for estimation of probable maximum flood. Data on floods, river geomorphology, cross section, hydraulics were used in this model to assess the flood risk and vulnerability in a typical dam break condition. Dam break analysis will make it possible to predict the flood and areas affected by flood downstream due to the breach which would be useful in assessing the losses in terms of life, property and economy and also in approximating the rehabilitation costs.

II. Description of The Study Area

The Neerasagar Dam, which was earlier known to be Dummawad tank was build in 1955 constructed across BedtiNala. The dam is located in Kalaghatagi taluk of Dharwad district in Karnataka located at latitude of 15° 19' 02" N & Longitude of 74°59' 23" E as shown in the enclosed Index Map (Figure 8). The reservoir has a catchment area of about 181.08 sq.km, and has a gross storage capacity of dam at FRL 28.9 Mcum and dead storage capacity of 2.75 MCum. Water spread area upto the foreshore at FRL is about 4.40 sq.km. The height of the Dam above the deepest foundation level is 29.56 m & the length of the Dam at crest level is 1356.36 mtrs. The spillway of the Dam is ungated and designed to discharge flood of 1048 cumecs. Dam serves as drinking water source to the twin cities of Hubli and Dharwad and pumps nearly 40.86 MLD of water per day

This dam is constructed mainly to supply drinking water to Dharwad and Hubli cities in Karnataka. There are many villages with significant number of population are located on downstream of this dam. Over last decade due to the changing pattern of the rainfall, the dam is overflowing more frequently than earlier period causing damage to the crops and property. In view of developing a contingent plan for reducing the losses, it is essential to review the hydrology of the dam as well as to develop the emergency action plan. In view of this, this study has been initiated to help the dam operator by providing the necessary information and for the villagers regarding the possible areas which would inundate due to the dam release and in case of dam breach.

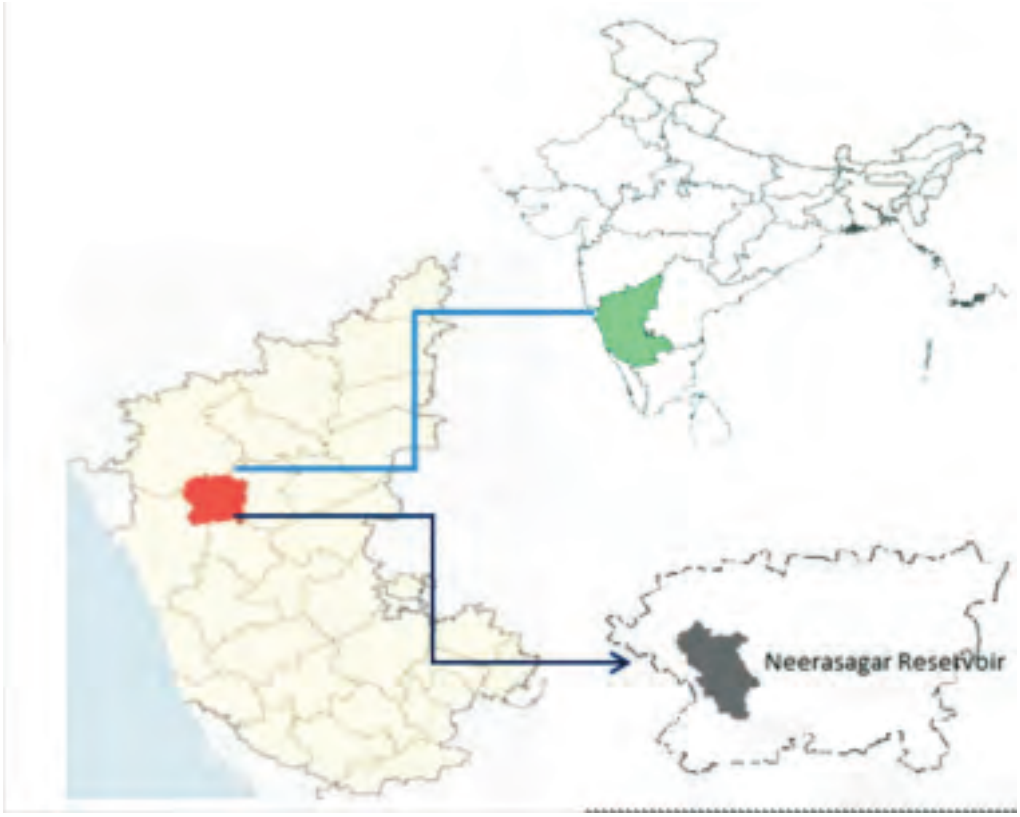


Figure 8: Map of the study location (Collaged map from open source)

III. Data and Methodology

HEC-River Analysis Software (RAS) developed at the Hydrologic Engineering Center (HEC), which is a division of the Institute for Water Resources (IWR), U.S. Army Corps of Engineers. This hydrodynamic model allows 1D steady and unsteady flow of river hydraulic calculations. It contains four modules, namely steady flow water surface profile computations, One-and Two-Dimensional unsteady flow simulation, sediment transport/ movable boundary sediment transport computations, and water quality analysis (HEC, 2010).

The HEC-RAS model requires data such as cross-section of dam and downstream river cross-sections., roughness coefficient, channel length, hydro-meteorology and others. Available data from various sources have been used in this study. Few datasets were derived used DEM (sourced from shuttle radar topography mission (SRTM) elevation data

of 30 m resolution). LULC maps were generated using LISS III imagery using Erdas Imagine Software. All layers for simulations were digitized into a common platform and standardized to UTM projection.

Estimation of probable maximum flood has been done by the method suggested by Central Water Commission (CWC, Flood estimation report of the West coast region sub-zone 5(a) and 5(b). The PMF estimation has considered a probable maximum precipitation (PMP) of 28 cm as per the India Meteorological Department, PMP atlas. The PMF estimate for the Neerasagar reservoir is presented in Figure below.

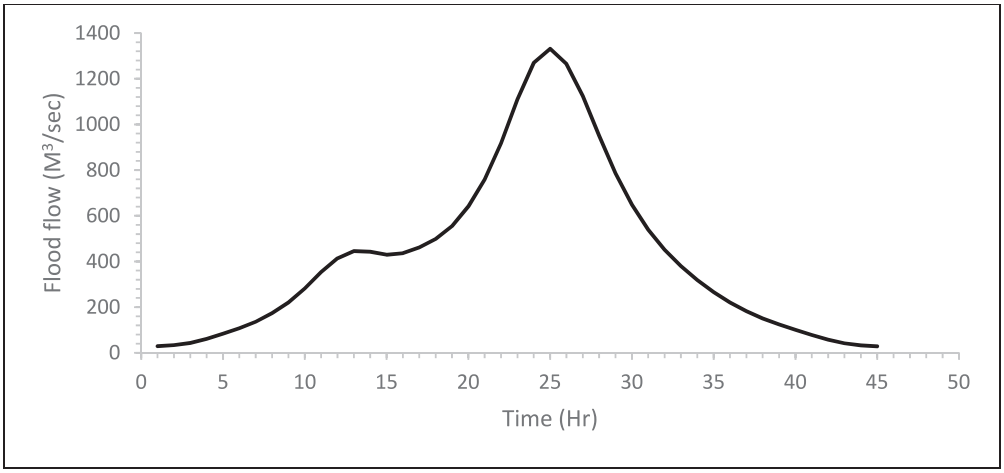


Figure 9: Estimated PMF for Neerasagar Dam
(Source: author)

US Corps Army's Hydrologic Engineering Center's River Analysis System (HEC-RAS) simulation model has been used for dam break analysis. Step-by-step methodology on the data requirements as well as how to use the tool has been provided elsewhere (Sharma, 2015). This method could be used to determining water depth, discharge, inundation area, and flood wave velocity & water surface profile in two dimensions. Analyzing of failure of dam is two steps process. 1) Analysis of actual breach of dam 2) The outflow from the breached dam to be routed through the downstream valley to determine the resulting flood at population centers.

Available literature on dam failure especially the earthen dams were mainly due to overtopping (Kumar, 2010) in which water flows over the crest of the dam. Another major reason for dam failure is the breaching. Head cut erosions starts from the downstream side of the dam embankment. When cutting reaches to upstream of dam mass failure will occur (Brunner, 2014).

In this study dam break analysis is carried out for worst condition to determine flooding area at downstream side of dam so breach parameters are taken to get maximum breaching of dam and peaked out flow from breached dam is taken considering full reservoir discharge (Wahi, 1998). Different breach parameters that could be estimated are the breach width, depth, side sloping angles and the breach time.

IV. Development of Dam Break Scenario in HEC-RAS Model

To develop the flood inundation map, one can use several dam release scenarios. However, dam breach (assuming the dam is at FRL or MWL and the PMF is entering into the dam) represents the possible extreme scenario, beyond which there are no other scenario exists. Therefore, the dam breach scenario has been considered in the present study to develop the flood inundation map (Xiong 2011). Dam break failures due to overtopping are resultant of inadequate capacity to storage water during large inflows into the reservoir from heavy precipitation run-off. The HEC-GeoRAS model set up was prepared using the available data for Neerasagar dam. The critical condition for a dam break study is when the reservoir is at full reservoir level (FRL) and design flood hydrograph is impinged. In this analysis, we have assumed that the initial reservoir level is at FRL and the PMF is inflowing to the reservoir.

The terrain of the study area where derived from DEM, and the 2-dimensional (2D), flow area boundary and Storage area boundary were marked and then mesh formation was done. A mesh of 50 m X 50 m was generated over the selected area downstream of the dam. There are 1228 cells covered the area with cell area of 2523 m^2 (See below). The Manning's value of 0.045 is used.

Figure 10: Two dimensional diagram of the flow area of Neerasagar Dam and downstream
(Source: author)

IV.1 Breach Parameters

Dam breach parameters are basic requirements for estimating the potential hazards associated with a failure of the project structure. These parameters are usually estimated using simple empirical models considering the breach to form in a pre-supposed way and growing in the shape of a trapezoid (Forehilch, 2008). In this study, dam break analysis has been carried out using the data on worst conditions. Various breach parameters considered for the present study is detailed in Table 2. We have considered the case of overtopping failure in which water flows over the crest of the dam. Head cut erosion starts from the downstream side of the embankment. When cut reaches to upstream of the dam, mass failure will occur.

Table 2: Dam Breach Parameters

Sl No	Parameters	Values used in the study
1	Centre Station	600 m
2	Final bottom width	400 m
3	Left side slope	1.5
4	Right side slope	1.5
5	Time to Breach	1hr
6	Water Surface Elevation triggering the failure	592.0 m
7	Storage volume at elevation triggering the failure	28.90 Mm^3

The anticipated dam breach parameter has resulted into a dam breach profile of the dam as shown in figure below

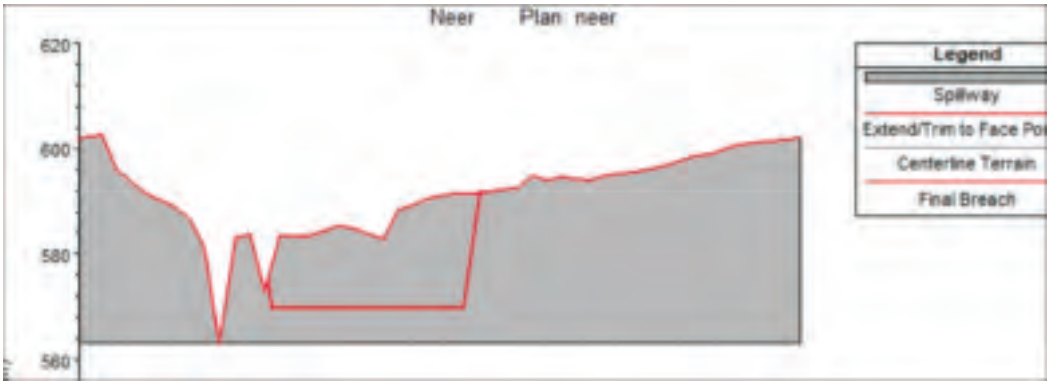


Figure 11: Dam profile defined in the HEC-RAS model
(Source: author)

V. Results

The present study is in continuation to dam break analysis and mapping of flood areas by Sujay et al., 2016. However, authors have not included vulnerability mapping in terms of how many people and different land parcel would be affected by floods resulting from dam break. By using the some of the basic data (River Cross-section and PMF) from the previous study, a 2-D hydro-dynamic model such as HEC-RAS 2D (it is referred as EC-RAS) was setup. Using the dam break scenarios, a simulation of 28 hours was used to cover the entire area which would probably inundated due to the dam breach in the present study. The results of the simulation are in the form of flood water depth, velocity, arrival time, discharge, inundation etc., that were obtained for downstream of the dam.

V.1 Flood Inundation

The estimated spatial changes in water depth are shown in. It can be seen that the maximum flood depth occurs both close to the dam and along the river for a distance of 1.5 km. As one might expect, the flood depth tails off quickly with distance from the dam. The depth of water at Jammihal is around 11 m and at Gambhapur, it varies between 1 and 7 m. The other villages which probably could get affected at Dhulikoppa (5 m depth), Muttagi (2 m depth) and Shiva nagar (1.4 m depth).

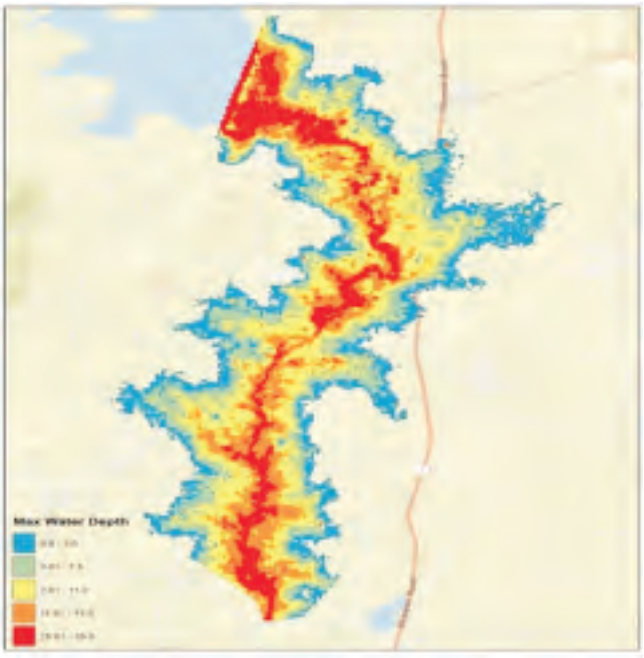


Figure 12: Spatial Representation of water depth resulted due to Dam Breach
(Source: author)

V.2 Flood Arrival Time

The spatial distribution of flood arrival time as derived from the model is presented in . The possibility of peak flood wave to arrive at Jammihal and Gambhapur were within 90 m of dam breach. However, the downstream village would take longer time to respond to the floods. The flood waves comes with a velocity of 16m/sec initially and thereafter drastically reduce to less than 1m/sec at a distance of 1.5 km from the dam. This velocity rate would damage the property and especially the crops which may get washed away. It is also a possibility that, the structures and people within the range of this flow of water may cause a threat to the life. Therefore, it very important to create an awareness and provide training to the people who are residing in the vicinity in regard of what are the steps to be adopted in such situations to save property and loss of life.

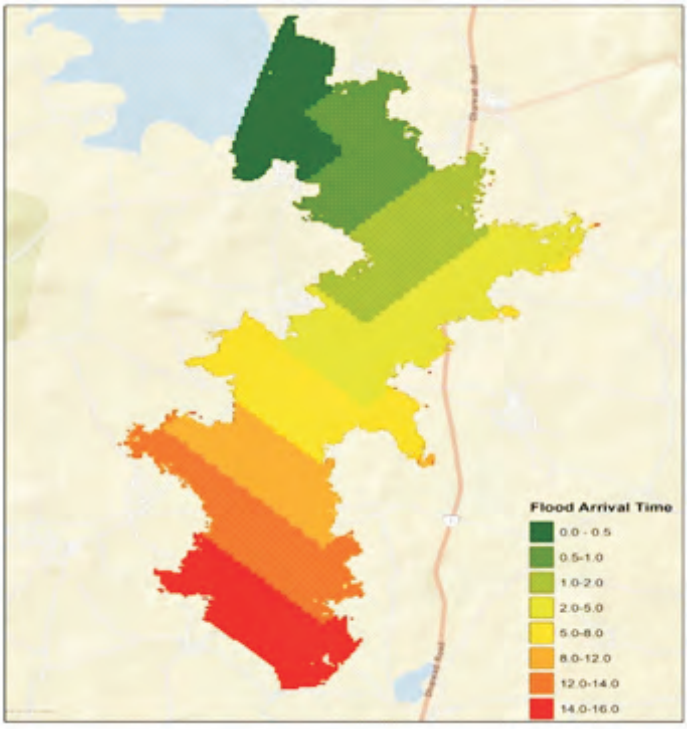


Figure 13: Spatial representation of flood arrival time resulted due to Dam Breach
(Source: author)

The above figure depicts the spatial vulnerability index due to the flood hazard and the subsequent dam breach. The vulnerability map were prepared considering flood depth, velocity, could be used to estimate the damages in the case of flood eventualities which is based on the flood depth, velocity, distance from the dam and the travel time were used to prepare the vulnerability map of the area.

It can be seen that the road and highway cross the flooding area are of higher risks (>4m water depth with H6 index), which is basically cover the main stream and adjoining areas as observed from the below.

Table 3: Vulnerable index of the downstream area of Neerasagar

Sl No	Distance from Dam(km)	HVI_Value	HVI
1	0	2.8	H5
2	1	7.3	H6
3	2	3.0	H5
4	3	4.6	H6
5	4	4.9	H6
6	5	4.9	H6
7	6	3.2	H5
8	7	4.8	H6
9	8	3.5	H5
10	9	3.5	H5
11	10	0.1	H1

The hydrological vulnerability index (table above), the higher HVI index are observed between 3 to 7 km from the dam. The higher the index indicates level of threat to the life and property. Therefore, such areas should not access during the flood situation. Also, when the index is more the 4, it indicates that, either the people are the vehicles are not allowed use areas.

V.3. Impact of dam breach

Impact of flooding surrounding the dam site will be due of submergence. Damages are in terms of loss will be to life forms, property, livestock and other services followed by health concerns for human and animals. As per available census data of 2011, population of villages, Muttagi, Jammihal, Gambhapur Dhulikoppa, Shiva agar 1455, 950, 787, 1455 respectively. Considering the population growth and subsequent growth in all sectors, the losses would be much more depending on severity of the floods. Assessing the exact impact on each sector would be difficult in the absence of updated information on human and livestock population and infrastructures.

The table below indicates the details of the area under various land use category that could get impacted due to the dam breach.

Table 4: Area (sq.km) to be affected due to dam breach

Sl.no.	Description	Area (Km^2)
1	Fallow land	0.03
2	Kharif + Rabi (Double Crop)	11.05
3	Kharif crop	2.73
4	Water bodies	0.48
5	Village zone (Gambapura + Jammihal)	0.11

We can see the cropped area is most vulnerable to flood, followed by water bodies that are used for drinking purposes. Assuming a family size of five for 800 households who will be directly/indirectly impacted, the rehabilitation cost would be several crores which are calculated based on various factors including the prevailing land costs, number of livestock they possess, available infrastructure etc., which may not be affordable to society (Kulkarni and Jagtap, 2017)., As time is the essence of dam failure, prior planning shall be best way to expedite the impact the dam breach. Proper upkeep and maintenance are key to prevent failures. In order to control dam breach during floods, precautionary measures may be considered. By giving proper consideration to weather forecasts and warnings, releasing of the water from dams well in advance on emergency situation, evacuation of the vulnerable community and effective disaster management strategies could be adopted. To alleviate extensive damage, strengthening the river banks and water bodies could be opted through planting riverine species such as Terminalia Arjuna, Lophopetulam wightianum, Garcinia species and some grass type like Vetiveria Zizanioides. Cympopogan caesus. This would also aid in recharging the water resources so as to mitigate the droughts which are usually aftermath of every floods.

VI. Conclusion

As is commonly understood that dams are beneficial to store water and supply during non-rainy season to meet various demands such as drinking water, irrigation and power generation, the damages are high during dam failure as well as dam breaches. When they collapse they can produce irrecoverable losses in terms of life, property, and infrastructure and adversely impact the landscape and environment as well. These, bring complex processes, accurate estimation of high risk zones and flood travel time are very essential. These study focuses on assessment of characteristics such as inundation, travel time, discharge etc. resulting from potential failure of Neerasagar dam using HEC-RAS hydraulic model. The results show that considerable losses occur in villages Jammihal, Gambhapur and Muttagi, with water level going upto 7 m and upto 30 m in the stream

depending on the flood intensity and distance from the dam. Due to high velocity of flood water, agriculture and road networks would be damages incurring a huge rehabilitation cost. As ecosystem impacts are huge, proper planning to avoid dam breakage and controlling dam breach are the best options for such eventualities. Proper care and maintenance of structure would reduce chances of dam failures. Protection of water bodies and river banks of through various measures such as release of water on time, afforestation etc. could result in safeguarding the ecosystem. In summary, results of the present study would useful in identifying safe zones for expanding residential areas, minimize flood risks in the downstream areas, plan emergency actions in downstream areas of Neerasagar dam which gets flooded either due to dam failure or dam breaching. More importantly, the owner of the structure should make a mandatory reviewing and maintenance of the structure as stipulated in the dam safety bill of 2019. Further, it is also, important to develop an Emergency Action Plan (EAP) for the dam for considering the various dam release scenario and extreme condition such as dam breek, which will be handy in operating the dam as well as to provide necessary information to the line department who will be involved in undertaking the evacuation of the people and live stocks during the flood situations.

References

- Agnihotri, P. G., and J. N. Patel. 2011 "Improving Carrying Capacity of River Tapi (Surat, India) By Channel Modification." International Journal of Advanced Engineering Technology, 2(2), 231-238
- Bergman N, Sholker O, Roskin J, Greenbaum N. 2014. The Nahal Oz Reservoir dam-break flood: geomorphic impact on a small ephemeral loess-channel in the semi-arid Negev Desert, Israel. Geomorphology. 210:83–97.
- Chavan, A.N., and Shetkar, R.V., 2019, Flood Analysis Using Integrated HEC-RAS and GIS: A Case Study of Nashik city, India, Journal of Water Resource Engineering and Management, 6(3).
- HEC (2010) HEC-RAS River Analysis System User Manual. US Army Corps of Engineers Institute for Water Resource Hydrologic Engineering Center (HEC), Davis.
- Kumar N, Lal D, Sherring A, Issac R K (2017). Applicability of HEC-RAS and GFMS tool for 1 D water surface elevation/flood modeling of the river. A case study of river Yamuna in Allahabad Sangam India. Model Earch Sys. Environ. 3(4). 1463-1475.
- Kumar, N., Kumar, M., Sherring, A. et al., (2019) Applicability of HEC-RAS 2D and GFMS for flood extent mapping: a case study of Sangam area, Prayagraj, India. Model. Earth Syst. Environ. 6, 397-405. https://doi.org/10.1007/s40808-019-00687-8

- Kulkarni S. R and Seema A Jagtap 2017. Dam break analysis of Pawana Dam. Inter. J. Recent Advancements in Engineering and Technology. Vol 5.Issue 2. 2347-2812.
- Lariyah M.A. M VIkneswaran B Hadiyah Z C Myda Thiruchelvam A.K Abd Isham H Rohani. 2013. Numerical modelling dam break analysis for dam break analysis for water supply project. Paper presented in the International conference on energy and environment.
- Pandya, H.P., and Jitaji. T.D., 2013. A brief review method available for dam break analysis Indian Jour. of Research. 2(4) 117-118.
- Pillai B RK, Saibal Ghosh and Gupta O P. 2012. Integrared dam break analysis -case study of Indira sagar and Omkareshewar projects. India water week 2012. Water, energy and food security. Call for solutions 10-14 April 2012. New Delhi
- Shi ZM, Xiong X, Peng M, Zhang LM, Xiong YF, Chen HX, Zhu Y. 2016. Risk assessment and mitigation for the Hongshiyan landslide dam triggered by the 2014 Ludian earthquake in Yunnan, China. Landslides. 1-17. Available from: http://link.springer.com/article/ 10.1007%2Fs10346-016-0699-1
- Sharma, S., 2015 Tutorials on HEC-GeoRAS and HEC-RAC modeling, DOI: 10.13140/RG.2.1.2805.8329
- Sravani, D., and Balaji, N.,(2013) Flood Inundation Mapping of Thamiraparani River Basin Using HECGeo-RAS and SWAT International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 7, pp.1408-1420
- Sujay, S. H., Shivpur, A.B., and Venkatesh, B., 2016. Flood plain mapping and dam break analysis for Neerasagar Reservoir. Inter. Rese Joun. Engineering and Technology. Vol3, Issue 6. 1279-1285.
- Timbadiya, P. V., P. L. Patel, and P. D. Porey. (2014) "One-dimensional hydrodynamic modelling of flooding and stage hydrographs in the lower Tapi River in India." CURRENT SCIENCE 106.5 (2014): 708-716.
- Wahl, Tony T.L., 2010. Dam breach modelling- An overview of analysis methods. Paper presented at 2nd Joint Federal Interagency Conference. Las Vegas. NV. Jun27-Jul1, 2010.
- US Crops Army's Hydrological Engineer center HEC-RAS River Analysis System User's Manual version5.0 Feb. 2016
- Xia J, Lin B, Falconer RA. 2010. Modelling dam-break flows over mobile beds using a 2D coupled approach. Adv Water Res. 33:171−183
- Xiong, Y., (2011) A Dam Break Analysis using HEC-RAS. Journal of Water Resource and Protection, 3, 370-379.

Chapter-3

Analysis of Knowledge, Attitude and Practice (KAP) with reference to Drinking Water in Alleppy District Kerala and evolve Effective Management Practices for a Sustainable Water Usage and Instill Green Thinking

Jayasree Vaidyanathan[1*] and S R Madhan Shankar[2]

Abstract

Water is the elixir for life and as per global standards India is not water secure with respect to drinking water. This paper discusses the knowledge, attitude, and practices (KAP) of rural and impoverished communities in the Kuttanad region of Alleppy which is severely water stressed amongst plentiful water sources. Some of the issues pertaining to drinking water supply are high water scarcity are the contaminated water sources, groundwater acidification, sparse public water supply, ambiguous distribution systems, and overpriced private vendors in addition to geography of the region which is below sea level with high inundation. Nearly 2.5 lakh citizens in this "Water-rich" region faces scarcity of various levels throughout the year where frequent floods, water logging, domestic effluents, poor sanitation and land management systems, chemical leaching etc., elevates the supply-demand mismatch, which is also aggravated due to lack of societal and state inertia. However, the commonly practiced solutions for water scarcity are consolidation of water resource database and collaboration among governing bodies which are by nature, piecemeal, and are applicable only for short terms risk alleviation. Integrated water and ground water management would considerably reduce the problems for exact understanding of status of crisis are at most necessary. This can be executed only through understanding the distribution pattern, the knowledge gaps, age old cultural beliefs and patterns of effective water usages at the regional level. Data collected through structured questionnaire on various aspects of water availability and supply and the knowledge of KAP of the vulnerable communities would help in understanding the

Jayasree Vaidyanathan[1(✉)*] and S R Madhan Shankar[2]

[1]Principal Investigator and Scientist, School of Natural Sciences and Engineering, National Institute of Advance Studies (NIAS), IISc Campus, Bangalore, Karnataka, India-560012. Email: jayasree_nias@yahoo.in

[2]Associate Professor and Head (PG), Department of Biotechnology, Dean Academics, Kongunadu Arts and Science College, Coimbatore-641029. Email: srmadhanshankar@gmail.com

issues and probable barriers and aid in devising a plethora of program priorities, viable alternatives as well as modalities of execution. Implementation of the observations and reflections from the study shall alleviate the water crisis and instill a sense of green thinking among the policy makers and the public there by ensuring effective water management and its sustenance. It has been observed that though Government of Kerala and the public has a vision to alleviate the water crisis, the existing practices and policies have not resulted in any pragmatic solutions. Survey results lead to the conclusion that for the Kuttanad region, small scale rainwater harvesting and simple purification technologies at household level could be the most appropriate and sustainable technological interventions till large scale interventions by the governing agencies are sought.

Keywords: Water resource management, Drinking water, KAP, Alleppy district

I. Introduction

I.1 India's water crisis

Access to potable water has always been a concern because of the challenges in terms of water availability, quality, and affordability across various geographical zones and economic strata. Even with abundant water resources, one of the biggest challenges today is the "Blue Catastrophe", the water crisis. Reliable and affordable drinking water is still a concern across the World as well as in India, Statistics show that nearly 54% of Indians are under varying degrees of water stress (UN,2018) and no Indian cities have round the clock water supply. Increasing population coupled with urbanization and economic development lead cities for increasing concerns on water that are evident from Niti Aayog report of 2018, which projected that 21 cities in India would have "Day Zero" condition by 2020, However, such situation has been witnessed much before by cities like Latur, in Maharashtra (2016) and Chennai in 2019. Growing water scarcity problems pose serious threat to ecosystem management, social sustainability and economic growth. This calls for derivation of effective management strategies.

The challenges evolving sustainable, equitable and efficient management of water resources are several. The causes of water crisis are multi-faceted (Tien et al., 2016), and are constituted by insufficiency of water, poor water quality and dwindling water situation due to over-extraction of ground water (Luthra and Kundu, 2013). Water availability is highly variable across and time and the scarcity is not only being witnessed in the naturally water scarce regions, but also in regions where the resources are in plenty. The per capita water availability has drastically reduced by 70% in the last 60 years due to population growth and exploitation of ground water resources. It is anticipated that the requirement would be 1447 BCM by the year 2050. India is one of the most populous countries in the world, which supports about 17.1% of world's population and about 500 millions of livestock population that accounts for 20% of world's livestock

population(Gangwar, 2013). In last three decades due to promising economic growth, population growth and rapid urbanization have considerable impacted the water demand. Drastic changes in the food consumption, lifestyle and land use patterns also play a major role in water requirement. Although India receives plenty of water as rainfall during monsoon, due to lack of proper and scientific methods of storage, only a small percentage of water is actually added to the reserve. In a country like India where there is significant mismatch of spatial distribution of available water with the population, the situation becomes alarming; ironically less water is available where more people live. While, as per the international norms, countries with per-capita water availability less than 1700 m^3 per year is categorized as water stressed, with per capita available water of 1545 m^3 India is definitely water stressed country (India-WRIS wiki 2015. Census, 2011). As per the records, per capita availability in India was 1720.29 cu.M per year (CWC, 2015) projected to 1486 cu.M/year in 2021 by Ministry of Jal Shakthi. While availability is declining, there has been an increasing demand due to rising population and industrialization which pushes the need in domestic sector alone to 125 lpcd in 2015, widening the supply-demand gap. With this trend on the gap would remain at 50 BCM by 2030. Some cities have adequate water but are also generated due to weak infrastructure, poor maintenance and faulty engineering. Ensuring a safe, equitable drinking water supply is a critical challenge today, faced by all major cities in India as they are constantly trying to balance economic growth and sustainable development.

I.2 Water Scenario - The city of Alleppy

Many Indian cities face acute water shortages which are under high rainfall zones (Nair, 2010), which includes some Kerala cities also like Kochi, Alleppy etc. (Guptan, 2019, Iqbal 2019). Even with water all over around, city of Alleppy flanked with network of lakes, rivers, canals and water bodies has acute water problems (Pillai, 2015). There were many reports on introduction of a number of water projects in Alleppy district to address water problems and the issue remaining unsolved (Sajimon, 2017). Most of the areas in Alleppy district are vulnerable to water crisis of varying levels. However, some specific portions are more vulnerable though surrounded by water, a significant population in Kuttanad being most susceptible.

Out of the 21 lakh population living in Alleppy district a major portion lives in the Kuttanad region which forms major part of the district. Per-capita availability of Alleppy district indicate adequacy in water supply (Economic Review, 2017), however urban and rural areas have differential access to potable water. Local water facilities such as canals, public wells, tube wells and ground water dug wells form the source of water which is distributed through piped network by the Kerala water authority (Anu 2019). Few tube wells connected to the reverse osmosis plants supply treated drinking water which fail many times due to shortage of ground water. Water is supplied on a daily basis though the

frequency and timing reduce during peak summer. Being surrounded with water bodies, quantum of water available is not an issue though quality concerns restrict available potable water. While the urban dwelling are have access to piped water from Kerala Water Authority (KWA), provision of water supply to rural areas are governed by local bodies and rural areas are highly regions of "water scarcity amongst plenty", with some specific areas more vulnerable (DC,2019). Nearly 46% of people living in rural areas have profound water issues. The available water is mainly used for domestic uses, irrigation and for industries which is only a very less portion.

The root causes of the water crisis are mismanagement of freshwater resources, poor maintenance of the water distribution system, land reclamation, land use pattern, lack of adequate attention to water conservation, efficiency in water use, water re-use, ground water recharge and wetland conservation. Peculiar geography, improper laying of pipelines, many water ways etc are leading to frequent disruption and break-up of water supply. Also, construction of new road networks, large scale reclamation of paddy fields for construction purposes and other development programs have only led to blockage of existing canals.

Many projects of drinking water by HUDCO, UIDSSMT, JBIC, KSCADCL and others were implements they were only partially successful in solving the issue and are insufficient to meet the demands. Even with lots of formal and informal discourses regarding the concern, still important gaps in terms of sufficiency in potable water and crisis management in ensuring water security..

Green growth and carbon neutrality at this water scarce region of Alleppy district can be a boon and certainly alleviate the water crisis. Strategies to achieve greener growth is the need of the hour in this "scarcity amongst plenty", region where efficient water harvesting strategies involving simple harvesting tanks and in built purification systems and supply is the viable solution to the pertinent problem of more than 50 years. A path dependency model based on the previous observations aligning with the current pattern of growth, consumer habits, technology and adequate infrastructure shall open up a viable solution for the problem of water crisis. Hence green growth and carbon neutrality will foster better economic dividends ensuring that the natural resources continue to provide efficient resources and environmental services on which the well-being of the individuals shall rely for a sustainable growth.

II. Objective

With a brief background on water situation in Alleppy district, the present study is an effort to relook at the water scenario under the purview of availability of resource, efficiency/deficiency in management of resources by civic agencies and the quality concerns which are most important aspects of drinking water supply. The study would

examine the existence of the drinking water paradox, the level of crisis despite resource abundance, usage pattern and factors that intervene efficient water management. Finding out the gaps and addressing the weakness of current management practices would provide road map to find viable measures to circumvent the scarcity. The study was carried out by collecting information and situation analysis through literature review, site visits, focal group discussions and data collection through a structured questionnaire. Results of the study would be useful in exploring possible alternatives to circumvent the water issues by devising a workplan for viable solutions.

III. Water management in Kuttanad –A case in point

Kutttand region in Alleppy district, Kerala has been selected for the present study as a specific case. Occupying the major portion of the district, the Kuttand comprising of almost 900 sq. km having a population of 2.4 lakhs, the region has many interesting aspects emanating from its bountiful resources, culture, evolution, agricultural practices and many more. Even with water bodies all around, the region suffers severe drinking water scarcity which is well known since several decades. Kuttanad faces severe water problems and floods of 2018 and 2019 only could aggravate the situation. Availability of safe and adequate drinking water is a serious concern as the region experiences frequent floods, water logging, contamination from the houseboat and domestic effluents, degradation of natural reserves, poor sanitation and land management systems in the catchment and supply-demand mismatch (Shiney and Geeja, 2013). Drinking water is an all-season problem in Kuttanad. Occupying a major portion under Alleppy district, most of the Kuttanad area is under large water bodies. However, since many decades a closer look at water supply and management in Alleppy in general and Kuttanad in specific, show that water supply is not meeting the demands. Public water supply is sourced from Neerattupuram plant in nearby Tiruvalla town, that produces 14 million liters of water a day. As per the supply standards @100 (CPHEEO-India) for rural areas, there is a need for 24 million liters to this region, which is not met due to less availability leading to a shortage of nearly 41 lpcd. The water from the plant incur a great loss while in transit, adding to water woes. The shortage of 10 million liters per day is partially made up from other sources like ground water, surface water bodies and private vendors.

Groundwater is the most reliable source which is directly pumped to customers without any purification (Saritha 2018). According to CGWB, though available ground water of nearly 129.35 cubic meters can be tapped from tertiary aquifers, the water not potable due to tidal impacts and pollution from various sources.

Most pipes were laid long ago through paddy fields which are prone to rusting and breaking and leads to water leakages, adding to the problem. Even viable alternatives like tube wells and dug are not feasible in this location due to the peculiar geography and poor

ground water quality. Limited water availability has often resulted in inadequacy and intermittency in the water supply.

Kuttanad has plentiful water available but potable drinking water has been constrained by quality issues. Due to the peculiar geography, lying in submerged condition this region face twin hazards of flood discharge during monsoon season and sea water ingress during non-monsoon. Population increase coupled with increasing development activities and house-boat tourism resulted in more water demand also in degradation of water bodies. Pesticide leaching from agriculture, multi-source chemical contamination, bacterial infectivity of surface sources and high concentrations of iron and fluoride in ground water impacts availability of safe drinking water. A times past of Kuttand shows plentiful drinking water of good quality. Water for all needs were sourced from backwaters itself and there existed many small tanks, water holding structures like Vallom" (locally called in Alleppy), which where man-made ponds that were used to store rainwater. These water holding structures were providing continuous supply and were disconnected during times of saline water ingress to maintain the quality. Later, in mid-70's with the construction of bunds in Thanneermukkom and additional pipe networks, these waters holding structures lost their prominence and are dump yards at present. With changing times and increasing demand for water among all sectors, water situation worsened in the city and surrounding areas with several panchayats in the Kuttanad-Neelamperoor, Kaavalam, Pulikunnu, Kainakari had/has acute water scarcity of which Kainakari being the worst hit. Some of the issues with respect to water supply in Kuttanad region are:- poor connectivity, frequent breakdown of existing pipelines, disappearance of traditional water management systems, poor sanitation coverage, changing lifestyle and people's attitudes, lack of community participation and the dynamics of gender issues.

The survey on understanding the knowledge, attitude and practice (KAP), pertaining to the sourcing and usage of drinking water in the vulnerable Kuttanadu region of Alleppy district in selected water scarce pockets. Special emphasis was for Kainakari region, the most vulnerable. They survey has brought out the limelight on the major issues pertaining to drinking water is this region. The survey also recalls the past practices of fetching potable water from clean and well maintained sources that degraded gradually.

In all scarce regions, major source of potable water is through municipal lines by KWA, with few individual residential connections and rest community taps. Municipal supply is constraint by intervening "Thodu" or the local canal, which separates the wards in the region, making water supply a great challenge as the pipelines terminates near Thodu and water cannot be supplied to the other side. Few villages namely Bhajanamadom, Chennamkary, Chavara etc. have no provision for water connection. Due to prevailing conditions, people at Bhajanamadom for instance are forced to take from Pallathuruthy, almost 10 km away from the village. Old, rusted pipes laid 35 years ago have undergone

extensive deterioration making it difficult to restore water supply. Added to this is the terrain, which makes water pressure low, contributing to deficiency in continuous water supply. Daily challenges for getting potable drinking water for basic needs pushes the civilians to use unclean water from whatever sources available, resulting in upsurge of water borne and communicable diseases in this region. To circumvent and reduce the burden on municipal supply, tube wells are dug in selected places, which are not fit for drinking due to high TDS and iron content.

Several people who ever interviewed on KAP on potable water recall that there used to exist small shallow ponds in selected places that used to serve as collection ponds of rainwater. Eventually, these ponds became obsolete and unusable when pipelines were laid, and piped water gained prominence. There was also mention about existence of huge fresh water ponds in this areas, which were shared by many villagers, and were abandoned due to saline water intrusion.

Being low lying, most of the areas are vulnerable to flooding during rainy season, which not only disrupts normal life, but also the water supply because of depletion of good water collection sources pollution of existing sources and inadequate scientific intervention to circumvent the crisis. Contaminated water resources and lack of responsibility towards protection and upkeep of the existing water sources have resulted to this state of desolation for the people in this region for whom water has become more of a curse than a boon.

Figure 14: Sources of Water; Source: V Jayasree IWP (2020)

The situation is slight more different when a few intervention strategies were employed by the local panchayat to supply drinking water twice or thrice per week to the residents of this region. The survey underlines that water is made available to the residents through water tankers brought on boats and supplied at common collection points. The civilians feel that this more stressful to collect and if miss out, will have to manage without water. Odd and unpredictable supply timing and frequency, inadequacy, time to spend on water collection, drudgery to transport to homes etc., upsets their daily routines which force them to buy water. Highly priced vendor who charge about Rs. 50/20 liter can, and spending nearly Rs. 600 to Rs. 800 per month would be an additional burden for majority of the people who are mostly economically weaker. They feel overburdened especially when it is basic right for them for good potable water, which civic bodies fail to provide.

Rain water harvesting (RWH) are promising solutions to mitigate water scarcity. However, vulnerable regions have additional problem related to establishment of RWH structures. People stated that concepts like RWH as well as roof top harvesting have potential, however the viability is subject to accessibility and affordability. There are many RWH units in Kainakari panchayat alone, most of them in a dilapidated state. Some of the units owned by individual houses were maintained well and are able to store water that can suffice for almost four months after rainy seasons. Few units are supplied by the local panchayat at a subsidized rate, mostly to socially and economically weaker population who are having enough spaces in their premises. These structures, that are supposed to serve as community storages are generally of 5000-20000 liters capacity, sufficient enough to cater to water requirement of few houses in the neighborhood. However, the attitude of the residents to this region to maintenance and sustenance of these structures also has a myriad feelings and sentiments. While majority of population have a positive

attitude towards cleaning and maintaining them properly, others are restricted by financial and space constraints that gets heightened by lack of proper awareness on the usage of the structures. Another major issue lie with the terrain as well as soil in their region that lack sturdiness to support such huge water harvesting structures, leaving the option to roof top harvesting that can serve as good quality water only during rainy season, and does not have much scope beyond rainy season. Post monsoon, the soil is very loose and has extensive water logging which makes the civilians apprehensive to invest in establishment of RWH structures. Hence even when they are able to sense that rain water collection and storage can alleviate the drinking water crisis, it is not practiced much in many areas such as Plassery, Pattalam and Uralassery,Kavalam, Punnapra etc., construction of ferro-cement RWH units were not viable option to address this issue.

In few schools as well as religious places such as the churches, authorities have provided RWH units which are also defunct due to lack of proper maintenance.

Ironically, though the school children are sensitized on the importance of conservation and usages, the measures to restore and utilize effective roof top water has not been advocated. Similar attitude is seen among the community also, but does not seem serious in deploying the existing solutions to ease out the issue. People are not thoughtful enough to seek solutions for themselves and feel it to be the responsibility of government to address the issue.

Figure 15: RO Units; Source: V Jayasree IWP (2020)

To support the system, there are a few reverse osmosis plants installed in many places where water is supplied at a nominal cost of Rs. 10/20 liters. Even such efforts are not gaining momentum as water to the plant is sourced from polluted water bodies and have apprehensions about the quality. Spent water is again adding to contamination of water bodies.

Some of these observations clearly indicate that the water usage, management and conservation strategies have moved far away from conventional practices, which does not seem sustainable due to unscientific operational procedures and the complete disconnect with geographical peculiarities which it fails to accomplish. The KAP assessment in specific regions of Alleppy district suggests the following.

1. Lack of state and societal Inertia

People in this area are subjected to high degrees of water problem that has been represented by them and no protracted action taken by the Government. Though many schemes have been implemented, are not a reality on ground which leave people to adjust to unprecedented conditions and cursing it as a fate. Local administration also takes it for granted without seeking permanent solutions to the crisis.

Lack leadership among the community to take up the issues to the next level, inadequacy in using the existing infrastructure and financial constraints are very evident in these regions.

2. Exploring feasible alternatives

At this juncture it is pertinent to think of viable solutions to address this issue of drinking water crisis based on past knowledge, the practices and instill a change of attitude among the subjects for viable solutions. Our interaction with subjects, as no single solution can solve this crisis; best approach would a multi-factorial multi-fold one involving all stakeholders. Both community as well as governing bodies agree upon RWH to be most viable, being practiced in the past and still has scope.

But implementation of this technology must be more robust, scientific and address concerns raised by the people on financial, institutional and infrastructure support systems. Revival of all water bodies, protection on sacred groves, enforcement of roof water harvesting in all buildings and pooling the same in a centralized system and supplying and the Netherland model of decentralized water supply could be attempted. Installation of additional RO units can be suggested; but since RO is a costly system, restoration and disinfection of the existing source of water through a scientific process and low cost technology can be attempted. Further a one pot solution to this issue is certainly not going to be viable. There has to be a blend of the right technology, support from local administration and Governmental bodies and adequate awareness among the subjects are quintessential to circumvent this issue.

IV. Conclusion

To conclude with, authors feel that despite the knowledge of challenges and solutions to solve the water crisis, the public as well the administration fail to derive and initiate actionable plans. The KAO analysis suggests simple decentralized micro-level supply systems in conjunction with low cost water purification technologies as the most feasible solution. in addition, community needs to be sensitized about their role in protecting and managing their resources and also on the 5 "R" concept of resource conservation namely reduces, reuse, recycle, replenish and finally respect, that can also act as step towards ensuring drinking water scarcity. Adding one more "R" for refuse if we don't want would add to conservation strategies. The pertinent aspect that is evidenced from the above study is that there has to be a scientific method of water collection, storage and distribution. Revisiting the ancient methods of conservation shall add value to solve the issue in otherwise water scarce regions of Kuttanad. Alongside there has to be strong policy which has to be administered through the local administration which shall provide solace to every persistent problem. A sense of Green thinking and notion of sustainability has to be instilled in the minds of the people so that any implementation of the technology or policy will sustain because of the cooperation from the subjects.

References

- Deccan Chronicle 2019. CPI seeks probe into Alapuzha drinking water shortage. https://www.deccanchronicle.com/nation/current-affairs/091119/cpi-seeks-probe-into-alappuzha-drinking-water-shortage.html
- Guptan Mahesh. 2019. Chennai water scarcity a warning for Kerala. Says the Expertshttps://english.manoramaonline.com/news/kerala/2019/06/24/chennai-water-scarcity-a-warning-for-kerala-says-experts.html
- Nair Shadanan 2010. Challenges in urban water management in a changing environment - a case study from growing tropical city. NOVATECH, 2010. pp-1-7.
- Ramabhadran Pillai R. 2015. Water scarcity continues to haunt Alapuzha. https://www.thehindu.com/news/national/kerala/water-scarcity-continues-to-haunt-alappuzha/article7533154.ece
- Sabin Iqbal 2019. River, River, Everywhere.But not much to drink I Wet Kerala. https://www.outlookindia.com/magazine/story/india-news-river-river-everywhere-but-not-much-to-drink-in-wet-kerala/301575
- Sajimon P. S. 2017.Acute water shortage in Alapuzha. https://timesofindia.indiatimes.com/city/kochi/acute-water-shortage-in-alappuzha/articleshow/57117874.cms

- Saritha V Balan 2018. https://www.thenewsminute.com/article/how-floods-have-worsened-kuttanads-water-pollution-crisis-88018
- Shiney Varghese and Geeja K George 2013. An investigation of drinking water problems in Kuttanad. Int. J. Scientific Research. Vol 2 Issue 4. 93-95
- Sonia Luthra and Amrita Kundu. 2013. India's water crisis. Causes and Cures. The National bureau of Asian Research. Available at <http://www.nbr.org/research/activity/ aspx?id=356>
- Tien Shiao, Andrew Maddocks, and Emma LoizeauxEmmaLoizeaux. 2016. 3 maps Explain India's growing water risks. WRI. 2016.
- United Nations Report 2018. World water development Report.
- CWC, 2015. Annual report 2015-2016. Central water commission
- (Anu, 2019) https://www.slideshare.net/AnuThomas72/aleppey-urban-study-147269062.

Chapter-4
Protection of Mangroves as Core Component for Implementing the Nature based Solutions

Pritha Acharya, Sonal Bindal and Anil Kumar Gupta

Abstract

With the beginning of the Anthropocene era, extreme forms of development with economic growth, expansion of concrete urban agglomerations, industrial development, etc. have been attained. This leads to the disturbance in nature's equilibrium. Nature Based Solutions (NbS) are the only key for saving the resources of earth for the survival of humans. NbS are being implemented into national and international policy and initiatives such as in the climate change strategies, regulations, investment in infrastructure and funding mechanisms. Among all other components of NbS, Mangroves are of prime importance for reducing the risk of disasters and improving the economy of the country. During several disasters in India, Mangroves have proved as saviours for both humans and infrastructures. For example, mangrove forests saved lives in the 2004 tsunami disaster, in 2019 they saved the Sundarbans from the gusty cyclone`s impacts and many more. This chapter focuses on the role of Mangroves of east and west coast of India. It was also found that there is a need for implementation of mangrove and other NbS solutions at grassroot level. Awareness programs are required to aware the local communities about the benefits of NbS and how it can help them economically. NbS should be implemented at the landscape scale and, in order to tackle social problems, NbS are part of the overall strategy, plan and intervention design.

Keywords: NbS, Mangroves, Disaster resilience

[1]Pritha Acharya, [2*]Sonal Bindal (✉), [3]Anil Kumar Gupta
[1]Research Fellow, National Institute of Disaster Management, Ministry of Home Affairs, Government of India, New Delhi 110 001, India; prithaacharya@gmail.com.
[2]Research Associate, National Institute of Disaster Management, Ministry of Home Affairs, Government of India, New Delhi 110 001, India; sonal.nidm@gmail.com; sonalbindal88@gmail.com ()
[3]Professor & Head of Division, National Institute of Disaster Management, Ministry of Home Affairs, Government of India, New Delhi 110 001, India;anilg.gov.in@gmail.com

I. Introduction

With the beginning of the Anthropocene era, extreme forms of development with economic growth, expansion of concrete urban agglomerations, industrial development, etc. have been attained. However, in doing so, the relationship of humans with nature is being over-exploited in a way that our impacts have overpowered our dependence on the natural ecosystems (Borrini-Feyerabend et al., 2013). With 5 out of 9 planetary boundaries already damaged, humankind faces three complex challenges of this era (Steffen et al., 2015). Firstly, mitigating and adapting to climate change, secondly, protecting biodiversity and thirdly, ensuring human wellbeing (Seddon, et al., 2020). As the society's understanding of their reliance of ecosystems and ecosystem services has increased, a transition to biodiversity based resilience has been observed. Globally, researchers have demonstrated that socio-economic trends and earth system trends are intriguingly linked as Natural Capitalis the foundation of all developmental processes (Cohen-Shacham et al., 2019). Natural capital complements and provides the foundation for other types of capital, including manufacturing, financial, human and social capital (Cohen-Shacham et al., 2016).

Climate change has aggravated natural disasters and extreme climatic events. Its repercussions can be seen in forms of increased frequency and intensity of weather events like floods, cyclones, heat and cold waves, droughts etc. (Seddon et al., 2020). In the past few decades, three-quarters of the land-based environment and about 66% of the marine environment have been significantly altered by human actions (UN, 2015). Such alterations have degrading impacts on natural ecosystems and are primarily responsible for the increase in global count natural disasters in recent years. Healthy environments are in a way capable of reducing physical danger to humans and their belongings, through the supplies of food, water, shelter and other essential ecosystem resources, as buffers and/or defensive barriers and reducing vulnerability and susceptibility. Between the 1990s and 2016, Mangroves have suffered the greatest loss among these ecosystems. Despite being the most productive ecosystems of the world, they are continuously regressing at an alarming rate. It is estimated that approximately 35% of Mangroves have been destroyed over the past 20 years, with annual losses of 1-2% worldwide (Carugati, et al., 2018). Indian Mangroves spread over 4639 sq. km only account for 0.14% of the country's geographical area but make up 3% of the global and 8% of the Asian Mangroves.

Natural capital is the finite stock of environmental assets, such as water, land, air, species and minerals that produces a flow of ecosystem goods and services which are important for human well-being and for the economy.

Nowadays, NbS are considered as assets to combat climate change as a long-term solution. NbS are defined by the International Union for Conservation of Nature (IUCN) as "actions to protect, sustainably manage, and restore natural or modified ecosystems, which address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits". The framework of NbS has proved promising in order to enhance social and environmental resilience, mitigate impacts on climate change, preserve habitats and biodiversity and boost livelihoods by preserving, restoring, enhancing and sustainable use of ecosystems and their services.

Mangroves have proven saviour both for humans and for infrastructures during many disasters in India. For instance, in the tsunami catastrophe of 2004 mangrove forests were spared lives, while in 2019 the Sundarbans were saved from the impact of the ravine cyclone and many others. This chapter focuses on all the potential NbS of India and the role of Mangroves of east and west coast of India. It was also found that there is a need for implementation of mangrove and other NbS solutions at grassroot level. This study is an attempt to encapsulate these pressing Mangroves associated global challenges, the need for development of conservation networks worldwide to be set out as solutions to work with mangrove ecosystems rather than conventional infrastructure solutions led to the emergence of the concept of Nature based Solutions (NbS).

II. Ecosystems and Nature Based Solutions

Ecosystems are the interactive units between the living (biotic) and non-living (abiotic) components of the environment which work together to sustain life on earth. Together these units perform a variety of functions, which provide a multitude of beneficial services to humankind. The plethora of services that ecosystem performs are essential for human well-being and sustenance of life and are categorized into four types of ecosystem services Figure below describes the link ecosystem services and constituents of well-being.

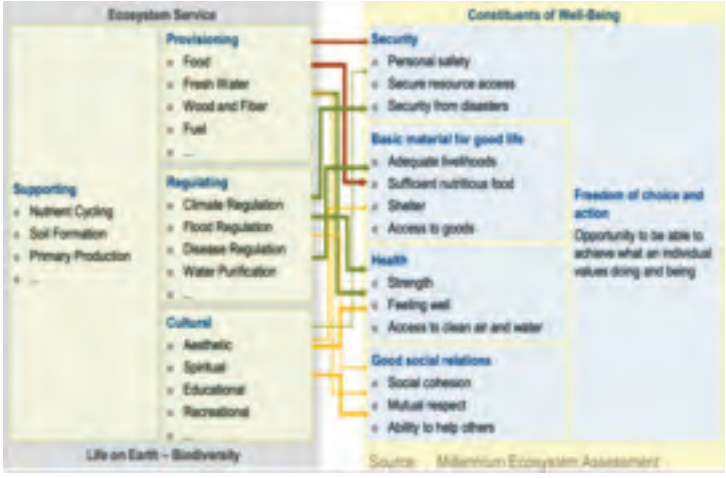


Figure 16: Ecosystem services and Human Well Being.
(Source: Millennium Ecosystem, 2005)

Disasters are mainly social constructs: they are largely determined by how a society manages its environment, the conditions of vulnerability that are present, its capacity to face adversity and what resources are available for recovery (IUCN, 2020). Healthy ecosystems are more resilient to extreme events and are adept to reduce vulnerabilities by lowering disaster risks in many ways by enhancing the adaptive capacity of the society (Santiago, 2016). Thus ecosystems are uniquely placed to protect us by:

1. Pose as natural barriers and cost-effective buffers to climate change and natural events
2. Providing livelihood benefits- increasing the coping capacity of vulnerable sections to recover from impacts of disasters
3. Ecosystem degradation, especially when related to forests and peat lands, reduces the ability of natural ecosystems to sequester carbon, increasing the incidence and impact of climate change and climate related disasters (IUCN, 2020).

III. Application of Nature Based Solutions

Nature based Solutions (NbS) are strategies that implement nature inspired models to address broader societal challenges by effectively substituting and balancing between natural and manufactured capitals. NbS leverages on the wide spectrum Natural Capital to provide dual benefits of human well-being and biodiversity benefits by providing options that protect, restore and sustainably manage ecosystems (Maes, and Jacobs, 2017).

NbS are thus designed to provide scope for social and economic benefits with solutions that successfully tackle problems including food & water security, climate change, human health and reducing disaster risks (IUCN, 2017). These solutions are simple in nature as they are functional in various environments including coastal, terrestrial, fresh water and urban settings (IUCN, 2020). Being a novel concept, NbS has found appreciation worldwide as a tool to achieve the global developmental agendas like the Paris Agreement, Sendai Framework for Disaster Risk Reduction and the Sustainable Development Goals (Cohen-Shacham et al., 2019). In environmental science and management, NbS is a new concept. NbS has links to other plant conservation and environmental management principles. Clear insights into NbS ability and falls are given in current experiences. NBS prepares and measures the various facets of sustainability. NBS has the power to stimulate as well as deter economic patterns.

The NbS have been applied in various parts of Europe for achieving sustainable development. Although addressing global environmental concerns, it has long been seen as difficult to achieve the economic goals of job creation, development and innovation. Nevertheless, the degree to which natural resources are used sustainably depends on long-term economic prosperity and stability. Consequently, to accomplish the dual purpose, the European Union invests in nature-based solutions (Cohen-Shacham et al., 2016).

Nature based solutions are being implemented into national and international policy and initiatives (e.g. climate change strategies, regulations, investment in infrastructure and funding mechanisms). The theme of the World Water Day 2018, for example, was 'Nature for Water' and was named 'nature-based waters' by UN Water's subsequent World Water Development Report. At the 2019 UN Summit on “Climate Action”, a nature-based approach was an important means of addressing climate change, as one of the main themes. A "Nature-Based Solution Coalition," including dozens of China and New Zealand countries, were created (Cohen-Shacham et al., 2019). Moreover, agroforestry as a NbS is also applied in rainfed areas of India for reducing community's dependence on forests and forest goods in order to safeguard forests (Kumar and Singh, 2020).

In NbS, attention is given to the role of vegetation in preventing or alleviating the impacts of natural hazards and climatic extreme events. Protecting forests with the aim of minimizing the danger of shallow landslides and other sloping processes are among the many examples of how vegetation can reduce the risk of disasters. This further encourages communities to cope with natural hazards. However, there is no comparative study of the functional components offered by vegetation in different forest environments. NbS has been applied to reduce the risk of shallow landslides (de Jesús Arce-Mojica et al., 2019). Many studies only focus on one specific control factor-such as root systems-without considering NbS as an integrated concept.

IV. Types of Nature Based Solutions

NbS is an umbrella concept that covers a variety of ecosystem-based solutions that respond to particular or multiple societal challenges while offering simultaneous benefits to human health and biodiversity. Approaches nesting under NbS can be easily divided in five categories which are, restorative, issue-specific, infrastructure-based, management and protection. The list of ecosystem approaches and their suitable examples are provided in figure below.

The restorative includes forest landscape restoration, ecological restoration, and ecological engineering based nature solutions in order to restore nature. The issue-specific category includes ecosystem-based disaster risk reduction solutions, ecosystem-based adaptation solutions, ecosystem-based mitigation solutions and climate adaptation services (Acharya et al., 2020). The infrastructure based solutions include green and natural infrastructures. The management includes the integration of coastal zone management and water resources management. The protection based solutions focused on area based conservation frameworks and methods, which integrates the protected area management and other effective area-based conservation solutions (Cohen-Shacham et al., 2019).

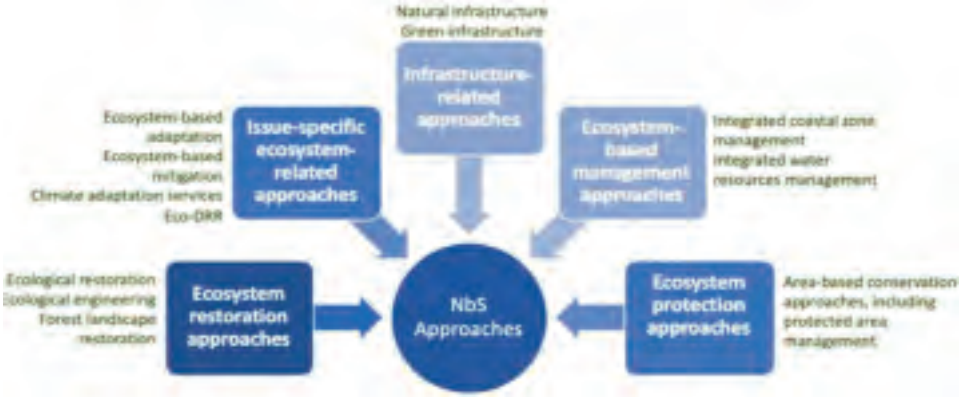


Figure 17: Ecosystem Approaches to Nature based Solutions
(Adapted from Cohen-Shacham et al., 2019)

Mangrove as key to Nature Based Solutions

Mangrove ecosystems are one of the most prized wetland ecosystems on Earth. They are transition zones between land and sea and exhibit the distinct ecological characteristics of what is said to be an 'edge effect'[9]. Their distribution may be restricted to intertidal zones of tropical and subtropical belt over 123 countries and territories (FSI, 2019), yet they are cherished worldwide for providing surplus socio-economic benefits. Mangrove forests are highly productive ecosystems with rates of primary production equal to those of tropical humid evergreen forests (Algoni, 2014). Mangroves serve as natural barriers to avoid coastal erosion and flooding and store as much CO_2 as other forests up to four times as much.

Figure 18: Benefits and Co-benefits of Mangrove Restoration
(Source: Adapted from IUCN, 2014)

[9]Edges of habitats reveal species composition, structure, and function representative of the unit of organization as compared with the adjacent area as well as having their own unique array of species and characteristics (Fonseca, 2008).

Mangroves attain coastal stabilization through anchoring shorelines and in doing so they act as buffers against rising sea levels, storms and storm surges. Figure above gives the list of benefits and co-benefits that Mangrove Restoration offers to society. Their unique ability to absorb organic waste makes them natural filters which are used for purifying waste water naturally. Mangrove ecosystems often are considered as biodiversity bouquets and provide critical habitats for critical species. Variety of terrestrial and marine animals uses Mangroves as their breeding grounds and nurseries. The mangrove flora provides green economy services for communities living in coastal areas. In addition, Mangroves play also a key role in human sustainability and livelihoods, being heavily used for food, timber, fuel and medicine (Carugati, et al., 2018). Ecosystems define the very basis of NbS, thus NbS should be thought as an umbrella concept covering a whole range of ecosystem-related approaches. By investing in NbS focusing on mangrove restoration or enhancement, societies can benefit through:

1. Mangrove's value can be reflected in the market price of products under provisional services.
2. Mangrove's value provides a good incentive for the tourism sector.
3. Mangroves value often isn't appreciated over conventional engineering structures, but they show astounding potential as natural infrastructure for coastal resilience.
4. Mangrove's role in carbon sequestration is now well accepted and their value is thus increasingly reflected in the carbon market (IUCN, 2017

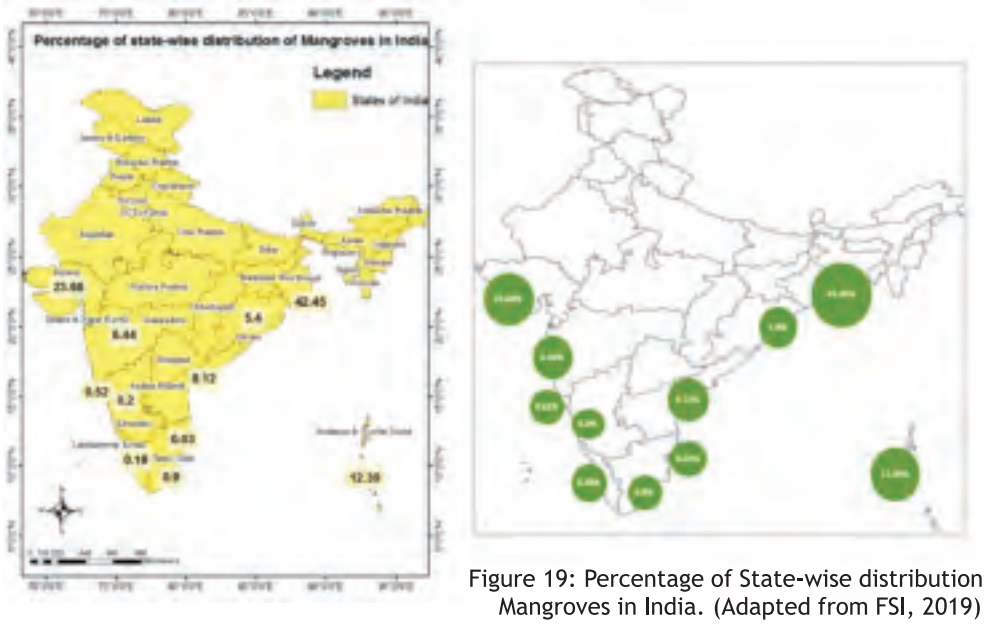


Figure 19: Percentage of State-wise distribution of Mangroves in India. (Adapted from FSI, 2019)

V. Nature based Solutions applied in India

Mangroves cover 15 million ha of land globally, 10,344 sq.km i.e., 6.8% of which resides in South Asia. India is home to 3% of the total mangrove cover in South Asia (FSI, 2019). The mangrove ecosystems in India are spread across 12 coastal states and occupy an area 4,975 sq.km i.e 0.15% of total geographic area of the country. State wise distribution of Mangrove cover is given in Figure 4. West Bengal has the highest Mangrove cover-accounting for 42.45% in the east coast followed by Gujarat-accounting for 23.66% in the west coast of India (FSI, 2019). The distribution of Mangrove forest as per their density is given in the figure below.

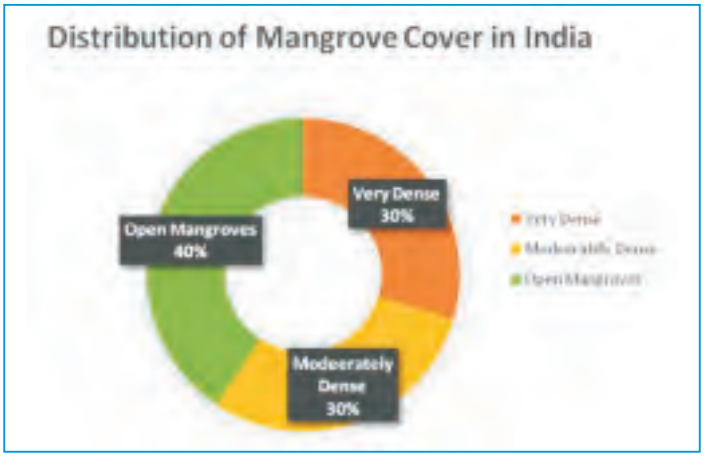


Figure 20: Distribution of Mangroves in India, from very dense, moderately dense to open dense.
(Source: Adapted from FSI, 2019.)

Mangrove ecosystems are vulnerable to anthropogenic activities and climate change. However, climatic variables have fewer consequences over Mangroves than anthropogenic factors (Ghosh et al., 2015). Climate change induced abrupt fluctuations in temperature and rainfall pattern remain a primary threat to Mangrove extinction (Gilman et al., 2008). Solid wastes like plastics and excessive sedimentation often clog the pneumatophores (aerial roots) and obstruct air supply to the plants (IUCN). Habitat destruction and conversion of mangrove patches for agriculture, aquaculture, shrimp and prawn farming practices on the other hand are responsible for more than half of mangrove loss globally. Fragmentation and clearance of Mangrove patches in addition impact the floral and faunal biodiversity that depend on these ecosystems. In many instances, it was observed that logging activities in and around Mangrove ecosystems have altered species composition (Cornejo et al., 2005).

The threats to Mangroves in the Indian coastal states broadly remain the same, but it is seen that the drivers may vary between the East and the West coast depending upon the climatic, socio-economic and ecological vulnerabilities (Ghosh et al., 2015). For example, in an analysis of the frequency of Cyclones in India, it was found that the East coast is affected more by them than the West coast at a ratio of approximately 4:1 (Mehrotra, 2020). Indian Mangroves are under threat from habitat loss and destruction as an outcome of conversion of Mangrove patch for aquaculture including shrimp & prawn culture and paddy cultivation. Coastal erosion is also a serious issue but it is restricted to small parts along the coast (Ponnambalam et al., 2012). Construction of dams often cuts the water flow which results in siltation, formation of mudflats, loss of connectivity within the creeks and at the same time alters the salinity further harming the plant species (Sundararaju, 2019). Setting up of extractive industries, discharge of industrial waste, sewage and agricultural runoff increases the pollution inflow. Among the other drivers, the socio-economic factors contribute the most to degrading Mangroves. The communities which live along the Mangroves are often marginalized and have limited livelihood options thus they use the forest resources extensively as economic derivatives (Ghosh et al., 2015).

A comparison of the mangrove covers on both the coasts it is found that the East coast has 25.7% more Mangrove covers than the West coast. Moreover, the Indian State of Forest Report 2019 indicated an increase of 54 ksqm Mangrove cover between 2017 and 2019. This is suggestive that people have started to recognize the importance of Mangrove for functions they provide. Das and Vincent (2009) have demonstrated that Mangroves protected villages and reduced death toll during Indian super cyclone. The villages with wider Mangroves between them and the coast experienced significantly fewer deaths than ones with narrower or no Mangroves by using regression analysis (Mahanty, 2002).

The Bhitarkanika Mangrove in Odisha, provides protection from flood and reduces subsequent destruction. The cyclone damage avoided in the Mangrove protected areas was heist; $ 33.3 compared to the unprotected areas; $ 153.74 (Ramachandra and Rajinikanth, 2005). Mangrove restoration projects in Andhra

Figure 21: Mangrove protecting coastal villages during storm. (Source: Oceanwhealth.org)

Pradesh aim at restoring coastal ecology along with promoting sustainable livelihood options and enhancing food production for local communities. By digging canals to direct the flow of water through mangrove forests, villagers support the growth of mangrove trees and contribute to the restoration of the geography and hydrology of the coastal ecosystem (Bennett, 2016).

Figure 22: Mangrove plantation and restoration activity at Andhra Pradesh.
(Source: Indiawaterportal.org)

VI. Challenges faced in implementation of NbS in India

India being a diverse country with multi-level economic status and has state-wise resource allocations. This further interrupts the implementation of NbS in India and few of the challenges faced are:

1. **Lack of awareness about NbS as a concept:** The NbS is a recently developed concept and the global conservation unions are still working extensively to develop effective implementation mechanisms. At a global level NbS have got substantial recognition, yet there is lacking awareness at local levels about the concept of NbS as a whole.
2. **Lack of knowhow of implementing suitable NbS solutions:** For attaining effective results of NbS, interventions should be focused at ground level. But the results often lead to malpractices due to inappropriate knowledge and lack of technical understanding of designing these interventions.
3. **Lack of sense of ownership:** Communities need to take ownership of activities or set of interventions that are being applied.
4. **Focus on short term monetary gains over long term developmental gains by conserving and utilizing Natural Capital:** Local communities often ignore the long term benefits of NbS interventions over small and immediate cash flow. These further results in overexploitation, habitat degradation and unsustainable practices by the local communities. Moreover, NbS is often ignored over the time frame difference between success results of NbS v/s conventional infrastructure.
5. **Mainstreaming of NbS in developmental planning:** Mainstreaming of NbS in developmental planning is often a concern to attain the desired results and uptake of NbS in local targets and developmental actions.

VII. Way forward

Mangroves are essential for the survival of humans, and sustainability of the world (Cohen-Shacham et al., 2019). NBS should be implemented at the landscape scale and, in order to tackle social problems, NbS are part of the overall strategy, plan and intervention design. In the fields of environmental protection and land use planning, assessment and valuation is important in order to promote the implementation of creative NbS. Valuation may refer to monetization (assessment of monetary value) or estimation of value and purpose.

With the growth and conservation choices better understood and accepted by NbS, the possibility exists to structure the definition rigorously to meet sound governance standards. In order to further improve NbS it is important to evaluate the application of NbS principles in a broad variety of cases and assess in more detail the relevance of NbS in global policy (for example, SDGs, SFDRR). Most significantly, the importance of operationalization of NbS principles 2, 6 and 8 needs to be demonstrated, which will enable us to address societal problems in the required way. It will entail a great deal of cooperation between stakeholders, including the private and public sectors.

VIII. Scope of NbS Interventions

The 2015 development agenda gave way to an integrative approach to development focusing on the well-being of all and upheld the scope of sharing co-benefits as well as equitable sharing. This led the global leaders to start visualising development as a holistic manner. Despite substantial increases in the scope and magnitude of biodiversity conservation and ecological restoration, there remains ongoing degradation (Cohen-Shacham et al., 2019). NbS concept is increasingly being referred to in scientific literature (e.g., Kabisch et al., 2016; Raymond et al., 2017a; Keesstra et al., 2018). Given the eight principles, NbS has potential to embrace the conservation norms promoting benefits to the society in an equitable and transparent way. The productivity and capacity of green infrastructure and services in the provision of large ecosystem services was demonstrated by Liquete et al., (2016). It also stressed the importance of incorporating various value systems and the views of stakeholders to facilitate environmental decision making.

References

- Acharya, P., Gupta, A.K., Dhyani, S. and Karki, M., 2020. New Pathways for NbS to Realise and Achieve SDGs and Post 2015 Targets: Transformative Approaches in Resilience Building. In Nature-based Solutions for Resilient Ecosystems and Societies (pp. 435-455). Springer, Singapore.
- Alongi, D. M. 2014. Carbon Cycling and Storage in Mangrove Forests. Annual Review of Marine Science, 195-219.

- Bennett, E. 2016,. Mangrove Restoration: Case Studies from Thailand, Vietnam and India. Retrieved from Lostfreetown.com: http://lostfreetown.com/lostfreetown/mangrove-restoration-case-studies-thailand-vietnam-india/ [Accessed on 10, 07. 2020]
- Borrini-Feyerabend, G., Farvar, M.T., Renard, Y., Pimbert, M.P. and Kothari, A., 2013. Sharing power: A global guide to collaborative management of natural resources. Routledge.
- Raymond, C.M., Frantzeskaki, N., Kabisch, N., Berry, P., Breil, M., Nita, M.R., Geneletti, D. and Calfapietra, C., 2017. A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. Environmental Science & Policy, 77, pp.15-24.
- Carugati, L., Gatto, B., Rastelli, E. et al. Impact of mangrove forests degradation on biodiversity and ecosystem functioning. Sci Rep 8, 13298 (2018). https://doi.org/10.1038/s41598-018-31683-0
- Cohen-Shacham, E., Andrade, A., Dalton, J., Dudley, N., Jones, M., Kumar, C., Maginnis, S., Maynard, S., Nelson, C.R., Renaud, F.G. and Welling, R., 2019. Core principles for successfully implementing and upscaling Nature-based Solutions. Environmental Science & Policy, 98, pp.20-29.
- Colls, A., Ash, N. and Ikkala, N., 2009. Ecosystem-based Adaptation: a natural response to climate change .Vol. 21. Gland: IUCN.
- ENVIS. 2020,. ENVIS Centre: Kerala State of Environment and Related Issues. Retrieved from ENVIS Centre: Kerala: http://www.kerenvis.nic.in/Database/Coastline_2346.aspx/ [Accessed on 12, 07. 2020]
- Fonseca, M. 2008. Edge Effect. Encyclopedia of Ecology.
- FSI. 2019. India State of Forest Report 2019. Dehradun: FSI, GoI.
- Ghosh S, Bakshi M, Bhattacharyya S, Nath B, Chaudhuri P. 2015.A Review of Threats and Vulnerabilities to Mangrove Habitats: With Special Emphasis on East Coast of India. J Earth Sci Clim Change 6:270. doi: 10.4172/2157-7617.1000270
- Gilman, E., Ellison, J., Duke, N., & Field, C. 2008. Threats to Mangroves from climate change and adaptation options: A review. Elsevier, 237-250.
- Hernández-Cornejo, R., N. Koedam, A. Ruiz Luna, M. Troell, and F. Dahdouh-Guebas. 2005. Remote sensing and ethnobotanical assessment of the mangrove forest changes in the Navachiste-San Ignacio- Macapule lagoon complex, Sinaloa, Mexico. Ecology and Society 10(1): 16.
- IUCN. 2016,. Services. Retrieved from Commission on Ecosystem Management: https://www.iucn.org/commissions/commission-ecosystem-management/our-work/cems-thematic-groups/services/ [Accessed on 09, 07. 2020]

- IUCN. 2017,. What are Mangroves worth? There's no easy answer. Retrieved from IUCN.org: https://www.iucn.org/news/forests/201704/what-are-Mangroves-worth-there's-no-easy-answer/ [Accessed on 09, 07. 2020]
- IUCN. 2020,. Eco-DRR: What are IUCN's solutions? Retrieved from Ecosystem Management: https://www.iucn.org/theme/ecosystem-management/our-work/environment-and-disasters/eco-drr-what-are-iucns-solutions/ [Accessed on 11, 07. 2020]
- IUCN. 2020,. Environment and Disasters. Retrieved from Ecosystem Management: https://www.iucn.org/theme/ecosystem-management/our-work/environment-and-disasters/ [Accessed on 12, 07. 2020]
- Ponnambalam, K., Chokkalingam, L., Subramaniam, V. And Ponniah, J.M., 2012. Mangrove Distribution and Morphology Changes in the Mullipallam Creek, South Eastern Coast of India. International Journal of Conservation Science, 3(1).
- Keesstra, S., Nunes, J., Novara, A., Finger, D., Avelar, D., Kalantari, Z. and Cerdà, A., 2018. The superior effect of nature based solutions in land management for enhancing ecosystem services. Science of the Total Environment, 610, pp.997-1009.
- Kerala Govt. 2020,. About Kerala. Retrieved from Official Web Portal, Government of Kerala: https://kerala.gov.in/about-kerala/ [Accessed on 12, 07. 2020]
- Kumar, M. and Singh, H., 2020. Agroforestry as a Nature-Based Solution for Reducing Community Dependence on Forests to Safeguard Forests in Rainfed Areas of India. In Nature-based Solutions for Resilient Ecosystems and Societies (pp. 289-306). Springer, Singapore.
- Maes, J. and Jacobs, S., 2017. Nature-based solutions for Europe's sustainable development. Conservation letters, 10(1), pp.121-124.
- Mehrotra, V. 2020., All you need to know about cyclones in India: Most affected states, list of 9 deadliest cyclones in India. Retrieved from India TV: https://www.indiatvnews.com/fyi/news-all-you-need-to-know-about-cyclones-in-india-most-affected-states-list-of-9-deadliest-cyclones-in-india-519361/[Accessed on 11, 07. 2020]
- Kabisch, N., Frantzeskaki, N., Pauleit, S., Naumann, S., Davis, M., Artmann, M., Haase, D., Knapp, S., Korn, H., Stadler, J. and Zaunberger, K., 2016. Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action. Ecology and Society, 21(2).
- IUCN. 2020,. What are Nature Based Solutions (NbS). Retrieved from Nature Based Solutions: https://www.nature-basedsolutions.com/ [Accessed on 13, 07. 2020]

- Keesstra, S., Nunes, J., Novara, A., Finger, D., Avelar, D., Kalantari, Z. and Cerdà, A., 2018. The superior effect of nature based solutions in land management for enhancing ecosystem services. Science of the Total Environment, 610, pp. 997-1009. Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., De Vries, W., De Wit, C.A. and Folke, C., 2015. Planetary boundaries: Guiding human development on a changing planet. Science, 347 (6223).
- Seddon, N., Chausson, A., Berry, P., Girardin, C.A., Smith, A. and Turner, B., 2020. Understanding the value and limits of nature-based solutions to climate change and other global challenges. Philosophical Transactions of the Royal Society B, 375(1794), p.20190120.
- Seddon, Nathalie & Chausson, Alexandre & Berry, P. & Girardin, Cécile & Smith, Alison & Turner, Beth. 2020. Understanding the value and limits of nature-based solutions to climate change and other global challenges. Philosophical Transactions of the Royal Society B: Biological Sciences. 375. 20190120. 10.1098/rstb.2019.0120.
- Sundararaju, V. 2019,. Scientific management of Mangroves is need of the hour. Retrieved from Down to Earth: https://www.downtoearth.org.in/blog/wildlife-biodiversity/more-to-roosting-than-meets-the-eye-63708/ [Accessed on 12, 07. 2020]
- Ramachandra, T.V., Rajinikanth, R. and Ranjini, V.G., 2005. Economic valuation of wetlands. Journal of Environmental Biology, 26 (2), p. 439. Santiago Fink, H., 2016. Human-nature for climate action: Nature-based solutions for urban sustainability. Sustainability, 8 (3), p. 254.
- Liquete, C., Udias, A., Conte, G., Grizzetti, B. and Masi, F., 2016. Integrated valuation of a nature-based solution for water pollution control. Highlighting hidden benefits. Ecosystem Services, 22, pp.392-401.
- Mahanty, S., 2002. Conservation and development interventions as networks: the case of the India Eco development Project, Karnataka. World Development, 30(8), pp.1369-1386.
- UN. 2015. UN Report: Nature's Dangerous Decline 'Unprecedented'; Species Extinction Rates 'Accelerating', Retrieved from Sustainable Development Goals: https://www.un.org/sustainabledevelopment/blog/2019/05/nature-decline-unprecedented-report/

Chapter-5
Impact of Peri-Urban Issues on the Environment and People: A Review on Indian Scenario

Saloni Sachdeva, Sumit Kumar and Jabili Chowdari

Abstract

With an increase in population, the urban system also tends to grow. The population emigrates due to economic reasons to the fringe areas on the periphery of the city, commonly known as Peri-urban areas. Peri-urban areas are closely associated with rural areas, hence have mixed characteristics. The relocation of the population leads to numerous new activities which further changes land use pattern of the area and environmental conditions. Also, set off diverse issues like natural source depletion, ecological challenges, unsatisfactory environmental conditions, and poor connectivity. Lack of governance adds up to these problems. An effective mechanism for planning and management is required to ensure the least damage to the environment and safeguard cultural practices of the area. Ceaselessly these areas are under physical, social, economic and environmental changes. These areas hold the utmost importance in spatial planning as they are believed to be the upcoming major urban centers. Thereby, proper management in the transformation of Peri-urban areas regulates the economic prosperity and sustainability of the resources.

Keywords: Peri-urban, Population overspill, Fringe, Infrastructure, Governance, Sustainability

Saloni Sachdeva (salonisachdeva02@gmail.com) Sumit Kumar (✉) (sumit29sep@gmail.co) Jabili Chowdari (jabili.chowdari@gmail.com)

Department of Environmental Science and Technology, Central University of Punjab, Bathinda

I. Introduction

India is swiftly expanding in terms of population and urbanization. In reference to the world, India constitutes of about 2.4% of surface area and 17.8% of the total population (Census of India, 2001). According to the UN World Population Prospects, the population of India grew to 1.36 billion with 1.02% growth rate in 2019. Peri-Urbanization is characterized as the socio-economic processes that metamorphose demographic and social anatomy of the rural and urban establishments (Dupont, 2015). It is usually believed that urbanization is a constructive force for the economy of the country, but it also leads to the emergence of the new economic growth nodes which subsequently give rise to the basic issues related to urban governance and environmental sustainability (Saxena & Sharma, 2015). Urbanization occurring on the periphery or close association of the established urban area is known as peri-urban areas. In India, urban transition is clearly reflected in the regions comprising of main cities and their outgrowth which can be termed as urban agglomerations. Expansion of urbanization in these outgrowths has resulted in expanding of the boundaries and rapid conversion of the rural areas to urban areas. Based on 2011 census data, urban agglomeration regions were increased to 53 from 35 in 2001. Over the time, not only the population has increased but the demographic growth has also been recorded ("Managing Peri-Urban Expansion", 2015).

According to Shaw (2005), there is a shrink in population in the core of the metropolitan cities and these inhabitants are moving outwards in the smaller towns nearby for the fulfilment of their basic necessities. Manifestations of this urban sprawl give rise to peri-urbanization, implying the conversion of the rural/semi-urban areas to urban centers. Residents in these emerging cores are exposed to poor water and sanitation conditions which despairs the health and well-being. Furthermore, these locations are highly vulnerable to natural disasters and susceptible to impacts of climate change.

The increase in population of the city has fraught carrying capacity, hence possessing strain on the peripheral regions. The demography of peri-urban areas is dynamic in nature as it allows aggressive flow of commodities, capital and people which intensifies the urban-rural linkage (Randhawa & Marshall, 2014). These areas provide advantage to wider range of sectors i.e., for the people, they serve as a source of dwelling place and for economic purposes; for the industry, they serve as a source of raw materials and for the government, they serve as the dumping site (Douglas, 2012). Also, they offer dynamic land use pattern and better residential alternatives at lower costs (Shaw, 2005). Social flux across these areas further has off-shoot effects in terms of economic activities. With the progress in expansion of pre-urbanization, the zone diversifies and undergoes changes. It creates enormous changes in the available opportunities; ultimately affecting the scale of agricultural activities. Such transitional fringes are in peril to environmental havoc due to their juxtaposition to cities by degrading the natural resources (mainly, land

and water) via dumping of the wastes. The native communities existing in these areas are exposed to ecological and livelihood insecurities, while presenting new obstacles for peri-urban governance (Simon, 2008). As a whole, peri-urban regions can become a market-oriented zones which is exploited for agricultural and natural resources in an unsustainable manner, if not regulated.

II. Drivers of Peri-Urbanization

In the twenty-first century, peri-urban areas have emerged to be one of the mainstreams of sustenance ball game across the world (Ravetz et al., 2013). Often, these areas are regarded as the litmus test of change and transition. They are considerably similar to established urban centers with inadequate supply of water and waste disposal facilities. Peri-urban fringes are small transitional space between the rural and urban area but according to McGee (1991), these processes take place in larger zones namely extended metropolitan region. A study by Webster & Muller (2009) explains that drivers for dispersal of population to the peripheries differ world-wide. It has been observed that the developed countries promotes urban welfare and international economic competition and result in decline in rural populations whereas in developing countries peri-urbanization decreases urban population at city cores and increases rural urbanization which results in a shift to urban life and scattered urban centres (Woltjer, 2014). Peri-urban areas are considered as the reflection of urban establishments, therefore in the end they become ultimate zone of impacts (Refer to Table 5). Foremost and interdependent drivers giving rise to these areas are:

- **Urban sprawl:** With steep increase in the population growth, the demand for unaffordable residential/industrial land and basic amenities also escalates. Thereby, the population moves outward on the periphery for cheaper accommodations (Narain et al., 2013). So, the large property developers focus on these areas, catering to range of income. Migration is defined as the feature as well as a factor for the increase in number of peri-urban regions. It is regulated by number of determinants like social disruption and economic reasons. Cities with complex structure and unpredictable development towards periphery often mediate urban sprawl (Joshi et al., 2011). This phenomenon is happening in several cities of India namely Delhi, Mumbai, Chennai, Chandigarh, Ahmedabad, Patna and Guwahati (Kundu, 2009; Narain et al., 2013; Tiwari, 2019). Peri-urban prime dwellers offering availability of inexpensive labour is yet another factor contributing to the expansion.
- **Industrial decentralization:** Peri-urban areas are alluring alternatives to manufacturing investments for two reasons. Firstly, they offer greater area and inexpensive lands with less freightage. And secondly, public policies enable establishment of manufacturing dispersed, and away from the core of the urban

centres for subsequent reduction in pollution. Hence leads to expansion of the peri-urban areas. Substantially the underlying motive is to ease truck traffic, pollution and manufacturing-activities induced accidents. Not only manufacturing industries, but the major co-operate offices have also been established in the peri-urban areas, thereby attracting more people nearby. (Footnotes)

Table 5: Major Urban Centres and Peri-Urbanization

Urban Centre	*Direction of Peri-Urbanization*	*Increase in Built-ip Area (in %)*	*Drivers of Peri-Urbanization*	*Impacts of Peri-Urbanization*
Chandigarh	Panchkula, Mohali and Kalka	14.5	Residential projects with development of Himalayan highway. IT park	*1. Decline in agricultural land.*
Chennai	Southwards	41	IT expressway (earlier Old Mahabalipuram Rd)	1. Decrease in tourism economy. 2. Encroachment of land by real estates. 3. Ecological problems like waste disposal, urban flooding and deterioration of water resources.
Patna	Along major river banks.	97	Rapid urbanization. Increased demand of natural resources.	1. Degradation of wetlands along NH-30. 2. Mismanagement of solid waste and sanitation.
Guwahati	Along the roads of the periphery.	40	Encroachment of land due to residential and industrial purposes.	1. Disappearing of wetlands 2. Decreased forest cover. 3. Displacement of tribes. 4. Urban flooding. 5. Ecological problems like waste disposal, urban flooding and deterioration of water resources.

Urban Centre	*Direction of Peri-Urbanization*	*Increase in Built-ip Area (in %)*	*Drivers of Peri-Urbanization*	*Impacts of Peri-Urbanization*
Ahmedabad	East and west of the city.	173	Initially: due to textile industry, but banned. Now: due to numerous industries such as automobile, pharmaceutical, chemical etc.	1. Air and water pollution. 2. Increased demand of water resources. 3. No agricultural activities.
Varanasi	-	345	Urban sprawl	1. Decrease in vegetation. 2. Shift from agriculture to non-agricultural activities.
Faridabad	-	-	Land acquired by factories and industries	1. Fragmented agricultural land. 2. Loss of land productivity. 3. Shift of control over local resource.
Hyderabad	-	-	Encroachment of land for residential and industrial activities	1. Depletion of lakes and dug wells. 2. Encroachment and pollution of Hussainsagar Lake from industrial effluents.

(Source: Ramachandraiah and Prasad, 2004; Prasad et al., 2009; Narain et al., 2014; Tiwari, 2019; Patel et al., 2019).

III. Transformations due to Peri-Urbanization

Relocation of the population to the periphery of the urban centres is highly regulated by economic reasons and land requirements. With the movement of people and goods, unplanned income-generating activities come into action. In these areas, urban and rural activities interconnect and convolute (Tacoli, 2003). Urbanization of Indian states is made possible due to changes in gross domestic product and urban population of respective cities (Pandey et al., 2013). The key attributes of peri-urbanization process include a change in economic and spatial pattern structure; change in employment structure and rapid urban growth. Transformations occurring in peri-urban areas are majorly criticised

for the ills, ranging from unplanned establishment of the settlements to lack of primary environmental services (Goodfellow, 2013). But, innovative policies can turn ills into economically benefitting resources thus bridge rural-urban activities. The expansion of peri-urban areas is associated with massive and unseen costs to transformation, which is why it is expressed as an epoch-making issue.

1. Demographic/Physical Changes

For the very first time in 2007, it was documented that a greater number of people resides in urban areas as compared to rural areas. This trend has been heightening since then, especially in India. Due to increase in the living cost in urban establishments, the population is forced to displace and move to the periphery. But no study has been done on the extent of these spaces to provide safe asylum to the migrants. In a country like India, rapid and unplanned growth has expedited the emergence of vulnerable groups, notably the groups living in unofficial settlements. Transportation and connectivity are the major key factors that uplift the expansion and development of the peri-urban areas. Urban densification and expansion result in mass transported systems and eventual building of subways and public transportation to reduce traffic jams. Although the reverse is also true when low density settlements are a luxury hence mass transportation is out of requirement. Nonetheless, with efficient transport policies, mass transportation influences sustainable urban use and boosts peri-urban development (Torres & Haroldo, 2008).

Peri-urban areas are not demarcated and defined zones but are the transforming zones trying to fit in with varying groups i.e. low income migrants and lucrative investors. Peri-urban areas show rural characteristics because of existence of agro-forestry sector whereas the flow of merchandise and workforce attributes to urban processes. Forbye, lack of legal and institutional federation endanger urban-rural relations and rural society's existence. Thus, these areas are defined as heterogeneous zone with rural morphology and urban processes (Caruso, 2001). It is believed that rural, peri-urban and urban areas function as a system rather than separately. Various researchers agree to the belief that rural development and urban planning are closely linked (Ravetz et al., 2013) to:

- Urban & Peri-urban areas: Urban areas put pressure on the periphery for space and resources whereas, peri-urban areas requires urban market and services.
- Rural & Peri-urban areas: Peri-urban areas function in terms of economics whereas, rural areas establishes relationship in terms of employment and services.
- Peri-urban communities: This linkage helps in the advancement of commercial and social growth across the community.

Land cover is expounded as the physical front which gives information regarding the distribution of physical structures of land. In contrast, land use pattern indicates the use of land by the people (Rawat & Kumar, 2015). Land use is highly regulated by the growth in population and urbanization in the area. Predominantly, the agricultural lands are transformed to urban settlement, forest area to agricultural land and rural areas to urban areas (Sharma et al., 2012; Patel, Verma & Shankar Singh, 2019). This trend has been communicated for major Indian cities (Pandey & Seto, 2015; Pandey et al., 2018). With dynamic changes in the activities in peri-urban areas, the land use disputes and changes in traditional livelihood are the mostly ineludible (Simon, 2008). A report by Indian institute for human settlement (2017) states that with no link between property records and legal institution has led to increase in property frauds.

2. Socio-Economic Changes

Urban growth is referred to as complex and two ways process that generates demographic and economic changes (Joshi et al., 2011) in the urban, rural and peri-urban areas along with inter regional relationships. While, rural and peri-urban activities act in feedback loops this subsequently leads to the major socio-economic changes in the area (Ravetz et al., 2013). A peri-urban lifestyle forms around land use activities. Instauration of such a lifestyle is based on global economic changes, social and functional decomposition as a result of development. Another factor playing a role is the urban identity (Woltjer, 2014). It is associated with living in peri-urban areas also called as mental urbanization a term given by Driessen et al., (1995). Development in majority of peri-urban areas is due a great vision of mental urbanization but not the urbanization pressure on rural areas. Physical aspects like variation in development and conversion to non-agricultural uses. Environmental aspects like lack of environmental sensitive planning of areas and improper waste and sewage management. Governance problems like missing link between planning and implementation of development result in competition with developed urban areas cumulating in unregulated development of peri-urban areas (Tiwari, 2019). Another negative impact of peri-urbanization is the emergence of unauthorized establishments which lacks sanity and basic services. Urbanization presents unequalled opportunities for improved living conditions and available resources but this scenario results in the unanticipated social impacts (Simon, 2008). Poor residents find these spaces affordable directing informal and scattered settlements. With advancement in urbanization in these spaces, the cost of living increases (Rostam, 1997) hence the land prices (Allen et al., 1999).

India is associated with dreadful health problems allied with traditional diseases and diseases due to deterioration of environment. Isochronal migration of people hauls communicable disease across peri-urban areas. Due to escalated rate of urbanization, a large segment of susceptible and immune people come in close vicinity to each other.

Also, the water quality and sanitation of these areas are substandard, contributing to the spread of diseases. Geographical factors such as terrain and zonation affect risks evolved. With change in land use pattern of the area, deforestation leads to degradation of the high-quality soil and increased surface run off. Unpredictable flow of surface run off can contaminate drinking water; contributing to spread of water-borne diseases (Birley & Lock, 1999). Another problem related with peri-urban areas is noise pollution which effects negatively on the mental and physical health of the people by disrupting their sleep cycle and hearing ability (Akhtar et al., 2020). Transitional regions are susceptible to communicable and non- communicable diseases (Allen et al., 1999):

- Communicable diseases are further spread via food, air and water resources. Vector borne diseases are correlated with the resource management. And, with changes in the landscape structure, the frequency and habitat of vector breeding varies concomitantly. Advancement of urban agriculture impacts significantly in the mosquito breeding. Atrocious management and disposal of the solid waste also contributes in breeding of mosquitoes and houseflies.
- Non-communicable diseases result due to ingestion of toxic chemical such as heavy metals. Agro-chemicals and Industrial/domestic waste water are the potential sources for non-communicable diseases. Chemical pollution can have detrimental effect on the quality of irrigation and agricultural productivity, which further consequents in malnutrition and food shortage for the inhabitants. Poor ventilation and combustion of the fuel come up with number of toxic gases such as sulphur dioxide, nitrogen dioxide, carbon monoxide/dioxide and particulate matter, resulting in unfavorable effect on biotic components of earth.

3. Environmental Changes

The rapid peri-urbanization processes have diverse and complex environmental consequences (Simon, 2008). They have been associated with the fragmentation and degradation of natural ecosystem, biodiversity loss, water- soil contamination, and air pollution (Torres, 2011). All of these environmental complications are a result of unsustainable practices prevailing in the peri-urban areas. The dynamic and low-density urban expansion over a time span of centuries linked to land-waterscape modification results in increased runoff, unpredictable flash floods and reduced catchment area ultimately affecting gross water availability of the area (Simon, 2008). In addition, the peri-urban sprawl has limited sanitation, poor housing conditions, lack of access to clean fuel, and no waste disposal facility often leading to environmental and health hazards pertaining to the disposal of wastes beyond local-regional absorptive capacities and air pollution (Allen et al., 1999; Torres, 2011). With transformation of the environmental factors, resident's vulnerability to natural disasters and climate change has been magnified (Gupta et al., 2017).

i. Freshwater Quality

Water security affects urban, peri-urban and surrounding rural areas, particularly the poor with little or no access to infrastructure for water provision and water allocated for irrigation. Agriculture, industries, and by-products of human settlements are the most prominent cause of water pollution around the world. Lack of access to infrastructure imposes drastic impacts on watercourses and its availability. Access to sanitation and wastewater management is strongly linked with water pollution hence sanitation and water distribution must be an intrinsic part of the peri-urban management practice and policies (Allen et a., 1999).

The peri-urban areas serve as the water supply facilities for cities. The region contains reservoirs or sinks for the recharge of underground water sources due to its high infiltration capacity compared to the urban areas. Urban areas have reduced infiltration because most of its soil surface gets covered by hard concrete surfaces. Urban expansion in periphery changes the water use pattern and water resources in peri-urban locations faces imbalance between extraction and recharge (Allen et al.,1999). This ultimately results in conflict between urban, peri-urban, and rural area for the water resources affecting the industries, domestic use, and agriculture practices. At the same time peri-urban areas serves as sink of urban waste, ranging from domestic, industrial and municipal solid waste further extending ground water pollution and affecting water security (Narain & Prakash, 2016).

ii. Air Quality

Deteriorating air quality is one of the serious problems, globally; particularly in urban settings of developing countries. The main culprits are expanding population, industrialization, increasing number of vehicles, and lack of infrastructure (Nagdeve, 2006). Another reason is the use of bio fuels to meet energy needs of peri-urban dwellers, especially around cities in Africa and Asia (WRI, 1996). Urban sprawls having easy access to fossil fuel restrict the use of renewable and alternative sources. Peri-urban regions lack efficient transport infrastructure and increasing use of motor vehicle results traffic congestion and ultimately air pollution. Increasing air pollution has further ecological complications like climate change and acid rain (Allen et al; 1999).

iii. Waste Disposal

Urban wastes are most likely to find its way to the peri-urban areas either legally or illegally, when it surpasses absorptive capacity, they have severe impact on the ecosystem and health of local population, specifically the poor and children. Availability of empty space and easy access establishes peri-urban area as backyard for waste disposal. The poor

waste management in peri-urban locality and overburdened urban waste disposal sometimes results in dispute and conflict between urban and peri-urban communities. Industrial waste, heavy soils and urban waste water ultimately ends up into the rivers and streams impacts agriculture peri-urban region resulting in decreased productivity (Allen et al., 1999). The poorest population in peri-urban have least access alternate resources, they are forces to utilize polluted water and eat fish that may contain increased level of toxic metals, finally suffer severe health consequences (Simon, 2008).

IV. Environmental Disasters and Vulnerabilities

Asia-Pacific region is among the most disaster susceptible region worldwide and had witnessed above 1600 natural disasters (UNESCAP, 2015) in last few decades. Natural disasters vary in typology as they may be hydro-metrological, biological, climate induced, or environmental, costing lives and huge economic destruction. A healthy ecosystem is the best defense against such disasters but unsustainable development patterns as in the case of peri-urban issues deteriorates ecosystem health (Gupta, et al., 2017). The most common environmental disaster associated with peri-urban fringe is flooding (Wijaya, 2018). Lack of sanitation and sewerage infrastructure results in stagnation of water, the problem worsens during rainy seasons.

Studies suggest the inherent vulnerability index (IVI), a parameter studied to assess the vulnerability of population living in urban areas is higher in the districts with high poverty levels and low human development (Anees et al., 2019). Not surprisingly peri-urban areas most often fall in these districts. An elaborate study done by Wajih and Mani (2016) shows a visible link between sub-standard living in poor urban areas and their impact on vulnerable sections of society especially children belonging to slums, low income developments and floating population (Gupta et al., 2017). (Refer to table below)

Table 6: Risks and Vulnerability Common to many Urbanising Cities

Peri -Urban Parts Of Cities	*Risks (Disaster And Health)*	*Factors*	*Vulnerability*
Indore	Floods, water and vector borne diseases, heat-wave	Water logging and floods, unequal water distribution, Improper sewage management, lack of solid waste management	Health, lack of proper education, child labour, illegal practices involving children
Gorakhpur	Floods, water and vector borne diseases	Water logging and floods, improper sewage management, unregulated housing and lack of ecosystem management	Vector-borne diseases, lack of proper education, child labour, illegal practices involving children

Peri -Urban Parts Of Cities	*Risks (Disaster And Health)*	*Factors*	*Vulnerability*
Guwahati	Floods, water logging, ecological degradation, vector borne diseases	Inadequate and unsafe water availability, unregulated housing	Unsafe housing, health, lack of proper education, child labour, illegal practices involving children
Panjim	Waterlogging, floods, water/waste borne diseases, heat wave	Salt water intrusion, improper sewage management	
Shimla	Landslides, communicable diseases	Inadequate and unsafe water availability, improper sewage system, lack of solid waste management	

(Sources: Wajih and Mani, 2016)

A study (Decision Intelligence Document Degradation and Loss of Peri-Urban Ecosystems, 2013) evidences the impact of urbanization directly on the degradation of ecosystem. Various attractive developmental trends namely urbanization, involve activities such as mining, deforestation, conversion of land, rerouting rainwater adding to increased ecosystem and livelihood vulnerability. Few too many peri-urban areas are ecosystem rich and behave as buffers for protecting city and its core from eco-climatic risks such as floods, drought, pests etc (Gupta et al., 2017). Despite their aiding features, peri-urban areas are not assisted with safe livelihood and equal opportunities.

V. Conclusion

Since 1940, the Indian population has increased by a factor of 2.5; out of which majority of the people reside in the urban areas. This phenomenon triggers the emergence of new growth nodes namely peri-urban areas. They can emerge from numerous interconnected ways but urban sprawl and migration are the prime drivers. Peri-urban areas are the chaotic transitional zones with combined attributes of urban and rural establishments, triggering problems such as deficient quality of life and non-existent legal regime. These spaces act as interface, which is under constant pressure for advancement in urbanization with palpable destruction to ecosphere. Health upshots are influenced by the environmental factors. Hence, climate variableness and disasters enhance susceptibility to children, particularly underprivileged. It is important to regulate and monitor the ecological footprint from urban centers to the periphery that overrun water and land resources. In order to control the lousy transformations, multisectoral policy is required. Thus, the present paper concludes:

- The Peri-urban areas are poorly defined geographical areas which comprehend attributes of both urban as well as rural areas.

- Peri-urban areas of India depict the transformation in physical properties and surfacing of the issues pertaining to environmental degradation and public health. This is due the alarmingly inadequate attention from concerned agencies to monitor and regulate developmental changes.
- The development of peri-urban areas is often assessed in terms of economic benefit. This particular framing leads to unnoticed environmental factors which can result in inefficient policies and strategies.
- The distinction between rural areas, urban areas from peri-urban areas is not defined due to continuous growth. Hence the responsibility of acknowledging the peri-urban issues do not bestow on either jurisdiction. Inadequate knowledge and lack of integrated studies results in the failure to address appropriate problems.

VI. Future Perspective

The transformation of peri-urban areas into urban agglomerations is imperative. Metropolitan cities and other urban centers will further expand and invite supplementary workforce and investments. Thus, proliferations of peri-urban areas are bound to happen. Often, these peri-urban areas remain underprivileged and over exploited for their resources benefitting only the adjacent cities. Empirical studies on issues such as sanitation, access to basic amenities, poverty and education in peri-urban areas should be facilitated in order to conceive efficient policies safeguarding social, economic and environment development. Organizations require attaining deeper insights and management strategies to recognize the importance of peri-urban areas and their role in development of a country. Indian government, both central and states need to strengthen their laws and regulations to enable balanced urban growth and promote sustainable economy.

References

- Akhtar, F., Khan, S., Lohdi, S., Badar, M., Idrees, M., & Zia, M. (2020). Peri-Urbanization and Noise Exposure: A Strategic Study in Quetta, Pakistan. Medread Journal of Environmental Science, 1(1): 1001, 1-7.
- Allen, A., Silva, N., & Corubolo, E. (1999). Environmental problems and opportunities of the peri-urban interface and their impact upon the poor (pp. 1-37). London: Development Planning Unit, University College London.
- Anees, M.M., R. Shukla, M. Punia and P.K. Joshi (2019). Assessment and visualization of inherent vulnerability of urban population in India to natural disasters. Climate and Development 12(6): 532-546. doi: 10.1080/17565529.2019.1646629
- Birley, M., & Lock, K. (1999). Health-hazard Classification. The Health Impacts of Peri-urban Natural Resource Development (pp. 21-40). Great Britain by Cromwell Press, Trowbridge.

- Caruso, G. (2001). Peri-urbanisation : the situation in Europe - A bibliographical note and survey of studies in the Netherlands, Belgium, Great Britain, Germany, Italy and the Nordic countries (pp. 24-106). France.
- Census of India: Area and Population. (2001). Retrieved from https://censusindia.gov.in/ Census_And_you/area_and_population.aspx
- Da Gamma Torres, H. (2011).Environmental implications of peri-urban sprawl and the urbanization of secondary cities in Latin America. Inter-American Development Bank. Washington, DC.
- Decision Intelligence Document Degradation and Loss of Peri-Urban Ecosystems. (2013).[Ebook]. Retrieved from https://www.rockefellerfoundation.org/wp-content/uploads/Degredation-and-Loss-of-Peri-Urban-Systems.pdf
- Douglas, I. (2012). Peri-urban ecosystems and societies: Transitional zones and contrasting values. The peri-urban interface (pp. 41-52). Routledge.
- Drukker, M., Krabbendam, L., Driessen, G., & van Os, J. (2006).Social disadvantage and schizophrenia. Social Psychiatry and Psychiatric Epidemiology, 41 (8), 595-604.
- Dupont, V. (2015). Peri-urban dynamics: population, habitat and environment on the peripheries of large Indian metropolises a review of concepts and general issues (14th ed., pp. 3-21). Rajdhani Art Press.
- Goodfellow, T. (2013). Planning and development regulation amid rapid urban growth: Explaining divergent trajectories in Africa. Geoforum, 48, 83-93. doi: 10.1016/j.geoforum. 2013.04.007
- Gupta, A. K., Singh, S., Wajih, S. A., Mani, N., & Singh, A. K. (2017). Urban Resilience and Sustainability through Peri-Urban Ecosystems: Integrating Climate Change Adaptation and Disaster Risk Reduction. Gorakhpur Environmental Action Group, Gorakhpur (UP) India.
- Indian Institute for Human Settlement. (2017). Land Records Modernisation Urban and Peri-Urban Areas: Policy Brief. Retrieved from http://iihs.co.in/knowledge-gateway/wp-content/uploads/2017/11/6.-Urban-and-Peri-urban-Areas.pdf
- Joshi, P.K., B.M. Bairwa, R. Sharma and VSP Sinha (2011). Assessing urbanization patterns over India using temporal DMSP-OLS night-time satellite data. Current Science 100(10): 1479-1482.
- Kundu, A. (2009). Urbanisation and migration: An analysis of trends, patterns and policies in Asia. Human Development Report Office (HDRO), United Nations Development Programme (UNDP), Human Development Research Papers

- Laquinta, D.L., A.W. Drescher. (2010) Urban Agriculture: A Comparative Review of Allotment and Community Gardens. Urban Ecosystem Ecology, 199-226.
- Managing Peri-Urban Expansion: A Study of Planning Approaches adopted in Delhi, Beijing and New York to Manage Regional Growth. (2015). Retrieved from https://pearl.niua.org/sites/default/files/Managing_Peri_Urban_Expansion.pdf
- Nagdeve, D. (2006). Urban air pollution and its influence on human health in mega cities of India. Epidemiology, 17(6), S261-S262..
- Narain, V., & Nischal, S. (2007).The peri-urban interface in ShahpurKhurd and Karnera, India. Environment and Urbanization, 19 (1), 261-273.
- Narain, V., & Prakash, A. (Eds.). (2016). Water security in peri-urban South Asia: Adapting to climate change and urbanization (pp. 1-32). New Delhi: Oxford University Press.
- Narain, V., Anand, P. and Banerjee, P. 2013. 'Periurbanization in India: A review of the literature and evidence', Report for the project - Rural to Urban Transitions and the Peri-urban Interface. Saci Waters. India
- Narain, V., Banerjee, P., & Anand, P. (2014). The shadow of urbanization: the periurban interface of five Indian cities in transition.
- Pandey, B., P.K. Joshi and K C Seto (2013). Monitoring urbanization dynamics in India using DMSP/OLS night time lights and SPOT-VGT data. International Journal of Applied Earth Observation and Geoinformation 23:49-61.
- Pandey, B., & Seto, K. (2015). Urbanization and agricultural land loss in India: Comparing satellite estimates with census data. Journal of Environmental Management, 148, 53-66. doi: 10.1016/j.jenvman.2014.05.014
- Pandey, B., Zhang, Q., & Seto, K. (2018). Time series analysis of satellite data to characterize multiple land use transitions: a case study of urban growth and agricultural land loss in India. Journal of Land Use Science, 13(3), 221-237. doi: 10.1080/1747423x.2018.1533042
- Patel, S., Verma, P., & Shankar Singh, G. (2019). Agricultural growth and land use land cover change in peri-urban India. Environmental Monitoring and Assessment, 191 (9). doi: 10.1007/S10661-019-7736-1
- Prakash, A. (2010). The periurban water security problématique: A case study of Hyderabad in Southern India. Peri Urban Water Security Discussion Paper Series, 4.
- Prasad, P. Rama Chandra, K. S. Rajan, Vijaya Bhole and C.B.S. Dutt. (2009). Is Rapid Urbanization Leading To Loss Of Water Bodies? Journal of Spatial Science (March 2009) Vol II (2):43-52.

- Ramachandraiah, C and Prasad. (2004). Impact of Urban Growth on Water Bodies: The Case of Hyderabad. Working Paper No. 60. Centre for Economic and Social Studies, Hyderabad. India.
- Randhawa, P., & Marshall, F. (2014). Policy Transformations and Translations: Lessons for Sustainable Water Management in Peri-Urban Delhi, India. Environment and Planning C: Government and Policy, 32(1), 93-107. doi: 10.1068/c10204
- Ravetz, J., Fertner, C., & Nielsen, T. S. (2013). The dynamics of peri-urbanization. Peri-urban futures: Scenarios and models for land use change in Europe (pp. 13-44). Springer, Berlin, Heidelberg.
- Rawat, J., & Kumar, M. (2015). Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh Block, District Almora, Uttarakhand, India. The Egyptian Journal of Remote Sensing and Space Science, 18(1), 77-84. doi: 10.1016/j.ejrs.2015.02.002
- Saxena, M., & Sharma, S. (2015). Periurban Area: A Review of Problems and Resolutions. International Journal of Engineering Research and Technology, 04(09), 15-18. doi: 10.17577/ijertv4is090051
- Sharma, L., Pandey, P., & Nathawat, M. (2012).Assessment of land consumption rate with urban dynamics change using geospatial techniques. Journal of Land Use Science, 7(2), 135-148. doi: 10.1080/1747423x.2010.537790
- Shaw, A. (2005). Peri-Urban Interface of Indian Cities: Growth, Governance and Local Initiatives. Economic and Political Weekly, 40(2), 129-136.
- Simon, D. (2008). Urban Environments: Issues on the Peri-Urban Fringe. Annual Review of Environment and Resources, 33(1), 167-185.doi: 10.1146/annurev.environ. 33.021407.093240
- Tacoli, C. (2003). The links between urban and rural development. Environment and Urbanization, 15(1), 3-12. doi: 10.1177/095624780301500111
- Tiwari, Pallavi. (2019). Dynamics of Peri Urban areas of Indian Cities. International Journal of Scientific and Engineering Research. 10.131-141.
- Torres, Haroldo. (2008). Social and Environmental Aspects of Peri-Urban Growth in Latin American Megacities.
- UNESCAP (2015).Towards a sustainable, inclusive and resilient urban future for Asia and The Pacific. Retrieved from https://www.unescap.org/sites/default/files/E71_13E.pdf.
- United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019: Highlights (ST/ESA/SER.A/423).

- Webster, D., & Muller, L. (2009). Peri-urbanization: Zones of rural-urban transition. Human Settlement Development, 1,280-309.
- Wijaya, N. (2018, April). Disaster Risk Reduction and Climate Change Adaptation Integration into Peri-Urban Development Planning: A Case Study of Bandung Metropolitan Area, Indonesia. In IOP Conference Series: Earth and Environmental Science (Vol. 145, No. 1, p. 012079). IOP Publishing.
- Woltjer, J. (2014). A global review on peri-urban development and planning. Journal Perencanaan Wilayah dan Kota, 25(1), 1-16.
- World Resources Institute (WRI), 1996, World Resources. A Guide Publication to the Global Environment. The Urban Environment 1996-97, Oxford University Press, Oxford. Retrieved from http://documents.worldbank.org/curated/en/242141468739495153/pdf/multi-page.pdf.
- Zoomers, A. (2002) Rural Development Policy in Latin America: The Future of the Countryside. Social Scientist November 2012, 61-84.

Chapter-6
Scenario of Solid Waste Management - Case Study from Vadodara City

Deepa Gavali

Abstract

Solid waste management is a mammoth and challenging task faced by every city with ever-increasing population. To complicate the situation is non-availability of area for new landfill site. To avoid the overloading of the existing landfill site, it becomes essential to recycle or reduce the waste at source. Keeping this as the manifesto, and to understand the quantum of waste generated from various sectors in Vadodara city a series of studies was undertaken. Vadodara City has approximately 500 hotels, out of which only 115 are registered and survey indicate that 93% of the hotels are depended on the civic body for collection of waste. Survey for the biodegradable waste generated indicated that 740 kg/day of fish waste generated. Apart from this, there is daily consumption of eggs approximately 24,000 eggs in the winters as recorded through the street vendor survey in the city. In absence of any mechanism to use this biodegradable waste, all the vendors are depended on the civic bodies to collect the waste. The household survey concluded that out of 754 tonnes of domestic waste generated per day, only 440 tonnes of waste is collected and rest is disposed in the open ground or the ravine areas. Additionally, there is generation of approximately 100 tonnes of concrete waste every day. Due to lack of mechanism to reuse the concrete waste the same is being dumped into the ravines and wetland areas rendering the city prone to severe flooding. The paper deals with simple solutions that need to be addressed through people participation and generation of revenue from the waste.

Keywords: Vadodara city, Hotel waste, Food waste, Floods

[12]Deepa Gavali (✉)
Director (Acting) and Secretary,
Gujarat Ecology Society,
deepagavali@yahoo.com

I. Vadodara city

Vadodara City is situated on the banks of the river Vishwamitri. River divides the city geographically into two regions- eastern and western. The city is spread over an area of 168 sq.km with a population of 21.8 Lakhs (as on 2019) residing within the city (https://vmc.gov.in/). The climate of the city comprises of three main seasons: Summer, Monsoon and winter. The summer is hot and dry with temperatures hovering above 40°C in the month of May. During monsoon it's humid and there are sporadic heavy torrential rains. The annual rainfall is about 950 mm with three months of rainy days. There are incidences of heavy rainfall in the city causing floods and the major floods have occurred in 2005, 2014 and 2019. The 2019 flood was the worst, when larger partof the city was affected resulting in economic damages. Winter is chilly due to the northerly winds.

The Union Ministry of Housing and Urban Affairs in the initiative to improve the city had launched the India Smart Cities Award on 25 June, 2017 with an objective to reward cities, projects and innovative ideas. Vadodara city was one of the 100 India Smart Cities identified. For the purpose of efficient administration, Vadodara city is divided into 12 wards.

II. Municipal Waste generated / day

The waste generated in the city is approximately 1,433 Tonnes per day (TDP) and the various type of waste generated is indicated in the table below. The household waste is the largest contributor of the city waste (754 TDP). The household waste comprises of 70% of kitchen waste, 20% plastic waste and others include largely the paper waste and renovation material waste (Muley 2018).

Table 7: Quantum of waste generated in Vadodara city for the year 2018

Sr. no.	*Waste Type*	*Waste Generated (TDP)*
01	Residential waste	754
02	Commercial waste	215
03	Institutional waste	110
04	Hotel and Resorts	125
05	Yard waste	14
06	Street Sweeping	215
Total		1433~1450
Average waste quantity generation		0.67 kg/capita/day

(Source - Ahluwalia and Patel, 2018)

Hotel and resorts waste amounts to 125 TDP and study was carried out on the category of waste generated in hotels (Bhatt 2019). The study revealed that plastics is the major contributor (44%) followed by paper (24%), food (20%) and packaging and green waste (6%). Other waste includes 3% glass waste, 1% includes cardboard and aluminium and milk-bag waste (Bhatt and Gavali, 2020).

Modus operands of the waste collection include door-to-door collection by the municipal corporation and finally dumping into the landfill site.

III. Issues with solid waste dumping

For Vadodara city, out of the total waste generated only 316.2 TDP is treated and the remaining 1133.8 TDP is diverted to landfill site. The treatment plant includes two biomethanation plants with a capacity of 300 TDP near Jambuva landfill site and another 15 TDP at Vohra Gamdi. Apart from this, there is organic waste converter to the capacity of 1 TDP and mulching drums able to convert 0.2 TPD into organic waste. Thus, a total of 316.2 TDP is being recycled and rest of the untreated waste is diverted to landfill site.

Waste contains organic material, such as food, paper, wood, and garden trimmings (Mewada et al., 2020). Once waste is deposited in a landfill, microbes begin to consume the carbon in organic material, which causes decomposition. Under the anaerobic conditions prevalent in landfills, the microbial communities contain methane-producing bacteria (Feng et al., 2019). As the microbes gradually decompose organic matter over time, methane (approximately 50%), carbon dioxide (approximately 50%), and other trace amounts of gaseous compounds (<1%) are generated and form landfill gas. Vadodara city has witnessed fire in the landfill site in 2018 and officials have stated the release of methane from the dumpsite as the major cause of the incidence (TOI, 2018). Landfills produce and release methane gas (CH_4) which is a contributor for causing greenhouse effect and play an important role for global warming and increasing the carbon footprint (Deepam Das et al., 2016).

The unscientific way of dumping MSW in landfills may lead to hazards like soil pollution, ground water contamination and air pollution due to emission of green house gases. Vadodara city has also witnessed two fire incidences at the landfill site in 2018 within a span of 15 days. The entire surrounding area was under the cloud of thick smoke and it took two days for the municipal authorities to contain the fire. Residents in the area complain of noxious smell and even after fire were under control, smoke kept coming out of the site for the next 2-3 days. Though no major casualty was reported, however there is always a danger looming around the land-fill site. With, the city expanding the operational landfill site has come close to the residential area posing threat to health and environment. It is rightly pointed that issue linked is the overloading of landfill sites, and

non-availability of space for creation of new landfill site for the urban centres (Muley, 2018). The cities need to manage the waste and recycle in a better mechanism to reduce the load of solid waste in the dumping sites.

Approximately 1133.8 TDP is supposed to be diverted to the landfill site, however not all waste collected reached the landfill site. The more convenient method adopted is diversion of concrete waste which is about 42.85 MT/day into the nearby water bodies and ravine areas of River Vishwamitri. Due to this practice Vadodara city has lost about 40 Ha of area under wetland from 2005 to 2020 (Gavali & Lakhmapurkar 2020). The ward wise loss in wetlands is depicted in the fig below. This loss of wetlands has led to deterioration of ground water quality through absence of proper recharge potential. This loss of wetlands has also resulted in waterlogging issue especially in the ward no 9 every year during heavy rains. The geological condition of this ward does not permit percolation of excess water and only surface water storage is the best option. But, this traditional waterbodies were reclaimed for creation of more building place resulting in poor urban planning and economic loss faced by the locals residing every year.

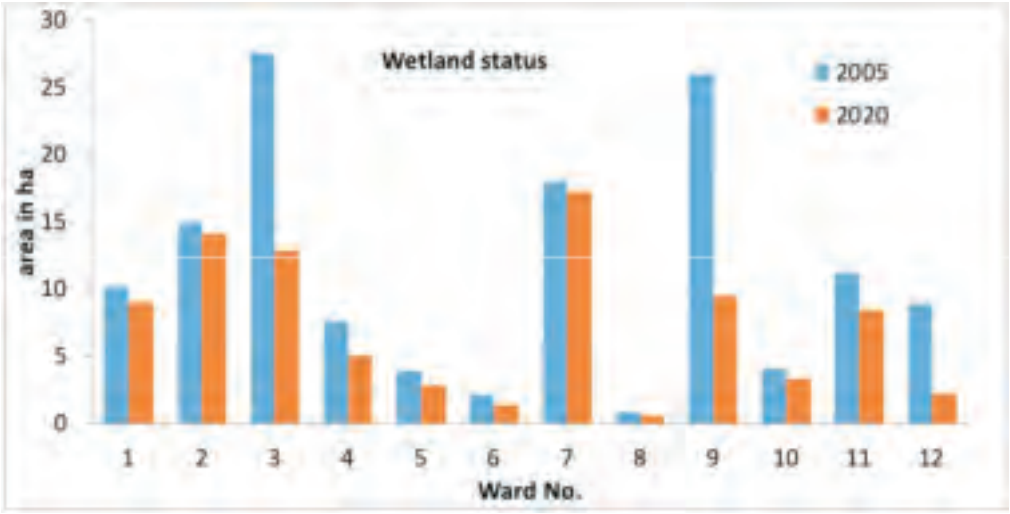


Figure 23: Loss of wetlands in the Vadodara city from 2005 to 2020 is different administrative wards of the city;
(Source: Gavali & Lakhmapurkar 2020)

The river Vishwamitri is a meandering river and its stretch within the city limits is 17 Km (Magdum et al., 2017). Survey of the ravine areas have indicated dumping of waste in the flood plains as shown in the google earth images below. The dumping is shown in small section of the river and similar dumping is reported in other stretches as well. Due to

dumping, the capacity of the river to carry floodwaters gets reduced. As a result, during heavy rains and cloudburst events, the water remains in the city and society for longer time. The residence time of floodwaters in societies close to river ranged from minimum of 3 days and extended to 5 days in 2019. The city has no mechanism for recycling of concrete waste and which stabilises the riverbank over the years and result in catastrophic flood events.

Figure 24

Figure 25

Figure 24, 25: Google maps showing the solid waste dumping and associated flood areas; (Source: Gujarat Ecology Society)

Notes: The yellow coordinates show dumping of solid waste in the ravine area and the red indicate the area affected by 2019 floods

In India, only 70-75% of the MSW gets collected and out of this only 20-25% of it is treated (Singh et al., 2018). Improper waste management is a public health and environmental crisis, economic loss, operational inefficiency and political and public awareness failure. Integrated solid waste management can be a nation building exercise for healthier and wealthier communities.

IV. Solid Waste Management practices suggested

Waste management is a major global concern today as it adversely impacts the environment. UNEP is already undertaking various programmes and projects to assist its member countries to achieve improved waste management systems. These programmes and projects include Integrated Solid Waste Management (ISWM) based on the 3R (reduce, recycle, and reuse) approach. Based on the studies carried out on the Solid waste generation in Vadodara city and few practices are described that could be implemented by different stakeholders.

Household waste: The citizens should be encouraged to segregate the waste and adopt compositing of wet waste like vegetable peels and kitchen waste. Case study in Beijing MSW management showed that recycling of kitchen waste and recyclables an emission reduction of 70.82% could be achieved (Xin et al., 2020). This can reduce the burden on the landfill site considerably.

Hotel industry: The hotel industry is one of the major contributors of organic or wet waste in landfills, which is the main cause of emission. The hotel industry is growing at a fast pace in India, and its pace will accelerate in the future (Singh et al., 2014). The study in the hotel sector in Vadodara showed that only 30% of the hotels segregated the waste and 90% of the hotels relied on the municipal corporation for collection of waste. As a result all the waste collected was diverted to landfill site. Further, no extra charges are paid for disposal of waste into the landfill sites. Segregation of waste should be compulsory in commercial sector especially hotel industry. Around 30% of a hotel's solid waste can be sorted, reused, recycled and recoverable in nature (Bhatt and Gavali, 2020).

- Arrangements should be made to collect the segregated recyclable and compostable waste from the hotels for proper disposal and not being dumped into landfills.
- The recyclable waste will generate substantial amount of financial returns to the hotel, while the manure developed from the compostable material can be used for internal consumption in horticulture and gardening, thus saving cost on expensive fertilizers.
- Eliminate the use of single use plastic items in hotels.
- Stimulate partnerships for circular economy models and support recyclers

Food waste creates GHG when it is discarded, unless it is composted or fed to animals. Survey was undertaken for the quantum of waste generated by the street vendors selling egg items. The quantum of egg shell waste generated in the city is to the tune of 80.255 kg/day, dumped into landfill site (Sharma, 2019).

Eggshells are one of the widely used food processing and manufacturing plants by-products (Faridi and Arabhosseini 2018).Egg shells are reused as a source of raw material for other industries like:

(i) bone substitute, as the starting material to prepare calcium phosphate bio ceramics (e.g. HAp)

(ii) as an absorbent of heavy metals from wastewater as it is a serious environmental problem in the ecosystem

(iii) as a fertilizer and calcium supplement in nutrition for human, animals, plants, etc

About 95% of the vendors were willing to consider this option of turning egg waste into useable form as one of good option. 90% of the respondents felt that recycling will reduce the unhygienic condition as sometimes the collection van comes late to collect the waste. Small-scale entrepreneurs should be involved into this to start the business of eggshell collection and conversion into useful products. This will also generate job opportunities and involvement of underprivileged people can be done. This will to generate revenue and also reduce the burden of landfills.

Study on fish waste revealed that 0.774 TDP of fish waste is generated in Vadodara city and these numbers tend to increase on holidays and weekends (Verghese, 2019). As per the data 85.9% of the fish Vendors used plastic bags for immediate storage of fish waste and thus the waste is disposed along with the plastic and that ends up together in the landfills causing more problems to the landfill's health. Majority of the vendors (73.2%) had their waste collected by the municipal corporation and eventually dumped into the landfill site. Fish waste can be solar dried and converted into manure, which has the potential of retaining soil moisture and improve the soil fertility. Thus, an alternative source of income can be generated and solve the issue of livelihood of small fishermen who sustains on sale of fish daily.

There is need to link research success in the lab and opportunity to create entrepreneurs in the world of solid waste management. One such story is of research team which concluded that extraction of UV-absorbing proteins from prawn shells can have potential applications as permissible eco-friendly sunscreen filters in polymer coatings, cosmetics, textiles, food, pharmaceuticals and biodegradable packaging products (Komalakrushna et al., 2020).

Training and financial assistance to small entrepreneurs willing to recycle most of the wet and kitchen waste. This could be very useful option especially when the country is fighting for pandemic COVID. Not only the quantum of waste reaching the landfill site be reduced but also an alternate source of livelihood will be developed.

V. Conclusion

India has the Municipal Solid Waste (Management and Handling) Rules, 2000 where it is mentioned that recycling of construction and demolition waste is essential. Every urban centre should identify the site for recycling of these wastes. However, Vadodara city is yet to demarcate a site and set protocol for management of the demolition waste. The 2019 floods is clear indication of absence of proper SWM in the city. It is rightly said, no environmental policy will be successful unless staff understand the need for change and are committed to making it happen. Taking a longer-term perspective, in the context of sustainable development, increases the likelihood that more immediate adaptation actions will also enhance future options and preparedness. Many adaptation and

mitigation options can help address climate change, but no single option is sufficient by itself. Effective implementation depends on policies and cooperation at all scales, and can be enhanced through integrated responses that link adaptation and mitigation with other societal objectives.

References

- Ahluwalia I J and U Patel (2018). Solid waste Management in India: An assessment of resource recovery and environmental impact. Indian council for research on International Economic relations. Working Paper No. 356 48 pp.
- Arvanitoyannis Ioannis S. and Aikaterini Kassaveti (2008). Fish industry waste: treatments, environmental impacts, current and potential uses. International Journal of Food science and technology. 43: 726-745
- Bhatt N and Deepa Gavali (2020). New emerging issue - solid waste from hotel industry in Vadodara city. In proceedings of National Symposium on Climate change, pollution and harmony with nature, on 25th January 2020, Vadodara, India.
- Deepam Das, Bijay Kumar Majhi, Souyajit Pal and Tushar Jash (2016). Estimation of land-fill gas generation from municipal solid waste in Indian Cities. Energy Procedia, 90:50-56.
- Faridi H. and Arabhosseini (2018). Application of Eggshell Wastes as Valuable and Utilizable Products: A review, Res. Arg. Eng.,64 (2), 2-12.
- Feng Shoushuai, Shaoxiang Hou, Xing Huang, Zheng Fang, Yanjun Tong, and Hailin Yang (2019).Insights into the microbial community structure of anaerobic digestion of municipal solid waste landfill leachate for methane production by adaptive thermophilic granular sludge. Journal of Biotechnology, 39: 98-106
- Gavali Deepa and Jayendra Lakhmapurkar (2020). Wetlands of Vadodara and Their Role in Water Resource Management. Paper presented in National Seminar on "Jal-aaj-aur kal" organised by SOCLEEN on 8th February in Vadodara.
- Komalakrushna Hadagalli, Rahul Kumar, Saumen Mandal and Bikramjit Basu (2020). Structural, compositional and spectral investigation of prawn exoskeleton nano composite: UV protection from mycosporine-like amino acids, Materials Chemistry and Physics,249. https://doi.org/10.1016/j.matchemphys.2020.123002
- Lee, S. (2007). "Hey Kermit, Being Green is Getting Easier (Part I)." Hotel News Resource. September 9. Available at.
- Magdum Akshata, Tejas Patel, Deepa Gavali (2017) Assessment of Physicochemical parameters and Water Quality Index of Vishwamitri River, Gujarat, India. International Journal of Environment, Agriculture and Biotechnology (IJEAB), 2

- Mewada M, S Albert and A Padhiar (2020). Municipal Solid Waste Management System in Vadodara City: Current Scenario. Journal of Environmental Science and Toxicology. 14 (2): 45-50.
- Muley Roshan (2018). Current Status of Municipal Solid Waste Management In Vadodara City. Dissertation thesis submitted In partial fulfilment of the requirements of the degree of Bachelor of Science in Environmental Science. M S University of Baroda, Vadodara. 81 pp.
- Sharma Shrusti N (2019). An Overview of Eggs and Coconut Based Waste Generated in Vadodara and Designing effective SWM Plan. Dissertation thesis submitted In partial fulfillment of the requirements of the degree of Bachelor of Science in Environmental Science. M S University of Baroda, Vadodara. 54 pp
- Singh C K, Anand Kumar and Soumendu S Roy (2018). Quantitative analysis of the methane gas emissions from municipal; solid waste in India. Scientific reports. 8: 2913: 1-8.
- TOI (2018). Vadodara Municipal Corporation to use chemical treatment in tackling fire. Times of India. Ahmedabad Edition. March 27, 2018.
- Verghese Sharon T (2019). Quantum of Fish Waste Generated Across Vadodara City and Chalking Out an Effective SWM Plan for the Same. Dissertation thesis submitted In partial fulfilment of the requirements of the degree of Bachelor of Science in Environmental Science. M S University of Baroda, Vadodara. 66 pp
- Xin Chunlin, Tingting Zhang, Sang-Bing Tsau, Yu-Ming Zhai and Jiantao Wang (2020). An empirical study on greenhouse gas emission calculations under different Municipal Solid waste management strategies. Applied Sciences. 10:673; doi 10.3390/app 100051673.

B
Resilient Agriculture

Chapter-7
Plant Growth Promoting rhizobacteria Pseudomonas putida RA for Climate Resilience and Agricultural Sustainability

Shalini Tiwari[1*], Ram Jatan[1*], Puneet Singh Chauhan[^1] and Charu Lata[2†] (✉)

Abstract

Pseudomonas genus is among the commonest studied plant growth promoting rhizobacteria (PGPR) that promote plant growth and development during various environmental stresses. Pseudomonas putida RA, a drought tolerant PGPR exhibits various plant growth promoting (PGP)-attributes. Considering its phyto-beneficial and drought stress endurance traits, it has been suggested as an excellent PGPR for crops. Chickpea (Cicer arietinum L.), a widely consumed leguminous crop, is adversely affected by drought stress leading to 40-50% reduction in its production. A comparative analysis of the effects of RA-inoculation on various morphological, physiological and biochemical parameters in two contrasting chickpea cultivars of 'desi' and 'kabuli' types during drought stress and subsequent recovery conditions suggested utility of RA in drought stress amelioration. Further, expression profiling of small RNAs identified from genome-wide profiling of tolerant chickpea cultivar in the presence or absence of RA indicated crucial role of RA in regulation of miRNAs and their targets expression under drought stress and paves the way for further functional characterization and utilization of selected candidate miRNAs in climate adaptation and agricultural sustainability development programmes.

Keywords: Agricultural sustainability, Climate resilience, miRNAs, Gene expression, PGPR.

Shalini Tiwari[1*], Ram Jatan[1*], Puneet Singh Chauhan[^1] and Charu Lata[2†] (✉)
[1]CSIR-National Botanical Research Institute, Rana Pratap Marg, Lucknow-226001
[2]CSIR-National Institute of Science Communication and Information Resources, 14 Satsang Vihar Marg, New Delhi-110067
[*]Authors contributed equally as first author
[†]Corresponding author
Email (✉): charulata@niscair.res.in; charulata14@gmail.com

I. Introduction

Chickpea (Cicer arietinum L.) is one of the most essential food legumes, and is also known as an adequate dietary protein source for human consumption worldwide (Tiwari et al., 2016). Although chickpea is cultivated in an area of 13.98 million ha across the globe, its total production is lesser than one ton per ha (Varshney et al., 2017; FAOSTAT, 2016). The cultivated chickpea has been mainly divided into two distinct genotypes, (i) desi: small seed, dark colour and reticulate seed coat, and (ii) kabuli: large seed, beige colour seed coat (Tiwari et al., 2016). Even with its economic significance, chickpea production has not reported any increment in yield or area (Varshney et al., 2017). Climate change has posed a significant threat to the sustainability and productivity of chickpeas. Drought, extreme temperatures (high and low), and inadequate moisture are important factors that influence crop yields in many parts of the world, and are likely to worsen as a result of climate change. Global climate change together with the rapidly increasing population is exerting tremendous pressure on agriculture sector to produce more food from less land. Therefore, climate change mitigation is one of the greatest challenges of 21st century and hence, obtaining a key to obtain potential yields of crop plants under abiotic stresses has always been a major goal of crop researchers. Drought is among the major abiotic stresses that restrict chickpea production by imposing 40-50% decline in its yield (Ahmad et al., 2005). Plants exhibits modulation in morpho-physiological and biochemical traits against drought stress that include leaf wilting, photosynthetic pigments, root elongation, and reactive oxygen species (ROS) generation (Lata et al., 2011a). Apart from membrane damage in plants, ROS impairs the normal cellular functions by causing oxidative damage via reacting with cellular biomolecules including membrane components and deoxyribonucleic acid (DNA). Drought stress response also revealed that it affects several genes and gene products at different molecular levels (Tiwari et al., 2017a; Lata et al., 2015). Overall, alterations in these factors lead to impairment in growth and development of plants resulting in yield loss in crops. Hence, the need of the hour is to develop improved crop varieties i.e. climate resilient chickpea cultivars or to choose alternate technology for sustainable crop production. Apart from various labour, cost and time intensive modern crop improvement techniques, application of PGPR as an alternate technology for mitigating plant stress, now holds great significance in the perspective of climate change and the use of excessive fertilizer in cultivated fields (Chauhan et al., 2019; Tiwari et al., 2016). Lately, several studies have reported the use of PGPR as potential tool for various abiotic stresses mitigation (Nautiyal et al., 2013; Tiwari et al., 2017 b). Among various beneficial microbes, Pseudomonas sp. are considered as one of the important member of rhizobacteria family that reported as potential elicitor for abiotic stresses (Tiwari et al., 2016). Likewise, a Pseudomonas putida strain MTCC5279 (RA), possess several phyto-beneficial traits including IAA production, phosphate solubilisation

and reported to impart abiotic stress tolerance (Jatan et al., 2019; Tiwari et al., 2016; Srivastava et al., 2012). Considering its remarkable PGP-attributes and stress tolerance properties, we aimed to perform a comparative study between two contrasting chickpea types, 'desi' (drought-tolerant) and 'kabuli' (drought-sensitive) in order to inspect the effect of RA-treatment on various morpho-physiological and biochemical parameters under drought stress. Further, expression analysis of selected small RNAs identified from genome-wide profiling of tolerant chickpea cultivar roots under drought stress was carried out.

II. Materials and methods

II.1 Plant material, growth conditions, and drought stress

Two contrasting chickpea cultivar viz., BG-362 (desi; drought-tolerant) and P-1003 (kabuli; drought-sensitive) were examined to study the effects of P. putida RA-inoculation under drought in the growth chamber of CSIR-NBRI, Lucknow under standard conditions. Surfaced sterilized chickpea seeds were sown in pots containing autoclaved soil. After one week of germination, half of the seedlings were inoculated with 1% bacterial suspension (~107 CFU mL-1), while the other half remain uninoculated. Further, well-watered one month old plants were subjected to drought for 0, 3, and 12 days by withholding water and then rewatered for 3 days for recovery of plants. In the harvested tissues, all morpho-physiological and biochemical activity were recorded on the same day of harvesting and for qRT-PCR analyses tissues were kept in liquid nitrogen and stored at-80°C until further use.

II.2 Analysis of physiological and biochemical parameters

Electrolyte leakage (EL) was determined in root tissues, respectively in all four treatments viz. 0, 3, 12 days and recovery as mentioned in Lata et al., (2011b). Proline content was determined as protocol of Carillo and Gibbon, (2011). Chlorophyll and carotenoid content was quantified according to modified method of Wellburn, (1994). For anti-oxidative enzymes assay, superoxide dismutase (SOD) activity was evaluated by Beauchamp and Fridovich, (1971) method. The absorbance was recorded in a microplate reader (Spectrum max plus; Molecular devices, US). All experimental data were the averages of three independent biological replicates with standard deviation (average $\pm$ SD). Duncan multiple range test (DMRT) at $P<0.05$ was carried out via SPSS v. 16.0 (Chicago, USA), and the graphs were plot in Microsoft Excel, 2016 to illustrate the results.

II.3 Expression profiling of miRNAs

In order to identify and analyse the expression profile of miRNAs, RNA-seq data was used from our previous study (Jatan et al., 2019). The miRNA read counts of the treated

libraries and the control library were used to determine the log2 fold change. MiRNAs with log2 fold change ±1.0 and p-value < 0.05 were considered to have significant differential expressions.

qRT-PCR data of Jatan et al., (2019) was used for deducing the correlation between the expression levels of selected conserved and novel miRNAs and the relative expression of respective target genes of all the six selected miRNAs. The heat map for miRNAs and target genes expression profile in all the samples was generated using TIGR Multi Experiment Viewer (MeV4) software package (Saeed et al., 2003). Primers sequences for miRNAs and their target genes are listed in Tables below.

Table 8: List of stem-loop quantitative real time PCR primer

miRNA ID	Stem-loop primer	Forward Primer	Source
mir156a-5p	GTCGTATCCAGTGCAGGGTCCGAGGTATTCGCA CTGGATACGACGTGCTC	CGGCATGACAGAAGAGAGT	Jatan et al., 2019
mir159b-3p	GTCGTATCCAGTGCAGGGTCCGAGGTATTCGCA CTGGATACGACAGCTCC	GCGAGTGTTTGGATTGAAG	-do-
miR160a-5p	GTCGTATCCAGTGCAGGGTCCGAGGTATTCGCA CTGGATACGACATGCCA	TATCTATGCCTGGCTCCC	-do-
mir166a	GTCGTATCCAGTGCAGGGTCCGAGGTATTCGCA CTGGATACGACGAATGA	GTAATACTTCGGACCAGGCT	-do-
mir8175	GTCGTATCCAGTGCAGGGTCCGAGGTATTCGCA CTGGATACGACTGGCGC	ATTTAATCCCCGGCAACT	-do-
Nov_miR71a	GTCGTATCCAGTGCAGGGTCCGAGGTATTCGCA CTGGATACGACAGGCGG	TATGTTGGGTCGATCGGT	-do-
OsU6	GTCGTATCCAGTGCAGGGTCCGAGGTATTCGCA CTGGATACGACACCATT	GGGGACATCCGATAAAATTGG	-do-
Universal reverse primer	CCAGTGCAGGGTCCGAGGTA		-do-

Table 9: List of target gene primers used in qRT-PCR analysis (Source: Jatan et al., 2019)

Gene(s)	Accession no.*	Forward and Reverse Primer Sequences	Amplicon Length
GAMYB	XM_004516467.2	F-5' CGGTTGTTCTTCACCACATA 3' R-5' GGAGTTGCAGTAGATGAATGT 3'	120
ARF18	XM_004497453.2	F-5' CAAAGATAACCGGCGAGAAA 3' R-5' TCATAAGATCCGAGCGAAGA 3'	114
ATHB-15	XM_004486719.2	F-5' ATCTCGCATCGGAAACTATG 3' R-5' GTGAAACTCCGTCCAACTTA 3'	101
ERF7	XM_004513832.2	F-5' TGAAGCCGGAGATCCATTT 3' R-5' TGATGTTGGTCTCCGATGAT 3'	88

Gene(s)	Accession no.*	Forward and Reverse Primer Sequences	Amplicon Length
PK	XM_004502959.2	F-5' CACCAACACCAAGCTATGTA 3' R-5' GAAGTGCATGAGATGATGAGA 3'	106
MAPKKK	XM_004504680.2	F-5' CCTGTGTCTCTTGTTGTTGA 3' R-5' CTGAAAGAACCCGAATCAGT 3'	110
GAPDH	AJ010224	F- 5' CCAAGGTCAAGATCGGAATCA 3' R-5' CAAAGCCACTCTAGCAACCAAA 3'	65

*GenBank accession / Reference no.

III. Results and Discussion

III.1 Effects of RA-inoculation on morphology of chickpea cultivars

To determine the response of RA-inoculation on morphology of both chickpea cultivars, plants were regularly examined at 0, 3 and 12 days of drought stress and 3 days of recovery in both inoculated and uninoculated plants. Root, shoot length and biomass were recorded on above mentioned stress duration and recovery. Results showed that both root and shoot length increased with progression of drought stress in both cultivars in the presence and absence of RA (Table 10). RA-treated BG-362 and P-1003 respectively, showed 18% and 24% more growth in root length than their individual uninoculated plants at 12th day of stress, whereas no significant difference was recorded in root length after recovery of stressed plants of both the cultivars. Earlier studies reported that the higher root length, and root density under drought stress increases root surface area for better water and nutrient absorption (Tiwari et al.,.,.,.,.,. 2016; Miyahara et al.,.,.,.,.,. 2011). Remarkable enhancement in root length upon RA-inoculation during stress might be due to the auxin produced by RA as this phytohormone is known to promote root growth (Srivastava et al.,.,.,.,.,. 2012; Overvoord et al.,.,.,.,.,. 2010). Interestingly, in the case of shoot length generally no significant difference was observed in both the cultivars but in P-1003 plants RA-inoculated plants showed significant increase by~12% than uninoculated plants at the 12th day of stress. (Table 10). Claeys and Inzé (2013), reported that in water limiting conditions, plant restrict their shoot growth and promote root growth for better stress avoidance. Since 12 days of drought stress manifests severe stress condition for sensitive cultivar, RA-inoculation showed remarkable difference in shoot growth of the sensitive cultivar as compared to the tolerant cultivar which is also confirmed in a previous study (Enebe and Babalola, 2018).

Table 10: Effects of drought stress on growth parameters of both cultivars in the presence or absence of RA. Data represent the average ± SD from three biological replicates. Different letters in the same column indicate significant differences according to Duncan's test (P≤0.05).

ROOT LENGTH (cm)				
TREATMENTS	Day-0	Day-3	Day-12	Recovery
BG-362 CONTROL	12.9±1.92 a	14±2089 ab	18.7±2.74 abcd	18.5±2.77 abcd
BG-362 RA	13±1.19 a	13.4±2.27 a	22.9±4.68 def	19.7±0.81 bcd
P-1003 CONTROL	15.7±2.38 abc	21±2.32 cde	21.2±0.30 cde	13.4±0.82 a
P-1003 RA	18.6±5.34 abcd	24±4.34 def	28.1±2.48 f	26.2±3.02 ef
SHOOT LENGTH (cm)				
TREATMENTS	Day-0	Day-3	Day-12	Recovery
BG-362 CONTROL	19.2±0.06 a	21.7±0.58 ab	23±1.95 bc	25.5±2.1 cd
BG-362 RA	21.8±1.11 ab	23.7±1.97 bc	25.6±1.43 cd	25.3±1.65 cd
P-1003 CONTROL	21.9±2.05 ab	23.2±0.94 bc	24.25±1.73 bc	25.9±0.99 cde
P-1003 RA	22.2±0.77 b	23.3±0.36 bc	27.4±0.58 de	28.5±0.83 e
BIOMASS (gm)				
TREATMENTS	Day-0	Day-3	Day-12	Recovery
BG-362 CONTROL	0.214±0.05 a	0.263±0.04 ab	0.268±0.03 ab	0.330±0.09 abcd
BG-362 RA	0.265±0.03 ab	0.291±0.06 abc	0.349±0.05 bcd	0.439±0.07 def
P-1003 CONTROL	0.316±0.04 abc	0.263±0.05 ab	0.391±0.03 cde	0.471±0.06 ef
P-1003 RA	0.3444±0.02 bcd	0.320±0.06 abc	0.402±0.06 cde	0.541±0.08 f

In another study on plant biomass, no significant change was observed among plant biomass and slight increment was observed at 12th day of stress than unstressed plants. But on comparing the inoculated and uninoculated plants, cv. BG-362 inoculated with RA showed significant increase in biomass by ~10% and ~23% at 3rd day and 12th day of stress while in P-1003 increment was~18% at 3rd day of stress (Table above). At 12th day of drought stress, non-significant difference was found in P-1003 cultivars. Remarkably, both cultivars on recovery showed significant increase in plant biomass and improvement was observed better in RA-inoculated plants than uninoculated. In recovered plants, increment was ~25% and ~13% in RA-inoculated than their respective uninoculated plants in BG-362 and P-1003, respectively. It was also evident from previous studies that PGPR-application improves stress tolerance by less reduction in the biomass under stress (Tiwari et al., 2016; Majeed et al., 2015).

III.2 Effects of RA-inoculation on physio-biochemical parameters in chickpea cultivars

To evaluate the electrolyte leakage during drought stress in both cultivars under inoculated and uninoculated conditions, root EL was calculated. Progression in stress durations led to significant increase in EL in both cultivars under both inoculated and uninoculated plants during drought stress (Fig. 26A). After 3 days of drought stress, both the cultivars showed significant increase in electrolyte leakage up to 30-40% under both inoculated and uninoculated conditions, however the same was comparatively less in BG-362. While after 12 days of stress, no significant difference was observed between RA-inoculated and uninoculated cv. BG-362 plants, but compared to control plants~50% increment was recorded. In contrast, in cv. P-1003 significant rise by ~96% was observed in uninoculated plants, however in RA-inoculated plant this increment was only up to ~51% under drought stress. Previous studies also supported the reduction in EL upon PGPR-inoculation as compared to unioculated plants under stress (Tiwari et al., 2016; Tiwari et al., 2017b; Chauhan et al., 2019). Interestingly, after recovery plants showed decreased level of electrolyte leakage in both the cultivars (Fig. 26A). To study the level of photosynthetic pigment, chlorophyll and carotenoid content were determined under stress condition in all the treatments. At unstressed condition, the chlorophyll content was approximately equal in all the treatments of both cultivars while after stress, the deterioration in chlorophyll content was observed (Fig. 26B). At 3rd day of stress, no significant difference was observed in RA-inoculated BG-362 while in P-1003 significant increase was found. Chauhan et al., (2019), also reported the increment in chlorophyll content upon PGPR-treatment under stress. After 12 days of drought stress 60-70% decrement was observed in chlorophyll content in both the cultivars and no significant difference was recorded between RA-treated and untreated plants (Fig. 26B). It might be due to the severe stress felt by cv. P-1003 plants in confirmation to Heidari et al., (2014) wherein comparative study on tolerant and sensitive plants species revealed that at initial stage of stress chlorophyll content increases but at severe condition its content decreases due to increase in oxidative damages. The carotenoid content was increased under stress condition, and at 12th day of stress the content was increased by~38% and ~45% in cv. BG-362 and by ~44% and ~36% in cv. P-1003 in uninoculated and RA-inoculated plants respectively (Fig. 26C). Figure clearly illustrated that carotenoid content was significantly higher in cv. BG-362 than cv. P-1003 by ~18% and ~23% in uninoculated and RA-inoculated plants respectively (Fig. 26C). However, rewatering significantly lowered the carotenoid content in both the cultivars. Increased carotenoid content in cv. BG-362 than cv. P-1003 showed its better stress endurance and tolerance capacity than sensitive

plants. Furthermore, proline accumulation was determined in the leaves of both cultivars and found that with the progression of drought proline content significantly enhanced and after recovery its level decreased to approximately normal levels (Fig. 27A). Though, RA-inoculation led to a considerable decrease in proline content relative to uninoculated plants at all stress conditions. At 12th day of drought stress, a reduction of ~45% and ~20% in proline content was recorded in RA-treated BG-362 and P-1003 cultivars respectively in comparison to their respective uninoculated stressed plants (Fig. 27A). Similar observation was also reported previously by Chauhan et al., (2019) in rice and by Tiwari et al., (2016) in chickpea. SOD, an anti-oxidative enzyme transforms hazardous radical superoxide (O_2–) into non-hazardous and less destructive molecules such as oxygen (O_2) or hydrogen peroxide (H_2O_2). Likewise, present study revealed a considerable enhancement in SOD activity with the drought stress progression and restored to normal levels under recovery in both cultivars. Under stress conditions, comparatively cv. BG-362 has higher SOD activity than cv. P-1003 suggesting its better ROS scavenging activity than sensitive cultivar (Fig. 27B). Compared to uninoculated seedlings, RA-inoculated cv. BG-362 showed ~7% less SOD activity while in cv. P-1003 SOD activity was increased by ~13% after 12 days of drought

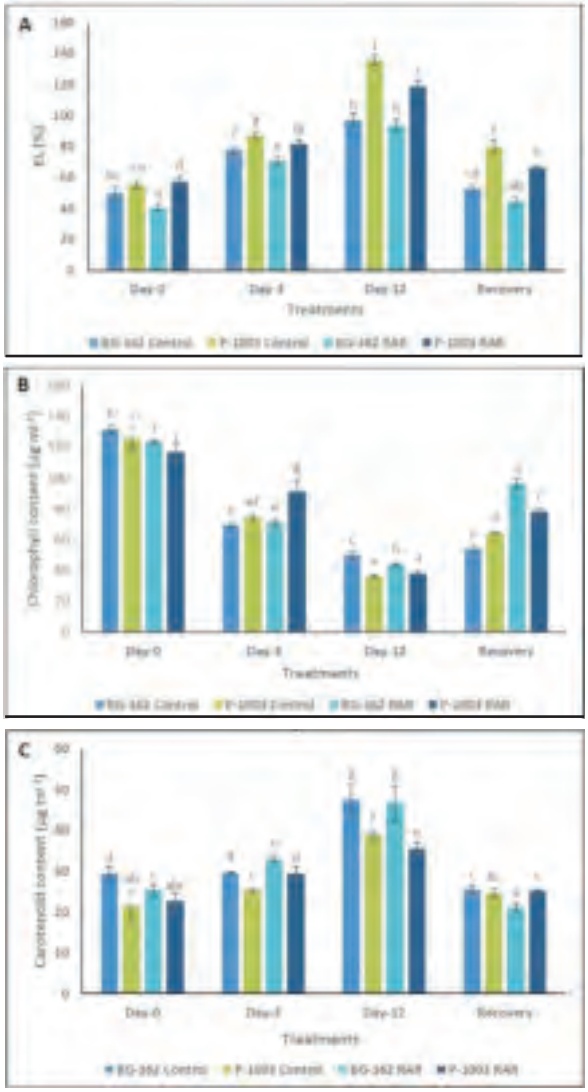


Figure 26(A-C): Determination of EL (A), Chlorophyll content (B), and Carotenoid content (C) in BG-362 and P-1003 subjected to drought at 0, 3 and 12 days and recovery with or without treatment of RA. Data represent the average ± SD of three independent experiments. Different letters on the graph indicate significant differences according to Duncan's test ($P \leq 0.05$). (Source: author)

stress (Fig. 27B). However, rewatered plants showed abrupt decrease in their SOD activity in both the cultivars and RA-inoculated plants showed significantly better restoration than untreated plants. Relatively less SOD activity in RA-treated plants than the uninoculated ones indicates that low oxidative stress is sensed by RA-treated plants. Kang et al., (2014) and Tiwari et al., (2016) also concluded that PGPR mitigate the harmful consequences caused osmotic stress by regulating antioxidants in cucumber and chickpea, respectively.

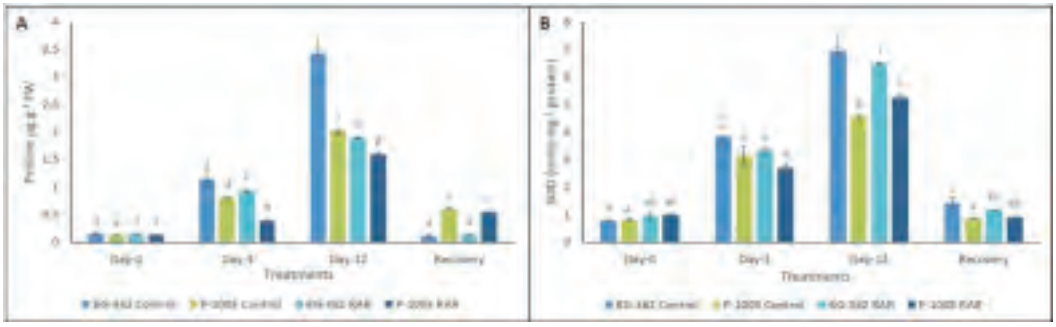


Figure 27 (A-B): Determination of Proline (A), and SOD (B) in BG--362 and P-1003 subjected to drought at 0,3 and 12 days and recovery with or without treatment of RA. Data represent the average ± SD of three independent experiments. Different letters on the graph indicate significant differences according to Duncan's test ((P 0.05). (Source: author)

III.3 Expression analysis of selected miRNAs and their target genes

Small RNA sequencing from chickpea root provided more than 4.3 million clean reads after length selection and removal of adapter and other rRNAs, and 121,469 reads were mapped to the chickpea genome (Jatan et al., 2019). In our previous study, we have predicted 923 conserved and 216 putative novel miRNAs from all the four libraries (Jatan et al., 2019). Approximately, 34% miRNAs were common in all four libraries and 34% were found in two or more libraries. However, 32% miRNAs were uniquely observed from a particular library. Unique conserved and novel miRNAs in the RA library were highly abundant compared to other libraries indicating that miRNA expression might be extensively controlled by RA-inoculation. Previous studies revealed the involvement of RA in the regulation of various stress-responsive genes and several transcription factors as well as miRNAs expression in different plants during drought and salt stress (Srivastava et al., 2012; Tiwari et al., 2016; Jatan et al., 2018). For the differential expression profiles, we have selected 55 miRNAs (40 conserved and 15 novel) from our previous study which were present in all the four libraries and have 5 counts in each library (Fig. 28). The expression patterns of five conserved (miR 166a, miR 160a-5p, miR156a-5p, miR8175,

miR159b-3p) and one novel miRNA (Nov_71a) examined using SL-qRT-PCR in Jatan et al., (2019) showed highest up-regulation of miR159b-3p (2.9 fold) and most markedly down-regulation of miR 8175 (-3.1 fold) during RA-inoculation as compared to the control. The qRT-PCR data of predicted target genes namely homeobox-leucine zipper protein ATHB15-like (target of miR166a), auxin response factor 18-like (target of miR160a), mitogen-activated protein kinase kinase kinase 1-like (target of miR156a-5p), ethylene-responsive transcription factor 7-like (target of miR8175), GAMYB-like (target of miR159b-3p) and uncharacterized protein with a putative protein kinase-like domain (target of Nov_miR71) were used to determine the correlation between expression patterns of miRNAs and their potential target genes (Jatan et al., 2019). Expression patterns of all six selected miRNAs demonstrated opposite correlations with their respective potential targets (Fig. 29).

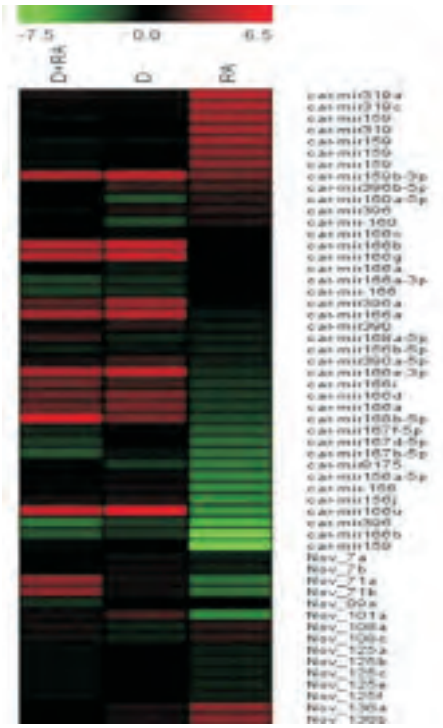


Figure 29: Differentially expressed miRNAs. D, drought; RA, RA-inoculated; D+RA, drought with RA-inoculated (Source: author)

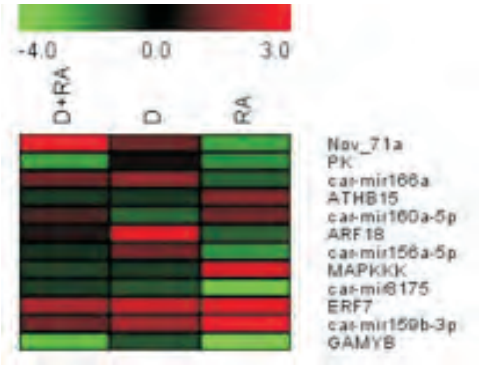


Figure 28: Comparative expression analysis of miRNAs by SL-qRT-PCR along with their respective target genes by qRT-PCR in chickpea (Source: author)

All the selected targets found to be significantly regulated by drought stress as well as upon RA-inoculation as compared to the control. Previous studies reported that the selected target genes including ATHB15, ARF18, MAPKKK, ERF7, GAMYB and protein kinases were involved in nutrient homeostasis, signalling, growth, development and in response to abiotic stress and these genes were also targeted by various miRNAs (Baldoni et al., 2015; Gentile et al., 2015; Sun et al., 2017; Wang et al., 2017; Deng et al., 2017, Jatan et al., 2019; Jatan and Lata, 2019). Therefore, the regulation of miRNA-target module might play a very crucial role in drought stress response/tolerance in chickpea during RA-inoculation. Taken together, RA may be involved in adaptation and restoration of cellular homeostasis during drought stress by the regulation of miRNAs. However, the detailed analysis of the molecular mechanisms needs to be further investigated in miRNA-mediated perception and response mechanisms in chickpea during drought stress response.

IV. Conclusion and future perspectives

Present study demonstrated that Pseudomonas putida RA ameliorates drought stress in both desi and kabuli chickpea varieties. Progression in drought stress significantly affect the phenotypic parameters of both cultivars by altering root length, shoot length and biomass and modulates physiological and biochemical properties such as EL, photosynthetic pigments content, proline content and antioxidative enzyme activity. These parameters showed better stress tolerance and survival by desi chickpea cultivar and positive effect of RA-treatment on its growth performance. Negative correlation expression pattern of miRNAs and their target genes suggested their involvement in the stress regulatory pathways, and ultimately in drought stress response in chickpea. Our findings thus provided an understanding of the physiological and molecular basis of the chickpea response and adaptation to PGPR-mediated drought stress.

References

- Ahmad, F., Gaur, P., Croser, J., (2005). Chickpea (Cicer arietinum L.). In: Singh, R., Jauhar, P. (Eds.), Genetic Resources, Chromosome Engineering and Crop Improvement-grain Legumes, vol. 1. CRC Press., USA, pp.185e214.
- Baldoni E, Genga A, Cominelli E. (2015). Plant MYB transcription factors: their role in drought response mechanisms. Int. J. Mol. Sci. 16. pp.15811-15851.
- Beauchamp, C. and Fridovich, I., (1971). Superoxide dismutase: improved assays and an assay applicable to acrylamide gels. Analytical biochemistry, 44(1), pp.276-287.
- Carillo, P., Gibbon, Y., 2011. Protocol: Extraction and Determination of Proline. Prometheus Wiki01/2011. http://www.researchgate.net/publication/211353600_PROTOCOL_Extraction_and_determination_of_proline

- Chauhan, P.S., Lata, C., Tiwari, S., Chauhan, A.S., Mishra, S.K., Agrawal, L., Chakrabarty, D., Nautiyal, C.S. (2019). Transcriptional alterations reveal Bacillus amyloliquefaciens-rice cooperation under salt stress, Sci. Rep. 9, p. 11912.
- Claeys, H. and Inzé, D., (2013). The agony of choice: how plants balance growth and survival under water-limiting conditions. Plant Physiol. 162(4), pp. 1768-1779.
- Deng M, Cao Y, Zhao Z, Yang L, Zhang Y, Dong Y, Fan G. (2017) Discovery of MicroRNAs and Their Target Genes Related to Drought in Paulownia "Yuza 1" by High-Throughput Sequencing. Int. J. Genome. 3674682.
- Enebe, M.C. and Babalola, O.O., (2018). The influence of plant growth-promoting rhizobacteria in plant tolerance to abiotic stress: a survival strategy. App. Microbiol. Biotechnol, 102(18), pp.7821-7835.
- FAOSTAT (2016) http://www.faostat.fao.org
- Gentile A, Dias LI, Mattos RS, Ferreira TH, Menossi M. (2015). MicroRNAs and drought responses in sugarcane. Front. Plant Sci. 6, p.58.
- Heidari, A., Bandehagh, A. and Toorchi, M., (2014). Effects of NaCl stress on chlorophyll content and chlorophyll fluorescence in Sunflower (Helianthus annuus L.) Lines. Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi, 24(2), pp. 111-120.
- Jatan, R. & Lata, C. (2019). Role of microRNAs in abiotic and biotic stress resistance in plants. Proc. Indian Natl. Sci. Acad. 85, 553-567.
- Jatan, R., Chauhan, P. S. and Lata, C. (2018) Pseudomonas putida modulates the expression of miRNAs and their target genes in response to drought and salt stresses in chickpea (Cicer arietinum L.). Genomics, doi: S0888-7543(18)30016-8.
- Jatan, R., Tiwari, S., Asif, M.H., Lata, C. (2019). Genome-wide profiling reveals extensive alterations in Pseudomonas putida-mediated miRNAs expression during drought stress in chickpea (Cicer arietinum L.), Environ. Exp. Bot. 157, pp. 217-227.
- Kang, S.M., Khan, A.L., Waqas, M., You, Y.H., Kim, J.H., Kim, J.G., Hamayun, M. and Lee, I.J. (2014). Plant growth-promoting rhizobacteria reduce adverse effects of salinity and osmotic stress by regulating phytohormones and antioxidants in Cucumis sativus. J. Plant Interact. 9(1), pp. 678-682.
- Lata, C., Jha, S., Dixit, V., Sreenivasulu, N. and Prasad, M., (2011b). Differential antioxidative responses to dehydration-induced oxidative stress in core set of foxtail millet cultivars [Setaria italica (L.)]. Protoplasma, 248(4), pp.817-828.
- Lata, C., Muthamilarasan, M., Prasad, M., (2015). Drought stress responses and signal transduction in plants. In: Pandey, G.K. (Ed.), Elucidation of Abiotic Stress Signaling in Plants. Springer, New York, pp. 195-225.

- Lata, C., Prasad, M., (2011). Role of DREBs in regulation of abiotic stress responses in plants. J. Exp. Bot. 62, pp.4731-4748.
- Majeed, A., Abbasi, M.K., Hameed, S., Imran, A. and Rahim, N. (2015). Isolation and characterization of plant growth-promoting rhizobacteria from wheat rhizosphere and their effect on plant growth promotion. Front. Microbiol. 6, p. 198.
- Miyahara, M., Takenaka, C., Tomioka, R., Ohta, T., (2011). Root responses of Siberian larch to different soil water conditions. Hydrol. Res. Lett. 5, pp.93-97.
- Nautiyal, C.S., Srivastava, S., Chauhan, P.S., Seem, K., Mishra, A. and Sopory, S.K., (2013). Plant growth-promoting bacteria Bacillus amyloliquefaciens NBRISN 13 modulates gene expression profile of leaf and rhizosphere community in rice during salt stress. Plant Physiol. Biochem. 66, pp.1-9.
- Overvoorde, P., Fukaki, H., Beeckman, T., (2010). Auxin control of root development. Cold Spring Harb. Perspect. Biol. 2, a001537.
- Saeed, A.I., Sharov, V., White, J., Li, J., Liang, W., et al. (2013). TM4: a free, opensource system for microarray data management and analysis. Biotechniques 34, pp.374-378.
- Srivastava, S., Chaudhry, V., Mishra, A., Chauhan, P.S., Rehman, A., Yadav, A., Tuteja, N., Nautiyal, C.S; (2012). Gene expression profiling through microarray analysis in Arabidopsis thaliana colonized by Pseudomonas putida MTCC5279, a plant growth promoting rhizobacterium. Plant Signal. Behav. 7, pp. 235-245.
- Sun R, Li C, Zhang J, Li F, Ma L, Tan Y, Wang Q, Zhang B. (2017) Differential expression of microRNAs during fiber development between fuzzless-lintless mutant and its wild-type allotetraploid cotton. Sci. Rep. 7, p.3.
- Tiwari, S., Lata, C., Chauhan, P.S. and Nautiyal, C.S., (2016). Pseudomonas putida attunes morphophysiological, biochemical and molecular responses in Cicer arietinum L. during drought stress and recovery. Plant Physiol. Biochem. 99, pp. 108-117.
- Tiwari, S., Lata, C., Singh Chauhan, P., Prasad, V. and Prasad, M., 2017a. A functional genomic perspective on drought signalling and its crosstalk with phytohormone-mediated signalling pathways in plants. Current genomics, 18(6), pp.469-482.
- Tiwari, S., Prasad, V., Chauhan, P. S., Lata, C. (2017b). Bacillus amyloliquefaciens confers tolerance to various abiotic stresses and modulates plant response to phytohormones through osmoprotection and gene expression regulation in rice. Front. Plant Sci. 8, p.1510.

- Varshney, R.K., Thudi, M. and Muehlbauer, F.J., (2017). The chickpea genome: An introduction. In The Chickpea Genome (pp. 1-4). Springer, Cham.
- Wang L, Hu W, Tie W, et al. (2017) The MAPKKK and MAPKK gene families in banana: identification, phylogeny and expression during development, ripening and abiotic stress. Sci. Rep. 7, p.1159.
- Wellburn, R.W., (1994). The spectral determination of chlorophylls a and b, as well as total carotenoids, using various solvents with spectrophotometers of different resolution. J. Plant Physiol. 144(3), pp. 307-313.

Chapter-8
The Potential of Wild Edible Plants in the Economy of Indigenous People: A Case Study from Male Mahadeshwara Betta (MM Hills), Karnataka

Meenakshi Negi, Sunil Natuiyal and Mrinalini Goswami

Abstract:

Wild Edible Plants refer to non-cultivated edible plants in the natural forest, fallow land and agricultural land. This paper examines the wild edible plants available in Male Mahadeshwara (MM Hills) Wildlife Sanctuary, their uses and scope of value addition to increase economic benefit and sustainable forest management. A total of 94 wild edible species has been recorded which are either sold in local market or have domestic use. The indigenous communitiesdepend significantly on wild edible plants, which is estimated to be approximately 28.15 tons per annum. Field-based assessment of nine wild edibles has shown that the collection of wild edibles by community is very low as compared to their production, where more than 75% of the resources are left unutilized. Analysis of value-addition process of those wild edibles, and comparison of production costs and market values of value-added products show that the wild edibles have immense potential to increase the income of the farm households, which can go up to two to fourfold. It is suggestive that promotion of value-added wild edibles has the potential to offer a safety-net for households' income where agricultural livelihoods are at risk because of environmental change including changing climate. It can also reduce the pressure on biotic resources and has potential in contributing the ecosystem sustainability and mitigating the threats due to disasters that are driven by variety of factors and aggravated by ecosystem degradation. Therefore, the policies need to be formulated for conservation of these valuable plants in the wild habitats. Also there is need for developing a proper management plan so that the sustainable utilization of these resources can be ensured for contribution in sustaining the local livelihoods. Conservation and sustainable utilization of bio-resources would provide a meaningful solution towards sustainable socio-ecological development.

Keywords: Wild edible plants, Value-addition, Rural livelihoods, Forest conservation

Meenakshi Negi, Sunil Natuiyal[1] (✉), Mrinalini Goswami
Centre for Ecological Economics and Natural Resources, Institute for Social and Economic Change, Dr. VKRV Rao Road, Nagarabhavi, Bengaluru- 560072
Email: nautiyal_sunil@rediffmail.com

I. Introduction

Wild edible plants are important food sources for the rural poor; especially the tribal communities living close to the forest. Wild edibles are freely available in natural habitats and the indigenous communities have thorough knowledge about the utilization of these wild plant resources in terms of collection and preparation of food items. Apart from their utilization by poor communities, wild plants are also currently commonly used as healthy food supplements in developed nations (Redzic, et al., 2006). Wild foods (mostly from flora) are used on a daily basis by approximately a billion people accross the globe (Aberoumandet al., 2009). Through ethnobotanical studies on wild edible plants, it has been found that over 7,000 species have been consumed as food during the history of mankind (Grivetti and Ogle, 2000). Wild edible plants are available in the local areas and are utilized on the basis of traditional knowledge of ecology (Pardo-De-Santayana et al. 2005, Redzic et al., 2006, Arenas and Scarpa 2007). They require lower inputs and costs and are important options to increase nutrition and reduce expenditure (Shackleton and Shackleton 2004, Jama et al., 2008). Such plants act as sources of benefits for-economically weak households, women, and children, which constitute the vulnerable sections of the society (Grivetti and Ogle 2000, Fentahun and Hager 2009). They support livelihoods and remain available even during droughts or conflict-driven famines (Gordon and Enfors 2008, Muller and Almedom 2008, Strauch et al., 2008).They can even tolerate the impacts of climate change such as water stress more efficiently compared with their domesticated relatives (Humphry et al., 1993, Addis et al. 2005), and resilient to rapid climate change, which is not found in many exotic species (Fentahun and Hager, 2009).

A large number of wild edible plants are still consumed in China, India, Thailand and Bangladesh in addition to domesticated species (Mazhar et al., 2007). India is a vast country where nature has bestowed with rich botanical wealth and a large number of diverse types of plants growing wild in different parts. India is one of the world's 12 mega diversity centres with 47,147 plants species including all lower groups (BSI, 2012) and is divided in 20 agro-ecozones. About 800 wild plants are consumed as food chiefly by tribal communities (Singh and Arora, 1978).In India nearly 50 million people live in and around forests and are dependent on the non-timber forest products for their subsistence living (Arora and Pandey 1996). Few reports are available on the forest-based economy of the tribal people in India and other parts of the globe (Ehrlich and Ehrlich 1992; Kant and Mehta 1993; Malhotra et al., 1992; Uma Shankar et al., 1996; Wells and Brandon 1992). Information about availability, prices and market channels is essential for assessing the importance of NTFPs at local, regional and national levels (Hegde et al., 1996). To achieve higher returns from wild edible plant parts, particularly fruits with their low-keeping quality and cheap prices, perhaps value addition is the best option to adopt, with due care to avoid overexploitation (Saundriyal et al., 2004; Maikhuri et al., 1994). No such study is

available in Male Mahadeshwara Hills region particularly with reference to wild edibles. Marketing wild edible plants successfully in rural areas depends on developing centralized processing facilities. Such facilities can be developed to select, collect, process and distribute the products through a well-established value chain. The facilities can also be used to process and market local and regional farm crops and provide training opportunities (Clements, 1998).

During field investigation in MM Hills region research team found that there are many wild edible fruit bearing trees in adequate quantity but it is not being utilized by the local people hence it's being recycled in the nature ultimately. The tribal community is found interested in conserving and cultivating the wild edibles. They have the knowledge about the importance and potential of WEP to uplift their socio economic status. The current demand of organic and healthy food can be met by conserving and promoting value addition to the wild edibles found in the study region. Focus should be done in bringing market channel near to villages for the transfer of products directly to the world. Substantial areas of populace of Karnataka living in urban areas need food and nutritional supply from the remote wild lands. The general populations in urban communities buy processed or preserved wild foods promoted by reputed brands; however there is a strong prospect locally processed wild edibles to bring to market in an economically protfitable and environmentally sustainable manner.

The present study intends to investigate the wild edibles present in MM Hills and to explore the scope of conserving and utilizing wild edibles for their economic and socioecological upliftment. Proposing approach level mediations to the government would empower it to make important move for protection of WEP and improvement of local economy through appropriate utilization of WEP while at the same time guaranteeing long haul sustenance. In this regard, a training programme was also conducted with objectives to orient the farmers about wild edibles and to assist them in value addition using mechanical techniques. The long term expected result of the training programme is to enhance good services and practices in NTFP marketability, and thereby improve their economy to become self-dependent. The broad objectives of this paper are 1. to assess availability of economically important WEPs for identifying potential species for livelihood development of indigenous community, and 2. to understand necessary strategy for processing and marketing of value-added products for the socio-economic benefits of indigenous people.

II. Study area

MM Hills Reserve Forest in Southern Karnataka, India, is adjoining the Cauvery Wild life Sanctuary (WLS) and Biligiri Ranga Swamy Temple Tiger Reserve (BRT) which has a greater biological diversity. Communities such as Soligas (tribal people) and the Lingayats (non-

tribal) have been residing for a long time in these forests. These forest dwelling communities depend on WEPs as supplementary food, especially during droughts and in the shortfall of agriculture produce (Harisha, 2011). These WEPs resources also provide essential nutrients vitamins and impart cultural identity to these communities (Harisha, 2012).

Changes in agricultural and land use policy, infrastructure development and better access to markets has been a driver of land use change in this region. Shift to market driven commercial crops (maize, tapioca, sunflower, etc.) has significantly affected wild edible plants' diversity, availability and use. In addition, natural forest, grazing land, fallows and roadsides, which were a rich source of wild edible plants, are now filled with invasive such as Lantana (Lantana camara L.) and Eupatorium (Chromolaenaodoratum L.) Lantana cover is very high in natural forest and fallow land-60% and 58% respectively-when compared to other land use categories (Aravind et al., 2010). To achieve higher returns from wild edible plant parts, particularly fruits with their low-keeping quality and cheap prices, perhaps value addition is the best option to adopt, with due care to avoid over exploitation (Dhyani and Khali 1993; Maikhuri et al., 1994, 1998).

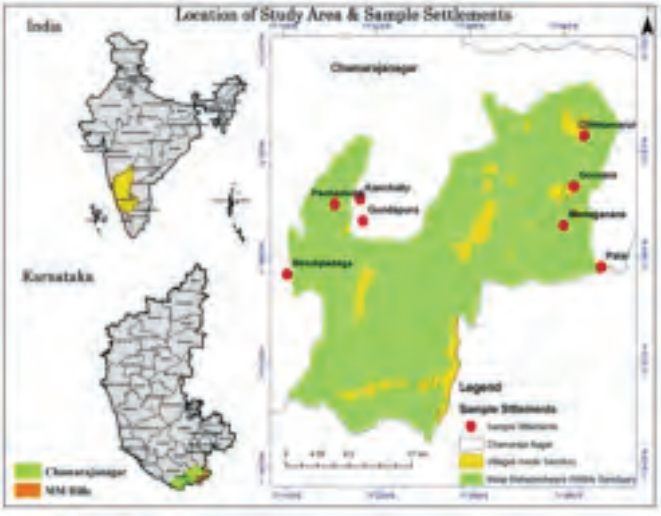


Figure 30: Location of study area
(Source: author)

Systematic and synchronized study was taken in the study area of Chamarajnagara district of Male Mahadeshwara Hills of Karnataka from the month of January 2018 to September 2019.The study area consists total of eight villages spread inside and periphery of Male Mahadeshwara Hills i.e. four peripheral villages (kanchally, buddhipadga, gundapura, Paxxhhedoddi) and four inside villages (Chikkamarur, Gorsane, Medaganane, Palar).

III. Methodology

Data collection

1. Interview and discussion

The heads of 40 randomly selected households were interviewed from each of the eight villages. The respondents were simply asked to list the names of different wild edible plants used and the parts consumed in closed ended questions (Mathers et al. 2009). Thus, the sample size for this survey was 320. Additionally, focal group discussions (Nyumba 2018) were conducted in the villages. In every such discussion, at least ten participants (including women) were present. The participants were selected in consultation with the respective village headmen, who also participated. The topics discussed included availability of wild edible plants and their conservation and utilization as well as related aspects.

2. Habitat survey

A vegetation survey was conducted in three ranges (Palar, PG Palya and MM Hills) of MM Hills (Figure 31). For this purpose, the entire MM Hills Reserve Forest was divided into 358 grids (1.8x1.8 km), out of which 180 were located in the three ranges. From among the 180 grids, 34 were randomly selected for vegetation survey. Three nested quadrats were laid to document trees (10 X 10 m), shrubs (5 X 5 m) and herbs (1 x 1 m) in each of the 34 grids (Misra 1968). Simultaneously, resource quantification was done in field by accompanying forest watchers who were actually local villagers employed by the forest administration. For every wild edible observed in a quadrat, the watchers estimated the annual yield of consumable parts based on the life stage of the plant as well as the quantity of the yield collected/utilized by the local villagers. Their adequate knowledge about the flora of MM Hills and its habitat enabled proper estimation.

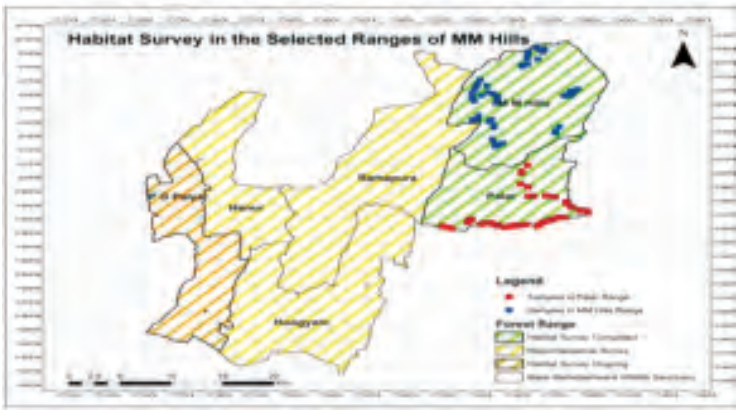


Figure 31: Habitat Survey in the selected ranges of MM Hills
(Source: author)

The number of individuals of every wild edible species recorded from each of the three quadrats surveyed in a particular grid was added up to obtain the total number of individuals of every wild edible species present in that particular grid. In this way, the number of individuals of different wild edibles present in each of the 34 grids was obtained. From this data, the average number of individuals of every wild edible per quadrat was calculated. Analysis for quantification of resources was done for nine species having the highest average. The estimated quantities for each of the nine species were calculated for all the three selected ranges based on their respective number of individuals present in the 34 grids studied. The formula used for calculations are as follows:

$$\text{Density} = \frac{\text{Total number of individuals of a species}}{\text{Total number of quadrats studied}}$$

$$\text{Abundance} = \frac{\text{Total number of individuals of a species}}{\text{Total numbers of quadrats of occurrence}}$$

3. Prioritization and market value assessment

A total of 10 wild edible plants were identified for prioritization for value addition based on six criteria; viz: (a) availability in the vicinity of the tribal people, (b) feasibility for making products, (c) traditional knowledge (d) ease of making value added products, (e) optimum abundance and density in the forest (f) economic returns from the processed products we prioritized ten wild edibles for value addition. A survey was conducted in eight local markets where locals either bought or sold the ten wild edibles. During the survey, the market prices both raw and value added products have of per kilogram of the wild edibles were collected from collectors, local shopkeepers, middlemen and buyers. After this, the same were compared with commercially sold products to assess their potential. Standard retail prices were also obtained from various online sources.

4. Feedback from participants

A two-day workshop covering theoretical and practical aspects of value addition of wild edibles was organized in CFTRI Mysuru from 14 to 15 March 2019 which was participated by 20 villagers from the studied villages. In the workshop, the participants were given hands on training and demonstrations about operating food processing equipments by experts. The manual and other training material was translated in the local language and lectures and demonstration classes were delivered in simple manner which helped them in better understanding of the issues and technicalities of value addition of wild edibles. At the end of the event, the feedback of the villagers was taken on various aspects of preparation of value added products from wild edible plant parts. For this purpose, a focus group

discussion was conducted to assess the willingness of the participants to adopt value addition of wild edibles for income generation. During this exercise, the participants, as a group were asked to rank 20 potential wild edibles found in MM Hills with respect to their respective availability in the area (A), feasibility to produce value added products (F) and market value of the value added products (M) on a scale of 0-10. The overall value (O) of each of the 20 plants in terms of their potential for value addition was obtained by taking the average of ranks assigned, as follows:

$$O = \frac{A + F + M}{3}$$

IV. Results and Discussion

Wild edible fruits are one of the most widely used non-timber forest products. Apart from being important sources of nutrition, medicine, and income, wild edible fruits also provide fiber, fuel, and a range of processed products (Sardeshpande and Shackleton 2019). In the current study, a total of 150 plant species were documented, out of which 94 yielded edible parts. Among these trees contributed the highest number of species (50 species i.e. 51%); Fig. 32. In case of majority of trees (47%) only fruits were consumed (Fig. 33).

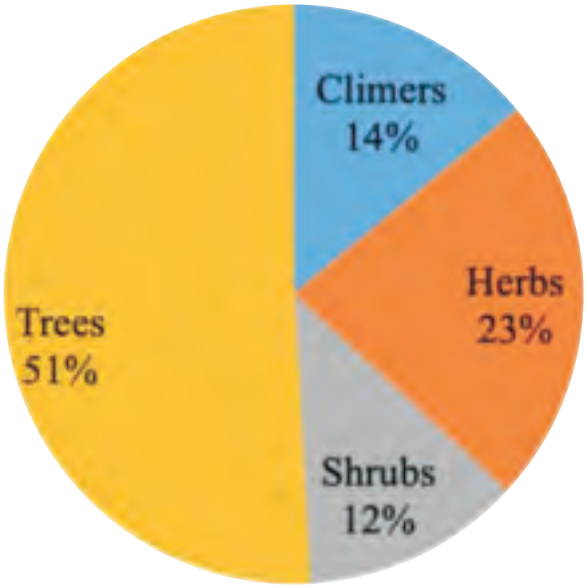


Figure 32: Habit of identified Wild Edible plants documented from MM Hills
(Source: author)

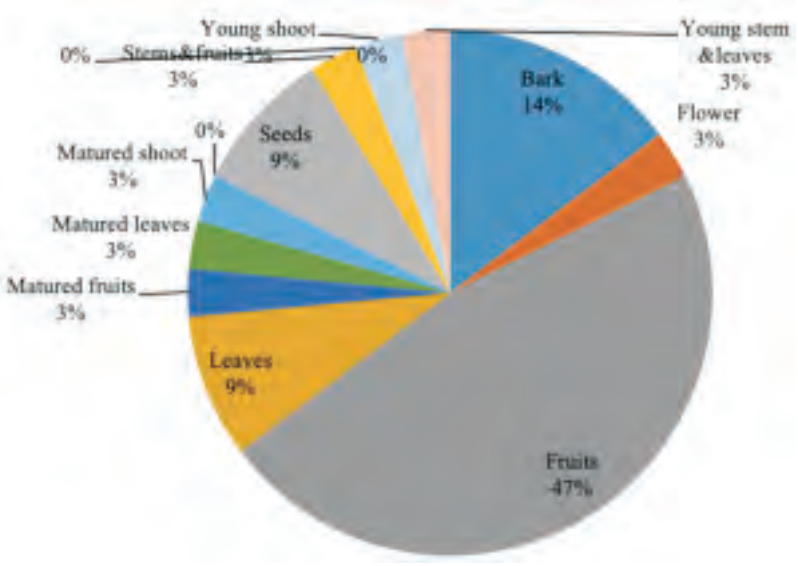


Figure 33: Percentage of plant parts used(Trees)
(Source: author)

The annual availability status of major wild edibles in MM Hills in terms of quantities of edible parts produced is depicted in Fig. 34. Gooseberry *Phyllanthus emblica* was the most highly available wild edible that yielded of 11000 kg of edible material annually, followed by Tamarind *Tamarindus indicus* (9000 kg). This was an important resource that had the potential to be harnessed for both domestic consumption and sale. However, in terms of annual yield per tree, the most productive wild edible was *Tamarindusindica* (300 kg of edible material), followed by *Syzygiumcumini* (150 kg of edible material) and *Artocarpushetero phyllus* (142 kg of edible material)

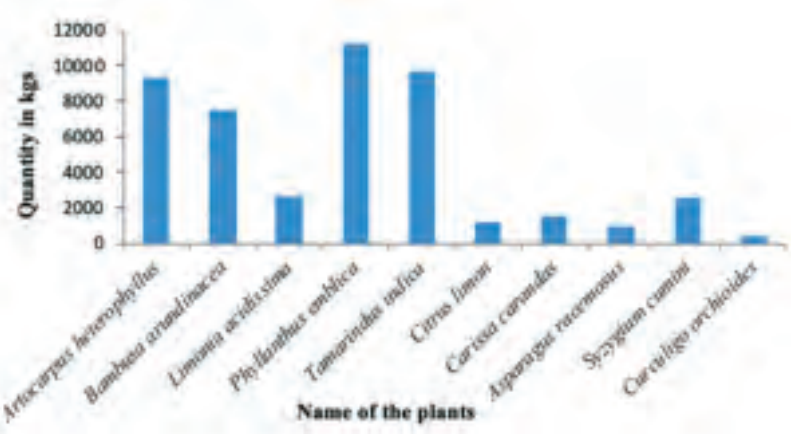


Figure 34: Annual availability of major wild edible plants in MM Hills
(Source: author)

All the surveyed households, except one collected wild edibles for domestic consumption. During the study, it was revealed that the quantity of wild edibles collected decreased in course of time, whereas, simultaneously, there has been an increase in the area under cultivation. The reduction in the utilization of wild edibles was greater than the increment in the agricultural area, indicating an increased preference towards agricultural crops. This is a serious issue because, apart from being a food source, wild edibles can also provide economic opportunities to supplement household income (Uprety et al., 2012). The locals of MM Hills were not properly aware of this aspect and thus, tended to overlook the importance of this resource. Consequently, a major of the production of the wild edibles is not utilized. As a whole, a majority (75.03%) of the overall edible production of the nine wild edible plants having the highest economic potential was wasted. The wastage was the highest (96%) for *Bambusaarundinacea,* which was followed by *Syzygiumcumini (94.59%)* and *Carissa carandas* (94.42%); Fig. 35. This is the wastage of a valuable natural resource of tremendous importance. Therefore, awareness should be created among people so that they are encouraged to utilize the benefits of wild edible flora in a sustainable way.

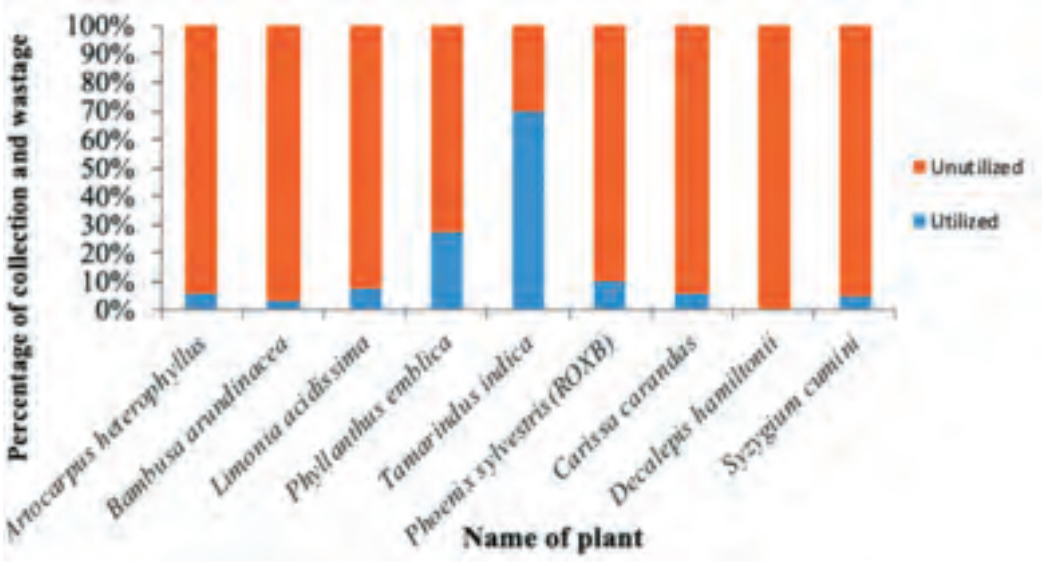


Figure 35: Percentage of collection and wastage of fruit production obtained from selected wild edibles of MM Hills annually (Source: author)

There is a need to take initiatives to create markets so that the economic potential of this resource could be harnessed and used for the socio-economic upliftment. Simultaneously, steps should also be taken to train villagers about sustainable gathering and conserve the

plants by preventing their over exploitation. This is because over exploitation of economically important species is caused by unsustainable harvesting and unhealthy competition to obtain more resources among gatherers (Uprety et al. 2012). In fact, the method of harvesting exerts a serious consequence on the survival of wild edible plants as well as ecology (Teklehaymanot and Giday 2010). This is especially required in the context of Bambusaarundinacea and Decalepishamiltonii which were abundantly found in MM Hills. In case of the former, young sprouts and in case of the latter, roots are collected for utilization. The extraction of both these parts leads to termination of the entire plant. Thus, while collecting such resources, it must be ensured that the extent of extraction is sustainable. The available quantity for extraction as mentioned in Table for these plants does not take this aspect in account and is an overall estimation. The gatherers should be trained or made aware to observe filed conditions and then, assess the quantity that should be actually extracted to maintain sustainability. This is also needed while extracting any part from any other wild plant species that causes the termination of that particular species. In addition, in order to reduce the biotic pressure, the villagers should be encouraged to cultivate the wild edibles in home gardens and community lands. Value addition of these plants could also provide tremendous benefits to the villagers in terms of deriving economic benefits through sustainable use of this natural resource. For this to be effective, proper hands-on training should be provided to the locals and an adequate system for access and benefit sharing should be designed so that wild edibles are properly and sustainably utilized without any ecological damage. In this context, the workshop organized in CFTRI yielded encouraging outcomes as it involved active participation of villagers who were the stakeholders at the grass-root level. The villagers became aware about the scenario of the market for wild edibles and economic benefits of value-added products. Based on their feedback, the potential of 20 wild edibles found in MM Hills in terms of value addition is mentioned in Table below. Among these, Tamarandusindica, Phyllanthus emblica and Syzygiumcuminiwere found to the have the highest potential for value addition. However, in case of these plants, a major portion of the production is not utilized (Fig) indicating the wastage of a valuable natural resource. The ten wild edibles that could be prioritized for value addition based on the current study are mentioned in Table 12.

Table 11: Potential of different aspects of wild edibles of MM Hills for value addition as mentioned by the participants of CFTRI workshop during focal group discussion on a scale of 0-10

Sl. No.	Name of wild edible	Availability (A)	Feasibility (F)	Market value (M)	Overall value (O)
1	*Syzygiumcumini*	5	8	8	7
2	*Limoniaacidissima*	4	6	7	5.6

Sl. No.	Name of wild edible	Availability (A)	Feasibility (F)	Market value (M)	Overall value (O)
3	*Tamarandusindica*	10	10	10	10
4	*Artocarpusheterophyllus*	4	7	7	6
5	*Citrus limon*	4	7	8	6.3
6	*Phyllanthus emblica*	7	9	9	8.3
7	*Moringa oleifera*	3	8	9	6.6
8	*Bambusabambos*	4	5	10	6.3
9	*Asparagus racemosus*	5	4	8	5.6
10	*Curculigoorchioides*	7	4	8	6.3
11	*Decalepishamiltonii*	1	4	9	4.6
12	*Magniferaindica*	3	5	7	5
13	*Solanum indicum*	9	3	2	4.6
14	*Carissa carandas*	6	4	3	4.3
15	*Phoenix sylvestris*	5	5	3	4.3
16	*Besella alba*	7	4	3	4.6
17	*Dioscoreaaculeata*	4	6	6	5.3
18	*Zizipusjujuba*	4	6	4	4.6
19	*Murrayacoinigi*	2	5	8	5
20	*Morusaustralis*	3	7	9	6.3

O = (A + F+M)/3

Table 12: Details of ten potential wild edibles of MM Hills that could be prioritized for value addition

S. No	Scientific name	Habit	Parts used	Products made	Market price in rupees	Density	Abundance
1	*Syzygiumcumini*	Tree	Fruit	Juice	350/ 500ml	1.578	22.5
				powder	85/100gm		
2	*Limoniaacidissima*	Tree	Fruit	Jam	80/450gm	2.526316	24
				Powder	200/100gm		
3	*Tamarandusindica*	Tree	Fruit	Candy	150/400gm	3.157895	20
				Juice	90/250ml		
				Sauce	45/200gm		
				Powder	200/100gm		
4	*Artocarpusheterophyllus*	Tree	Fruit	Jam	160/300gm	1.894737	27
				Chips	400/500gm		

S. No	Scientific name	Habit	Parts used	Products made	Market price in rupees	Density	Abundance
5	*Citrus limon*	Tree	Fruit	Pickle	22/100gm	1.894737	18
				Juice	70/250ml		
6	*Phyllanthus emblica*	Tree	Fruit	Flakes	195/200gm	4.736842	45
				Candy	150/400gm		
				Juice	210/1000ml		
				Powder	60/100gm		
7	*Carissa carandas*	shrub	Fruit	Juice	400/500ml	1.263158	18
				Pickle	200/500gm		
8	*Bambusabambos*	Shrub	Young shoots	Pickle	125/100gm	34.73684	123.75
				Canned	182/250gm		
9	*Asparagus racemosus*	Herb	Root	Powder	200/100gm	0.631579	18
10	*Curculigoorchioides*	Herb	Tuber	Powder	210/100gm	23.68421	450

Wild food is an iconic and important ecosystem service (Schulp et al., 2014) and hence, must be conserved. For the sustainable management and use of wild edible fruits, ecosystem services, economic incentives, market innovations, and stakeholder synergies should be incorporated into their conservation strategies (Sardeshpande and Shackleton 2019). This is crucially important because wild edible resources can provide alternative livelihoods and thus can contribute to climate change resilience. If the potential of these resources is adequately harnessed, then these can increase the adaptive capacity, especially in the rural areas. In fact, the vulnerability of local communities to food insecurity is reduced by wild food resources, which provide a buffer in times of food shortage (Balemie et al., 2006, Misra et al., 2008, N'danikou et al., 2011). However, in the study area, this resource is wasted rampantly. In view of this, following recommendations are provided sustainable utilization through value addition.

Financial support

There is often a want for smallholder farmers to access credit to purchase inputs, inclusive of ingredients, packaging, etc. When conventional banking systems are not appropriate, opportunity sources of finance need to be explored including non-governmental groups that perform micro-finance initiatives, which have greater favorable interest prices and payback periods.

Technical support

Information dissemination about food safety can be transferred to the farmers for smooth marketing of the products prepared. This includes good hygiene practices while

harvesting the fruits, proper handling while product preparation etc. which will prevent it by contamination of foreign particles or development of microbes also mitigate risk of rejecting the products by consumers.

Farmers can be acknowledged with types of wild edibles, quantity available for processing and in addition quality required by consumers then they can decide which machine can be used and packaging material available nearby. Depending on product they can decide the storage facility available and how to transport it safe. The sustainable use of WEB would help in green growth also would enable farmers for their livelihood development. This avenue if properly developed can be an alternate source of income generation for the farmers/tribals living in and around forested landscapes. Once livelihood is ensured the direct pressure on biotic resources would be reduced. The reduction on the resources has positive impact thus ensure ecosystem sustainability and contribute in disaster risk reduction.

Market instrument

Farmers need to examine issues such as the types of processed products that customers or other buyers (medium- and large-scale processors etc.) want to buy, how much they want to purchase per week or month; what price they are willing to pay, where buyers are located, how to move products to such locations, and how much it will cost to sell. Market research helps farmers understand the possible demand for their products and helps to quantify anticipated on-farm production profitability. This knowledge lowers the risk of making the wrong choices. The kind of market research needed depends partly on the types of village buyers, their location and the type of competitors found in market.

Networking

Local markets are better option for farmers as they can transport the products to shorter distances using their own vehicles. This ensures that the time spent away from the farm is less, and they maintain control over the way that foods are treated and its consistency. The main potential drawback of local markets is the possibility of lower prices compared to those available from both urban markets and other types of buyers (e.g. retailers or food processing companies).

Proper market analysis and feasibility studies can be conducted to determine the variation in costs of selling and probable benefits, so that farmers can choose the most visible options available in their vicinity.

Knowledge exchange

This can be done by creating groups of farmers or women so that training and support can be provided to entire communities in a cost-effective way. The processing of wild edibles

often involves a wide range of skills: some, such as harvesting at the appropriate maturity level, appear to be easy but often require long experience and/or preparation.

To sell their crops at an appropriate price, without incurring high selling costs, farmers should be able to negotiate with customers, which includes trust and communication skills, and knowledge of consumer demands and customer expectations for quality and price. The preparation, confidence building activities and the provision of market information will strengthen each of these areas.

Different approaches are required by government and stakeholders, when promoting processing to increase food safety or nutritional status compared to those used to create or support small, income-generating on-farm processing companies.

Conservation and cultivation

Wild edibles are significant part of NTFP which support survival of forest communities. It has potential to sustain the rural livelihood but they are deprived of harnessing it as the area (MM Hills) was declared as Wildlife Sanctuary in 2013. The strict conservation policy has led invasive species in forest to grow excessively and deprive the valuable wild edible plants to thrive for nutrient, water etc. Restricting grazing activities has also affected in encompassing of leaf litter on the forest floor which in turn has affected natural germination of fruit seeds fallen from trees. A few important wild edible plants saplings and seeds were collected and grown in vicinity of tribal village to conserve and cultivate for ensuring the economy furthermore releasing the biotic pressure. Hence, appropriate steps should be taken for conservation depending upon prevailing situations and requirements.

Food and nutritional significance of wild edibles

Wild plant food is an important natural resource which can provide nutrition, resilience to climate change and disasters as well as economic benefits. This resource is never fully utilized and mostly remains overlooked in terms of income generation and commercialization. There is a need of scientific and technological interventions as well as awareness so it could be conserved and sustainably utilized for upliftment of livelihoods. This is especially required for economically underprivileged rural people in Hotspot areas who reside in villages abundant with this valuable bio resource. It is highly relevant in the current situation when reverse migration is taking place on account of COVID-19 pandemic. The current study examined the economic potential of wild edible which are widely available in the ecosystems being resided by tribal communities, scope of their value addition to increase economic benefit and establish a pathway for their commercialization. Several economically important types of WEP, including high economic and ecological importance are present in the Western Ghats and Himalayan

regions, which can be cultivated for commercial purposes. There is an urgent need to generate awareness among the stakeholders and assign the responsibilities to the Local Government Institutions (LGI) and Community Based Organisations (CBOs) for adopting and sustaining nutrition-sensitive wild edible based food practices in the tribal areas. Primary data on dietary intake, availability, sustainable harvest potential, traditional uses, nutritional quality and antinutritional values of wild edibles are important aspects essential to strategize effective and adequate nutritional security based on available bio-resources. This will further build avenues for commercialization, domestication and value addition of selected wild tubers.

V. Conclusion

Wild plant food is an important ecosystem service which has the potential to provide nutrition and economic benefits. The wastage of these locally available nutritious foods is tremendous and can be harvested for sustainable livelihood development and nutritional security. Proper institutional support is required to make it a mainstream livelihood to develop a more resilient community under the circumstances of changing climate. There are also several associated traditional beliefs. In the current times, due to changes in lifestyles, preference towards agricultural crops and so on, the utilization of wild edibles has decreased and the related traditional knowledge is being lost. This has reduced the utilization and collection of wild edibles, which in turn has led to wastage of this valuable natural resource. There is a need to conserve wild edibles and make the human society aware of their importance. Value addition would lead to the sustainable utilization of wild edibles with better economic incentives to the local societies living in forested landscapes of India.

Acknowledgement

The research has been funded by SEED Division, Department of Science and Technology, Government of India. The authors are grateful for the co-operation received from the Forest Department and local villagers.

References

- Aberoumand A. and Deokule S.S. 2009. Studies on nutritional values of some wild edible plants from Iran and India. Pakistan Journal of Nutrition 8 (1):26-31.
- Addis G., Urga K. and Dikasso D. 2005. Ethnobotanical study of edible wild plants in some selected districts of Ethiopia. Human Ecology 33 91):83-118.
- Arenas P. and Scarpa G.F. 2007. Edible wild plants of the chorote Indians, Gran Chaco, Argentina. Botanical Journal of the Linnean Society 153(1):73-85.

- Balemie K. and Kebebew F. 2006. Ethnobotanical study of wild edible plants in Derashe and Kucha Districts, South Ethiopia. Journal of Ethnobiology and Ethnomedicine 2:53.
- Clements S.1998. Harvesting and marketing edible wild plants. Oregon State University Extension Service.
- Ehrlich P.R., Ehrlich A.H. and Daily G.C. 1993. Food security, population and environment. Population and development review:1-31.
- Fentahun M.T. and Hager H. 2009. Exploiting locally available resources for food and nutritional security enhancement: wild fruits diversity, potential and state of exploitation in the Amhara region of Ethiopia. Food security 1(2):207.
- Grivetti L.E. and Ogle B.M. 2000. Value of traditional foods in meeting macro-and micronutrient needs: the wild plant connection. Nutrition Research Reviews 13(1):31-46.
- Humphry C.M., Clegg M.S., Keen C.L. and Grivetti L.E. 1993. Food diversity and drought survival. The Hausa example. International Journal of Food Sciences and Nutrition 44(1):1-16.
- Jama B.A., Mohamed A.M., Mulatya J. and Njui A.N. 2008. Comparing the "Big Five": A framework for the sustainable management of indigenous fruit trees in the drylands of East and Central Africa. Ecological indicators 8(2):170-179.
- Redzic S. 2006. Wild edible plants and their traditional use in the human nutrition in Bosnia - Herzegovina. Ecology of Food and Nutrition 45(3): 189-232.
- Maikhuri R.K., Semwal D.L., Singh, A. and Nautiyal D.C. 1994. Wild fruits as a contribution to sustainable rural development: a case study from the Garhwal Himalaya. The International Journal of Sustainable Development & World Ecology 1(1):56-68.
- Mathers N., Fox N. and Hunn A. 2009. Surveys and questionnaires. The NIHR Design Service for the East Midlands.
- Misra R. 1968. Ecology Work Book, Oxford and IBH publishing Co., New Delhi.
- Misra S., Maikhuri R.K., Kala C.P., Rao K.S. and Saxena K.G. 2008. Wild leafy vegetables: a study of their subsistence dietetic support to the inhabitants of Nanda Devi Biosphere Reserve. India. Journal of Ethnobiology and Ethnomedicine 4:15.
- Muller J. and Almedom A.M. 2008. What is "famine food"? Distinguishing between traditional vegetables and special foods for times of hunger/carcity (Boumba, Niger). Human Ecology 36(4): 599-607.

- N'danikou S., Achigan-Dako E.G. and Wong J.L.G. 2011. Eliciting local values of wild edible plants in Southern Bénin to identify priority species for conservation. Economic Botany 65(4): 381–395.
- Nyumba T.O., Wilson K., Derrick C.J. and Mukherjee N. 2018. The use of focus group discussion methodology: Insights from two decades of application in conservation. Methods in Ecology and Evolution 9: 20–32.
- Pardo-De-Santayana M., Tardío J. and Morales R. 2005. The gathering and consumption of wild edible plants in the Campoo (Cantabria, Spain). International Journal of Food Sciences and Nutrition 56(7): 529-542.
- Sardeshpande M. and Shackleton C. 2019. Wild Edible Fruits: A Systematic Review of an Under-Researched Multifunctional NTFP (Non-Timber Forest Product). Forests10:467.
- Schulp C.J.E., Thuiller W. and Verburg P.H. 2014. Wild food in Europe: A synthesis of knowledge and data of terrestrial wild food as an ecosystem service. Ecological Economics 105: 292-305.
- Shackleton C. and Shackleton S. 2004. The importance of non-timber forest products in rural livelihood security and as safety nets: a review of evidence from South Africa. South African Journal of Science 100(11):658-664.
- Shankar U., Murali K.S., Shaanker R.U., Ganeshaiah K.N. and Bawa K.S. 1996. Extraction of non-timber forest products in the forests of BiligiriRangan Hills, India: Productivity, extraction and prospects of sustainable harvest of Amla Phyllanthus emblica (Euphorbiaceae). Economic Botany 50(3):270-279.
- Singh, H.B. and Arora, R.K. 1978. Wild edible plants of India. Indian Council of Agricultural Research.
- Sundriyal, M. and Sundriyal R.C. 2004. Wild edible plants of the Sikkim Himalaya: Marketing, value addition and implications for management. Economic Botany 58(2):300-315.
- Teklehaymanot T. and Giday M. 2010. Ethnobotanical study of wild edible plants of Kara and Kwego semi-pastoralist people in Lower Omo River Valley, Debub Omo Zone, SNNPR, Ethiopia. Journal of Ethnobiology and Ethnomedicine 6: 23.
- Uprety Y., Poudel R.C., Shrestha K.K., Rajbhandary S., Tiwari N., Shrestha U.B. and Asselin H. 2012. Diversity of use and local knowledge of wild edible plant resources in Nepal. Journal of Ethnobiology and Ethnomedicine 8:16.

C
Disaster Resilient Construction

Chapter-9
Green Buildings: A Sustainable Green Growth approach towards Disaster Resilience

Juhi Ramrakhiyani

Abstract

An increasing trend and rapid occurrence of disasters have devastating impacts on not only life but also on property and infrastructure. The human induced climate changes have resulted into sudden and increasing onset off natural disasters. Due to increase in climate related events, the frequency and the magnitude of disaster impact has variably increased. In order to mitigate the loss caused by these extreme events, it is therefore of utmost importance to build a resilient society rather than only a responsive one. Hence a comprehensive approach of green growth provides a roadmap for sustainable environment, along with fostering economic growth, disaster resilience and socio inclusiveness. Green growth is balanced collaboration of environmental services related to climate change scenarios and at the same time enriching economic benefits for development. Green buildings/infrastructure is one of the way to achieve green growth. It aims to reduce the impact of after effects of disasters through systematic efforts to manage and analyse the causative factors and also encouraging and promoting the use of renewable resources. To increase the socio economic resilience of the society in terms of green growth, green infrastructure provides a way towards sustainable approach. A green building provides a structural stability during disaster as many lives are put in danger due to improper construction. The case studies mentioned reflects the importance of sustainable approach for making a disaster resilient society.

Keywords: Green growth, Green buildings, Climate change, Disaster resilient, Environment friendly, Renewable resources

Juhi Ramrakhiyani [✉],
Sector Manager
Gujarat State Disaster Management Authority
Email id:ramrakhiyanijuhi@gmail.com

I. Introduction

Disaster induced either due to natural or anthropogenic factors related to climate change or environmental changes poses a grave danger on environment sustainability, economy growth and social inclusiveness. In order to make society resilient towards disasters with minimum disruptions in the economy, sustainable and environmental friendly preventive measures should be adopted (Refer Figure 1). Although many engineered structural and non-structural mitigation and preventive measures are currently in place to lessen the impacts posed by disaster may it be natural or man-made on society. However, less focus has been given to green growth which not only serve as sustainable mitigation strategy against disasters but also strengthens the socio-economical services of the society.

The effect of environmental change and climate change should be considered when surveying the supportability of continuous and new improvement endeavours. The winning acts of over-misuse of normal assets, including releasing human strong waste and waste water into the characteristic water bodies, have quickly disturbed the crumbling of nature and influenced the manageability of improvement.

Hence, an integrated disaster risk informed investment with eco-friendly sustainable measures will lead to growth of economy of the society along with building resilience to disaster. Green buildings/infrastructure is one of the example which provides aid to minimise the climate change episodes resulting into disaster.

Various frameworks like The Sendai Framework for Disaster Risk Reduction 2015-2030, Sustainable Development Goals 2030, Paris Agreement etc. provide a roadmap to achieve green growth in terms of sustainable development socio-economic inclusiveness and strengthening of the micro and macro climatic events.

The Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030 outlines seven clear targets and four priorities for action to prevent new and reduce existing disaster risks. The Priority 4 of SFDRR states "Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction" implying the importance of a resilient infrastructure at times of calamity. Also Sustainable Development Goals 2030 highlights the prioritization of Climate change as it also exacerbates disasters and combating it is absolutely vital to guaranteeing our survival and the wellbeing of future generations. The Goal 9 of Sustainable Development Goal further emphasises to build resilient infrastructure, promote sustainable industrialization and further foster innovation. Connected together, these deliberately arranged organizations of green components can give different advantages in the type of supporting a green economy, improving personal satisfaction, securing biodiversity and upgrading the capacity of environments to convey administrations, for example, catastrophe hazard decrease, water cleansing, air quality, space for amusement and environmental change relief and adaption.

Figure 36: Roadmap to achieve Green growth including resilience and sustainability
(Source: author)

The physical environment consists of the natural elements such as water, wind, and earth and their corresponding hazardous event (e.g., hurricane, flood, tornado and earthquake). The built environment includes transportation networks as well as buildings and essential utilities (Tyler.J.2016). These interactions together have resulted in lives lost, homes and infrastructure destroyed, and economies shattered. Hence, Resilience is a capacity of a society to withstand, be durable and recover back from any hazard or catastrophe.

Due to rapid industrialisation, urbanisation and population growth, the risk in urban growth has increased tremendously. In order to build a disaster resilient society, investments in green growth has to be carried out for sustainable urban

Figure 37: Components of Disaster Impacts on society
(Source: author)

development. Green infrastructure includes green buildings, roofs etc. which includes proper building codes, using solar panels on rooftops, green roofs, green walls, water harvesting mechanism, enhanced roof area, flood resistive material, over-sized roof drainage, withstand high wind velocity, use of non-combustible or flammable materials. This results into economic inclusiveness along with protecting climatic variations.

Incorporating Disaster Risk Reduction in urban planning will help to safeguard the investments made in development of urban sectors. For instance, due to climate change there is increase in urban flash floods or cloudbursts, which results into heavy downpour of rainfall. Due to concretization, prevalence of impervious strata's and improper drainage system accumulation of water occurs.

Hence, damage occurs due to high intensity rainfall in terms of loss of livelihood, deterioration of environment and loss of property and infrastructure occurs. Imminent Disasters like earthquake and cyclone have the capability to collapse any engineered structure due to its high magnitude and intensity. It becomes of utmost important to opt for green building as improper construction and use of building material will results into putting millions of live into danger and high mortality rate. Hence, in the year 2019, Coalition for Disaster Resilient Infrastructure (CDRI) an international coalition of countries was held at New York, to promote research and in the fields of infrastructure risk management, standards, financing, and recovery mechanisms. CDRI's mission is to rapidly expand the development of resilient infrastructure and retrofit existing infrastructure for resilience, and to enable a measurable reduction in infrastructure losses.

In order to mitigate the disaster impacts, involvement in green growth like green buildings gives a sustainable way for resilient development, where disaster resilience refers to ability to suffer less damage and less time to recover from any hazard or calamity like earthquake or cyclone. Green building are those infrastructure which from their structure and application are sustainable and environment friendly. As a result, green buildings provides co-benefits of insurance against disasters, preventing obsolescence and preventing deterioration. During the time of disaster, green building provides durability against environmental cause like climate change, provides protection against disaster and design for adaptability and deconstruction.

Green buildings not only helps to mitigate disaster related risk or make the society disaster resilience but also helps to promote the use of renewable resources like solar energy. Solar panels installed in the rooftop of the building make it further promote environment friendly approach. A green building consisting of green roof i.e. vegetated roof can help to store storm water at times of heavy rainfall. It also mitigates the Urban Heat Island effect by reducing the temperature and increased roof insulation, providing a better aesthetic appeal.

Green building follows "Build Back Better" of Sustainable Development Goal 9 which emphasise that investment in infrastructure and innovation are crucial drivers of economic growth and development. It also refers to the ability of building to increase the strength while minimising the cost of its repairing damage and making it environment friendly.

Green infrastructure or blue-green infrastructure is a network providing the "ingredients" for solving urban and climatic challenges by building with nature, while in terms of disaster management it refers to concept as the ability of buildings and critical infrastructure to withstand the shock of a disaster. This paper gives an introduction to the alternative way of making disaster resilient society by investing in green growth approach which aims to reduce the disaster related risks. In addition it also, describes minimisation of disaster losses and prevalence of disaster resilient communities by following sustainable measures.

Following are the case studies which highlights the various tools and techniques adopted globally to attain disaster resilience in sustainable manner with help of green infrastructure.

II. Case studies

1. Bamboo houses, Assam

Due to devastating floods of 2017, SEEDS had built 80 bamboo houses as a part of flood driven programme in Assam. This NGO took up the initiative to rebuild and reconstruct house to design and build house in flood affected area. The development was formulated with a vision to build resilient communities through participatory design, illustrating a model of contemporary vernacular architecture.

Vulnerable to natural disaster, the self-reliant communities of Assam have developed indigenous construction and planning techniques over the centuries, creating a built-environment exclusive to the terrain. However, due to haphazard development in the region, the traditional knowledge systems are being ignored, leading to an unsafe environment, loss of lives and livelihoods.

Figure 38: Bamboo Home (Source: SEEDS)

In an area where the annual phenomenon of flooding and repeated loss due to that perpetuates poverty, environmentally sustainable solutions were discovered in the vernacular architectural typology of stilt houses built in bamboo.

A 23-square-meter core house built atop stilts was designed following sphere humanitarian standards for disaster response within the given budget constraint, its high stilts helping to cope with the annual flooding while its flexible joinery system allows the homeowners to shift the floor higher in case of over flooding - a unique feature that was adopted from the traditional practice of the region. Local families along with architects came up with a hybrid housing design - one that married modern technology with local traditional architecture.

The layout of the house is simple and multipurpose, the stilts are high enough to allow day-to-day activities such as weaving, rearing livestock, and the storage of boats, used during floods or a play space for children, and a semi-open verandah is provided for social interaction, food preparation or basketry as done traditionally by the communities resulting to resilient community.

This shows how architects and artisans worked together to develop disaster-resilient construction details that could be built using local materials and skills. Required changes were made to enhance the conventional construction details such as deeper bamboo footings encased in concrete; stilt bamboo columns waterproofed with a rubberized coating; introduction of cross-bracings and use of indigenous tying techniques with rattan and bamboo dowels to make the structure resistant to lateral forces during floods and earthquakes.

2. Rebuilding Green in Greensburg:

Current consideration given to environmental change and its effect on social and financial improvement is additionally adding to quickening the acknowledgment that cataclysmic events are a basic factor influencing wellbeing, security and profitability of the structure inhabitants. Consequently, it is critical to create and authorize safe fabricated climate to make inhabitants more strong, and to secure lives and property in the midst of catastrophe. Further, debacle hazard due to changing atmosphere presents a test to the organizers and fashioners of the fabricated climate to make them high strong for calamities on the grounds that, unseemly development puts millions lives what's more, properties unnecessarily in harm's way. In considering the approaches to improve strength capacity of structures, green gathering idea has picking up speed in psyches of organizers and creators of fabricated climate, as green structures are commonly planned and fabricated all the more cautiously.

As per report on From Tragedy to Triumph-Rebuilding Green Buildings after Disaster the study shows "After a devastating tornado in Greensburg in 2007, the people used this opportunity to rebuild as green community which will lessen the impact of disaster along with posing less harmful effects on environment. The Greensburg building includes green features such as a well-insulated roof and walls, energy efficient lights and equipment, wind turbines, and recycled waste oil used for heating water. Along with the debris are reused post disasters.

3. Mitigation measures against hurricanes and tornadoes in Nebraska using precast insulated concrete walls with extruded polystyrene (XPS).

As per Green Building Solutions for an infrastructure to survive any natural disaster, it must not only account for the lateral forces on the walls and roofs, wind-driven rain, and storm surges along the coast, but also flying debris. A study shows that tornadoes or hurricanes in Nebraska cause damage to infrastructure mainly because of flying debris as result of high speed of hurricane. This results into breaking of outer shell of the homes or broken glass or window pane. As a result, the infrastructure is made of insulated concrete walls. This green infrastructure helps to combat wind and wind driven rain forces.

As part of disaster resilience, the precast concrete panels are mechanically fastened to the foundation hence structurally strengthened to withstand disaster. The high R-value per inch of the extruded polystyrene (XPS) or polyisocyanurate (polyiso) insulation core reduces thermal movement through the wall in any season, and the mass of the concrete moderates the effect of outside temperature extremes during the day.

The insulated concrete wall consists of non-combustible material. Concrete being a non-combustible material does not burn, soften, or distort, so concrete homes are more likely to remain standing after a fire.

4. Installation of floodwater vent ,New Jersey

As per the report on Strategies for Multifamily Building Resilience as part of Disaster Preparedness for Affordable Housing Organizations it was highlighted that during Super storm Sandy, Hoboken, New Jersey suffered heavy damage to its buildings and infrastructure. Due to this the property faced escalating insurance costs. In order to mitigate future risks and to reduce insurance premiums, flood proofing strategy was chosen.

Hence as mentioned, Installation of nine smart vents on first floor and 9 inches of gravel and concrete fill to raise the floor to ground level was carried out. Also to minimize heat loss during cold weather and as environmental friendly approach insulated Smart Vents were selected. The use of gravel and concrete made the building resilient towards natural calamity by raising its level to ground level.

5. Green Mass Damper

As per the article published in Forbes, a study of Japan was carried out explicitly describing the effect of green buildings on natural disaster. The article highlighted the use of pendulum effect which strongly shakes the rooftop green area insulated by the building itself and laminated rubber (normally the same as that used in a seismic isolation structure), so that the dampers installed between the laminated layers can reduce the burden on the building itself by absorbing the energy of the earthquake. These dampers are used in the Roppongi Hills Keyakizaka Complex. Also a research was carried out in New Zealand and it was explored that the green roof's ability to resist seismic forces and the potential for the green roof to be used as an energy dissipater to reduce the response of the building to lateral dynamic loading, such as wind loading. Shake table tests showed the substrate layer was capable of resisting most seismic events and with the addition of plants it became resistant to all but the most severe earthquake events. The composition of the roof substrate may vary, but typically, it is characterised by low density with high field capacity and permeability to keep the load on the roof low while capturing optimal amounts of water. Tuned Liquid dampers (TLDs) are used on structures to dampen the response during excitations. TLDs are essentially pools of water that utilise the sloshing of water, during excitations, to dampen movement (Reed et al., 1998). TLDs share many of the same properties as a green roof's drainage layer raising the possibility of the green roof acting like a TLD with the drainage layer having multiple barriers to smooth flow, creating turbulent flow to dissipate energy. (Carmody et al., 2009)

6. Green roof, Los Angeles

Designing of Green building features can help to reduce impact on the environment or human health through less-resource intensive use of water, energy, and other materials. The reinforced-concrete building uses a special moment-resisting frame system to meet codified standards for seismic design. The green roof is composed of light grasses and four inches of soil overtop the roof system and reduces storm water runoff. The heavier dead load of the saturated soil required larger column and beams for the green roof building.

Similarly the analysis is composed of structural analysis, loss estimation, and environmental analysis. For the structural analysis step, Open SEES seismic analysis program was used to conduct a nonlinear analysis of a two-dimensional, three-bay model of each building. Subjected to increasing levels of seismic intensity, both experienced greater inter-story drifts at higher ground motion intensities. At each intensity level, the larger beams and columns of the green roof building resulted in lower inter-story drifts than the non-green roof building.

Generally, Performance Assessment Calculation Tool (PACT) provides a user-friendly platform for scenario based, intensity-based, and time-based loss calculations. PACT

provides three basic but integrated functions: 1.Gathering and organizing building information, fragility functions and demand parameters 2. Performing loss calculations including repair cost, downtime, and casualty estimates; and 3. Providing overall and performance group specific loss information obtained from the above calculations.

Hence for the loss estimation, PACT is used to integrate building usage, structural and non-structural components, collapse potential, and results of structural hazard analysis into predictions of needed seismic repairs and associated costs. In the environmental analysis, we consider a building life cycle of material extraction, product manufacturing, material transportation to site, construction, operation, maintenance and repairs, and end-of-life. Assessment and Adoption, allow the design team to assess the life cycle performance of the building and improve the design based on the results, before adopting a final design for construction. (Huggins et al., 2014)

III. Conclusion

Environmental change is required to cause more serious and the sky is the limit from there incessant characteristic perils. As our urban communities and coasts develop more powerless, these dangers can lead to debacles that are far more awful than those we have seen until now. We have a good, social and financial commitment to construct flexibility which can be attained by green growth. Due to increasing climatic change events & various environmental episodes the occurrence of natural disasters has increased. One should be aware of all the vulnerabilities and should address the risks associated with the disturbances to make the society resilient. This will result into mitigation of long term disruptions and increased acceptance for design related to sustainable and green infrastructure to enhance resilience. The methodology looks to reinforce soundness and agreement inside and across urban areas in comprehension and making arrangements for hazard from catastrophic events and environmental change.

Green growth acting as sustainable approach towards disaster resilience includes:

1. Mitigating the side effects of structure on the environment, climate and society by identifying and understanding risk scenarios
2. Providing with better savings and returns to community hence economic development and financial strengthening
3. Sustainable planning and urban development design process resulting into safeguarding of natural ecosystems.

It can be concluded that till date emphasis has been laid on reducing risk of human lives and seldom importance is given to climate, environment and urban planning w.r.t infrastructure during any catastrophic event. Green buildings, energy efficient and water conservation practices along with environment friendly approach plays an important role towards sustainability in terms of disaster resilience. Resilience comes in practice when

buildings are sustainable in true sense of fulfilling their minimum requirements of following building codes. The topic gives a way for building Back Better Greener and Safer

References

- Carmody. M et al., (2009). "Seismic Response of Green Roofs". In Conference of New Zealand Society for Earthquake Engineering, 2009.
- Harshini. m. et al., (2013). "Green buildings, Resilience Ability and the Challenge of Disaster Risk". In Conference: International Conference on Building Resilience 2013, Sri Lanka
- Tyler.J. (2016). "Sustainable Hazard Mitigation: Exploring the Importance of Green Infrastructure in Building Disaster Resilient Communities". Consilience: The journal of Sustainable Development.Vol.15, Issue 1 (2016), pp. 134-145.
- W.Huggins SJ, Liel AB (2014)."Integrating green and resilient building design for enhanced disaster recovery". In Proceedings of the 3rd International Conference on Urban Disaster Reduction, Earthquake Engineering Research Institute, Boulder, CO, USA, 2014.
- Enterprises Green Communities (2015). Ready To Respond Strategies for Multifamily Building Resilience.
- Jain, G., & Bazaz, A. (2017). Urban Risk and Resilience in India. Indian Institute for Human Settlements.
- Performance Assessment Calculation Tool User Guide for Beta Version 1.0 (May 27, 2007), ATC-58 Guidelines for Seismic Performance Assessment of Buildings
- U.S. Department of Energy (2009). Energy Efficiency and Renewable Energy.
- Green Buildings Turn the Table on Natural Disasters
- https://www.forbes.com/sites/williampentland/2013/06/02/green-buildings-turn-the-table-on-natural-disasters/#10bb97bc4dde Accessed on May 26, 2020
- India Launches Global Coalition for Disaster-Resilient Infrastructure
- https://sdg.iisd.org/news/india-launches-global-coalition-for-disaster-resilient-infrastructure/ Accessed on May 26, 2020
- Sustainable Environment and Ecological Development Society (SEEDS)
- https://www.designboom.com/architecture/seeds-disaster-resilient-bamboo-housing-assam-india-10-07-2019/ Accessed on May 26,2020
- United Nations Development Programme

- https://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-9-industry-innovation-and-infrastructure.html Accessed on May 22, 2020
- United Nations Office for Disaster Risk Reduction
- https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030. Sendai Framework for Disaster Risk Reduction 2015-2030 Accessed on May 27, 2020
- Solutions for Natural Disasters / Accessed on May 27, 2020

Chapter-10
Climate Change Resilience Solutions for Built Structures

Payal Rastogi

Abstract

Increase in frequency and intensity of extreme natural events like earthquakes, hurricanes and floods etc. are one of the most visible signs of Climate Change and associated disaster risks.Lots of people die around the world during various climate disasters annually, due to bad infrastructure. It is been said that disasters don't kill people, buildings do. It is imperative for all infrastructures to be made climate resilient. We can implement existing solutions and find new innovative products and technologies to mitigate climate change impacts in our daily lives. We have listed few existing solutions and methods which are in practice across the globe to mitigate and safeguard against climate disaster risks. These solutions are easy and simple ones which can be implemented by any local person in their respective areas. When more people understand about Climate change and its severe impact, more green growth can be expected.

Keywords: Climate change, Green growth, Carbon neutrality, Climate change risks, Existing built structure, Infrastructure, Climate resilience, UNSDG 13.1, Paris agreement

Payal Rastogi [✉]
Founder, Carbonfixers
Email: payalrastogi@carbonfixers.com

I. Introduction

United Nation Sustainable Development Goals has a (Goal 13.1) which talks about taking immediate action towards climate change and its impact. It also suggests we must strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries. Paris Agreement (Paris Agreement), which was signed on October 2016 also has a clause under Article 8 on climate risk and management. It advices conference of parties on enhancing understanding, action and support, including the Warsaw International Mechanism, on a cooperative and facilitative basis with respect to loss and damage associated with the adverse effects of climate change.

Building Climate Resilience houses for people and robust infrastructure will help safeguard the lives, built structures, flora, fauna and biodiversity of the area which gets spoiled; as mostly it becomes impossible to restore the area to its original form after the disaster has occurred.

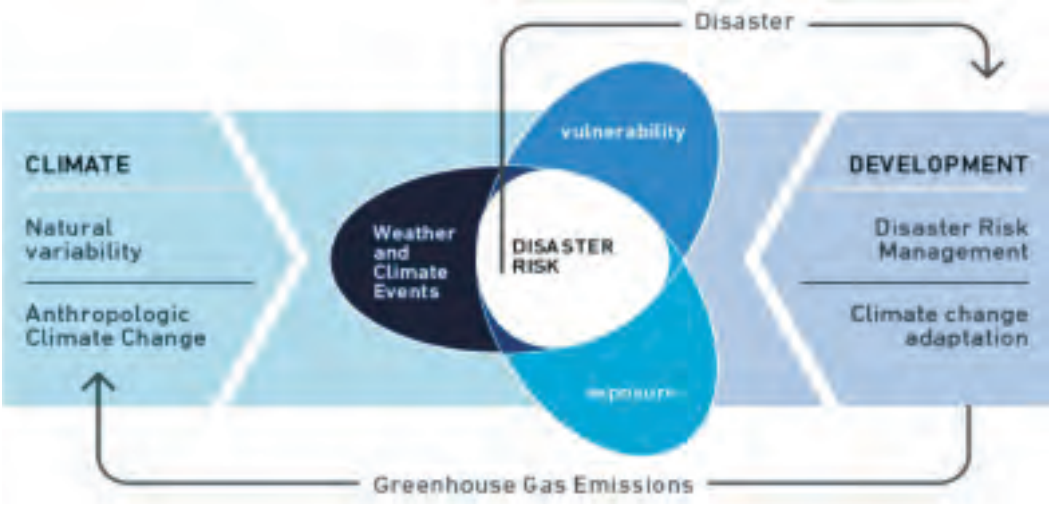


Figure 39: Link between Greenhouse Gas Emissions, Climate Change and Disasters
(Source: https://www.preventionweb.net/understanding-disaster-risk/risk-drivers/climate-change)

The above diagram on (Climate Change) clearly describes the relationship between climate disaster risks and Green House Emissions. We think retrofitting and renovation of existing built structures with some new products and solutions is a great way to improve its life cycle and manage the climate risk.

Building Climate Change resilience among the vulnerable communities must be our priority. In order to provide some easy solutions, we have tried listing some easy solution and methods that can be easily sourced, planned and implemented by communities. None

of these solutions listed below are exclusive, they are easy and can be implemented by area locals too.

II. Solutions

Solutions for Built Structures

These are some of the most common practices and technologies installed by communities to safeguards against natural disasters. They are structural, non structural, materials and technologies currently in use by some building owners and the government.

All climate sensitive areas should be redesigned to safeguard against climate change disaster risk management.

1. Solutions against Floods.

Annually so many people die from floods across the world. They also create huge damage in the existing infrastructure including roads, drainage, and houses. Vulnerable communities and poor people suffer the most. It is one of the most common natural disasters. It's very important that all such areas must implement these solutions in no time. Few of structural and non-structural measures in flood management are listed below for basic understanding.

1.1 Permeable pavements

Permeable pavements are alternative paving surfaces that allow flood water to runoff and filter through voids in the pavement surface into an underlying stone reservoir, where it is temporarily stored and/or infiltrated.

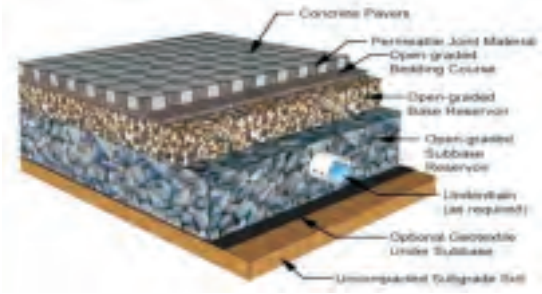


Figure 40: Typical Permeable Pavement Section
(Source: https://www.pinterest.com/pin/512847476296496125/)

1.2 Drainage Infrastructure to control flood water and maintain regular water levels.

Following are the three types of drainage system that helps in mitigating effects of flooding on the building.

- French Drains: They reduce the hydrostatic pressure and remove excess moisture from the soil by collecting surface water and groundwater.
- Full Gutter System: Gutters are ideal for collecting roof runoff and capturing rainwater to direct away from the building's foundation.
- Sump Pump: A small pump is installed in basement or crawlspace to collect excess water. Buildings may have a sump pit, which channels water to collect in the specific area. Buildings which lack any such facility can install an isolated pump.

1.3 Porous concrete

It contains little or no sand, creating a substantial void content. Using sufficient paste to coat and bind the aggregate particles together creates a system of highly permeable, interconnected voids that drains quickly.

By capturing storm-water and allowing it to seep into the ground, porous concrete is instrumental in recharging groundwater, reducing storm-water runoff.

Figure 41: Pervious Concrete
(Source: https://www.quora.com/Is-it-possible-to-use-lean-concrete-sub-base-instead-of-granular-sub-base-GSB-for-making-rigid-pavements)

1.4 Good Old Flood Gates

All Floodgates are 68 cm (2'3") high because many researchers have suggested that above this level, water pressure on the outer walls can be powerful enough to cause structural damage.

A jacking mechanism attached to the rear of the frame allows both the frame and cover to expand telescopically width ways into the walled area (the reveal) immediately in front of the door.

Figure 42: Flood Gate resisting floodwater from entering building
(Source: https://aquobex.com/products-list/floodbreak/)

A single floodgate provides superior protection than over 50 sand-bags yet it weighs less than one! A Floodgate is also a lot easier to store and is completely reusable.

1.5 Creation of Scenic Wetlands

As water moves into a wetland, the flow rate decreases, allowing particles to settle out. The many plant surfaces act as filters, absorbing solids and adding oxygen to the water. Growing plants remove nutrients and play a cleansing role that protects the downstream environments.

Figure 43: Pekapeka wetland in Hawke's Bay
(Source:https://www.pinterest.es/pin/315885361353433835/)

Downstream water flows and ground water levels are also maintained during periods of low rainfall. Wetlands help stabilize shorelines and riverbanks.

Although wetlands are naturally occurring phenomenon but it can also be artificially created by method of 'Wetland Construction'.

1.6 Raising plinth level of buildings

Raising elevation includes moving key or essential equipment from low-lying elevations within a structure to areas that would not be subject to flooding. Having building support systems such as computers, heating and air-conditioning units, and electrical stations located in the basement areas puts the functionality of the entire building at risk during a flood event. It is one of the most common practices among building owners.

1.7 Land use Planning and Zoning

Wise land use is at the center of non-structural flood mitigation activity and is an effective tool for reducing risk at the community level.

2. Solutions against Storms –a.k.a Various Atmospheric Disturbances.

Storms are most frequent and make maximum damage to properties. Cyclonic storms are characteristic of the low lying coastal areas and are often subject to storm surge from the sea. Whereas for the inland region, storms are often associated with thunder and lightning activity, heavy rains, localized flash flooding, land gales and destructive gusts or squalls. Coastal areas may also be susceptible to hailstorms as well.

2.1 Providing Shear Wall for resisting sway

Winds during a storm supposedly bring sway to tall buildings. This sway is resisted by providing shear walls. These walls arrest the deflection of structural members in lateral direction as they are providing in order to resist lateral forces i.e. parallel to the plane of the structural wall. Shear walls are vertical element of a building that resist horizontal

forces. Also, shear walls can be provided in the sub-structure (if foundation is mat) and to the super-structure as well.

2.2 Keeping Roof Intact

Roof is the most susceptible part of the building to be blown away during winds and storm like situations. Insulating the openings from high wind effects helps by keeping wind out of the building. For that, most commonly used technology are storm shutters which can insulate the openings like doors, windows, garage doors, etc. from letting heavy winds enter the building.

2.3 Wind Retrofit - Strengthening structural elements and connections

For existing buildings, a major task of wind retrofit is to strengthen the structural elements, in specific, the columns while also strengthening the connections. Strengthening columns is done usually by encasing them with concrete, thus making them resist the wind force. Connections can be restored using connector studs and gusset plates. Gusset plates can be designed as per requirements of the structural connection.

2.4 Wind clips

Wind Clips (also known as "hurricane clips" or "hurricane side clips") are roof tile locking devices that engage the sides of roof tiles to hold the tiles to the roof structure. Wind Clips are recommended for all roof tiles requiring additional fastening for high wind regions. Uplift loads are greatest in corners and eaves, followed by the field tile.

2.5 Impact-resistant Glazing Systems

Laminated glazing systems typically consist of assemblies fabricated with two (or more) panes of glass and an interlayer of a polyvinyl butyric (or equivalent) film laminated into a glazing assembly. Laminated systems are non-porous and have slightly different pass/fail criteria as per different codes. The glass panes in the system can fracture during heavy winds but the interlayer remains intact to prevent water from entering the building.

2.6 Shape of the Building

The square plan is better than the rectangle. The rectangle is better than the L-shaped plan. This is not to say that all buildings must be square. For lightweight roofs it is best that they be of hipped shape (sloping in all four directions, usually), steeply pitched (30 to 40 degrees), with little or no overhangs at the eaves (with parapets if possible) and with ridge ventilators where these are practicable.

2.7 Maintenance of neighborhood

One of the major risk during storms and high wind events are the flowing debris and branches of trees that fall out. On a community level, it shall be made sure that no debris

is stored in the area which can potentially pose a risk during storm like situations. Also, weak branches of trees must be cut-out.

3. Solutions against Earthquakes

Earthquakes have taken more human life than any other natural calamity. Most of the countries' building codes have stringent earthquake criteria that structural designers sometimes don't adhere to. However, existing buildings specially the old ones are more at risk because of the primitive codes that would have been used in their design.

3.1 Strengthen existing connections

Since joints are the weakest part of a building they are most vulnerable to deformities which ultimately may lead to damage of structural load bearing members. Use of 'fibre reinforced plastic' for strengthening concrete joints is gaining wide popularity. Using FRP curtails the rotation of joints, thus increasing strength to bear earthquake loads. Also, using FRP provides ductility ad thus joints of RC members perform well during earthquakes.

3.2 Seismic Bracing

A building with full bracing will be effective against an earthquake because it will not lose its shape and collapse. S-waves (shear waves) which are responsible for most of the damages during an earthquake shake the buildings from left to right, which weakens the structure. The bracing helps keep the shape of the building, and if the foundations are built on bedrock, the building may resist even the biggest earthquakes. It also ensures that non-structural elements, fixtures, appliances and equipment remain at their places intact during the event of an earthquake.

3.3 Add shear walls

Shear walls help to restrain the lateral movement of a building during an earthquake. These walls are laid parallel to the structural members and provide extra stiffness in order to resist torsional forces generated during earthquake.

Shear walls can be of concrete or steel. Concrete shear walls are heavy and less effective than the steel shear walls. Shear walls provided in panels are the nest practice to install shear walls in an existing building.

3.4 Fiber-Reinforced Plastics

The immunity to corrosion, high strength-to-weight-ratio, and convenient handling and installation make FRP a material of choice in a large number of projects where inelastic deformation capacity and high strength are the prerequisites.

Fiber reinforced plastics (FRP) has widely been recognized as an effective seismic retrofit material for new and existing concrete structures. Japan is a leading country in terms of applications of fiber reinforced plastic reinforcement for concrete.

Studies reveal that the main failure of structural members are due to the insufficient ductility and shear strength. The effectiveness of fiberglass material to confine concrete columns has been acknowledged on a global scale. Improvement in structurally deficient concrete columns has been a proven and most significant application of fiberglass materials.

3.5 Base Isolator and Dampers

Base isolation is a technique that is developed to prevent or minimize damage to buildings during an earthquake. It has been used widely in India, Japan, Italy, New Zealand and the USA. A fixed-base building (built directly on the ground) will move with an earthquake's motion and can sustain extensive damage as a result. When a building is built away (isolated) from the ground, resting on flexible bearings or pads known as base isolators, it will only move a little or not at all during an earthquake.

Another method is the installation of seismic dampers. This dampening is provided by a lead-based device that looks very similar to a car damper (shock absorber). Ground movement forces the lead to pass through a narrow gap. When the direction of movement changes, the flow of lead is reversed. The principle is still the same as the lead rubber bearing, with kinetic energy being converted into heat energy, thereby preventing the building absorbing the kinetic energy.

3.6 Epoxy Injection

Epoxy injection is an effective method of repairing wear and tear of concrete. It is a method that can be applied to existing buildings in recovering strength of concrete members which undergo wear and tear after use or have been damaged due to earthquake. Crack injection consists of applying a structural binding agent into a crack for the purpose of filling the crack and adhering to the substrate material. For concrete and fully-grouted, reinforced masonry walls, epoxy is typically injected into cracks under pressure.

3.7 Reduce dead-weight of building

Reducing weight of masonry walls helps immensely by reducing the dead-weight of a building. Solid brick wall of 11-12 cm thick made with clay and gypsum finish weighs around 300 kg/m^2. However, new solutions like 'dry wall' or 'walls with foam concrete' helps reduce the weight of masonry walls to just about one-sixth or one-fourth of traditional masonry walls.

Dry walls are 12 - 12.5 cm thick gypsum, plasterboard or similar material wall utilized in constructing interior walls and ceilings. Foamed concrete walls typically consist of a slurry of cement and fly-ash or sand and water and act as light-weight mixes popular for constructing non-load bearing masonry walls of a building. The foam is created using a foaming agent, mixed with water and air from a generator.

4. Solutions against Landslides

Landslides are a mode of ground failure in which sloppy surfaces fail due to slip loads and huge mass of earth rolls down a slope to effect habitat downhill. The mass movement can be of the following, fall, topple, slide, spread or flow.

Structural protection against landslides can be done at community level rather than at individual level for buildings.

4.1 Retaining walls

Retaining walls are vertical structures built at the downhill of slopes for protection against falling debris or mass movement from uphill through the slopes. There are of different kinds based on the how they help to retain material behind them.

- Gravity walls manage to resist pressure from falling debris behind them by virtue of its own weight.
- Piling walls are made of steel and usually applied in tight spaces. They are embedded 2/3rds in the earth's surface and thus balance themselves against landslide mass.
- Cantilever walls have a large structural footing and convert horizontal pressure into vertical pressure on the ground below.
- Anchored walls use cables or other strays anchored in rock or soil behind to increase resistance against horizontal pressure.

4.2 Fill slopes and Soil Nailing

It involves the installation of soil nails through the fill materials with the provision of a surface grillage connecting the soil nails head. The existing trees can be preserved during the construction process. The soil nails are embedded in competent subsurface stratum to ensure sufficient anchorage against pull-out. Because of the construction advantages offered through the use of soil nailing, the method is now commonly used for upgrading fill slopes.

4.3 Ground anchor wall

Ground anchors consisting of cables or rods connected to a bearing plate are often used for the stabilization of steep slopes or slopes consisting of softer soils, as well as the

enhancement of embankment or foundation soil capacity, or to prevent excessive erosion and landslides.

Permanent tieback anchors are used widely for stabilization of active landslides. Several types of structural reaction systems are used with anchors. In some cases, each anchor is attached to an individual concrete reaction panel. In other cases, a continuous reaction panel, or 'waler wall', acts as a reaction beam for each row of anchors.

4.4 Cellular Confinement System

The system is a three-dimensional cellular confinement system manufactured from high-density polyethylene (HDPE) strips, that are ultrasonically welded together to create a strong, lightweight expandable panel.

The system confines and reinforces vegetation on steep slopes by increasing the soils natural resistance to erosion and protects the root zone layer during establishment of vegetative cover on the surface of the embankment.

The perforated cell walls encourage lateral drainage and frictional interlock, increasing the structural performance of the system. On non-vegetated slopes it prevents the migration of granular infill thus resulting in greater stability. The cellular confinement system provides economical solutions in applications, like ground stabilization, slope protection, retaining walls and channel and tree root protection.

4.5 Mat-Polymer

Mat Polymer is a geo-mat made from a three-dimensional matrix of UV stabilized, non-degradable synthetic fibers, heat bonded where they cross, extruded onto polymeric geogrid reinforcement. The reinforcing geogrid strength can be selected to suit the project requirements.

Used on vulnerable soil slopes, exposed to erosion, this geo-mat immediately increases the soil's resistance to erosion by providing an environment that enhances the growth of vegetation through the mat. Its most common use however, is within the protection works to landfill membranes or in mine-remediation works. The geogrid reinforcement provides greater structural integrity, when the mat is used to contain and reinforce soil on long slopes.

4.6 Steel-grid Mesh

Steel-grid Mesh is a high strength, high stiffness steel geo-composite combining the versatility and practical benefits of double twist mesh with the exceptional stiffness and mechanical durability of high tensile steel cables. The steel cables are integrally woven into the double twist mesh during manufacturing, forming a single, easy to deploy product.

4.6.1 Steel Grid Mesh for Slope Protection

The meshing system is an innovative complete system for rockfall mitigation and slope consolidation works. It is used as a drapery or as a high stiffness (low extension) bolted facing when anticipated loads exceed the capability of traditionally used mesh. This steel grid mesh system can be used in conjunction with anchor plates, specific U-bolts and mesh connectors for additional slope stability works.

4.7 Early warning systems

Acoustic emission devices can be made use of for early warning systems for risk mitigation of landslides. The ALARMS sensors are permanently installed and transmit a real-time SMS text message when the acoustic soil activity reaches a pre-defined threshold. Imminent landslides are normally accompanied by increased acoustic emissions levels (high-frequency stress waves) due to inter-particle soil friction and displacement.

4.8 Restricting/Discouraging construction activities

Civic authorities and Governments need to regulate the construction activities in zones susceptible to landslide as these activities contribute immensely to lose debris and soil erosion which catapult the slipping of sloppy surfaces in variable altitude regions.

4.9 Horizontal drains for dewatering

Horizontal drains can help lower the water table in a slope and are a common solution for stabilizing hillsides. They are installed by drilling horizontally and installing perforated or slotted pipe into the slope to collect water and convey it to a suitable discharge point.

III. Conclusion

Climate change is going to impact every single existing building and infrastructure across the world. If the solutions listed are implemented we will be able to mitigate the risk before it happens and save our communities and biodiversity, especially in sensitive areas. All the future renovations and new infrastructure must have the planning and design for 360 degree sustainable construction including climate change risk mitigation.

It is a reported fact that these climate change disasters create huge economic void and losses in the cities and in people's lives. All Natural Disasters have their own economic costs associated with losses and destruction they make. For e.g. floods, the average cost per event is estimated to be around $4.3 billion. These areas and its infrastructure are rarely rebuilt to its original form and usually left abandoned. Land Use must be restored and effectively regenerated for redevelopment of the area. New built structure should not be approved without plans for disaster risk management as part of the design master plan. To support green growth, climate change adaptation and mitigation measures must be included as a mandatory practice.

References

- (n.d.). Retrieved april 12, 2021, from https://www.sheltercluster.org/sites/default/files/docs/Battling%20the%20Storm%20-%20typhoon%20resistant%20construction.pdf
- Climate Change. (n.d.). Retrieved April 12,2021, from preventionweb: https://www.preventionweb.net/disaster-risk/risk-drivers/climate-change/cost per event is estimated to be around $4.3 billion. (n.d.). Retrieved april 12, 2021, from https://interestingengineering.com/5-natural-disasters-that-have-affected-the-economy-with-billions-of-dollars
- Cyclonic storms. (n.d.). Retrieved april 122021, from https://www.sheltercluster.org/sites/default/files/docs/Battling%20the%20Storm%20-%20typhoon%20resistant%20construction.pdf
- Earthquakes. (n.d.). Retrieved april 12,2021, from https://www.iitk.ac.in/nicee/wcee/article/13_2283.pdf
- Goal 13.1. (n.d.). Retrieved April 12, 2021, from SDG TRacker: https://sdg-tracker.org/climate-change
- huge economic void . (n.d.). Retrieved from https://www.ncdc.noaa.gov/billions/time-series
- Landslides. (n.d.). Retrieved april 4,2021, from https://www.sciencedirect.com/science/article/pii/S1674775513000875
- Paris Agreement. (n.d.). Retrieved april 12,2021, from https://unfccc.int/files/adaptation/groups_committees/loss_and_damage_executive_committee/application/pdf/ref_8_decision_xcp.21.pdf
- steel grid mesh. (n.d.). Retrieved 4 12, 2021, from https://www.maccaferri.com/in/products/rockfall-steelgrid-high-strength-mesh/:
- Strucural. (n.d.). Retrieved 4 12, 2021, from https://cementconcrete.org/water-resources/solutions-to-flooding/1279/

Chapter-11
A Framework for Resilient and Sustainable Post-Disaster Housing Strategies

Arindam Biswas

Abstract

The destruction brought by disasters demands urgent requirement of constructing or renewal of houses and infrastructures and hence provides an opportunity to "build back better" with integrating the long-term sustainability. During the gradual evolution of the disaster victims from a temporary shelter to permanent housing, the affected communities are dependent on relief and external aid. The lack of resources, knowledge and capacity to redevelop housing and community hamper the future growth of the affected people. In these circumstances, it is important to learn from both the successful and unsuccessful cases and augment knowledge and capability to institute resilience. This paper aims to develop a framework for India's post-disaster shelter strategies by synthesising evidence from secondary research and follows a case study approach from the best practices around the world. The framework considers land, institutional and legislative settings, knowledge and capital, and capability as tools for developing the framework. The framework can be used directly or to develop further models for a sustainable implementation of post-disaster housing strategies. It will help to derive improved post-disaster housing policy in India to "build back better".

Keywords: Resilience, post-disaster pousing, Build back better, Disaster risk reduction

Arindam Biswas (✉)

Associate Professor, Department of Architecture & Planning, IIT Roorkee, Roorkee - 247667, Uttarakhand,

e-mail - arindam.biswas@ar.iitr.ac.in

I. Introduction

Urgent sustainability problems demand accelerated and transformational changes. Disasters provide the necessities for speeding up such changes towards sustainability by eliminating the restrictions of "normal times". Disasters are recognized as catalysts of change for expediting measures towards sustainability. However, the path to achieving sustainability is not very easy. In case a disaster creates much widespread havoc, the severe impact leaves both the administration and people hapless and puzzled. After the initial shock, the full attention of the administration and community focuses on rescue and relief operation, which starts by constructing temporary shelter to accommodate the homeless people. The journey from a temporary shelter to permanent housing becomes a challenging task.

India is one of the most vulnerable countries that experience natural disaster very frequently (Ministry of Home Affairs. 2011). The major natural disasters in the recent past that created a massive physical and economic destruction are the 1999 Odisha cyclone, the 2001 Gujarat earthquake, the 2004 Indian Ocean tsunami, the 2013 Uttarakhand flash floods and the 2020 West Bengal cyclone. The magnitude of theses disasters is such that it creates impending physical loss and deep emotional distress of losing the assets among the victims. A family suffers the most due to the sudden loss of housing as it affects their protection and security, survival and health, social needs such as privacy and dignity, and livelihoods (Corsellis & Vitale, 2005). Depending on the extent of housing damages, the post-disaster housing strategy consists of four stages - emergency shelter, temporary shelter, temporary housing and permeant housing. Quarantelli (1995) refers to the shelter as a place to stay during the immediate aftermath of a disaster suspending daily activities, and housing denotes the return to household responsibilities and daily routine (Quarantelli, 1995, Biswas & Puriya, 2020). Emergency shelter is a place where survivors stay for a short period immediately after a disaster, temporary shelter is used for a short stay after an unexpected disaster preferably for a few weeks after the disaster, temporary housing is the place where the survivors can reside temporarily, usually planned for six months to three years, and a permanent housing refers to the rebuilt houses or resettled areas to live permanently (Félix, Branco, & Feio, 2013).

The research aims to develop a framework to capture the issues, complexities and consequences of post-disaster housing contextualities. The purposes of deriving a framework are that it facilitates multidisciplinary efforts toward a better understanding of complex issues (Ostrom, 2009) and break them down into manageable sets of practical activities. An approved legislative and institutional framework allows the state to determine post-disaster housing policy including housing distribution, tenure ship, construction standards and housing development process. The research develops a

consequential framework that leads to improved knowledge on the relevant attributes that contribute towards post-disaster housing strategy.

II. Issues of Post-disaster Housing

A neighbourhood's housing vulnerability depends on the types of disaster. Disasters like tsunami and flash flood wipe out almost everything on its path, but threats from earthquake, cyclone and flood depend on housing conditions and construction typology as well. A well-conditioned house can survive certain disasters, but a weak house in the same neighbourhood is vulnerable to the same disaster. Thus, the poor and economically deprived people who live in unsafe housing are more vulnerable than the economically privileged people.

Post-disaster housing strategies need to consider technical, social, legislative, economical and institutional issues for a systematic rehabilitation from temporary to permanent housing. The attributes which determine a sustainable implementation of post-disaster housing solutions are;

i. land tenure ship and procurement;

ii. housing ownership including the percentage of rental housing and the extent of physical damage;

iii. legislative framework and institutional norms on land and housing units distribution, construction method;

iv. the willingness of the community to rebuild on the same location;

v. livelihood options associated with the housing's locational proximity;

vi. financial capacity of the community and the state; and

vii. knowledge and capacity of the community and the state.

Access to land identified for temporary or permanent housing is essential as multiple actors may claim concurrent rights on it. Land supply can be augmented through the financial capacity of the state (for outright purchase or lease of land) or legislative capacities such as land acquisition, land banking and land pooling.

Once a disaster strikes a neighbourhood, a survey determines the extent of damage of an individual house. In case of varying damages to housing, the state may distinguish housing that is restorable from the ones which are beyond restoration. An approved technical standard needs to be in practice to certify the housing conditions. Once the housing is classified into restorable and beyond restorable, a survey to conduct housing ownership

and rental housing occupant of those housing reveal the number of temporary and permanent housing requirement.

Disasters such as tsunami and flash flood create widespread destruction irrespective of the housing typologies and conditions. Many survivors fear to rebuild housing in the same location due to psychological and safety issues. Therefore, the housing rehabilitation program needs to recognise the community's views before deciding on in-situ rehabilitation or relocating in a new site.

Livelihoods are not only simple forms of waged employment but also a range of formal and informal activities for obtaining resources (Corsellis & Vitale, 2005). A disaster exemplifies a community's ability to generate livelihood and shrinks its skill development capacity. Some livelihood options require to stay nearby of the housing location e.g. fishers, farmer, unskilled and semi-skilled labour engaged in local enterprises. People belong to such occupation face a dilemma between housing location and livelihood opportunities.

Financial capacity of the community and the state is an important consideration, particularly for emerging economies. Adequate and continuous funding is essential for an effective "build back better" development.

The state and the community's knowledge and confidence to confront the disaster and rebuild life are important psychological and social attributes that lead to developing resiliency. Post-disaster shelter strategy is an important attribute towards resiliency development (Biswas & Puriya, 2020). One objective of housing is to maximize the opportunities for displaced persons to regain their livelihoods and community life. It needs to promote dignity, self-respect and discourage the culture of dependency (Biswas, 2019; Biswas & Puriya, 2020; Corsellis & Vitale, 2005).

III. Framework for Post-disaster Housing Strategies

The focus for the resilient post-disaster housing strategy is to improve subjective well-being of the victims after a disaster. The housing damage has a significant effect on human well-being and happiness of household (or individual), above and beyond human losses. Researches have shown that housing provides physical and mental well-being, in addition to providing the basic need. Among the different age and gender group, it mostly affects the maternal and infant health (Cairney, 2005; Millett, 2020). The impact of emergency housing like informal settlements and emergency shelter degenerate subjective well-being of the beneficiaries (Mitchell, Maccio & Fages, 2018). The extreme consequence of abandoning housing and taking shelter in emergency accommodations further leads to diminishing dignity and falling moral. The conditions further amplify in loss of professional and personal confidence to cope with life's challenges.

The proposed framework that concentrates on minimising time and cost towards recovery contributes to minimising the physical and mental agony of the disaster victims. The framework broadly distinguishes disaster in two categories (Figure 44).

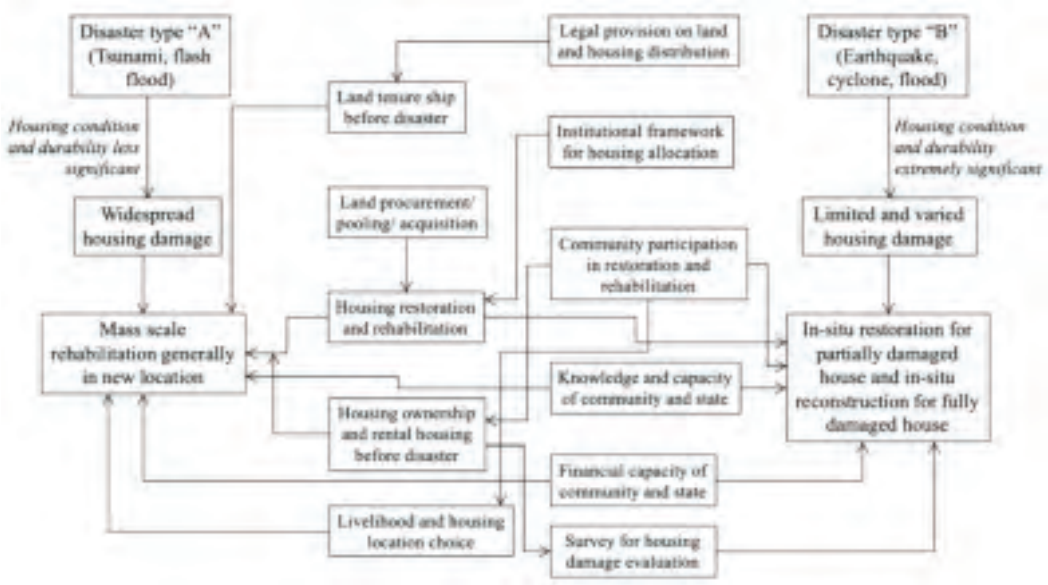


Figure 44: Relationship between the attributes relevant for post-disaster housing location choice (Source: author)

The first category of disaster (type "A") causes widespread housing damage irrespective of the housing condition and durability of individual houses. Tsunami, flash flood and similar disasters exonerate brutal forces to wipe out any settlement on its path. The evidence across the world suggests that it is tough to standardise preventive structural systems for housing against such disasters. The only option to reduce threats from such disasters is to minimise exposure to it. For such devastations, the community faces a dilemma between relocating to a new place to avoid similar threats in the future or rebuild on the same site with additional measures and safeguards. Relocating to a new site depends on extensive community consultation mostly due to its impact on livelihood and sustenance. It is particularly relevant for small traders, farmers, fishers, informal workers, and workforce employed in local enterprises. It is also necessary for the state to source adequate land for rehabilitating the victims. In case the land is not available, appropriate legislative provisions and financial strength of the state and individuals are necessary for land supply.

The next challenge for such cases would be to derive an effective land distribution strategy among the effected people for housing and community services. Appropriate policy and financial capacity are necessary to choose whether to distribute land or housing and the methods for such distribution. A state can adopt land swapping based on the land tenure records or monetisation of land based on the land value of the disaster-affected area. A mutually agreed period between the buyer and seller is necessary to determine the land valuation.

In case the state supply or subsidise housing to the victims, a housing distribution policy is necessary to determine pre-disaster housing ownership and rental housing ratio. At present, India's post-disaster housing policy is non-existent, which follows a diabolical approach of supplying housing to the victims. A study of the 2004 Indian Ocean tsunami reveals such a deplorable post-disaster housing rehabilitation strategy. The housing rehabilitation program aimed at meeting the numbers instead of focusing on the physical, social, economic and cultural necessity of the victims. A house is not only a concrete and bricks ensemble but a place that nurture physical need, familial emotion, cultural expressions and social discourse. A dialogue with the community to understand their need was necessary before the implementation of housing rehabilitation. Even though the housing was supposedly durable than the community's pre-disaster housing condition, many community members did not occupy the housing (Figure 45). It broadly shows the state's top-down bureaucratic and engineering method of solving housing problems and the failure of the state to understand a household's aspirations connected with housing.

Figure 45: New housing by the state over the ruins from the tsunami in Pulicat village, Tamil Nadu (Source: author)

The second category of disaster (type "B") causes limited housing damage to the robust structure and extensive damage to fragile structures. Earthquake, cyclone and flood exonerate less destructive forces compared to tsunami and flash flood (type B). The standardised structural system for housing construction to safeguard failure against type B disasters is common across the world. However, the housing may still collapse or endure severe damage during a disaster. It occurs due to several reasons, e.g. design defect, construction deficiency, use of sub-standard material, and excessive shock beyond the design limit. Once, damage to housing occurs from any disaster; an independent survey is necessary to assess damages to individual houses. The survey distinguishes them based on repairable and beyond repairable categories.

The survey also needs to consider housing tenure ship and rental housing percentage to facilitate housing provision to all irrespective of housing ownership. In case of in situ rehabilitation, the community participation revolves around rebuilding common infrastructure like road, water supply, sewage and drainage; determining the housing damage; and participating in the future roadmap of the community rehabilitation process.

For in-situ rehabilitation, safeguard the community from future disasters are important. It includes both community safety and individual protection. Adequate improvement of building regulations and community protection strategies reduce exposure to future disasters. It also improves a community's resilience to cope with disasters and overcome its consequences in future. The infrastructural improvement needs to accompany with the confidence building measures of the community. Informing about the measures taken by the state and institutions and infrastructural augmentation help to grow confidence among the community members. It is important to develop long time resiliency of the community.

Post-disaster rebuilding process helps to strengthen individual and institutional capacity. Individuals start to consider disaster as a serious threat and begin to enhance knowledge and skills to avoid exposure to such disasters. The role of institutions is very crucial for improving disaster resilient social and physical infrastructure. A standard operating procedure and regular institutional training help people to be agile and alert during the disasters. Countries prone to frequent disasters like Japan and Taiwan institutionalise such measures and benefits from early precautions that save life and property. The institutional capacity, knowledge and skills also help to lead the rehabilitation process in medium and long term.

IV. Conclusion

The paper discusses a framework for the resilient and sustainable post-disaster housing strategy. The framework considers physical, social, economic, institutional and legislative attributes to understand the complexity of "build back better". The paper also refers to an existing case to show the piecemeal approach of post-disaster housing rehabilitation strategy. The top-down, bureaucratic and engineering-led approach does not consider the symbiotic relationship between housing, sustenance and well-being of people. It commodifies housing only as an asset and disregard all other purposes of housing in one's life.

The attributes considered in this framework and the networking between them allow us to visualise comprehensive contextualities related to housing. The framework distinguishes disasters in two categories and derives post-disaster housing strategies for both typologies. In situ rehabilitation poses different consequences than out of site rehabilitation. The paper contributes to developing a comprehensive understanding of post-disaster housing strategy depending on disaster typologies. Consideration of these attributes will help to arrive at a sustainable post-disaster housing strategy. The framework conceptually demonstrates that its potential institutionalisation will help communities to build a resilient society. Moving forward, the framework needs to capture empirical data for its functioning and continuous improvement with validated results. The paper proposes further researches on the framework's application on empirical studies focusing on different disasters.

References

- Corsellis , T., & Vitale, A. (Eds.). (2005). Transitional Settlement Displaced Population. Cambridge: University of Cambridge .
- Quarantelli, E. L. (1995). Patterns of sheltering and housing in US disasters. Disaster Prevention and Management: An International Journal, 4(3), 43-53.
- Félix, D., Branco, J. M., & Feio, A. (2013). Temporary housing after disasters: A state of the art survey. Habitat International, 40, 136-141.
- Biswas, A., & Puriya, A. (2020). Comparative Assessment of Indian Post-Disaster Temporary Housing Strategies. ASCE Journal of Architectural Engineering, 26(1).
- Biswas, A. (2019). Exploring Indian Post-Disaster Temporary Housing Strategy through a Comparative Review. International Journal of Disaster Resilience in the Built Environment, 10(1), 14-35.

- Cairney, J. (2005). Housing Tenure and Psychological Well-Being During Adolescence. Environment and Behavior, 104, 65-71.
- Millett, S. (2020). PEW. Retrieved from https://www.pewtrusts.org/: https://www.pewtrusts.org/en/research-and-analysis/articles/2020/03/18/housing-plays-key-role-in-peoples-health-and-well-being
- Mitchell, A., Macció, J., & Fages, D. M. (2018). The Effects of Emergency Housing on Wellbeing: Evidence from Argentina's Informal Settlements. The European Journal of Development Research, 31, 504-529.
- Ministry of Home Affairs. (2011). Disaster management in India. New Delhi: Government of India.
- Ostrom, E. (2009). A General Framework for Analyzing Sustainability of Social-Ecological Systems. Science, 325, 419-422.

Chapter-12
Eco-friendly Approach for Construction: A Case Study from Uttarkashi, Uttarakhand

Pankaj Khanna, Suhani Gupta and Mohak Gupta

Abstract

This case study introduces a system of building construction through use of environmentally responsible, locally available building materials to enable earthquake-resistant construction. Under a project implemented by Development Alternatives and supported by Department of Science and Technology (DST) titled of ***'Delivery Model for Eco-Friendly Multi Hazard Resistant Construction Technologies and Habitat Solutions in Mountain States, Focus: Uttarakhand'***, the technologies have been demonstrated in a community building at Kamad village in Uttarkashi, Uttarakhand. The building mitigates the use of energy intensive building materials like burnt clay red bricks, cement, steel, sand and promotes the use of locally available materials like stone, soil and chir pine timber in the mountaineous region. It strengthens traditional construction practice of stone masonry by incorporating reinforcement in stone masonry for increased ductility of construction in order to better resist earthquakes. It uses Stabilized Compressed Earth Blocks (SCEB) to replace burnt clay bricks sourced from plain regions and to increase indoor thermal comfort in the predominantly cold climate of the region. Further, it uses precast RCC building elements in place of conventional RCC. It also strengthens traditional timber based construction through the use of wooden truss and roofing shingles made from abundantly available chir pine in the region. The project established a delivery model for local availability of these materials and building elements through both community based production and a building material micro-enterprise in Uttarkashi. Hence, the project demonstrates a way for environment-friendly and disaster-safe construction while at the same time generating economical gains for the local community.

Keywords: Economic growth, Earthquake resistant construction, Local economy, Earthen construction, Timber-based roofing, Local resources

Pankaj Khanna, Suhani Gupta and Mohak Gupta [✉]
Development Alternatives, New Delhi
Email: mgupta@devalt.org

[19]Disaster Risk Assessment of Uttarakhand - State Level Assessment Volume 3A - under Uttarakhand Disaster Recovery project-jointly conducted by DHI Water & Environment (S) Pte Ltd., Asian Institute of Technology, and Evaluacion de Riesgos Naturales, Mexico DF - http://usdma.uk.gov.in/PDFFiles/Atlas_Vol3A_20190131.pdf

I. Context - Uttarkashi

Uttarkashi is situated in the extreme north-west corner of Uttarakhand, bounded with Tibet and Kinnaur district of Himachal Pradesh to its north. The district faces a range of disaster-risks. With majority of the district lying in seismic zone IV, it is highly vulnerable to seismic activity of intensity which can cause heavy damage. According to a study of disaster risk in Uttarakhand, earthquakes and fluvial floods are the two major disaster risks in the region. According to the assessment, "the average annual economic loss, based on the probabilistic assessment of earthquake and fluvial flood risk is about INR 2,545 Crores and that the losses due to earthquake are far more significant, accounting for more than 95% of the total loss.

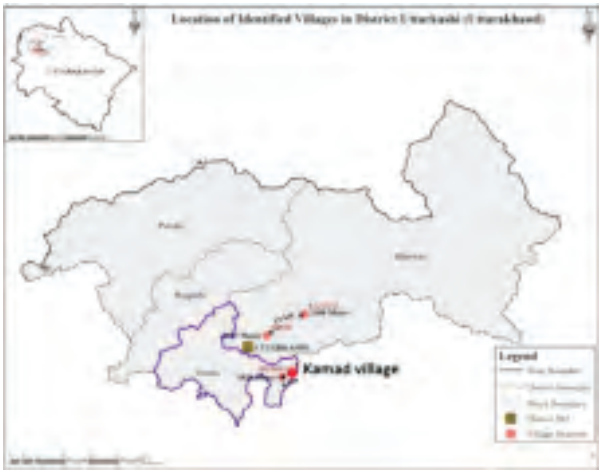


Figure 46: Project Location in Uttarkashi District
(Source: author)

II. Rationale for the project

Construction practices in the mountain regions have been changing rapidly, mainly under the influence of cement-based practices. These are perceived as stronger, particularly to resist earthquakes and the penetration of cement and workforce from plain regions (such as Bihar) have accelerated this change. Also, burnt clay bricks which are transported from kilns in the plain regions (such as Roorkee) are being used as an alternative to traditional stone masonry. **In this context, the key challenges to green growth are increased environmental impact of construction practices, increased seismic vulnerability of the built stock and inability to enhance the local economy through construction**. In response, the initiative was implemented with the following objectives-

- Introducing building technologies which have a lower environmental impact through localized sourcing and production, high compatibility with earth-quake resistant construction and high local economy component.
- Demonstrating the technologies in three buildings chosen in consultation with the village community
- Capacity building of construction personnel in villages for implementing the introduced technologies and in principles of disaster-resistant construction

- Research and assessment of sustainability performance of building technologies

Figure 47: Current construction trends in rural areas of Uttarkashi Left Image - Brick and RCC Slab Construction in Siror Village
(Source: author)

III. Approach - Technology identification and delivery system

1. Technology selection criteria

At the outset, a baseline assessment was conducted in four villages of the Uttarkashi district to understand the local habitat design, current trends of construction and gaps/ shortcomings which make buildings vulnerable in the region. This helped in identifying the key criteria for appropriate technology selection and, subsequently, for evaluation of sustainability of the implemented technologies in the given regional context.

The following criteria/indictors were used for technology selection –

Table 13: Criteria and Indicators for Technology Selection

Sustainability Criteria	Implication
Hazard resistance-Earthquakes and high velocity winds	Structural integrity of building -proxy attribute of technical correctness of prevailing construction
Environmental impact	This is a hybrid attribute combining criticality of resource use and Embodied energy
Local Economy Component	% contribution to village economy
Affordability	Cost of construction of wall/roof and maintenance
Climate responsiveness	Resistance to transfer of heat and cold
Cultural integration	Link with traditional construction practice

2. Building technologies and their rationale for use

i. **Reinforced Random Rubble Masonry -** Stone masonry continues to be practiced in the region, despite increased difficulty in accessing stone for construction. Although the senior masons are aware of the importance of correct placement of stone for more strength of masonry, there is negligible awareness of ways to increase the earthquake resistance of stone masonry through embedded reinforcement. The purpose of introducing reinforcement is to increase ductility of traditional Random Rubble type stone masonry in lean cement mortar. Two types of reinforcement are incorporated - (a) Single bar vertical steel in critical locations- corners, wall junctions and sides of door-window openings, and (b) Horizontal seismic bands with 2 steel bars at the plinth, sill, lintel and roof level.

ii. **Stabilized Compressed Earth Blocks -** SCEB were introduced in the project as a replacement for burnt clay bricks which are transported from more than 200 km away to rural areas. The main raw materials for SCEB - soil and coarse sand are locally available - hence SCEB are a good option for local production of masonry material. SCEB are made by compressing earth/ soil mix by simple mechanical means. The basic concept underlying compressed earth blocks is densification of the soil mix using external energy - this imparts them sufficient strength, eliminating the need to fire them in as kiln, like in the case of burnt clay bricks. One of the biggest benefits of using SCEB in the project was the involvement and leadership of women from the community in producing SCEB.

iii. **Concrete blocks -** Concrete blocks are large sized masonry units made by compacting a well graded concrete mix. Since they can be produced easily using simple moulds, they are already being produced by house-builders in the mountain region, though the quality is very poor due to little awareness of good practice in concrete. The project introduced a small vibrating table and basic tools and accessories for a uniform mix quality. In addition to regular blocks, special blocks with a single cavity were produced for incorporating single bar vertical reinforcement wall using a well graded cement concrete mix.

iv. **Timber understructure and shingle roof -** Chir Pine is one of the most abundant timber resource of many parts of Uttarakhand, including Uttarkashi. However, its potential as a disaster-resistant structural roofing material remains un-utilized. With technical support from Forest Research Institute (FRI) Dehradun, chirpine timber truss for gable roofs and chir pine roofing shingles were introduced in the project. Treatment of timber through dipping wood in a chemical solution is an important part of this technology, which significantly enhances the durability of timber.

v. **Plank and Joist roof slab -** Plank and Joist roof is a system which uses precast RCC elements to construct a flat slab which can also be used as an intermediate floor. It consists of two types of precast structural elements- **Plank** of size 1'x5' functions as a small component of the slab and **Joist** which is a beam (typical section 6x6" till a span of 13') to divide the roof area and to support the planks. The technology is developed and validated by the Central Building Research Institute (CBRI) Roorkee. The technology has been introduced as an alternative to cast-in-situ RCC slab construction. It enables faster construction of roof slabs, eliminates the need for scaffolding support, reduces steel consumption in RCC slab construction by 20% and can be produced easily in a local micro enterprise.

vi. **Precast RCC door window frame -** The traditional use of timber door window frames is today more difficult due to limited access to good quality timber. Steel door window frames have emerged as an affordable option. Precast RCC frames were introduced as a more durable alternative to secondary timber and steel frames.

Figure 48: Building technologies for environment friendly and disaster resistant construction Top left Image -Stabilized Compressed Earth Blocks (SCEB), Top Middle, Image- Concrete Blocks during Production Stage, Top left Iimage - Precast RCC Plank and Joist during installation Stage, Bottom left Image- Chir Pine Timber Shingles, Bottom Right Image of Precast RCC Door Window
(Source: author)

3. Delivery system of building technologies

One of the main aspects of implementing alternative technologies in the project was to establish a system for localized delivery and availability of the building material and the access to the requisite skilled masons to implement the technology. The core of this delivery model is about anchoring the production and delivery services in the local region. This was done at three levels-

i. **Level 1: Community based production and supply** - This training has been divided in two parts - one is ***Production training*** of new building materials and second is ***Mason training*** in disaster safe construction practices. The production training was conducted with local artisans, masons and carpenters from four to five different villages in the region. The artisans were trained in the production of Stabilized Compressed Earth Blocks (SCEB), Concrete Blocks and Timber understructure and shingle roof, Precast RCC Plank, Joist and Door window frames. The mason training was conducted with local masons in which disaster safe construction techniques were theorized and demonstrated in the pilot building.

ii. **Level 2: Construction training and technical support -** This training was majorly conducted during the construction of demonstration building through site supervisor and technical experts at different stages of construction.

iii. **Level 3: Micro-Enterprise training and market support -** the project team has worked with the entrepreneur to develop a business plan, a strategy for product pricing and communication information for product marketing. This training was conducted for hands on support for enterprises by actual production orders to women's groups, enterprises and construction service orders to masons and carpenters.

Figure 49: Left image Showing the Production of SCEB by Women's Group of the Village. Middle image Showing the Production Training of Plank and Joist. Right image Showing the Production and Installation Training of Timber Truss. (Source: author)

IV. Technology demonstration - Design concept and Structural validation

The proposed technologies were demonstrated in the community building located at one of the assessed villages - Kamad village, Uttarkashi. The design consists of earthquake resistant construction techniques followed by the use of all proposed walling and roofing technologies in the building. The structural safety of the given building technologies was essential for architectural design, hence the building has been designed as two independent structures - one single storey and other is a 2-storey structure, keeping the shape and size of the structures and openings into consideration for seismic resistance. Both the structure are combined with a covered corridor and verandah at the ground floor along with Mild Steel (MS) staircase to access the first floor of the building.

The entire design of the building was based on structural guidelines which have been developed for earthquake resistant construction in the country, with focus on non-engineered construction in rural areas. Following documents were consulted at the design stage for structural integrity of building –

i. Guidelines for Earthquake resistant non-engineered construction - IAEE and NICEE (National Information Centre of Earthquake Engineering)

ii. Manual on Hazard Resistant Construction in India - developed under Government of India - UNDP - Disaster Risk Management Programme.

The draft designs prepared on the basis of above guidelines were submitted to an organization National Centre for People's Action in Disaster Preparedness (NCPDP) for Structural Validation of the design. The basis for validating the drawings are provisions of IS 4326:Design and construction of earthquake resistant buildings and IS 13828: Improving Earthquake resistance of low strength masonry buildings-Guidelines. As per IS 4326 this building being a community centre is considered as Category E building, hence design aspects were identified based on the prescriptive recommendations. The design and construction details went through two stages of check and modifications to satisfy requirements for structural safety as specified by NDPDP.

The architectural design of the community building is comprised of a ground floor of total area 482 sqft with - Community hall, kitchen, store and verandah and first floor of total area

389 sqft with - Guest room and terrace. The proposed technologies were used in the following building elements -

- **Random Rubble Masonry with reinforcement:** For Foundation and masonry till sill level
- **Stabilized Compressed Earth Blocks**: For construction of walls

- **Concrete Block**: For construction of walls (2-storey building)
- **Timber understructure and shingle roof**: For construction of the roof (2-storey building)
- **Plank and Joist roof slab:** For construction of the roof (1-storey building)
- **RCC door-window frames :** For all doors and windows

V. Sustainability

A comparative sustainability assessment was conducted for technology against the sustainability criteria - Natural hazard, embodied energy, critical resource usage, local economy component, job creation, affordability and thermal comfort. In this case, values of each sustainability criteria attribute were calculated and normalized using a scale range from 0-10 for comparative assessment. The normalized values generated for each technology under each attribute were plotted to generate technology charts to show an overall sustainability footprint of each technology - 'The bigger the plot area and the more balanced its shape, the more sustainable the building technology'.

Figure 50: Building Drawings of Community Building at Kamad village, Uttarkashi. Top-Left-Ground Floor Plan, Top Right- First Floor Plan, Bottom Left- Front Elevation, Bottom Right-Building Section
(Source: author)

Figure 51: Images of Community Building at Kamad Village, Uttarkashi, Left - Image of 2-storey structure along with Roof of Timber Truss from the Back of the Building, Right Top - Image of the entire building, Right Bottom - Images of Corridor and Verandah of the building with red burnt clay bricks (Source: author)

Stabilized Compressed Earth Blocks

Red burnt clay bricks

Figure 52: Left and right graph showing the comparative sustainability assessment of two walling materials Stabilized Compressed Earth Blocks produced locally available soil and red burnt clay bricks transported from far away plain regions. (Source: author)

VI. Conclusions and learning for replication

The area of habitat and buildings has many crucial linkages to green growth objectives. In the context of mountain regions, the emergence of non-local materials and practices is one of the key issues to be addressed. While at the one hand, it increases the overall carbon intensity of construction, its contribution to disaster-resistance of the building remains minimal. The environmental damage caused by building construction is fueled by disregard for sustainable harvesting of critical resources like sand. The potential for employment opportunities which are anchored in the local economy is an equally important component of green growth. The currently emerging construction practices, with their focus on greater and inefficient use of non-local industrialized materials and dependence on non-local personnel are inadequate in unlocking this social and economic potential.

Capacity up gradation - The experience of introducing the alternative building technologies in Kamad village illustrates some important points about promoting these technologies at scale. Firstly, there is appreciation of technologies which can be produced at the local level by the community itself, as shown in the case of concrete blocks and SCEB which was a completely new material for the community. The team of women who produced the SCEB value the work as it generates an avenue for income for them. The current generation of masons, many of whom have migrated from plains region is mostly trained in brick and RCC construction and negligible understanding of construction principles for earthquake resistant construction. Training of local manpower will continue to be a critical component of not just using new technologies but also to building safe with conventional technologies.

Micro-enterprise potential - There is also good potential for small scale precast concrete building elements such as plank and joist roofing elements and door-window frames. The village community felt it is an advantage to be able to build a small roof slab (for instance 12'x12') in 1 or 2 days with precast elements. The precast elements micro-enterprise established in Uttarkashi has good potential for its products, which have attracted the interest of a home builders and also the PWD in Uttarkashi. There needs to be a government push for these micro-enterprises by facilitating finance for their improved infrastructure.

Efficient use of an abundant natural resource - Timber such as ChirPine is an abundant resource in the region. Even though it is second grade timber, it has great potential for uses in construction with the help of chemical treatment. Leading institutions like FRI, Dehradun have a rich knowledge base of timber based construction but it has been stagnating for many years with no transfer to real projects on land. The local carpenters trained in the project feel that Chir Pine shingles are an excellent alternative to

Corrugated Galvanized Iron (CGI), sheets, provided there is an extension of their treatment and production to the villages. There is an urgent need to strengthen the area of timber-based products for construction in conjunction with the sustainable forest management practices which can ensure long-term supply of timber without negative environmental impact, With the right policy support, supplemented with technical support, the resurgence of timber - based practices can be a strong step in the direction of eco-friendly construction in mountainous regions.

D

Strategic Issues

Chapter-13
Insights into Embankment Safety Assessment using Life Cycle Approach

Shikha Thakur[1], Prerna Yadav[2], Deepanjan Ghosh[3]

Abstract

Any product, or project during its life cycle goes through the stages of procurement of raw materials, its manufacture and usage till disposal. A way to assess the environmental impacts of these stages is the study of its life cycle, called Life Cycle Assessment (LCA). It involves a cradle to grave analyses of production systems which provides us the sum total of all material and energy inputs. The LCAs are carried out to quantify the total environmental costs inclusive of all externalities for a particular product or a project. This approach helps to minimize the anthropogenic impacts with more sustainable endeavours being taken up. In this paper we discuss embankments as a case study which play a role in flood control. Embankment breaches have led to devastating floods, owing to inadequate maintenance. It is important to note that breaches in embankments are an inherent fault in their designs. With the documentation since the colonial era, it is argued in the paper that a comprehensive safety assessment of embankments based on the Life Cycle approach is needed to minimise their overall economic and environmental costs. This is an attempt to suggest a dynamic LCA approach based assessment of embankments to reduce the impact of floods in India.

Keywords: Life cycle assessment (LCA), Embankments, Disaster, Embankment breaches, Floods

[20]Shikha Thakur*(3), Junior Research Fellow, CSIR-NCL, Pune-411008, Maharashtra, India, s.thakur@ncl.res.in

Prerna Yadav^, Junior Research Fellow, IIT-Bombay, Mumbai-400076, Maharashtra, India, yprerna03@gmail.com

Deepanjan Ghosh†, Director G2B Biologics Pvt Ltd, Pune-411037, Maharashtra, India, deepanjan.ghosh5@gmail.com

I. Introduction

Life cycle assessment (LCA) is a methodology developed and designed to assess the cumulative potential environmental impacts in order to augment the overall environmental impact. It is a comprehensive tool developed and designed to minimize the environmental footprint of a project or a product or an infrastructure. It has been developed as a window to Environmental Impact Assessment (EIA). The limitations in monetary and temporal costs have been responsible for it not being a common practice. Despite this, a well thought-out LCA is needed to understand the resource cost in its production, dispersal, and disposal, which would help us understand the environmental costs accrued and move towards a sustainable future.

For centuries, embankments and dams have served as a protective barrier against floods and have augmented irrigation (Kulshreshtha, 2010). They have been built for retention of water for irrigation and drinking water supply, and protect people, land and property from flooding. Most embankments have been built to reduce losses in case of river inflow increase to human settlements. Embankments are raised platforms to limit the river from traversing through the river banks by limiting the width of the river during excess inflow conditions. The physical dimensions of an embankment are location specific, dependent on the flow volume of the river, the height gradient, the flood discharge, and siltation (sediment load of the river). The construction material for embankments generally comprises locally available materials such as sand, soil, and clay. The local human resource is used as labour input for the embankment construction with the project being financed by the state. It is important to note that breaches in embankments are an inherent fault in their designs. The potential breaches and consequent flooding are the primary risks from potential embankment failure (Samuels et al., 2002). Many embankments are highly prone to breaches and augment the risks of disaster as they protect from smaller floods but aggravate the effects of larger ones. The construction blueprint of embankments mostly falls short of the safety standards set, and thus the chances of failure during an unprecedented event of flood are high. The sudden collapsing of the embankments would result in disasters (Dixit., 2009; Rahman et. al., 2013). Population boom and construction activities along the embankments reflects a change in the perspectives of people. These people who live along the embankments have started considering the embankment zones to be safe, forgetting the history of floods and disasters on the river banks (Kulshreshtha, 2010). The most important reasons for embankment breach is sediment deposition and permissible aggregations within the embankments, the possibility of failure is much higher when deposition and aggregation increases (Chitale 2009). When a river is embanked, the sediment/ silt in the flood water gets slowly settled at the bottom thus raising the riverbed gradually. With silting up of the riverbed, the flood water level rises and an increase in embankment height becomes a

necessity. The major challenges with embankment are the fact that they transfer smaller floods rather than failing to stop the floods entirely (Kulshreshtha, 2010).The costly maintenance along with fertile riverbank sediment load deprivation, clogged drainage, silting up the riverbed and increment in flood level, water-logging due to leaks and breaches are often disastrous. These are few of the environmental costs and impacts of unplanned embanking of rivers. Impacts of embankments could be enumerated as limited groundwater recharge and lower soil moisture in areas of shallow flooding. This has implications on agriculture, livelihoods, health, and migration as groundwater has become the mainstay of food and water security in India (Cullet, 2014). Meanwhile there is a reduction in regular flooding for villages inside the embankments but the fatality of large floods multiplies owed to embankment breaches. The reduction in smaller floods reduces the innate capacity of the community to deal with flood events and thus, losses are greater. The marginal section of society is the most affected. For instance, women go through psychological stress owed to miserable conditions when they are displaced to temporary shelters (roadsides or embankments as islands) during the disaster without adequate food or protection. A more thoughtful and thorough design strategy with standard blueprints for the embankments are needed. This is necessary in a country like India which is vulnerable to numerous floods because of the large number of rivers originating either from the glaciers in the Himalayas or the monsoon fed rivers of peninsular India (Wu et al., 2014; Costa 1985; Foster et al., 2000; Allsop et al., 2007). The social impacts of the embankment construction also needs to be put into consideration, so as to have a comprehensive approach for tackling the future disasters. A paradigm shift in mitigating the floods and its consequences is the need of the hour.

Box 1: History of Enbankments in India

In India, the idea of embankments as permanent structures has been traced to 18th century colonial prerogative of insulating the rivers of Bengal. This was a response to defaulting on state taxes because of frequent floods. Embankments emerged as the first structural measure to control, regulate, and subjugate floodwaters. They proved counterproductive with clogged drainage systems, magnified flood heights, and substantial maintenance costs. In the early 20th century decades, a shift away from embankment construction was seen, indicative of the environmental impact i.e. the obstruction of the river's natural flow. After the 1928 Flood Committee Report on Orissa floods, removal of embankments for the drainage of the river was the only ecologically viable, socio-culturally adaptable, and economically feasible option. At the time of Independence, some 5,280 km of embankments existed along the rivers protecting an area of three million hectare. Post the devastating floods of 1954 in the states of Bihar, Uttar Pradesh, West Bengal, and Assam, a three-phased program against floods in second Five Year Plan (FYP) (1956-61) was put-forth. It included construction of embankments, channel improvement, increased ground level of villages and towns, and construction of dams. By the

third FYP (1961-66), 7,000 new embankments were constructed. In fifth FYP (1974-78), the focus shifted to raising the height and strengthening existing embankments. In eight FYP, the proposal was to invest in embankments and flood control works. It was to be done in collusion with employment programs such as MGNREGA of the present day. In ninth FYP (1997-2001), benefits of flood forecasting and warning systems in mitigating loss of life and mobile property were recognized and investments were shifted therein. This is indicative of the shift from purely structural reliance to non-structural forms of mitigation. Though even in the tenth FYP, the structural part dominated. For instance in the state of Bihar, despite the limitations of embankments, the investments in them have been huge, an approximate Rs. 7,460 million since 1955 by the state government on construction and maintenance of 3,454 km of embankments. Still 56.5% of flood victims are from Bihar, the most affected state in India. Yet, there has been no quantification of reduction in vulnerability to flood hazards or marginalization. 'In monetary terms, the state accrued monetary losses from floods have been officially quoted at approximately Rs 9.49 million (1989-90) to Rs 5,147.8 million (1998-99).

Source: Moench and Dixit (2004): Adaptive Capacity and Livelihood Resilience: Adaptive Strategies for Responding to Floods and Droughts in South Asia

II. Embankment associated risks

One of the key deficiencies and gaps in existing national and local disaster management policies as per the World Bank report of 2011 includes an assessment of deficiencies in the key risk mitigation structures such as embankments. River Embankments are the key infrastructure parts of a comprehensive disaster management strategy which encompasses their construction, repair and rehabilitation. They have served as a primary risk reduction factor (Wedawatta et al., 2016). The prevalence of earthen embankments across our country and their chances of breaching at times of higher river inflow eventually lead to the augmented risks of disaster. The construction plan of an embankment rarely satisfies all the testable parameters, and thus the chances of failure during an unprecedented event are significantly higher. The large flood events leading to over-topping and embankment failure results in extensive damage and plain inundation. Embankment failures result in high-velocity river water flow across the flood plain and land degradation with structural damage. With the changing climate scenarios, increased frequency and magnitude of flooding events is being observed (Gilvear and Black, 1999). The problems related to the primary construction material i.e. soil used in embankment construction are its permeability, which determines the percolation velocity of water and thus its stability. The high river current velocity, its incident flow angle and the anthropogenic activities in the surrounding area i.e. agriculture, traffic and construction also add up to the elevated risk of embankment failure (Niederleithinger et al., 2008). Post an embankment failure the protected side is often water-logged as drainage gets blocked, and thus, both sides get inundated. With climate change and other

transformations, the number of natural calamities increased manifold and thus the ability of precise prediction of natural events such as floods declined. The human-induced changes in hydrologic systems, greater economic activity in vulnerable regions, and patterns of development poorly adapted to inherent variability of natural systems.

III. Life Cycle Approach based evaluation of Embankments

The aim of this paper is to use LCA based approach or Life Cycle Approach for an insight in the ingenuities of a disaster owed to anthropogenic activities, we take up embankments as a structural unit whose assessment is imperative to reduce the implications of floods. The role of LCA approach in disaster management is a conceptual approach put forth by the authors to minimize the devastations caused due to floods, particularly when they are becoming increasingly frequent owing to climate change.

The four main phases of our LCA approach are based on the principals of Life cycle Assessment and go as: goal and scope identification, analyzing the inventory, assessing the impacts to be elicited by any project (or product), and ultimately the interpretation of the information obtained. The top-down technocratic approach such as embankments construction rarely functions as envisioned. Common to any other Life Cycle Assessment, the Life cycle approach based study for an embankment consists of previously mentioned four phases.

Firstly, we need to start with defining the goal & scope of the study. In case of studying sand embankment, the goals have to be defined based on whether the embankment is already existing or it is to be made. This is necessary because a lot of current embankments are in dire need of safety assessment and restoration efforts. The study should be focused on the 1) embankment coverage (if it covers the entire length along which it was supposed to be there), 2) being earthen in nature it undergoes wear and tear so the policy build-maintain-rebuild should be applied, 3) proper maintenance of the embankments should be done, 4) inadequate heights of the embankment should be managed based on the flood records maintained and forecasted for the area, 5) communities living outside the embankment protected area and on the embankments should be relocated to safer places.

The goal and scope phase should look at the life cycle of an embankment in its entirety, from its conception to it being there intact and unfailingly during a disaster. The second phase which is inventory analysis should take into account the material and resource inflow. Construction of the embankment would take place by using locally available soil, mud and human labour, this needs to be analyzed and also its consequent effects on the environment. Here we need to extensively catalogue each and every resource used in the project and the particulars of human and financial resources need to be holistically analyzed. Care should be taken to utilize and strengthen the local socioeconomic

resources and pursuits. The various impacts this embankment is going to have over the environment and the nearby communities would be the third phase, called impact assessment. Soil compaction, water spillage, landslides, and ecosystem losses will happen which will account for the impact assessment phase of the LCA approach based study. The communities which will be impacted due to the success or failure of the embankment should also be included in the assessment. The indicative results of all the impact categories should be studied in this phase. Each impact category should be assessed based on normalization and weighting of the individually assessed parameters. The final phase takes into account the interpretation of the complete life cycle of the project (or product) involved. It would also look at the effectiveness of the embankment in safeguarding the local communities against the disasters. Here we should consider both the disasters that may happen due to flooding of the river and the augmented disaster of embankment breaching. The interpretation in this approach is directly connected to all the phases of LCA and we need to consider all of the goals, assumptions, inventory and the associated impacts.

We propose a rigorous study of embankment failure and the associated risks in every LCA approach assessment. The counteractive measures to mitigate embankment failure should be assessed and developed keeping in mind the ways that decrease the socio-economic costs. The study should look at the land-use patterns and the drainage pattern of the river system. It should consider the hydrologic system changes and the current anthropological load on the flood basin. Added protection in terms of provisional spillways connected to pre-existing drainage channels of the river should be given utmost priority. A way out for drainage of water or the water channel should be demarcated based on the natural course of the river and it should not be blocked or occupied under the aegis of anthropogenic activities. Studies on use of alternate materials over the conventionally used soil and mud for embankment building report the ill effects of replacement of the renewable resources. Though new embankment construction designs prefer their use, they have not been proved to be a suitable replacement to the conventional embankment building materials. Ecotoxicity of an alternative material is not always directly at the embankment, but it is associated with processes of obtaining those materials. For example, phospho-gypsum briquettes which are made of phosphor-gypsum is a by-product of the fertilizers industry and cause environmental toxicity at the production facility. Also, for situations wherein a switch over to a new product is to be made, static Life Cycle Assessment based approach doesn't provide us appropriate results. Dynamic LCA based approach needs to be used in those cases whereby the impacts of the alternate can be studied with necessary underlying assumptions with respect to temporal change. Embankments which are originally made to protect people from the disaster, becomes the place of high vulnerability at times of disaster and turns into a fiasco. The socio-

economically marginalised people in the times of calamity use these embankments as their sites of protection, they climb onto the embankments with all their belongings, converting the embankment to a plinth raised village. The dire need to build embankments should be complimented and aided with building up of resilient livelihoods in and around the embankments. The resilience in the community towards embankment breaches and the resultant disasters will ensure that people and the ecosystem recover after the disruption to the normal state of the river and the embankment.

To take this idea of having the mandate to carry out LCA study for embankments forward, we suggest the integration of Life Cycle Assessment based approach in the planning of river embankments and possibly include it into the Indian standard Guidelines for Planning and Design of River Embankments (Levees) IS 12094:2018. Including a Dynamic LCA while doing cost benefit analysis is important and should be considered in determination of the benefit cost ratio (IS 12094:2018). A major limitation in performing an assessment based on the Life Cycle Assessment approach is the complexity and uniqueness of every project and the associated river system. This can be partially simplified by the use of software and mobile applications which can augment the technical understanding of the personnel in the field by simplifying data collection and compilation. This would improve the ease of performing the study and increase its compliance. This data can then be analyzed by an expert panel and used for further planning and management of river embankments. The available monitoring and early warning systems can be used to monitor the embankment in real-time and be fed so as to replicate a dynamic LCA to predict deviations and take necessary actions. This monitoring can be used to augment the Indian standard Guidelines for Construction and Maintenance of River Embankments (Levees) IS 11532:1995 which will provide a real-time risk assessment as well as mitigation plan for disaster preparedness. Incorporation of such systems and policies would be of great benefit and outweigh the cost of carrying out a LCA based assessment for embankments.

IV. Conclusion

Research and administrative systems should be focused on human recovery, learning and adaptability to the conditions, and develop a strong ability to cope up with disasters. In terms of disaster mitigation, a LCA based approach should be used and it should include the socioeconomic compensations and relief costs provided by the government to the affected communities. Reasonable amendments should be interpreted from these studies towards building disaster resilient communities. This would benefit both the environment and the economy in the long run. The counteractive measures suggested to mitigate such disasters should be assessed and developed to increase its longevity and effectiveness.

The technocratic whim of humans to control nature is a predominant cause of many disasters. They happen due to human settlements and activities that have been inconsiderate towards the natural cycles of rain, river flow, tectonic movements, and thereby altering the natural environmental cycles. The increased load on the land resources forces the people to move to the more vulnerable land areas, thus aggravating the magnitude of natural and man-made disasters. The disasters which could have been easily evaded become a challenge to the very survival of humans. As with our current study many embankments built with the sole purpose of protection of human settlements occasionally transition into becoming the cause of disasters because of ill care. The build-maintain-rebuild paradigm should be put forth in place of our build-forget-build attitude. The implementation of the LCA approach based embankment assessment will be a keystone policy in India's disaster mitigation strategy against floods as the systematic implementation of these studies will have incremental de-risking effects. Along with the iterations of the proposed dynamic LCA approach the initial complicacies of the implementation will have a multi-fold impact on embankment safety as well as sustainability. The accelerated growth in technology and connectivity will facilitate in improvement of the current systems and align the flood risk assessment to ensure maximum safety and minimum losses to the citizens of our country.

References

- Allsop, N. W. H. A., Kortenhaus, A., and Morris, M. W. (2007). "Failure mechanisms for flood defense structures." FLOODsite Rep. T04-06-01, FLOODsite Consortium
- ASCE/EWRI Task Committee on Dam/Levee Breaching. (2011). Earthen embankment breaching. Journal of hydraulic engineering, 137(12), 1549-1564
- Broers, J. W., Hoefnagels, F. E. T., & Roskamp, H. L. (1994). Life Cycle Assessment of a Road Embankment in Phosphogypsum Preliminary Results. In Studies in Environmental Science (Vol. 60, pp. 539-542). Elsevier
- Chitale, S.V., 2009. Kosi Disaster – Caution and Precaution, ISH Journal of Hydraulic Engineering, 15:1, 101-107
- Costa, J. E. (1985). "Floods from dam failures." US. Geological Survey Open-File Rep. 85-560, Denver, Colo.
- Cullet P. (2014), Groundwater Law in India - Towards a Framework Ensuring Equitable Access and Aquifer Protection, Journal of Environmental Law, Vol. 26, 55-81
- Floods, Embankments and dams - S.M. Kulshreshtha - Disaster Mitigation: Experiences and Reflections, Editors - Pardeep Sahni, Alka Dhameja, Uma Medury-Eastern Economy Edition, New Delhi, 2010

- Foster, M., Fell, R., & Spannagle, M. (2000). A method for assessing the relative likelihood of failure of embankment dams by piping. Canadian Geotechnical Journal, 37 (5),1025-1061
- Foster, M., Fell, R., &Spannagle, M. (2000). The statistics of embankment dam failures and accidents. Canadian Geotechnical Journal, 37 (5), 1000-1024
- Gilvear, D.J., and Black, A.R., 1999. Flood-induced embankment failures on the River Tay: implications of climatically induced hydrological change in Scotland. Hydrological Sciences- Journal-des Sciences Hydrologiques, 44 (3)
- Levasseur, A., Lesage, P., Margni, M., Deschenes, L., and Samson, R. 2010. Considering Time in LCA: Dynamic LCA and Its Application to Global Warming Impact Assessments. Environmental Science & Technology. 44 (8): 3169-3174
- Moench, M. and Dixit, A., 2004. Adaptive Capacity and Livelihood Resilience: Adaptive Strategies for Responding to Floods and Droughts in South Asia. The Institute for Social and Environment Transition, International, Boulder, Colorado, U.S.A. and the Institute for Social and Environment Transition, Nepal. Nepal 2004
- Muralikrishna, I.V., and Manickam, V. 2017. Environmental Management. Chapter 5, Life Cycle Assessment.
- Niederleithinger, E., Weller, A., Lewis, R., and Lorenz, B. 2008. Evaluation of geophysical methods for river embankment investigation.
- Pehnt, M. (2006). Dynamic life cycle assessment (LCA) of renewable energy technologies. Renewable energy, 31 (1), 55-71
- Quantifying sustainability, Life cycle assessment: the basics. https://www.pre-sustainability.com/sustainability-consulting/lca-methodology-basics
- Samuels, P.G., Morris, M., and Ghataora G. S. 2002. Improving the accuracy of prediction of breach formation through embankment dams and flood embankments. Conference paper
- Schweitzer, F. 2009. Strategy or disaster. Flood prevention related issues and actions in the Tisza River Basin. Hungarian Geographical Bulletin. Vol 58 (1)
- Talukdar, P., Dey, A. 2019. Hydraulic failures of earthen dams and embankments. Innov. Infrastruct. Solut. 4, 42 (2019)
- Wedawatta, G., Kulatunga, U., Amaratunga, D., and Parvez, A. 2016. Disaster risk reduction infrastructure requirements for South-Western Bangladesh- Perspectives of local communities. Built Environment Project and Asset Management, Vol. 6 (4): 379-3290
- Wu, D., Jin, L., Peng, J., Dong, Y., & Liu, Z. (2014). The thermal budget evaluation of the two-phase closed thermosyphon embankment of the Qinghai - Tibet Highway in permafrost regions. Cold regions science and technology, 103, 115-122.

Chapter-14
Analysing the Indian Integrated Paper and Pulp Industry through a Circular Economy Lens

Urviya Hasan

Abstract

Implementing an efficient mechanism to manage our wastes and effluents is incredibly crucial in order to work towards a sustainable future. Circular economy targets a system of reusing beneficial materials, which would otherwise be disposed of as waste, in an effective manner in order to reduce the amount that reaches the landfill or ends up in the rivers. The Integrated Paper and Pulp industry provides an opportunity to implement this methodology in its processes. With various organisations using Depithed bagasse and waste paper as raw materials for making pulp, the amount of forests that needs to be deforested has been reduced significantly. Similarly, the waste produced from its operations (such as fly ash, lime grit etc.) is being used as a raw material in the integrated cement industries to reduce the overall impact on the environment. Besides initiating several plantation schemes, the use of bioenergy derived from natural resources is also being seen increasingly in various Indian industries. This paper sees to highlight the efforts being undertaken by various paper and pulp organisations to incorporate the concept of circular economy in their actions and if it has proven to be successful in reducing its imprint on the environment.

Keywords: Circular economy; Sustainable; Paper and pulp; Cement

[21]Urviya Hasan [(✉)]

(Urviya.h@gmail.com)

(of a material, substance, or by product) eliminated or discarded as no longer useful or required after the completion of a process.

I. Introduction

Waste[21] is an unwanted by-product of any process. It is usually disposed of after primary use. With the increase in demand of various products, the amount of waste generated too has increased significantly - leading to an increase in the air, water and land pollution. According to certain estimate - one A4 size sheet of paper requires approximately 10 litres (The World Counts, n.d.) of water to manufacture. Paper and paper products are also responsible for close to 26% of the waste in landfills (The World Counts, n.d.). These pollutants cause serious environmental impacts and can be extremely hazardous in their composition. Proper management and handling of such waste are a critical aspect of sustainable development. India has developed several guidelines such as the Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008 and The Air Prevention and Control of Pollution) Act, 1981 in order to keep a proper handle on the effects of such industries.

The Paper and pulp industry is regarded as a highly polluting industry. It is extremely water-intensive, leads to deforestation and produces a large amount of pollutants. Paper and Pulp industry has often been at the epicentre of several sustainability debates in India and globally over the years. It is extremely important that cleaner technologies are adapted which are more effective in integrating Environmental, Economical as well as Social aspects in the overall functioning of this industry. This requires that a thorough analysis of the mechanisms as well as processes prevalent in this industry be done in order to identify which processes are the most polluting and how we can replace them with cleaner technologies.

India has over 700 paper and pulp mills (Sadia & Ashfaq) producing over 25 million tonnes of paper in a year (ASSOCHAM, 2018). It is a highly in-demand industry and hence the production has been constantly increasing (ASSOCHAM, 2018). This increase in production has led to a string of environmental impacts which need to be addressed immediately and properly mitigated using better technologies. This paper aims at integrating the fundamentals of circular economy and viewing if any of these by-products can be utilized in other industries.

II. The Indian Paper and Pulp Industry

Figure 53: Paper and Pulp Industry in India
(Source: author)

The Indian Paper Industry is responsible for close to 4% of the total paper produced in the world (IPMA, n.d.). Having a turnover of almost 70,000 crore INR, this industry provides indirect employment to over 1.5 million people (IPMA, n.d.).

The Indian Paper industry is close to a century old. The first paper mill was set up in West Bengal in 1812. However, it was later shut down, but the oldest standing paper mill in India is Royal Paper Mill, established in 1867 (Bhilani, n.d.). These paper mills undertake old to modern techniques of creating paper and utilise different types of raw materials such as wood, bamboo, bagasse, wheat straw etc. Based on the current spread, approximately 58% of the current paper mills run of recycled material while about 25% use wood as raw material, the rest 17% use agro-based residues such as bagasse. (IPMA, n.d.).

Although, India's per capita paper consumption is about 13 Kgs with the global average being 57 Kgs, it is fast becoming one of the largest markets for paper globally. (IPMA, n.d.)

There are many different types of papers that are produced in Paper Mills. This can include Printing/Writing paper, Packaging/Paper board, Newsprint and Speciality paper among others. The major demand for these papers comes from the educational sector as well as FMCG for packaging.

III. Process of Making Paper

There are several steps involved in the manufacturing of paper. These include (Pulp and Paper Manufacturing Process in the paper industry) –

i. The fibres are separated and clearing during the Pulping process. This can be done by using Kraft's process.
ii. The residual then enters the Refining Stage
iii. The next step involves Diluting to form a thin fibre mixture.
iv. They are then placed on a thin screen which leads to the formation of Fibres.
v. The mixture is then pressurised. This enhances the density of the material.
vi. The mixture is then Dried
vii. The mixture is provided with a surface to get a finishing touch

IV. Environmental Impacts of Paper and Pulp Industry

The Indian Paper and Pulp industry has several measurable impacts on the environment. These can be majorly clubbed into three categories – Air Pollution, Water Pollution and Land Degradation.

Air Pollution -

Air Pollution is caused due to the harmful gases and pollutants which are released during the paper making process. They are mainly released from the digesters, evaporators as well as during recovery. We can further divide them into two separate categories -

1. Gases

i. Compounds of sulphur such as mercaptans and H_2S (Hydrogen Sulphide). These are known to have significant health effects such as headaches as well as difficulty in concentrating by those that come in contact with it (Kangas, Jappinen, & Savolainen, 2010). They are mainly found during evaporation and Kraft's process.

ii. Various Oxides of Sulphur (SOx) and Nitrogen (NOx). These are known to be a major cause of acid rain. These are mostly found near the lime kiln as well as Kraft's process (Anderson, 2017).

2. **Particulate Matter**

   i. Fly ash is one of the harmful pollutants produced in the paper and pulp industries. They are majorly released from the power boilers. They can cause severe respiratory problems to people who are exposed to it. Being light and small in size, it can easily be breathed in and can cause inflammation in the lungs which can in severe cases prove to be fatal (Evans, 2014).

   ii. Sodium and Calcium based particles are extremely harmful. While sodium particles such as sodium sulphate and sodium carbonate are released during the recovery furnace and lime kilns, calcium carbonate and calcium oxides are a major by-product of the lime kilns. While sodium sulphate is a known irritant and can cause respiratory ailments, calcium oxide can prove to be very harmful for the aquatic animals. (Environmental Protection Agency , National Council of the Paper Industry for Air and Stream Improvement, 1973)

   iii. Char which is released from the bark burning process. (Sadia & Ashfaq)

Water Pollution -

Water is a very integral part of the paper manufacturing process. It is estimated that almost 100-250 m^3 of water is used per tonne of paper produced. (Tewari, Batra, & Balakrishnan, 2008). Water is used for almost all the processes involved in the manufacturing. The following are the most common water effluents found in the waste streams generated-

1. Dyes and lignin compounds. These are known to reduce the sunlight absorption capacity of the water bodies by creating a film on their surface. This has a significant impact on aquatic life. (Hassaan & Nemr, 2017)
2. Inorganic Chemicals such as NaOH, Na_2SO_4 etc. as well as bleach can severely reduce the potability of the water.
3. Solid particles such as discarded fibre, pigments, dirt etc. can prove to be extremely harmful for aquatic life.
4. Colloidal organic chemicals such as alcohols, adhesives, sugars, turpentine etc. can lead to high Biochemical Oxygen Demand (BOD) as well as high Chemical Oxygen Demand (COD (Singh & Singh, 2019)).
5. Toxic Chemicals such as compounds containing chlorine pose severe health risk if consumed. (FilterWater, 2016)

Land Degradation -

Land Degradation caused by Paper and Pulp Mill can be further studied in two categories-

1. **Solid Waste Management**
   i. Solid particles such as grit, fibre, dregs, bark etc. along with other mill wastes. If not disposed properly can lead to soil degradation.
   ii. Sludge is released from the primary as well as the secondary treatment and the Kraft mill recovery process. The sludge can leach into the soil and hence needs proper treatment before disposal.
   iii. Ash is released from the coal fired broilers. The ash contains silica components and has been identified as carcinogenic if exposed for a long duration. (Afework, Hanania, Stenhouse, & Donev, 2018)
   iv. Discarded Paper is a major waste which is found at landfills. Although biodegradable, they need to be rid of various dyes and other agents in order to be properly recycled - owing to which they are known to remain at landfills for many years.

2. **Deforestation**

Deforestation is a major global cause of greenhouse gas emissions. Wood being one of the primary raw materials for paper production has led to cutting of trees across the world. Although many large mills have now adopted sustainable forestry, with forests certified by Forest Stewardship Council (FSC) or Rainforest Alliance (RA) among others, there has still been a significant rise in irresponsible and illegal logging. Deforestation also leads to severe soil erosion and loss of biodiversity. (Matthews, 2016)

V. Circular Economy

Since time immemorial, we have been using a linear model of economy which involves making, using and then disposing of the products. This has led to a high amount of waste generation and is proving to be extremely unsustainable. Circular economy has been developed as an alternative to this model which looks at Making and then Reusing / Recycling. The idea is to reduce the amount of waste that ends up at the landfills and instead derive innovative applications of the waste generated to increase their lives or use them raw materials for other products. This has given birth to the concept of Waste to Wealth.

Several of the by-products which are generated during the manufacturing process are being used as a raw material in the production of other products leading to reduced waste. The following are some methods by which Circular economy can be implemented in the Paper and Pulp Manufacturing Process. They can be further divided into -

1. **By Products of Paper Manufacturing process used for other purpose**
   i. Production of Cement - The lime generated from converting wood to pulp by using sodium hydroxide can be used as a replacement for extracted limestone as this is relatively contaminant free. (University of Georgia College of Agricultural and Environmental Sciences, Cooperative Extension Service, along with the Pollution Prevention Assistance Division., 2017) Further, other by-products such as Fly Ash as well Dregs and grits are known to improve concrete performance by increasing its strength and durability. Limestone is one of the key components of producing cement. It is otherwise blasted or excavated from open quarries which itself is a highly polluting process.
   ii. Production of Leather - Syntans are used in the leather making process to improve its physical as well as chemical properties. They also provide antimicrobial properties to the leather. They are usually derived synthetically, however, studies have shown that Syntan A and B can be derived from the non-acidic as well as acidic components in Black Liquor Solids. They are similar in size and structure as commercial phenolic syntans (Balasubramanium, et al., 2018).
   iii. Production of Brick - Studies have shown that a fly ash as well as lime can be used as raw material in brick kilns for the production of bricks. A 55% fly ash, 30% sand, 15% lime and 14% gypsum composition is optimal for generating an industrial grade brick which can be ideally used as a construction material (Banu, Billah, Gulshan, & Kurny, 2013).
2. **By Products of other Industry utilised in Paper Manufacturing**
   i. Bagasse - This is a by - product of the sugar manufacturing process. Bagasse is leftover when sugarcanes are processed to make sugar. They account for close to 30-40% of the total waste generated in this process. Residual bagasse has a structure which is similar to the structure of hardwoods like eucalyptus which are the most common type of wood used for paper production. Depithed Bagasse pulp is increasingly being used instead of wood-based pulp in many mills across the country. (Mzimela, Mochane, & Tshwafo, 2018)
   ii. Agro-fuel - During the process of cutting trees for logs, there is a lot of residual pith and wood dust which is generated. This can be used in the chemical pulping or mechanical pulping process. (DDS Calorimeters, n.d.).
   iii. Waste Paper - Waste Paper which is usually taken to the landfills can be recycled as utilised in producing pulp after some processing. In India, only 20% of the wastepaper is collected while the rest ends up in landfills of which about 30% is recycled. Integrating this approach will prevent their accumulation in landfills. (Ravindranath, 2015)

3. **By Products of Paper and Pulp Industry utilised within Paper Manufacturing**

   i. Black Liquor Solids - Black Liquor solid (BLS) are a by - product of the Kraft recovery proces.. Pulp mills these days reuse the BLS as a fuel in recovery boilers leading to the production of steam to power the machines.

   ii. Paper Sludge as well as recovered paper - These can be used as fuel by combustion. The calorific value of the paper sludge needs to measure for proper combustion. The recovered or mixed recycled paper can be easily separated from the waste stream and has high heating value. It also leads to low sulphur and NOx emissions. (DDS Calorimeters, n.d.)

   iii. Wastewater - The water that is used during the processes for washing of materials can be treated and reused in irrigating the gardens or sustainable forestry. They can further be used in toilets as well as other housekeeping activities.

VI. Impact of Circular Economy on Paper and Pulp Industry

Introducing the concept of circular economy throughout the manufacturing process will lead to various positive effects.

i. Less Pollution - The amount of exhaust fumes and particulate matter that reached the atmosphere and caused global warming will be significantly reduced. Substances like Fly ash which otherwise are very harmful in nature can be removed from entering the environment.

ii. Cleaner Water Bodies - The removal of sludge from the waste streams will reduce the risk to aquatic life and give rise to cleaner water bodies.

iii. Saving Water - Reusing wastewater in housekeeping and irrigation purposes will significantly save water.

iv. Less deforestation - Using materials such as bagasse and waste paper for the pulp making process will reduce the consumption of wood in the process.

v. Soil Erosion - Deforestation was a major reason for soil erosion. A reduction in deforestation will lead to a subsequent decrease in soil erosion.

VII. Circular Economy and Climate Change

Climate Change is increasingly becoming a matter of concern for all industries. Each industry has to be extremely critical of how their actions can negatively impact the environment. According to a recent report (; Material Economics, 2019) authored by Ellen McArthur Foundation, there are 3 key principles which can help the circular economy, combat climate change.

1. Design products and systems to avoid emissions-producing waste and pollution from the very beginning

The first step of the process begins from the procurement of raw materials. Using materials which have a lower emission can reduce the overall footprint of the operation. In the case of Paper and Pulp, one of the most crucial raw materials is wood. This can be replaced with agro-based products such as bagasse. Bagasse is a by-product of the sugar industry and it can be used to produce pulp for the paper making process.

The Seshasayee Paper and Pulp Industry (Das, 2020) is primarily a paper mill which later diversified into a sugar mill. The bagasse produced from the sugar mill is used as a raw material for producing the pulp in the paper mill. Similarly, Tamil Nadu Newsprint and Paper Limited (About TNPL, n.d.) has also replaced the majority of their wood-based pulp with bagasse- based pulp. Moreover, several mills such as ITC Paper Mills (Gupta, Surjeet Das, 2006) are using waste paper as a substitute for wood.

2. Reduce Consumption of Raw Material

The main idea is to reduce the consumption of virgin raw materials. Using the same product in different ways in order to prolong its usage as well as reduce the inflow of new material will help control the overall footprint of the process. The industry has to be creative in deriving maximum benefit from the materials already a part of the process.

Bagasse is a useful raw material for making pulp as well as a biofuel. Similarly, saw-dust and waste pulp can also be reused as a source for energy. The Tamil Nadu Newsprint and Paper Limited use several agro-based materials as a source of energy. Similarly, Seshasayee Paper and Board Limited use Bagasse pith for fuel. While Emami Paper Mills Limited (Compliance to MOEf Conditions) uses waste pulp as a co-fuel, West Coast Paper Mill (Environmental Statement) uses sawdust. This helps reduce the consumption of raw materials with a higher footprint such as coal.

Several by-products of the paper and pulp industry can also be reused in other industries as raw material for their processes. Fly ash and lime produced during paper manufacturing is being used in brick and cement manufacturing respectively by ITC Paper Mills. Emami Paper Mills Limited reuse the boiler ash in manufacturing bricks and road constructions. The ash generated during paper manufacturing by West Coast Paper Mills is being used in manufacturing bricks and filling abandoned mines.

Moreover, paper and pulp is a highly water intensive industry. The wastewater generated during the process can be reused for other in-house operations. ITC Paper Mills recycle used water for irrigation and housekeeping operations. TNPL recuses wastewater in irrigation processes. Seshasayee Paper and Board Limited has set up a deal with several sugarcane farmers to provide treated wastewater for irrigating their farms.

3. Employ agricultural methods that regenerate ecosystems and sequester carbon in the soil.

Agricultural methods have very low emissions. The industries need to utilise agro-based techniques to limit their footprint. Taking up plantation schemes as well as signing on with farmers to develop better practices.

TNPL has taken the initiative to undertake several plantation schemes to become self-reliant in wood procurement. Emami Paper Mills Limited uses ETP sludge as manure in their belt development.

VIII. Conclusion

Circular Economy can act as a crucial tool in order to mitigate the challenges being faced by the paper and pulp industry. With several mills already taking the initiative, their overall footprint has been significantly reduced. In order to fully analyse the situation, we can broadly divide it under the banner of sustainability and critically assess each pillar of the Triple Bottom Line Approach.

1. Economic - One of the most major costs handled by the mills is the procurement of raw materials. By recycling their by-products as well as reusing certain material, they can very well have a positive impact on their overall spending. Moreover, several mills sign long-term deals with sugar mills to use their waste (bagasse) as a raw material.
2. Social - By integrating farmers as well as nearby communities, the mills help to generate income-based activity for them. This further helps strengthen the socio-economic climate of their region.
3. Environment - Plantation schemes will help sequester carbon. Moreover, recycling will help reduce the amount of waste being generated. The lower emission will lead to lesser pollution. Overall, having a positive impact on the environment in general.

Circular Economy is the future of doing better business. It can be clearly seen that the current linear model will not be able to derive positive long term results.

References

- About TNPL. (n.d.). Retrieved from TNPL: https://www.tnpl.com/About-us
- Afework, B., Hanania, J., Stenhouse, K., & Donev, J. (2018, September 3). Bottom Ash. Retrieved from Energy Education: https://energyeducation.ca/encyclopedia/Bottom_ash
- Anderson, S. (2017, November 27). NOx and SOx – What's it all about? Retrieved from Dixon: https://blog.dixonvalve.com/nox-and-sox-whats-it-all-about

- ASSOCHAM. (2018, February 27). Indian paper industry is likely to touch 25 MT by 2020: ASSOCHAM. Retrieved from assocham.org: https://www.assocham.org/newsdetail.php?id=6771
- Balasubramanium, P., Vedhanayagam, M., JayaKumar, G., Sreeram, K., Rao, J. R., & Nair, B. (2018). Studies on Paper and Pulp Industry Waste for Leather Making: An Insight in Converting Waste to Wealth. Waste Management and Resource Efficiency.
- Banu, T., Billah, M. M., Gulshan, F., & Kurny, A. (2013). Experimental Studies on Fly Ash-Sand-Lime Bricks with Gypsum Addition. American Journal of Materials Engineering and Technology, 35-40.
- Bhilani, D. B. (n.d.). Indian Paper Industry and its Challenges. Retrieved from Inpaper International: http://www.inpaper.com/magzines/inpaper/apr-june-y1k/c-pro-drbihani.htm
- Compliance to MOEf Conditions. (n.d.). Retrieved from Emami: emamipaper.in/downloads/moef-%20from-oct'13-ar'14.pdf
- Das, T. K. (2020). Industrial Environment Management. John Wiley and Sons Inc.
- DDS Calorimeters. (n.d.). Pulp & Paper Mill - Energy from Biomass in Paper Mill. Retrieved from DDSCalorimeters: https://www.ddscalorimeters.com/energy-from-biomass-in-pulp-paper-mills/
- Ellen McArthur Foundation; Material Economics. (2019). Completing the Picture: How the Circular.
- Environmental Protection Agency , National Council of the Paper Industry for Air and Stream Improvement. (1973). Atmospheric Emissions from the Pulp and Paper Industry. North Carolina: Environmental Protection Agency.
- Environmental Statement. (n.d.). Retrieved from West Coast Paper Mill: http://westcoastpaper.com/images/docs/Env%20Audit%20Statement%202011-2012.pdf
- Evans, L. (2014, July 31). Ash in Lungs: How Breathing Coal Ash is Hazardous to Your Health. Retrieved from EarthJustice: https://earthjustice.org/blog/2014-july/ash-in-lungs-how-breathing-coal-ash-is-hazardous-to-your-health
- FilterWater. (2016, December 29). The Harmful Effects of Chlorine in Water. Retrieved from FilterWater.com: http://www.filterwater.com/t-articles.harmfuleffectsofchlorine.aspx
- Gupta, S. D. (2006, February 11). Waste to Wealth. Retrieved from ITC: https://www.itcportal.com/media-centre/press-reports-content.aspx?id=534&type=C&news=Waste-to-wealth

- Gupta, Surjeet Das. (2006, february 11). Waste to Wealth. Retrieved from ITC: https://www.itcportal.com/media-centre/press-reports-content.aspx?id=534&type= C&news=Waste-to-wealth
- Hassaan, M. A., & Nemr, A. E. (2017). Health and Environmental Impacts of Dyes: Mini Review . American Journal of Environmental Science and Engineering, 64-67.
- IPMA. (n.d.). Overview. Retrieved from ipma.co.in: http://ipma.co.in/overview/
- Kangas, J., Jappinen, P., & Savolainen, H. (2010). Exposure to Hydrogen Sulfide, Mercaptans and Sulfur Dioxide in the Pulp Industry. American Industrial Hygiene Association Journal, 787-790.
- Matthews, D. (2016, October 12). Sustainability Challenges in the Paper Industry. Retrieved from ChEnected: https://www.aiche.org/chenected/2016/10/sustainability-challenges-paper-industry
- Mzimela, Z., Mochane, M., & Tshwafo, M. (2018). Sugarcane Bagasse Waste Management.
- Pulp and Paper Manufacturing Process in the paper industry. (n.d.). Retrieved from Paper and Pulp: https://www.pulpandpaper-technology.com/articles/pulp-and-paper-manufacturing-process-in-the-paper-industry
- Ravindranath, S. (2015, February 16). Wealth from Waste. Retrieved from Financial Express: https://www.financialexpress.com/opinion/wealth-from-waste/43315/
- Sadia, A., & Ashfaq, A. (n.d.). ENVIRONMENTAL MANAGEMENT IN PULP AND PAPER INDUSTRY. Journal of Industrial Pollution Control.
- Singh, R. L., & Singh, R. P. (2019). Advances in Biological Treatment of Industrial Waste Water and Their Recycling for a Sustainable Future. Uttar Pradesh: Springer.
- Tewari, P., Batra, V., & Balakrishnan, M. (2008). Efficient water use in industries: Cases from the Indian agro-based pulp and paper mills. Journal of Environmental Management, 265-273.
- University of Georgia College of Agricultural and Environmental Sciences, Cooperative Extension Service, along with the Pollution Prevention Assistance Division. (2017). Land Application of Pulp Mill Lime Mud. Georgia.

Chapter-15
Disaster Risk Management and Role of Education: Examining Teachers' Understanding

Shalini Dixit and Gargi Sehrawat

Abstract

Disaster risk management (DRM) requires a holistic approach with covers societal attitude and economic policies. Instead of addressing disasters in isolation it requires working at the individual and collective level towards a sustainable society. Education, especially the teachers, are ideal sources to develop climate sensible behaviour in students and bring awareness about disaster risk in society. However, research in this direction has systematically missed individual attitude and behaviour. We have very little understanding about how the education system and teachers are responding to this call in India. Therefore, the present study was designed to explore the knowledge and classroom behaviour of teachers regarding sustainability and disaster risk (DR) awareness. Interview and observation schedules were designed to reveal the awareness and classroom behaviour of teachers. Thirty-five teachers from two schools in Bangalore, were interviewed and observed in their classroom. Teachers' responses and classroom observations were analysed. The results revealed that teachers narrowly understood sustainability as 'saving the environment' by reducing pollution and conserving water. Moreover, there was a mismatch between teachers' responses to the questions and their classroom behaviour. The findings of this study provide insight into the required modification in teacher education and curriculum to achieve education for sustainable development and DRR.

Keywords: Education for sustainability; Sustainable development; Disaster risk awareness; Teachers' understanding

[22]Shalini Dixit (✉), Ph.D Assistant Professor,
Gargi Sehrawat, Research Associate
School of Social Science, National Institute of Advanced Studies,
Indian Institute of Science (IISc) Campus, Bangalore
e-mail: shalinidixit3@nias.res.in, shalinidixit3@gmail.com

I. Introduction

Science has given concrete measures and indicators of deteriorating ecosystems. The construction and developmental activities undertaken by human are exploiting the natural resources. The emissions caused by human activities produce greenhouse gases which trap the heat of the earth making it warmer than before. The retained heat and the atmospheric aerosols alter the climatic conditions of earth. With the changed in the structure of living and land usage, the green cover of the land has reduced considerably. Such changes in land usage has also increased the amount of heat that is reflected back into the atmosphere. The increasing global surface temperature brings the possibility of more droughts, melting glaciers, and storm like conditions. It causes many other impacts such as, rising sea levels and increase in wind speed in tropical storms etc. These extreme conditions turn into disasters like earthquakes, storms, and drought. Thus, the increase in global temperature has made its impact on physical and biological systems also causing displacement in search of livelihood and better living conditions. Though there are philosophical debates about the role of economic activities and political decisions having damaged the environment. It is true that traditionally trade and economic activities have directly exploited the environment and have caused damage to climate. At the same time societies want 'growth' and 'development' resulting in better living conditions. Thus, climate change becomes a complicated concept, difficult to define in the form of sustainable development. Nevertheless, the initial premises of sustainable development are unanimously agreed upon: the assertion that human activities have led to drastic change in climate over the past decades. Several international and national agencies, government and non-government bodies are in consensus with the urgency of the need to control climate change though a regulated and sustainable development.

II. Climate Change and Disaster Risk Management

Natural disasters and catastrophes pose a major challenge for sustainable development. Conditions like degrading ecosystems further cause a risk to people and assets, that impact both, Sustainable Development and Disaster Risk Management. Increasing natural disasters caused due to climate change like, droughts, heat waves, floods, will impact education provisions and livelihood, which will in turn affect education (Bangay and Blum 2010). Das (2010), gives the evidence of these impacts in his study in Bangladesh. Cyclone Sidr (2007) destroyed 74 government primary schools and damaged nearly 9000 which affected the education of over one lakh students. Cambodia floods in 2000 destroyed 18 percent of the country's schools.

Having acknowledged the urgency of the matter, the question is where to start. Ibrahim et al. (2013) suggest that instead of having an event based reactive approach, countries should adopt disaster risk management (DRM) model for better preparedness and

response to it. This model suggest working at multiple levels, including country specific pre-disaster management and post disaster resilience building.

This approach focuses on adopting sustainable economic policies (prevention), thereby reducing the risk of disaster. Along with the sustainable practices, this model proposes pre-disaster activities such as, mitigation, adoption, readiness and post-disaster activities such as relief, restoration and rehabilitation. The path and goal of such an approach is nothing else than sustainable technologies and pathways. Figure 1 shows the said DRM model.

Figure 54: Showing the neo-Disaster Risk Management - Sustainable Development Model, which gives equal importance to 'risk reduction' and 'resilience enhancement:
(Source: Ibrahim et al., 2013)

III. Why Education for Sustainability is Crucial for Disaster Risk Management?

At both the stages of disaster management, prevention and recovery, education has a vital role to play. Apart from having better economic resources educated people can perceive a risk and act in a better way, given that they have access to more knowledge compared to an uneducated person. In a study conducted in Thailand villages after the 2011 Tsunami and earthquakes Muttarak and Pothisiri (2013) found that only 29.4% of the people with no education or with only elementary education were prepared, whereas 41.2% of the people with tertiary education were prepared. Non-formal education also play a key role in enhancing preparedness, which include community-based training. The informal training passed on in communities increases preparedness. It is also evident how empowering and educating women can have a positive effect on the community, and also reflects the positive impact of education on reduced vulnerability.

Various agencies have expressed need for proactive risk reduction measures. The 2006 campaign of UN International Strategy for Disaster Reduction (UNISDR), focused on incorporating DRR in the school curriculum along with ensuring safe educational infrastructure. At the Third UN World Conference on Disaster Risk Reduction, the main problem discussed was population growth, environmental degradation and climate changes which have led to natural disasters. The conference highlighted the need to integrate the disaster risk reduction into economic development for a sustainable future. Following the Tsunami, DRR education became quite popular in Japan with various characteristics that are unique to their system. Given the number of natural disasters Japan witnesses the type of DRR education provided varies based on the region.

Case studies from various countries show that the most common approach adopted to spread DRR knowledge is to integrate it in disaster related themes in specific school subjects. Moreover, the pedagogy adopted for such modules usually lacks application-based methods (Selby and Kagawa 2012). Keeping DRR only as a sub topic (and not as a focus theme) with poor teaching method cannot be expected to yield any results. As Ibrahim et al., (2013) recommend it is important to place these discussions in a broader context of sustainability. This argument in support of Education for Sustainable Development (ESD) has been propounded by several research organisations including the united nations. In 1992, the Earth summit in Rio, proposed to include sustainable development in education (Chapter 36, Agenda 21), Later, at the 57th UN assembly, Japan proposed to dedicate an entire decade to ESD and call it the UN Decade of Education for Sustainable Development (UN-DESD). It focuses on individual attitude and behaviour as psychological processes are involved in the decisions taken while acting upon our

[23]Abbreviations: disaster risk management (DRM); Sustainable Development (SD); Education for Sustainable Development (ESD)

environment (Fabio and Rosen 2018). Since attitudes and values towards the environment depend on the upbringing and the nature of social interaction, the World Conservation Strategy (WCS) called for changes in the attitudes and values through education (Martin 1990). Inclusion of DRM and SD in the development policies will help reduce disaster impacts, thereby directing us towards disaster resilience. The UN SDGs include the discussion on DRR under Goal 11 (making cities and human settlements inclusive, safe, resilient and sustainable), and Goal 13 (taking urgent action to combat climate change and its impacts) (Shabudin et al., 2017; United Nations 2015). Having said that, DRR is an indispensable part of SD and should be assumed to be so in this paper, wherever SD is mentioned.

The above discussion highlights that education can be a starting point to collaborate ESD and DRR. It is an undisputed fact that the school plays a huge role in a student's life, in laying the foundation of environmental ethics as these habits, values and attitudes (Shohel and Howes 2007). A student will protect a commodity, person, place, if they have a sense of belonging towards that or them. This may happen when the person is actively engaged or involved with the place or commodity. Therefore, the school should provide opportunities to the students to engage with the school surrounding, to nurture a sense of belonging towards school. This feeling of belonging when imbibed in them from school, will be carried forward by them to the places they move globally, which in turn will result in them being sensitive towards their society and planet. ESD can help us in moving towards a more sustainable economy that also conserves the means and conditions of production. A sustainable economy will have social and economic stability and sustainability by protecting and enhancing the support systems that it depends upon while also bringing harmony among citizens (Robinson et al., 1990). According to Huckel and Sterling (1996), the role of education in forming a sustainable society is crucial and obvious as in a fast-changing world, we are educating students for a world that does not exist anymore. The current education system prepares students for the competitive economy that is already weighing under the social and environmental issues. Education can contribute towards sustainable development by facilitating behavioural change, that is both at an individual and societal level. It can help spread awareness about the issues as well as by strengthening resilience in case of extreme conditions, along with providing means to respond towards climate change (Bangay, 2016). Nicholas Stern, in Stern Report (2006) emphasized on three themes that have an impact on climate change, those were: Carbon pricing, technological innovation and behavioural change. Bangay C (2016), points out that two of these themes can be influenced through education.

Education for Sustainable Development (ESD) is capable of instilling problem solving skills along with literacy, and inculcate a sense of responsibility towards the environment, which will result in environmentally sound actions and a sustainable future (Muttarak and

Lutz, 2014; Shaw and Uitto 2014). As shown by several studies, environmental problems are behavioural problems caused by values, beliefs and thoughts of people (Fabio and Kenny 2018; Koger and Winter 2011) and thereby making it important to acknowledge the aspect of altering behaviour in order to achieve greater resilience and vulnerability to threats (Heazle et al., 2013)

IV. Education for Sustainable Development in India

Sustainability has been one of the core values of education in India in realm of policy making and textbook writing. The NCERT textbooks are model textbooks for all state run schools and are found to be much in sync with the idea of sustainability. Written with the guidelines from NCF (2005) the current NCERT textbooks have much focus on connection with the surrounding, sensitising students to the surrounding and humanitarian values. Right from the primary to higher secondary classes there are several themes weaved into the curriculum which address the values of a sustainable society and development. Most of the subjects in different grades provide not just information but attempts to build an attitude towards sustainability and prepare them in case of disasters. The themes covered in the book include everyday real-life incidents, challenges related to natural resources like fuel, water, forests, protection of animals and pollution, etc. Class 7 textbook in Science has a chapter called Winds, Storms and Cyclones (Chapter 8), in which one section, 8.7 Effective Safety Measures, gives details on the action that can be taken by people in case of cyclones making them proactive in such situations. The advantages of technology in keeping us two steps ahead of these disasters are also mentioned, making students appreciate and understand the use of technology.

The class 9 textbook on Economics is all about sustainability of resources, poverty as a challenge, and food security in India. Through the different chapters the book explains the factors of production of goods and services including the land, labour, human capital and physical capital through stories and case studies. The Geography textbook for class 9 titled Contemporary India includes themes about current location, demographic details, climate and population of India. The textbook gives details on the physical features of India, developing a sense of awareness about these features, and the importance of each feature. Awareness would lead to sensibility towards the natural features of India. It also highlights the importance of these features to us humans. The chapter on Climate discusses the factors affecting climate, apart from the human factors. Similarly the Science textbook for class 9 has its focus on Weather, Climate and Adaptation, Winds, Soil, Water: A Precious Resource; Forest: Our Lifeline and Wastewater Story. Most of the topics covered provide scope for further discussion and establishing connection between students surrounding and environmental degradation.

However, when it comes to transmitting these values to teachers the realities are not very optimistic.

Role of teachers in Education for Sustainability and Disaster Risk Reduction

Simply teaching about climate change will be of little significance, it is important to build up on the existing knowledge through lived experiences (Grajal and Goldman, 2012). Teachers are the ones who instil knowledge as perspective and skills to the students. To make the ESD effective it is important for the teachers to go beyond just the textbooks and draw connections with the community experiences and indulge students in hands-on activities. Teacher training was considered to be an important aspect in the Germany Session in 2009, conducted to enhance the link between ESD and DRR. Teacher training is a crucial aspect of DRR education, studies have shown that "training" is mostly described as telling teachers about the content they are expected to deliver and only in some cases, facilitating students towards DRR is given importance. Training is usually once in a blue-moon event and the results are not followed up (Selby and Kagawa 2012). Trained teachers would use extensive knowledge they have and provide it to students using effective pedagogy. However, the readiness of teachers for the same is questionable.

In India, the environmental concerns were incorporated in our constitution right from 1976. The commitment of the government for environmental education is evident in its various provisions for the same. Enviornmental education has been part of school curriculum in all the states in different forms. Currently two ministries are involved with imparting education for climate change, i.e. Ministry of Human Resource Development (MHRD) and Ministry of Environment and Forests (MoEF), While MHRD functions through NCERT for climate change education, the MoEF is currently providing active funding for climate education. The Centre for Environment Education (CEE), an NGO supported by MoEF and other funding implements programmes for climate change education in schools across different states in India. Environmental Studies as a subject is taught as a standalone subject in classes 1-5 and is integrated with social science and science later on. However, when it actually comes to students learning and teachers teaching about the environment things are not very clear and optimistic. As is the case with pedagogies of other subjects in India, the system remains examination driven, and performance based rather than actual value and behaviour cultivation amongst students. In usual cases, teachers are delivering agents of prescribed curriculum who struggle to make students cram and perform well in exams (Kumar 2005). Nevertheless, with curriculum being much filled with material related to environmental education, it was thought to be a worth while exercise to know teachers' understanding and awareness about issues related to the environment.

V. The Present Study

Since teachers are the key to generating and sustaining the pro-climate behaviour, it was deemed crucial to study the way the teachers deal with the issues related to climate change, disasters and sustainability in their classrooms. It would give us an understanding of the ways in which the knowledge about sustainability is transacted in our classrooms. Following are the details of the study:

VI. Sample

Based on purposive sampling we selected two schools, one government affiliated with CBSE and another private school with ICSE board, both are located in Bangalore. In order to understand teachers' knowledge and motivation all the subject teachers were interviewed to obtain data about how they perceive the concept of sustainable development and its significance in the curriculum. In total 35 teachers, teaching in grades 6-9, were interviewed from both the schools. These were teachers teaching English Hindi, Kannada, Mathematics, EVS, Science, and Social Science subjects. The age of the teachers ranged between 25 to 50 years.

VII. Data

We aimed at getting descriptive data, we undertook Interaction with Teachers (through open ended interview questions) and Observation of Classroom interactions.

The interview questions were designed to bring out their perception of the concept of sustainable development in the staff. In this paper we focus on two specific questions

a. What are the issues that pose a challenge to sustainable development in our school/ city/country?

b. Does the current curriculum have themes related to sustainability

The interviews were then transcribed, and the data received was further analyzed. The data analysis of the responses was done by content analysing the answers. We counted the frequency of the responses and summed them up to get a total frequency count of factors mentioned.

Classroom observations

Inclusion of relevant content in the curriculum is not enough if the classroom transaction does not put enough stress on the content. Therefore, the method of non-participant observation was used to collect data and cross check the data collected from textbooks and teacher interviews. The aspects observed during these visits were,

- The relevance of the content, along with
- The effort of the teacher to make it relevant for the students or the pedagogy applied to transact the content, and

- The student-teacher dialogue.

Visits were made to the schools during which classroom practices were observed in order to obtain data on the kind of classroom discourse taking place in schools and to assess the degree to which sustainable development was included in these discussions.

VIII. Results

Teachers were asked to share their understanding of sustainable development. The responses of teachers were explored to match the ideas around Brundtland's definition: "development that meets the needs of the present without compromising the ability of future generations to meet their needs" (1987). Accordingly, the expected answers from the teachers were kept broad. The responses that included phrases and terms like "overall development" (economic, environmental, social), "preserving for the future generation", "saving resources", "adopting environmental friendly practices", "Sustainable development goals", were considered to be partially or fully correct depending on how many of the terms or how close their definition was to the definition given in the Brundtland Report. Following are the key findings:

What are the Challenges to Sustainability?

Teachers were asked their perception about challenges to sustainability, in order to understand their awareness of the kind of challenges our country faces regarding sustainable development. They issues they listed as challenges are given in **Table 14 :**

Table 14: Challenges to Sustainability Factored by Teachers

Factors posing challenge towards SD	Frequency (Percentage)
Global warming	3 (3.6%)
Pollution	11 (13.1%)
Deforestation	2 (2.4%)
Overpopulation	5 (6%)
Wastage of resources/electricity	11 (13.1%)
Use of plastic/ Lack of practice of 3 R's	3 (3.6%)
Consumerism/ Greed	2 (2.4%)
Insensitivity/ Lack of respect towards nature	2 (2.4%)
Health problems/ unhealthy lifestyle	2 (2.4%)
Lack of discipline/ rules	3 (3.6%)

Factors posing challenge towards SD	Frequency (Percentage)
Lack of initiative/ leaders	2 (2.4%)
Unplanned development and infrastructure/ architecture	4 (4.8%)
Lack of public transport/ Traffic	11 (13.1%)
Improper waste management	5 (6%)
Political problems/ corruption	4 (4.8%)
Income disparity	3 (3.6%)
Lack of quality education/ Awareness and Education system	8 (9.5%)
Gap between education and practice	3 (3.6%)

It should also be noted that none of the teachers (all teaching to the grades between 6-9) acknowledged disasters as a challenge to sustainable development, when they were questioned about it. Although, 3 of them mentioned global warming as a challenge, and 11 of them mentioned Pollution. This reflects the lack of DRR education in the curriculum, and lack of its knowledge among teachers.

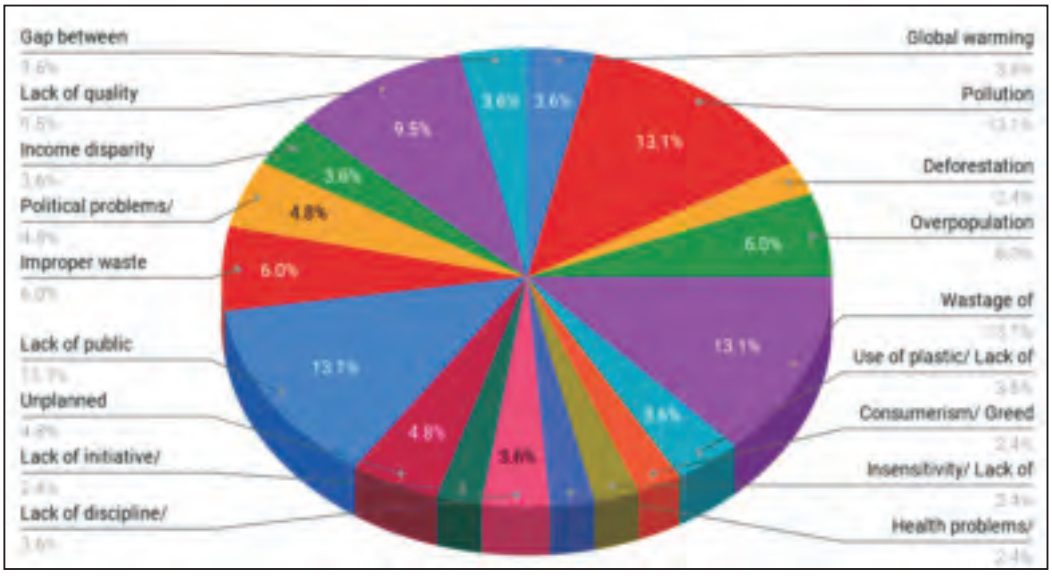


Figure 55: Challenges to Sustainability Factored by Teachers
(Source: author)

The majority of teachers considered wastage of resources, traffic, and pollution to be a major challenge, followed by lack of quality education. As we can see in the pie chart, over 60% of the teachers mentioned factors related to the environment as challenges to sustainability. The fact that challenges like poverty, hunger, dignity and equality are not included in the list of challenges further helps us in understanding their views on sustainable development and not following rules. Two of the teachers also attributed it to the greed and consumerist lifestyle of people. Whereas, two of them considered lack of empathy towards nature to be the problem.

DRR is integrated in the curriculum through infusion of limited subjects, typically Geography and Natural Science. However, given the kind of school culture we foster, the act of curriculum transaction is purely for acquisition of knowledge instead of the skills required for DRR. It becomes difficult to incorporate the values and attitudes of DRR in a culture that prioritizes objective subject knowledge. Understanding the science behind hazards does not prepare students to act accordingly when one occurs. There is a need to combine ECC (Education for climate change and DRR through integrated planning at various levels, in order to enhance resilience of communities (Selby and Kagawa 2012), but we did not observe that happening in the classroom.

During the course of school observations, we got to observe a few instances where the topic of discussion was on very little of which is there in the curriculum, natural disasters and climate change. In the following instance, Mr Mathew, (name changed) was teaching about landslides in class 8, Geography. She had the following conversation with students:

T36- I have a question, why is the land getting spoiled?

S- constructional and agricultural activities

T36- yes human activities, tearing of trees, deforestation, human interference leads to problems or you can say disasters, selfish nature of human only thinking of development and not nature. In your book, there is a small incident on landslides, how it happened and how people reacted, please read that from home. For us it is important to know what are landslides. It is basically mass movement of rocks.

S- because there is less humus present in the soil.

T36- yes because of deforestation, when the tree is cut the soil becomes loose. So how can it be prevented

S- increasing vegetation

T36- retention of wall, the wall can protect the other parts and people from the landslides, reduced grazing, reduced use of pesticides, mapping hazards. So all that is there in this chapter, we will do QA tomorrow.

The focus of the teacher while teaching landslides, is simply to impart the knowledge about what a landslide is, for the purpose of preparing students for upcoming examinations. He gave no attention to the causes behind landslides and prevention methods. More discussion on the topic would have helped generate more awareness and sensitivity towards the environment along with inculcating disaster risk reduction knowledge. This satisfies only the "Learning to know" aspect of ESD according to the three aspects of ESD given by Shaw, (2014), leaving the "Learning to do and "Learning to be" aspect untouched.

It is a common sight to find collage and posters on climate change, charts hung around the school walls. Same was the case with the schools we visited. The bulletin boards labelled "Save Earth" and "Global Warming" were a usual sight like the one given below:

Figure 56: School notice board
(Source: author)

There was an incident observed in one of the classrooms observed in which a discussion on Amazon fires in Science class 7, by Ms Rohini (name changed), where the chapter reading on rainforests was being done. She paused the reading to talk about the Amazon forests, raising awareness about the importance of forests and harm caused by human activities on forests.

⋯so you see forests are so important. For amazon fire also, to protect the environment some person came forward and gave 35 crores. Because he realises how important it is to save the forests... Now so many animals died, plants died, climate will change. Because I told you, it is a chain reaction, thick forests more rain.

After this brief explanation the topic got diverted by the teacher when he cracked a joke followed by which the class dispersed. No seriousness on the part of the teacher or the

student was seen about the Amazon fire. It was seen only when the students were copying down questions and answers from the board regarding this topic. In the above case it was seen that students are interested in learning more about climate, but the teachers do not find it a fruitful exercise to carry it forward.

Nevertheless, in 3-4 isolated cases teachers made an attempt to explain and bring the topic much closer to students' experience by discussing issues around the students. For example in an episode in Class 5 Environmental Studies, the teacher was observed saying the following

The new Bangalore is made on lakes- HSR, Whitefield and all. That's why when it rains, these areas get floods. Don't you feel its strange that it is not even near ocean or rivers still its getting floods. There was no water in the lakes, so they filled it with mud and build a city over it. There were floods in bangalore 3 years back.

The teacher discussed how unplanned construction over natural water bodies can cause natural disasters. Thereby, emphasising the importance of planned sustainable structures. She touched upon all the aspects of our daily lives when we experience water wastage and avoid doing anything about it by considering it a normal part of our life. Leaking tap, wastage of impure RO water, and overflowing water tanks are some of the common sights that we often ignore. Teacher discussed all these with the students in great depth along with discussing all the ways that these circumstances can be avoided. Students' active participation made the class more engaging and interesting as they brought up experiences from their daily lives. These types of discussions while transacting curriculum can make the students more aware of their surroundings and relate their life with the curriculum, which allows them to have a greater understanding of the curriculum, in turn helping them to apply that learning in their everyday practice. This discussion was an example of the Type 2 Approach given by Vare and Scott (2007), according to which they identify that there is a problem in the social or environment order, and critically analyse the other possible options or solutions for that problem, and act critically for sustainable development.

However, overall, a gap in the knowledge exchange and practice was also observed in both the schools. One particular incident where a boy complains about a leaking tap in the washroom to a teacher, was observed. The teacher was seen laughing it off and asking the student to sit in his place. Also, both schools were observed having leaking taps and flush tanks in the washrooms multiple times, either they were left open by the students or they were broken. The words should align with the practice in the school setting. If the formal curriculum involves water saving concepts, the same should be practiced in schools too. This non-alignment of ideas causes gaps in the curriculum and gives rise to hidden curriculum, which gives an idea to students that their real life and school life is not

connected, thereby resulting in conception that school knowledge cannot or need not be applied in real life.

It was repeatedly observed that students would move out of the room without switching the lights and fans off. Even though some teachers were teaching the students about the importance of using resources judicially, it was not being practiced by the students in their daily lives. This brings into light the gap between the formal education and the real life of a child. The school is merely treated as an institution to prove the ability of memorizing the facts in the formal curriculum and present it during examination. The school is supposed to have walls but it is not supposed to be a barrier between learning and real life, like it is now. The actual learning occurs through the child's lived experiences and has the maximum impact on them. The curriculum and pedagogy should be linked with the real life of the child and he should be able to apply the learning acquired through the formal education at school, in his real life.

IX. Discussion

The interaction with teachers revealed a lack of information and apathy towards issues related to climate change and sustainability. It should also be noted that none of the teachers acknowledged disasters as a challenge to sustainable development, when they were questioned about it. They did not mention issues like global warming never occurred in the relevant subjects also. Eight out of thirty -five teachers were not comfortable with the term sustainability and climate change. They asked the researcher to discuss something else. This reflects the lack of DRR education in the curriculum, and lack of its knowledge among teachers. When teachers were asked whether the curriculum provided information on climate and sustainability only 34% teachers gave affirmative responses. They also added that they require special training to bring address these aspects in much detail in the classroom. Unfortunately remaining 64% believed that the curriculum does not mention issues related to sustainability. Each subject provides an opportunity to understand and practice with various aspects of sustainability, along with helping them gain the skills required. For example, in Science, students learn about the interconnectedness of various systems of the world, thereby understanding how one affects the other. They understand the cause and effect relationship, and become responsible for their actions towards the environment (NCERT 2017).

During school observations, it was observed that the theme that dominated the school display boards was global warming and practice of environmentally friendly habits. Each classroom had posters drawn by students stuck all over the classroom boards and walls that said "Save Water", "Save electricity" and "Plant trees". These are good aids to instil perspective towards sustainability. This could make students environment sensitive, encouraging sustainable friendly actions, and scientific knowledge. No doubt, poster

making promotes sustainable development by educating students about the judicious use of electricity by using the first model of Sustainable Development in Education (Shohel and Howes 2006) but as seen in the classroom observation and interviews, it was done mechanically rather than as a learning exercise.

When asked about sustainable development the approach taken by teachers was very relaxed and casual. They though it to be part of moral teaching and did not want to waste much time on it. Their focus remained on examination and marks of the students. The observations in the present study confirm the earlier studies about teaching learning in India. Evidently teaching has been only a means to deliver the facts already present in the textbook, which is further expected to be reproduced on paper by the students during an examination (Kumar 2005). It is obvious that paucity of time and vast syllabus prevents teachers from indulging in topics, such as sustainability that is not "necessary" from an examination perspective.

X. Conclusion and Suggestions

In the present study teachers appeared to be inadequately informed about the various ways and resources to teach about sustainability. They consider sustainability to be an ad-on aspect of education by the teachers and thus receives their less attention and effort. Teachers' knowledge and motivation is more of a systemic limitation. One cannot say that textbook knowledge will be enough to help students instil the required values and skills, a teacher would still be required to go beyond the textbook which further brings us to training of teachers. Knowledge of environmental hazards and knowing the definition of climate change is not enough, we lack the proactive attitude and therefore, there needs to be a system of assessment for the students in order to assess not only their knowledge about the concept but also their skills and behaviour towards DRR, climate change, and sustainable development (Selby and Kagawa 2012). The view that environmental education should take place outside the classroom, and in the environment, is considered to be an extra activity or project work, instead of an important part of education by the majority of educators. In order to perceive the problems and look for solutions, it is important to fully immerse and understand the environment through first-hand experiences. The present study shows that though our textbooks provide adequate information and activities for that same, there are no meaningful transaction of information about the climate change and disaster risk reduction. Though the present study is limited in its application due to its small sample size the results are corroborated by the other studies on quality of teaching and learning in India. This makes it important to work with the teachers and build their attitudes and values for sustainability through pre-service and in-service training, so that they bring can those values to the students.

References

- Baez JE, Fuete A. A., & Santos, I.V. (2010). Do Natural Disasters Affect Human Capital? An Assessment Based on Existing Empirical Evidence (IZA Discussion Paper No. 5164). Retrieved from http://ftp.iza.org/dp5164.pdf
- Bangay, C. (2016). Protecting the future: The role of school education in sustainable development - an Indian case study. International Journal of Development Education and Global Learning, 8(1), 5-19. https://doi.org/10.18546/ijdegl.8.1.02
- Bangay, C & Blum, N. (2010). Education responses to climate change and quality: Two parts of the same agenda?' International Journal of Educational Development, 30(4), 359-68.
- Barnes, J. & Dove, M. (2015). Climate cultures: anthropological perspectives on climate change. New Haven: Yale University Press.
- Cook, J. et al., (2013). Quantifying the consensus on anthropogenic global warming in the scientific literature. Environmental Research Letters. Vol. 8, Issue 2. http://iopscience.iop.org/article/10.1088/1748-9326/8/2/024024/meta
- Das. P,K, (2010). Climate change and education, Bangladesh. Dhaka: UKaid.
- Das, R. & Schwarz, R. (2017). Sustainable Lifestyles in Germany and India. Dhaka, Bangladesh: Germanwatche.V. .
- Dasgupta, P. (2013). The nature of economic development and the economic development of nature. Economic and Political Weekly, 48(51), 38-51. Retrieved from https://www.jstor.org/stable/24478403?seq=1
- Dickinson, J.L., Crain, R., Yalowitz, S. & Cherry, T. M. (2013). How Framing Climate Change Influences Citizen Scientists' Intentions to Do Something About It. The Journal of Environmental Education, 44(3), 145-158. https://doi.org/10.1080/00958964.2012.742032
- Fabio, A.D., Kenny, M.E., (2018). Connectedness to nature, personality traits and empathy from a sustainability perspective. Current Psychology, 1-12. doi: 10.1007/s12144-018-0031-4
- Fabio, A. D. & Rosen, M. A. (2018) Opening the Black Box of Psychological Processes in the Science of Sustainable Development: A New Frontier. European Journal of Sustainable Development Research, 2(4). doi: 10.20897/ejosdr/3933
- Heazle, M., Tangney, P., Burton, P., Howes, M., Grant-Smith, D. Reis, K. & Bosomworth (2013) Mainstreaming climate change adaptation: an incremental approach to disaster risk management in Australia, Environmental Science & Policy, Vol. 33, pp. 162-170.

- Hoffmann, R., & Muttarak. R., (2017). Learn from the Past, Prepare for the Future: Impacts of Education and Experience on Disaster Preparedness in the Philippines and Thailand. World Development, 96, 32-51. https://doi.org/10.1016/j.worlddev.2017.02.016
- Huckle. J. & Sterling, S. R. (2016). Education for sustainability. London: Routledge.
- Hulme, M. (2017). Why we disagree about climate change: understanding controversy, inaction and opportunity. Cambridge: Cambridge University Press.
- Ibrahim, K., Koshy, K. & Asrar, G. (2013) Development with a difference: neo-disaster risk management for sustainable development. Geomatics, Natural Hazards and Risk, 4(3),187-192.
- Koger, S. M, & Winter, D. D. (2011). The Psychology of Environmental Problems: Psychology for Sustainability (3rd ed.). London, New York: Psychology Press.
- Kumar, K. (2005). The Political Agenda of Education. New Delhi: Sage.
- Martin, P. (1990). First Steps to Sustainability: The School Curriculum and the Environment. UK: World-Wide Fund for Nature.
- Monroe, M. C. (2003). Two avenues for encouraging conservation behaviors. Human Ecology Review, 10, 113–125.
- Muttarak, R. & Lutz, W. (2014) Is education a key to reducing vulnerability to natural disasters and hence unavoidable climate change?' Ecology and Society. 19(1), 42. http://dx.doi.org/10.5751/ES-06476-190142 (accessed 19 May 2015).
- Muttarak, R. & Pothisiri, W. (2013). The Role of Education on Disaster Preparedness: Case Study of 2012 Indian Ocean Earthquakes on Thailand's Andaman Coast. Ecology and Society, 18(4), 51–67. https://doi.org/10.5751/ES-06101-180451
- NCERT. (2017). Towards a Green School: on Education for Sustainable Development for Elementary Schools.
- Robinson, J.B., Francis, G., Lerner. S., & Gibson, R. (1990). Defining A Sustainable Society: Values, Principles and Definitions. Alternatives: Global, Local, Political , 17(2), 36-46. Retrieved from https://www.researchgate.net/publication/236686307_Defining_A_Sustainable_Society_Values_Principles_and_Definitions
- Selby, D., & Kagawa, F. (2012). United Nations Children's Fund Disaster risk reduction in school curricula: case studies from thirty countries. Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000217036?posInSet=36&queryId=7a99e94c-5c81-42ce-a848-01e989bbd9eb

- Shabudin, A.F., Azhar, S.N.F. & Ng, T.F. (2017). Learning lab on disaster risk management for sustainable development (DRM-SD). International Journal of Climate Change Strategies and Management, 9(5), 600-625. https://doi.org/10.1108/ijccsm-08-2016-0114
- Shaw, R. & Uitto, J. (2014). Education for Sustainable Development and Disaster Risk Reduction. Tokyo, Japan: Springer . https://doi.org/10.1007/978-4-431-55090-7
- Shohel, M.C. & Andrew, J. H. (2011) 'Models of Education for Sustainable Development: A Bangladeshi Perspective', Journal of Education for sustainable Development, 5(1), March 2011
- Stern, N. (2007). The Economics of Climate Change: The Stern review. Cambridge: Cambridge University Press
- United Nations (2015). Transforming Our World: The 2030 Agenda for Sustainable Development, United Nations, New York, NY.
- Vare, P. & Scott, W. (2007). Learning for a Change. Journal of Education for Sustainable Development, 1(2), 191–198. doi: 10.1177/097340820700100209.
- Weiss, B. (2001). Ethics assessment as an adjunct to risk assessment in the evaluation of developmental neurotoxicants. Environmental Health Perspectives, 109(Suppl. 6), 905–908.
- Young, D. (2015). The link between sustainable development and disaster risk. Retrieved from https://www.weforum.org/agenda/2015/03/the-link-between-sustainable-development-and-disaster-risk/

E

Green Growth & Carbon Management

Chapter-16
Green Growth and Flood Proofing: A Case of Land Use Change in Hyderabad

Vikas Sehra* Milap Punia#

Abstract

Hyderabad is one of the fastest growing cities in India. It has been frequently facing flooding in recent years. Land use change analysis is one of the key instruments in assessing green growth and flood resilience in the cities. In the present study development of Hyderabad is analyzed for the year 1990, 2000, 2010 & 2018. Results show that green cover and water bodies have continuously declined over the years. This has severely limited the city's capacity to absorb water during rainfall. There is need to rethink the development trajectories, as a large section of urban population have settled in flood prone sites and are frequently at risk of livelihood loss. Green growth and flood proofing measures as water harvesting, rain gardens, blue roofs, green roofs and bioswales can be equally effective in residential and industrial areas. Reforestation and preservation of forest, open spaces along with planning corridors around lakes and rivers will provide flood proofing for long term. Bioretention in storm drains and tree trenches, with permeable pavements along roads and frequently flooded settlements will play critical role in letting out the excess water. Study concludes that green growth and flood proofing will be instrumental in mainstreaming Sendai Framework and Sustainable Development Goals at the local level.

Keywords: Urban flooding, Green growth, Flood proofing, Vulnerability, Disaster resilience.

*Research Scholar, Centre for the Study of Regional Development (CSRD), Jawaharlal Nehru University, New Delhi.
E-mail: sehravikas@gmail.com.

#Professor, Centre for the Study of Regional Development (CSRD), Jawaharlal Nehru University, New Delhi.
Email: milap.jnu@gmail.com.

I. Introduction

Hyderabad is 4th largest city of India; it is one of largest bustling centers of urbanization. Greater Hyderabad Municipal Corporation (GHMC) was formed in April 2007 by merging 12 municipalities of Ranga Reddy & Medak district with erstwhile Municipal Corporation of Hyderabad (MCH). Hyderabad has faced increased frequency and intensity of flood over the years. There are few studies on urban flooding in the city and very less literature on green growth and flood proofing in the context of Hyderabad. From 8th to 10th August in 2008, Hyderabad received 237 mm of rainfall, which severely challenged its drainage network and disrupted daily life. Such flooding has become frequent as in 2016, 2017 & recently in 2020. Encroachments of water bodies, vegetation and poor drainage have left Hyderabad vulnerable to floods even with small rainfall. Currently the water bodies are under tremendous pressure due to rapid urbanization. Expanding built-up area has consumed ecologically sensitive sites. Increasing numbers of people are settled in vulnerable and risk prone localities. More often than not these flood prone sites are location of slum settlements in dilapidated conditions. Such vulnerable population with inadequate resources and capacity are worst hit by floods.

The increased impervious surface and deteriorating condition of water shed has resulted in an increased incidence of urban floods. Over the last century, Hyderabad has been hit by major floods in 1908, 1915, 1916, 1933, 1962, 1970, 2000, 2008, 2016 & 2017. However, urban flooding is no longer restricted to the years with heavy rainfall. Even small amount of rainfall leads to clogging of drains and water logging. Preservation of existing vegetation and promoting reforestation will greatly reduce such reoccurrence. Restoring the urban lakes and network of channels spread across the city becomes very essential to come over the depilating effects of flooding. Protecting the river from the degradation due to pollution and encroachments will require integrated effort at various scales. Urban storm management is also important factor as in many cases they became carriers of city waste ultimately disposed in the larger water bodies. Such pollution has caused long-term degradation and damage to city's flood resilience by exposing population to hazards. Thus, there is an immediate need for management of the urban watershed in Hyderabad through green growth and flood proofing initiatives.

Flood proofing is a combination of structural and non-structural measures to reduce flood vulnerability and potential damage. It aims to employ the various interventions for integrated flood management and resilience . The concept of green growth can be traced back to Rio+20 conferences. Target 4 of Sendai framework urges to "Substantially reduce disaster damage and disruption...". Green growth policies, complements flood proofing measures by encouraging green technology innovation and sustainable use of natural resources. It guides towards resilience building to natural hazards by engaging key stakeholders and taking into account interests of vulnerable population. In this context

present study analyses the land use in Hyderabad and consequent increase in flood vulnerability in the city to seek inputs for green growth-flood proofing measures. The next section explains the methodology followed by land use land cover analysis for the year 1990, 2000, 2010 & 2018 in Hyderabad. Further green growth and flood proofing opportunities are pointed out and last section of the study gives concluding remarks.

II. Methodology

The following systematic steps were followed in the present study for acquiring the required data from the available sources, its processing, interpretation and generation of thematic maps.

Multispectral satellite data set was obtained from USGS earth explorer for the year 1990 (Landsat 4-5), 2000 (Landsat 7), 2010 (Landsat 4-5) & 2018 (Landsat 8) for land cover supervised classification of the study area. The remote sensing data were calibrated using semi-automatic classification plugin (SCP) in QGIS for conversion to surface reflectance to remove the effects of the atmosphere and convert from radiance to reflectance values of the land surface. A false color composite of the scene displaying bands 4, 3 and 2 as RGB was used as a guide to classification. In this three-band image, areas with similar spectral characteristics can be identified for e.g., bright red areas in the image represent high infrared reflectance which usually represents dense vegetation.

A supervised classification approach was used to cluster pixels in the Landsat scene into five classes corresponding to pre-defined training areas viz., Built-up, Agriculture/Fallow Land, Vegetation, Barren Land and Water Bodies. SCP provides various comparison algorithms to determine if a specific pixel qualifies as a class member such as minimum distance, maximum likelihood, and spectral angle mapper. For the present investigation the maximum likelihood method was used. Training sets were selected using regions of interest (ROI) as described. Maximum likelihood classification assumes normal distribution and calculates the probability for a given pixel belonging to a particular class. In post-processing class statistics were extracted from the image. Accuracy assessment was done using random points. Finally land use classification maps were prepared for the selected years for the study area. Lastly various approaches of green growth and flood proofing were reviewed to be applicable in the context of Hyderabad.

III. Results & Discussion

1. Land Use & Land Cover in Hyderabad

The study area was divided into five major land use /land cover categories. The map of spatial distribution of land use /land cover categories within the study area for the selected years are shown in Figure 57 (1, 2, 3 & 4).

One can observe drastic changes in land use and land cover in recent years in Hyderabad (Table 15). Particularly in water bodies which primarily increase flood resilience of a city. In 1990 area of 22.71 sq.km was under water bodies covering 3.66% of the land cover. This was reduced to 19.98 sq.km in 2010. In 2018 it stands at 8.18 with just 1.32% of land cover. Hence it has seen continuous decline and from 1990, it reduced by14.54 sq.km.

Vegetation act as sponge during flooding to absorb excess water during heavy rainfall. But it has continuously declined from 1990 to 2018. In 1990 it constituted 29.36% extending to 182.31 sq.km and reduced to 158.96 (25%) in 2000 further to 108.30 (17.44%) in 2010. In 2018 it covered 74.35 sq.km, which is just 11.98% of the land cover. From 1990 to 2018 vegetation reduced by 107.96 sq.km. The reduction was mainly due to conversion of forest land use to other land cover classes as built up, barren land & agriculture. Other change that can be observed is addition of small parks and gardens as green cover.

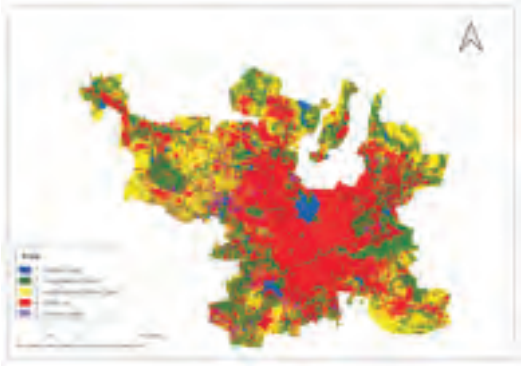


Figure Land use in Hyderabad 1990

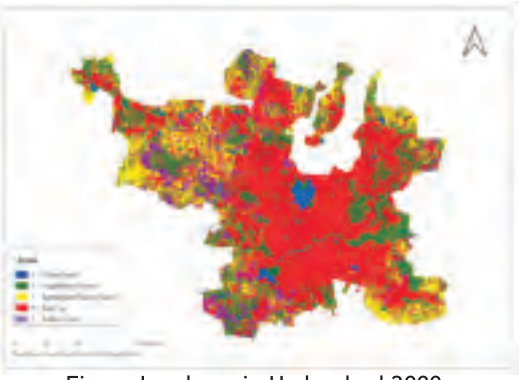


Figure Land use in Hyderabad 2000

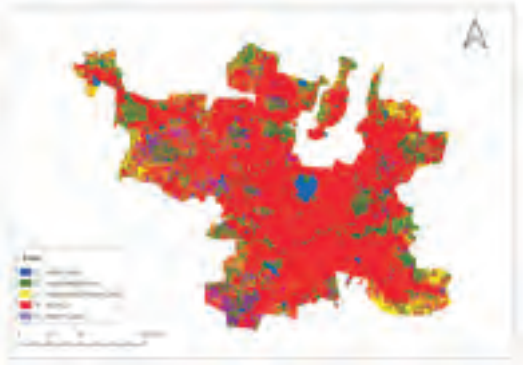


Figure Land use in Hyderabad 2010

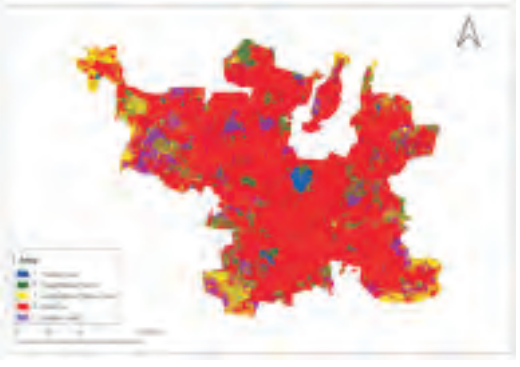


Figure Land use in Hyderabad 2018

Figure 57: Land use / land cover categories
(Source: author)

But such addition at some of the place such as north of Hussain Sagar, is at the cost of small water bodies. Hence such change has been detrimental to flood resilience of the city.

Agriculture & fallow land covered most of the periphery of erstwhile MCH and constituted 160.26 sq.km (25.81%) in 1990 which reduced to 115.31 sq.km (18.57%) in 2000 and further to 89.98 sq.km (14.49%) in 2010. In 2018 it covered 70.43 sq.km which is 11.34% of land cover. Agriculture has been majorly taken over by built-up area. Part of the agriculture land has been converted from vegetation/ forest areas.

Table 15: Year wise Area of Land Use Classification in GHMC (Square Km)

Class/Year	1990	2000	2010	2018
Water Body	22.71	21.99	19.98	8.18
Vegetation	182.31	158.96	108.30	74.35
Agriculture & Fallow Land	160.26	115.31	89.98	70.43
Built Up	180.63	230.23	311.51	384.16
Barren Land	74.95	94.37	91.09	83.74

Barren land constituting cleared and degraded forest show increase from 1990 to 2000 19.42 sq.km (12.07%). but after that it has seen steady decline in 2000 it covered 94.37 sq.km (15.20%) which reduced to 91.09 sq.km (14.67%). In 2018 it covers 83.78 sq.km covering 13.49% of land cover. Hence it has seen major decline like other classes of land use and mostly have been used up by built up.

Built-up area have seen drastic increase over the years consuming almost all other land use classes. In 1990 it just covered 180.63 sq.km almost equivalent to vegetation cover. In 2000 it increased to 230.23 sq.km further to 311.51 sq.km in 2010. In 2018 built-up area occupied 384.16 sq.km, which is an addition of 203.53 sq.km over 1990 land cover. It has increased at the cost of agriculture, water bodies, vegetation and uncultivated barren lands. This has increased the impervious surface in the city and reduced its capacity to absorb the water. Hence even during small rainfall the city faces severe congestion and heavy rainfall results in property and life loss. Further insight in land use change dynamics can be obtained from directional and ward level analysis.

A look at the directional changes in land use cover shows that major changes have occurred towards west where in 1990 area was dominated by agriculture, barren lands and vegetation. But in 2000 and 2010 the vegetation was largely changed into barren land and agriculture area came under built-up area. Most of the small lakes have disappeared

over the years in the area. At present whole area have been dominated by built-up area with complete absence of agriculture and just outcrops of barren land and vegetation. Another major highlight in the west itself is the Pattencheru which was dominated by small water bodies and vegetation. But in 2018 small water bodies have completely disappeared and peripheral area have been completely overtaken by agriculture, industries and built-up area.

In the central region around Hussain Sagar Lake had dense built-up area since 1990, but here also some of the negative changes in the land use can be observed over the years. Hussain Sagar Lake had larger expansion in the 1990 but the peripheral areas of lake have increasingly covered by built-up area or turned into parks. Small outcrops of lakes towards north have completely disappeared. In vegetation also while central area has seen development of many parks, the natural vegetation has totally disappeared in the region except the small KBR forested area.

Northern area was dominated by forest, agriculture and big-small lakes. While small lakes have disappeared in 2018, big lakes such as Jeedimetla Cheruvu have shrunken in size. Vegetation areas have been overtaken by built-up and barren land except the forest area in extreme north. Agriculture area has seen drastic decrease being covered with built-up area.

In eastern side the usual trend of increasing built-up area over the years continued. The most prominent changes here occurred around the Musi River where in 1990 & even in 2000 there was heavy vegetation around the river. But in 2010 most of it has been covered by built-up. Also, in some places it has been converted into agriculture land use. Towards south of the river there was large patch of forest which slowly has shrunken over time.

In 1990 extreme southwest was dominated by barren land and vegetation. Vegetation here have been taken over by barren land and built-up in 2010. And in 2018 most of the south west peripheral region has come under agriculture and built-up. The large water body as Mir Alam tank has shrunken in size and vegetation outcrops around it in 1990 have disappeared in 2018. In south east the area was covered with agriculture land use and vegetation outcrops. Over the years vegetation has disappeared and agriculture area shrunken.

Ward wise changes in Land use & Land cover map of Hyderabad also give important insights. It can be seen that wards of the old city that is ward no. 42,43,44,45,56, etc. have high built-up density, also the wards in city center as 72,75,96,98 etc. have shown high built-up density. We don't see much variation in the built-up area of erstwhile MCH in recent years. As it can be seen that Hyderabad is heavily urbanized and overall built-up area dominates even in the peripheral wards, where in 2010 itself it has taken over the erstwhile agriculture lands, barren lands and forests. Hence, in present the peripheral

wards such as wards no. 34,33,3129,121110,7 etc. have high built-up density and only dispersed outcrops of agriculture lands, wastelands, forests and water bodies are found. In wards such as 35,.48,49,55,69,68,74,73,76,77 some presence of forested area is found

A comparative look at land use land cover map shows that the over the years built-up area has increased for e.g., wards such as 31,34,49,29,12,11,6,1 have seen increased cover of built-up area in 2018 than earlier years. This increase in some of the wards has majorly taken place at the cost of barren land. But the worrisome trend is that such reclaiming of barren lands, at many places has been due to growth of slums and squatter settlements as in ward no. 111,112 etc. Further some of the interior wards have seen reduced water bodies. Hyderabad has many large and small water bodies dispersed all over the city. The largest i.e., Hussain Sagar in the center of the city which comes under the ward no.96 and is surround by the wards 72,74,80,94,95,95,97,98,147,146 etc. Along the Musi River, wards saw major changes in vegetation which dominated the scene in 1990 but have mostly disappeared in 2018.

To highlight the socioeconomic aspect of increasing built-up it is to be noted that some of the major slums in the city are in Alwal, Kapra, Kukatpally, L.B.Nagar, Malkajgiri, Patancheruvu, Quthbullapur, Rajendar Nagar, Serillngampally and Uppal, which have seen increased built-up area over the years. Hence increased urbanization may not necessarily transform into inclusive and resilient city. Hence from the above observation of land use and land cover in Hyderabad for the selected years, it can be seen that though increase in built-up area has led to improvement in connectivity, employment opportunities and residential conditions in the region, which attracts greater attention and resources such as development of IT, pharmaceutical and chemical industries. But this has left many areas flood prone and some of people more vulnerable to flood hazards. It's the inclusive policies and governance which has to take lead in ushering green growth-flood proofing initiative to improve flood resilience in the city.

IV. Green Growth and Flood Proofing: The Way Forward

Flood proofing is the set of method for building flood resilience. Flood proofing through green growth aims to retain or slow down the runoff water. Such methods try to work with natural processes and flow of water as working against them demands continuous vigilance and maintenance (e.g., repairs due to erosion). In cities different methods can be employed at various scales to retain or slow down runoff to prevent floods. It can range from individual building, wetlands to public infrastructure as roads, pavements and storm water networks

For buildings it can be achieved through wet flood proofing by allowing temporary flooding or through dry flood proofing by preventing water from entering the building

using resistant materials of low permeability in construction. Green growth provides more sustainable ways to prevent flooding for e.g., maintaining green open spaces in the city have immense impact on runoff water. Flood proofing infrastructures as rain gardens, detention ponds, bioretention etc. can further complement to make city flood resilient.

At large scale flood detention areas in historically flooded areas may be extended. The concept of "Room for the River" in Netherlands and Germany allows for floodwaters to move and retained in extended historical flood plains along the Rhine River. Similarly, in USA Wetland Reserve Program aimed to acquire and maintain floodplains with minimum land use pressure along the Savannah River .

For such initiatives green financing options, have to be explored to encourage residents and industrial establishments in the city to opt for viable climate friendly and disaster risk reduction pathways. The Climate Smart Cities Assessment Framework by Ministry of Housing and Urban Affairs (MoHUA) and USA's The Property Assessed Clean Energy (PACE) Financing can be used as guiding frameworks for climate resilient parameters and financing mechanism .

In Hyderabad some of the green growth and flood proofing measures/ opportunities are as follows.

- GHMC may take lead in collaborating with Industrial Area Local Authorities (IALAs), Special economic Zones (SEZs), other industrial areas and housing societies to encourage for installing blue roofs & roof gardens in the city.
- While the guidelines for water harvesting are clearly given in building bylaws, efforts are needed for implementation, to bring awareness and communicating its benefits not only for flood prevention but also for recharging groundwater. Water harvesting will be particularly useful in the old city area where, there is less scope for maintaining large open green spaces such as in wards no. 42,43,44,45,56, etc. having high built-up density.
- Tree trenches and permeable footpaths can be setup along the roads, sidewalks and storm drains for slowing down and absorbing the overflowing flood waters. As observed in land use analysis many slum and squatter settlements are near the drains which get overflown. Tree trenches and permeable footpaths can provide partial relief in these areas.
- Bioretention in storm water drains can be very effective for flood prevention particularly in big Nalas through the congested built-up areas such as in Himayatnagar along Domalguda locality, Kukatpally Nala, S R Nagar Nala etc.
- Partnering with institutions such as TISS Hyderabad, BITS Hyderabad, JNTU & IIT Hyderabad, for finding innovative solution for storm water drainage such as installing retention ponds, bioretention, bioswales and identifying sites for rain gardens.

- Construction of large rain water storages in developed and commercialized areas such as beneath parking spaces of GVK One Mall, Inorbit Mall and others.
- Extended detention wetland can be built on the concept of Room for Rivers along the Musi River particularly in the frequently flooded low-lying areas. Even Musi river corridor may be contemplated by securing areas along the river with minimum land use pressure and frequent flooding. Similar application will be beneficial in case of lakes in the city.
- Vegetation and open space as forests, parks, grasslands along the river and lakes have to be preserved and extended to more areas for making Hyderabad flood resilient.
- As pointed out in the land use analysis some of the parks have come at the expense of small lakes such as Chacha Nehru Park came up on site of Masab Tank. Hence, we need to be wary of such deceiving increase in vegetation which will be detrimental in the long run
- Many settlements and housing societies have come up in the lake bed for e.g., Allwyn colony which was severely flooded in 2016. Such sites will need multiple combinations of green growth and flood proofing for prevention of future floods.
- Presently Hyderabad has very less forest cover and efforts should be made towards increasing the forest cover in the city and protect already existing cover as in wards no. 125,128 & 9
- Another area that needs attention is the solid waste dump site of the city such as in Jawahar Nagar near ward no. 1 and 2 of GHMC. These are often along the squatter settlements which make them vulnerable to diseases outbreaks during flooding. Green growth measures for disposing the solid wastes & green cover in the nearby open spaces will help reduce the risk in these sites.
- Similar to Master plan for the city, Green Master Plan may be prepared prioritizing the investment and regulations to encourage green growth and innovation in flood proofing.
- For green financing, the PACE financing mechanism may be explored for Hyderabad by linking it with Pradhan Mantri Awas Yojna Urban (PMAY-U), Smart Cities Mission or Atal Mission for Rejuvenation and Urban Transformation (AMRUT).

Above green growth and flood proofing approaches are not be seen as isolated one-time solution but should be integrated with planning at various levels as continuous process. Such approaches will require being responsive to concern of highly vulnerable population to flooding and engaging key stakeholders.

V. Conclusions

Land use land cover analysis brought forth increasing impervious surface in the city; except built-up areas all other land use classes have seen continuous decline over the years. This has increased runoff flow and severely limited the city's capacity to absorb water during rainfall. Green growth-flood proofing offers much needed opportunity to integrate environmental concerns and human wellbeing in developmental planning for promoting urban resilience. Decrease in ecological sensitive sites as forest and water bodies have been most detrimental for the city. Preservation of existing forest and encouraging reforestation along with open spaces will provide much needed relief from increased runoff during rainfall. Areas around lakes and rivers have to be protected from further encroachments. Rather efforts should be made to regain areas for creating room for rivers and corridors along them. Storm water drains installed with bioretentions will play critical role in letting out the excess water. Many squatter settlements are close to flood prone drains therefore tree trenches and permeable pavements have to be installed along such drains. Residents and industrial establishments have to be encouraged for water harvesting and flood proofing measures as rain garden, blue roof, green roofs and bioswales. Indian cities have come a long way but in face of climate change, there is need to rethink the trajectory of development. Green growth-flood proofing provides an opportunity to integrate Sendai Framework and Sustainable Development Goals as continuous planning process.

References

- Bignami, D. F., Rosso, R., & Sanfilippo, U. (2019). *Flood Proofing in Urban Areas*. Springer.
- Dash, P., & Punia, M. (2019). Governance and disaster: Analysis of land use policy with reference to Uttarakhand flood 2013, India. *International Journal of Disaster Risk Reduction, 36*. https://doi.org/10.1016/j.ijdrr.2019.101090
- De Graaf, R., Roeffen, B., Czapiewska, K., Dal Bo Zanon, B., Lindemans, W., Escarameia, M., Walliman, N., & Zevenbergen, C. (2012). The effectiveness of flood proofing vulnerable hotspots to improve urban flood resilience. In Klijn & Schweckendiek (Ed.), *Comprehensive Flood Risk Management*. Taylor & Francis Group. https://doi.org/ 10.1201/b13715-199
- Freitag, B., Bolton, S., Westerlund, F., & Clark, J. (2009). Floodplain Management: a new approach for a new era. In *Island Press*. https://doi.org/10.1080/15715124.2005.9635242
- Gupta, A. K., Gotmare, S., Nair, U., & Babu, S. (2019). *Green Growth Benefits for Climate and Disaster Resilience: Concerns for Urban and Infrastructure Systems*.

- OECD. (2013). *Putting Green Growth at the Heart of Development*.
- Opperman, J. J. (2014). *A Flood of Benefits: Using Green Infrastructure to Reduce Flood Risks*.
- Opperman, J. J., Luster, R., Mckenney, B. A., Roberts, M., Meadows, A. W., & Wrona, A. (2010). Ecologically Functional Floodplains: Connectivity, Flow Regime, and Scale. *Journal of the American Water Resources Association,* 46(2), 211-226. https://doi.org/10.1111
- Ramachandaraiah, C. (2005). Hyderabad's Floods: Nature's Revenge. *Economic and Political Weekly, September.*
- Sehra, V., & Punia, M. (2020). Overcoming Barriers to Urban Flood Resilience: A Case of Hyderabad, India. *Flood Impact Mitigation and Resilience Enhancement*. https://doi.org/10.5772/intechopen.93195
- WMO/GWP. (2012). *Flood Proofing: A Tool for Integrated Flood Management*.

Chapter-17
Carbon Management and Greenhouse Gas Extenuation

A. Geetha Bhavani and Ashish Panda

Abstract

Greenhouse gas emission dropping is one of the precarious challenges to climate change, which plays an essential role in executing the carbon and climate commitments are implemented by planning for mitigation. Government panel on climate change like to limit the temperature to 2 degrees by 2050 with CO_2 emissions peaking. The setting of bold objective to carbon neutrality often drives deeper cuts in emission beyond to would be achieved with intention to use existing resources wisely and economically. The effective demonstrations of sustainable policies will help all to bring together as a community around with common action and commitments. The carbon mitigation efforts are often useful to follow a carbon management hierarchy with waste reduction concept of reduce, reuse, recycle (3R's) by various strategies. The efficiency and conservation are often endeavours as first adoptions to involve the technological improvement to equipment and infrastructures. The additional strategies include green revolving fund, renewable energy credits, power purchase agreements etc. will allow the accumulated the revenues and enable the carbon neutrality. Energy production and consumption have high environmental impacts. The key components of effective campaign on energy conservation will reduce the energy GHG emission with proper action planning and measurements of cogeneration, deep conservation, alternative to fossil fuels, biomass, landfill gas, renewable energy technologies, solar photovoltaic electric arrays, wind energy, geothermal, transportation solutions and waste minimization.

Keywords: GHG emissions, Conservation, Efficiency, Best practices.

[25]Dr.A.Geetha Bhavani (✉)*, Mr. Ashish Panda^

*Department of Chemistry, School of Sciences & Noida International University Research Innovation Centre, Noida International University, Gautama Buddha Nagar, Greater Noida-201308, India.

^National Institute of Disaster Management, NDCC-II Building, Jai Singh Road, New Delhi-110001, India.

*Email: ageethabhavani@gmail.com

I. Introduction

The carbon counter balance is significant component of climate action plans (CAPs). Climate change going to increase the temperature from 2 to 2.4 degrees globally, this may cause the catastrophic effects with rising of CO_2 emissions. Inter-government panel has laid the Acts and roadmaps to reduce emission to slow down the adverse effects of gases like CO_2 and chlorofluorocarbons (greenhouse gases-GHG) (Gupta et al., 1999). The local planning group shall evaluate the individual the sources may also need to include the GHG inventory. The evaluation criteria includes: (i) Possibilities of avoiding or reducing the GHG emission; (ii) Tractability of steps towards reduction measurements of future emissions; (iii) Estimation on financial clash or investments; (iv) Possibility to create negative or/and positive environmental side-effects; (v) Relationships with other chances for synergistic measures; (vi) Possibilities of involving local people in awareness programs. At the beginning of the any process it is necessary to achieve carbon neutrality with constructive planning which may provide robust strategies of carbon offsets (Akashi et al., 2013).

II. Parameters

Project evolution is most prioritised parts of mitigation plan with discussion of techniques and approaches for responsibility of these tasks. Characteristically, the projects of GHG emissions reducing were planned according to following parameters to considerations to make a proper decision (Allwood et al., 2011).

1. The life of the project cost including maintenance, productivity, capital cost/improvement, safety, comfort, health etc.
2. The funding obtainability from a number of sources including budgets, borrowing, incentives and grands from finding foundations and government.
3. The state or regional interactions on GHG mitigation resourcefulness (e.g. creativities to affects fossil fuel power generator to control greenhouse gas).
4. The possible synergy of opportunities of energy saving which leads GHG emissions mitigation measurements.
5. Possibilities of scale-up and impacts.
6. Lifespan of the project and transferability.
7. Public relations value and the stakeholder feedback to provision and enthusiasm.
8. The strategic development plans to align the capacity building.

The above points will allow making decision after quantifying the collected data and comparative material will be ranked with applicable criteria. The comparative material analysis is potential carbon mitigation developments and procedures.

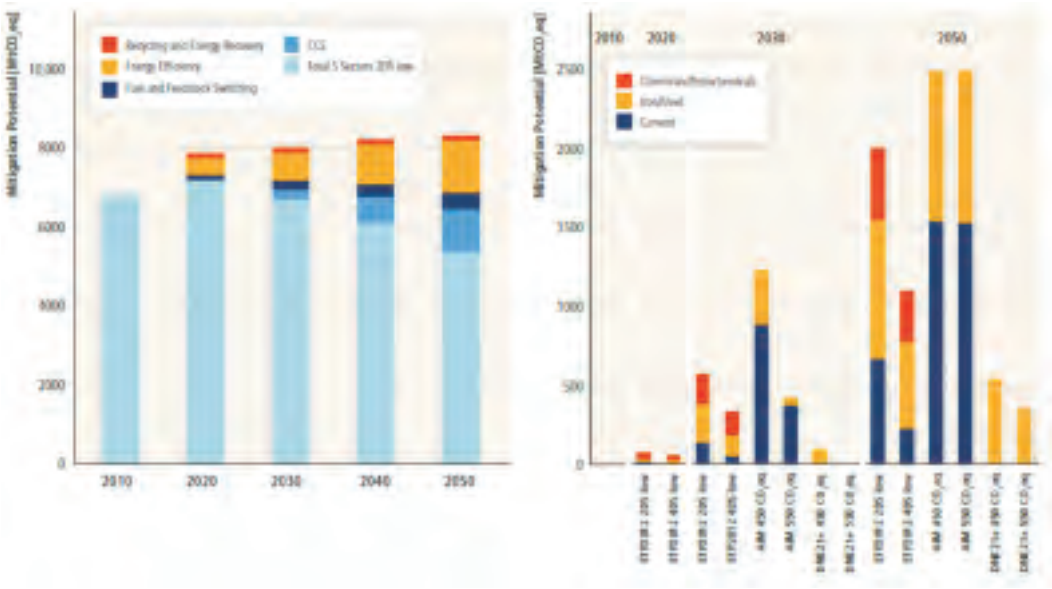


Figure 58: Mitigation of direct CO_2 annual emissions in five major industrial sectors: Iron/Steel, Cement, Chemicals/Petrochemicals, Pulp/Paper and Aluminium [4].

The policies for material efficiency or resources productivity to promote the mitigation GHG emissions are essential in industries. Figure 58 clears the direct CO_2 emissions from various industries (IPCC, 2007). Still the integrated approach is lacking to account for waste management, level of demand (direct and/or indirect) and climate concerns.

III. Planning for Resilience

Resilience is the capacity of communal for endure to adapt and antedate for predictable and unanticipated climatic changes as it is essential to dropping greenhouse gas emissions. The resilience is dependent upon exceptional set of forth coming goals, features, strengths, existing capacity and future vulnerabilities. The Figure 60, summaries the strategic steps for resilience design to evaluate and diminish vulnerability and adaptive capacity. The capacity should go outside handling extreme and hypothetically catastrophic measurements should proactive strategy for desirable futures. Resilience building is a repetition process steps give the impression to be linear and in reality capacity may be occupied on manifold steps instantaneously.

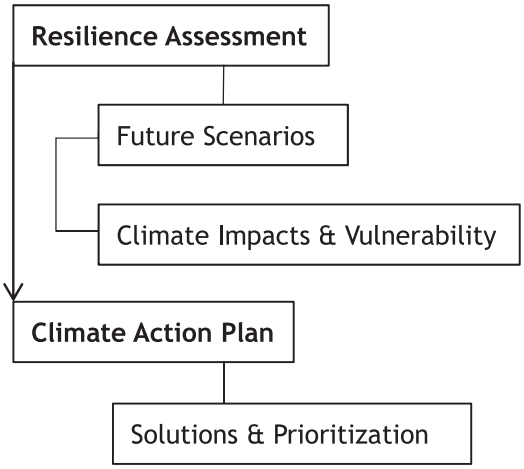


Figure 59: Challenges to Sustainability Factored by Teachers

The climate and carbon assurances are required for counter-signers to revise and resubmit the CAP;s not less frequently than each two years. The counter-signers are expected to appraise and amend their mitigation objectives and actions over period as circumstances changes and new guidelines, technologies and presidencies emerges (Arrow et al., 2010).

III.1 Reduction Efficiency

Appraising GHG reduction efficiency projects based on the predominantly to prioritizing the actions. The action plans will consider dividing the total project cost by reducing GHG emissions by $/MTCO$_2$. The cost saving is like reinvestment of any other project is positively threshold implemented through offset.

III.2 Energy conservation and Efficiency

The generation of electricity by burning of fossil fuels leads to release of CO_2, which primarily cause global warming. The capacity of energy conservation and efficiency improves to lower the GHG emissions. Energy manufacturing and utilization will certainly have communal and ecological impacts. Energy conservation evades these impacts. A few points should be taken into consideration for energy conservation operations: 1) A strong program with proper planning with capacity building awareness programs under effective leadership to catalyze complete effort; 2) Aggressive policies addressing on settings, schedules, purchase of green energy, operations, safety issues, restrictions, compliance; 3) The conversation committee activity facilities with regular meetings to empower and aggressively opportunities on conservation; 4) Inclusive implementation of operation

measures; 5) Periodical re-commissioning; 6) Smart energy programs; 7) Prioritization to improve the efficiency with proper documentation (IPCC, 1996).

III.3 Energy Conservation Measures

Various capacity building procedures are needed to regularize for conserving energy in commercial importance. Here are the few energy conservation methods for capacity building: 1) Strict policies towards conservation development; 2) Database on high and low performances; 3) Encouraging the use of solar energy; 4) Energy ranking; 5) Proliferation of reliance on task in order to increase without adversely affecting productivity; 6) Energy administration systems to be operated remotely; and 7) CO_2 sensors fusing green chemistry programs. These points will evaluate the carbon footprint depending on produced carbon intensity (Mitra et al., 2004).

III.4 Deep Conservation

Effective reduction of GHG emissions needs dissimilar energy conservation strategies, which are not only efficient but super-efficient one. This means of conservation of energy may be called "deep conservation". The capacity building programs needs to be more effective to reach each and every individual by classifying approaches, techniques and products for achieving deep conservation. Sometimes all the exertions will bang up against the parameters of existing programs of hands-on retrofitting options to explore, however prospects flourish.

III.5 Cogeneration

Cogeneration is "amalgamation of heat and power", for options for coal and oil (natural gas or biomass) heating. To increase the fuel efficiency the electricity and heat is generated through cogeneration with various technologies. The technologies aim to generate both heat and electricity using turbines and internal combustion engines to lower the GHG emissions. Cogeneration has a tendency to be most economical for electricity purchase and relatively low fuel is used. The proper sized cogeneration facilities are highly energy efficient to decrease the carbon footprints by (i) the carbon intensity of the fuel used for cogeneration and (ii) the carbon intensity of the replaced and /or purchased for electricity cogeneration.

III.6 Alternative to Fossil Fuels

The options for prevailing climate friendly adoptions are biomass, landfill gas and geothermal (Bajželj et al., 2013).

The biomass fuel comprises few types of organic materials like oat hulls, wood chips, corn husks, etc. It is also necessary to find long term dependable supplier to produce biomass for challenging situations. The sustainable production of biomass is quiet challenging. The subjects related with biomass are low density of heat, requisite high measurements of

fuel, required specific equipment, its air discharges and ash surplus products. The biomass is considered as renewable energy and theoretically carbon neutral, as it is released, captured and sequestered into new biomass for further uses. The annual biomass production is equal to consumption and proficient without any environmental damage. The life-cycle net calculation for carbon emissions of biomass production is generally based on electricity and heating.

Landfill gas is methane, formed by the decaying of garbage in landfills. Methane is most powerful GHG and 20 times more probable of CO_2 until not expelled in atmosphere (Bhavani et al., 2013). Landfill gas is a suitable alternative fuel for power plants or co-generator.

Geothermal energy has various forms like hot water coming from taps through deep wells, and heat energy is used to produce electricity. This energy may replace the central power plants. Below the earth the temperature is more or less constant and may store and/or released through ground source heat pump system and delivered by loop pipelines.

III.7 Other Solar options

Conservation and efficiency aim to reduce the energy load to bare minimum and meet the requirements with also external source in the energy form. In direction to accomplish the climate neutrality or deep cuts in GHG emissions the alterations are necessary to adapt carbon free renewable energy technologies like wind, solar, biomass, geothermal and hydrothermal process. The selection of renewable energy sources and applications leads for green power.

Government made policies for setting of photovoltaic solar electric arrays for energy conservation and cost effective with subsidised rates and incentives offers. At present situation still needs more solar panels to meet present energy load requirements. It is necessary to adapt the solar energy as an alternative to setbacks to meet initial high cost to install will long payback hampers in community. Large financing policies are helping the energy conservations programs to measure and pay for solar energy. Many huge sized wind turbines are installed to encourage the energy conservation programs. The wind turbine recognitions GHG emission are free power and away from pollution fossil fuels. India's efforts in large scale solar energy based power generation and also including spurt in domestic solar power generation should be included.

III.8 Waste Management

Waste management and disposal put into practise can influence the carbon footprint levels. The mitigated waste is burned for waste to energy plant for fuel combustion. The waste reduction awareness programs improve the recycle, reuse, reduce concepts for green environment.

Figure 60: The hierarchy of waste management (IPCC, 2007)

The Figure 60 shows the ideal hierarchy of waste management steps. The priority order and colour coding is based on the five main groups of waste hierarchy classification of Prevention; Preparing for reuse; recycling; other recovery e.g., Energy Recovery; and Disposal.

IV. Gaps in Data and Knowledge

The industrial and other sectors are addressing and evaluating the key challenges through capacity building programs with best practices on keeping industrial data on public domain for effective utilisation. The past industrial data definitely provide significantly support to find the solutions on key challenges like, 1) Significant outcomes; 2) Data reproducibility; 3) Data dissimilarities; 4) Incomplete data process information; 5) Data of technology used for specific energy used; 6) Data on compliances and 7) Quality of data available in public domain (Chakraborty & Roy, 2012). The collected data from industry and associations are highly combined and provides little information about the process used. The major gaps in knowledge are recognized are:

1) The methodology of approach and sidestepping double counting due to different ways in attributing emissions;
2) The deep analysis is required to assess mitigation potential, which is connected with demand, costs and material efficiency;
3) The industry and industrial related precise mitigation options for climate change impacts for adaptations;
4) Complete statistics on sector and sub-sector specific option based on mitigation connected with cost, methodology and clear expectations;
5) A long-term circumstances of demand reduction approaches through a better-quality modelling of materials flow and inclusion of local suppliers with model parameters, integrated models.

V. Best Practices to Reduce Greenhouse Gases

The key components for any affective capacity building are the statement of 'energy conservation'. The government is committed towards implementing its climate action plans to control emissions as CO_2 is majorly responsible for causing greenhouse gases and global warming. Many capacity building programs are footsteps to reduce the demand for fossil fuels which reduces the greenhouse gas emissions. The footsteps are (Bassi et al., 2009): 1) Reduce, Reuse, Recycle; 2) Use of less energy by lowering air conditioning and heat; 3) Replace the old electric bulbs with compact florescent light (CFL), light emitting diodes (LED) bulbs; 4) Driving less or using car-pooling or driving smart; 5) Encouraging the purchase of energy efficient products; 6) Using less hot water by insulating; 7) Keeping "Off the switches"; 8) Planting trees; 9) Taking the report cards from the energy manufacturers for energy upgrades; 10) Inspiring everyone for learning and practicing conservation; 11) Using hybrid cars; 12) Avoiding excessive packaging; 13) Purchasing green energy by solar and wind power; 14) Encouraging teleconferencing more; 15) Using non-toxic household products; 16) Reducing food waste and allow compost to reduce carbon offsets to promote sustainable development.

VI. Conclusion

The air quality remarks the urbanization, which is affecting the community health and environment. The consumption of energy escalates GHG emission levels to be contingent on economic growth. For any GHG emission policies are aimed to accomplish the reduction of greenhouse gases even more. The government is planning to reduce the GHG emissions the cost-effective economic factors are needed to be identified and addressed. The best available control technologies on 'Energy Conservation' should be prioritized, which will also be a part of sustainable development. By adopting the best practices, the emissions can be controlled and reduced substantially.

References

- Gupta, P.K., A.P. Mitra, (1999). "Greenhouse gas emissions in India: ADB Methane Asia Campaign [MAC-98]. Report No. 9, Centre of Global Change", National Physical Laboratory, K.S. Krishnan Marg, New Delhi 12, India.
- Akashi O., T. Hanaoka, T. Masui, and M. Kainuma (2013). Halving global GHG emissions by 2050 without depending on nuclear and CCS. Climatic Change, 1-12: 1573-1480. ISSN: 0165-0009.
- Allwood J.M., M.F. Ashby, T.G. Gutowski, and E. Worrell (2011). Material efficiency:
- A white paper. Resources, Conservation and Recycling 55: 362-381. ISSN: 0921-3449.
- IPCC, 2007c. (2007). The Intergovernmental Panel on Climate Change (IPCC) - Climate Change 2007: Mitigation of Climate Change, Summary for Policymakers, IPCC Secretariat, Geneva, Switzerland, May.
- Arrow K.J., P. Dasgupta, L.H. Goulder, K.J. Mumford, and K. Oleson (2010). Sustainability and the Measurement of Wealth. National Bureau of Economic Research, Cambridge, MA.
- IPCC. (1996). Revised IPCC guidelines for national greenhouse gas inventories. Reference Manual, Vol. 3. Inter Governmental Panel on Climate Change, Bracknell, USA
- Mitra, A.P., Sharma, Subodh, K., Bhattacharya, S., Garg, A., Devotta, S., Sen, Kalyan, (Eds.), (2004). "Climate Change and India: Uncertainty Reduction in GHG Inventories". Universities Press (India) Pvt. Ltd., Hyderabad.
- Bajželj, B., J.M. Allwood, and J.M. Cullen. (2013). Designing Climate Change Mitigation Plans That Add Up. Environmental Science & Technology 47: 8062-8069.
- DOI: 10.1021/es400399h, ISSN: 0013-936X.Bhavani, AG., W.Y. Kim, J. Y. Kim, and J. S. Lee. (2013). Improved activity and coke resistance by promoters of nanosized trimetallic catalysts for autothermal carbon dioxide reforming of methane, Appl. Cat. A: Gen., 450, 63-72. DOI:10.1016/j.apcata.2012.10.008
- Bassi A.M., J.S. Yudken, and M. Ruth. (2009). Climate policy impacts on the competitiveness of energy-intensive manufacturing sectors. Energy Policy 37: 3052-3060. ISSN: 0301-4215.
- Chakraborty D., and J. Roy (2012). Climate Change Adaptation and Mitigation Strategies: Responses from Select Indian Energy Intensive Industrial Units. Department of Management Studies, Indian Institute of Science, Bangalore and Public Affairs Centre, Bangalore.

Chapter-18
Carbon Sequestration for Clean Energy and Green India

Shirish Panda

Abstract

As we are becoming more conscious of environmental degradation caused by increasing consumption of energy, each entity whether the source of energy or a household or industry, is compelled to take measures for reducing CO_2 emissions. In this context, CO_2 sequestration has emerged as a technology option for the reduction of its concentrations in the atmosphere. It describes long-term storage of CO_2 or other forms of carbon to either mitigate or defer global warming and avoid dangerous climate change. Apart from increasing the share of renewable energy resources in addressing the global energy demands, carbon capture and sequestration (CCS) has been recognized as a potential mitigation measure to slow the atmospheric and marine accumulation of greenhouse gases, which are released by burning fossil fuels. Carbon dioxide is naturally captured from the atmosphere through biological, chemical or physical processes. Some artificial sequestration techniques exploit these natural processes, while some use entirely artificial processes. A wide variety of separation techniques are being pursued, including gas-phase separation, absorption into a liquid, and adsorption on a solid, as well as hybrid processes, such as adsorption/membrane systems. These above processes basically will capture carbon emitted from power plants, factories, fuel-burning industries and so on. The concept of CCS is still a nascent science. This chapter aims at discussing the processes by which carbon management takes place in the energy sector. Important themes covered are; perspectives in carbon capture and sequestration technology, advancements in the pre-combustion, combustion and post-combustion capture, terrestrial sequestration and CO_2 storage in the oceans.

Keywords: Carbon sequestration, Carbon capture, Global warming, Climate change

[26]Shirish Panda (✉)
Scientist 'D', Office of the Principal Scientific Adviser to the Government of India, Vigyan Bhawan Annexe, Maulana Azad Road, New Delhi -110011
email: spnd.vig@nic.in

I. Introduction

Global warming is caused when the atmospheric concentrations of greenhouse gases like CO_2 increase, mainly due to the excessive burning of fossil fuels like Coal and Petroleum. Global warming is the enhanced greenhouse effect causing further warming of the Earth's surface and its lower atmosphere, due to the accumulation of anthropogenic greenhouse gases like CO_2 as well as other major and minor greenhouse gases namely nitrous oxide, methane and chlorofluorocarbons, tropospheric Ozone, and sulfur hexafluoride. Among these CO_2 has the largest contribution.

Without swift action, global temperatures are set to rise by 1.5°C by the year 2030 and 2°C by the year 2050 - and will continue to climb beyond then (IPCC, 2019). Those increases will cause disastrous effects, including record-breaking sea-level rise, flooding, wildfires, extreme weather events, famine, and wildlife habitat destruction, a decline in crop productivity, water scarcity, and vector-borne diseases among others. The rise in sea level will increase by about 0.8m in the year 2100 from now when it is 0.1m only at present. Emissions across the globe were 7 billion metric tonnes in the year 2000, and it is estimated that by the year 2030 it would increase to more than 13 billion tonnes when the water availability will get reduced by 30%. A similar estimate indicates that if the temperature rise is half degree centigrade 17% would be the fall of wheat production in India (Qasim, 2010).

In the ultimate analysis we may conclude that air pollution and its exchanges in the earth system have led to see where distortion in the climate pattern and could destroy the human race, if no corrective actions are taken.

II. The problem with the solution

Much before the discovery of Petroleum fuels, civilization and industrialization grew around fossil fuels as the most important energy resource. Even today, coal remains the largest source of electricity and the second-largest source of primary energy. It is also the main source of air pollution and greenhouse gas emissions. When we look at the carbon emissions in developed countries, we find the per capita emission of CO_2 is disproportionately higher in these countries as compared to the emissions in developed/developing economies.

Fossil fuels are meeting about 80% of the total energy needs. The United States possesses one-quarter of the known coal supply, and the United States, Russia, China, and India account for two-thirds of the reserves. Coal plays a vital role in meeting global energy needs and is critical to infrastructure development - 38% of the world's electricity and 71% of the world's steel is produced using coal. Coal plays a vital role in meeting global energy needs and is critical to infrastructure development - 38% of the world's electricity and 71% of the world's steel is produced using coal (IEC, 2018).

Several other studies have analyzed the future energy growth patterns and have concluded that the current pattern of growth will lead to a unilateral increase in greenhouse gas concentrations in the atmosphere. CO_2 concentration in the atmosphere was 379 ppm in 2005 while pre-industrial value of CO_2 was 280 ppm. Global energy-related CO_2 emissions grew 1.7% in 2018 to reach a historic high of 33.1 giga tonnes. emissions stagnated between 2014 and 2016, even as the global economy continued to expand. But the dynamics changed in 2017 and 2018. The result was that CO_2 emissions increased by nearly 0.5% for every 1% gain in global economic output compared with an increase of 0.3% on average since 2010. coal-fired power plants were the single largest contributor to the growth in emissions observed in 2018, with an increase of 2.9%, or 280 mega tonnes, compared with 2017 levels, exceeding 10 giga tonnes for the first time. As a result, coal-fired electricity generation accounted for 30% of global CO_2 emissions. The majority of that generation is found today in Asia, where average plants are only 12 years old, decades younger than their average economic lifetime of around 40 years (IEA, 2019). It is highly unlikely that these countries will turn their back on coal any time soon, and for this reason, the capture and storage of emissions from fossil fuel power plants must be aggressively pursued.

By the year 2030 it is estimated that 25% of the existing flora and fauna would become extinct. We are on a path to generate so much carbon dioxide, methane, and other greenhouse gases that it appears nearly impossible to cut emissions enough to avoid the worst. Therefore, additional efforts are required to handle the situation. A big initiative to address the situation was launched under the leadership of the USA, called the Carbon Sequestration Leadership Forum (CSLF) in June 2003 with the number of nations finding the sea as well as a charter in Washington on 25th June 2003.

III. Carbon Capture & Sequestration (CCS)

Broadly speaking, there are three types of contributors to carbon emissions mitigation:

- Demand reductions due to the increased price of energy
- Fuel switching primarily away from coal, and
- Carbon capture and sequestration from fossil fuels.

'Carbon sequestration' is the term given to capturing atmospheric carbon and converting it into forms unable to contribute to global warming. In the global atmosphere, CO_2 is present in a concentration lower than nitrogen and oxygen, and this has created a thermodynamic barrier in CO_2 capture, hence making it a limiting step in the sequestration process. Once captured, the second step is to store the captured carbon in long-lived pools. The main objective of carbon sequestration is to balance the atmospheric carbon pool to keep the CO_2 concentration below a threshold level.

We need to have a technology for CO_2 sequestration or Carbon capture and storage for stabilizing Greenhouse gas concentrations in the atmosphere. CCS Technology has three major Technologies namely capturing CO_2 in the atmosphere emitted from large sources, fixing it or transporting it to a possible location where it can be safely stored, and finally the process of fixation. Point sources like natural gas reservoirs, coal-based power plants, and energy-intensive industries are considered as the most feasible for CO_2 capture.

IV. Practical CCS

There are various sequestration strategies which have been classified differently by different people because a unique classification is not possible for such a huge number of categories. In this chapter, we will look at the various strategies under the following headings:

IV.1 CO_2 Fixation in Nature

In nature, the process of fixation occurs in many ways, few of which are enumerated under as examples (Goel, 2010):-

- CO_2 dissolves in water turning into HCO_3
- CO_2 reacts with minerals to form $CaCO_3$
- Plants capture CO_2, convert it into organic matter in the presence of daylight, a process known as photosynthesis.
- Algae capture CO_2 to form bio-diesel
- Bacteria and Achaea convert it into organic matter through oxidation
- Oceans absorb CO_2 and contribute to the growth of phytoplankton.

Though these natural processes are supposed to maintain a balance, the activities of humans have disturbed these natural Carbon removal processes, and have led to global warming.

IV.2 Chemical Methods for CCS

Since the last few decades, substantial research has been carried out to discover chemical and biological methods for catalytic transformation of CO_2 to a plethora of various synthetic and biological materials, such as carboxylic acids, esters, lactones, polymer biodiesel, bio-plastics, bio-alcohols, exopolysaccharides, etc.

Carbon, in the form of CO_2 can be removed from the atmosphere by chemical processes, and stored in stable carbonate mineral forms. The process involves reacting carbon dioxide with abundantly available metal oxides- either Magnesium Oxide (MgO) or Calcium Oxide (CaO) to form stable carbonates. Though this process is natural, it takes longer without assistance. When CO_2 is dissolved in water and injected into hot basaltic

rocks underground it has been shown that the CO_2 reacts with the basalt to form solid carbonate minerals. A test plant in Iceland started up in October 2017, extracting up to 50 tonnes of CO_2 a year from the atmosphere and storing it underground in basaltic rock (Darrel, 2017).

The capture of carbon dioxide produced by the combustion of fossil fuels used in electricity generation can be achieved by amine scrubbing of the flue gases. This process is costly and may, in the future, be replaced by options such as membrane separation, molecular sieves, or desiccant adsorption. Another method uses a liquid metal catalyst and an electrolyte liquid into which CO_2 is dissolved. The then converts into solid flakes of carbon. This method is done at room temperature.

IV.3 Physical Methods for CCS

IV.3.1 Geological sequestration.

It refers to the storage of CO_2 underground in used/depleted oil and gas reservoirs, saline formations, or deep, un-minable coal beds. Once CO_2 is captured from a gas or coal-fired power plant, it would be compressed to $\approx$100 bar so that it would be a supercritical fluid. In this fluid form, the CO_2 would be easy to transport via pipeline to the place of storage. The CO_2 would then be injected deep underground, typically around 1 km, where it would be stable for hundreds to millions of years. At these storage conditions, the density of supercritical CO_2 is 600 to 800 kg/m) (Benson & Surles, 2006). Rock porosity, rock permeability, absence of faults, and geometry of rock layers are the important parameters in determining a good site for carbon storage. There are several large-scale carbon capture and sequestration projects that have demonstrated the viability and safety of this method of carbon storage, however, this can be dangerous. Reservoir design faults, rock fissures and tectonic processes may act to release the gas stored into the ocean or atmosphere, which might trigger a catastrophe.

Norway has achieved tremendous success in this. It has injected 1 million tonnes of CO_2 every year in a saline aquifer under the sea bed since 1996. The project is called Sleipner, and is located in the North Sea. In 2000, a coal-fueled synthetic natural gas plant in Beulah, North Dakota, became the world's first coal-using plant to capture and store CO_2, at the Weyburn-Midale Carbon Dioxide Project

CO_2 has been used in enhanced crude oil recovery operations in the United States since 1972. CO_2 is transported to the oil-producing fields through a large network of CO_2 pipelines. The CO_2 would mix with the crowd in the depleting oil reservoirs and help flush out the remaining reserve by reducing its viscosity. At the surface, the gas mixture containing both CO_2 and natural gas will have to be separated from the oil before it is sent for refining

IV.3.2 Ocean Storage

Oceans are mammoth reservoirs of CO_2 and are a potential candidate for CO_2 sequestration in seawater at different depths. A shallow depth of less than 300m may however release it back to the atmosphere, through surface plumes. Injecting it to a depth of 1000m might be useful but this may add danger to the survival of marine species. Liquid CO_2 injected at a depth of 3000m can result in the formation of a permanent lake, being denser than water. This option is likely to avoid any harm to the marine ecology, but the cost of storage, in this case, will be enormously high.

IV.3.3 Industrial Intervention

At an industrial scale, utilization of CO_2 as raw material is not significant as compared to its abundance. The only options are to either reduce it, or stow it away once produced. CO_2 capture technology in fossil fuel-based energy production can be introduced at three stages as under

Pre combustion

The coal is first converted into syngas (mostly CO and H_2) or liquid fuels. The CO can be converted into CO_2 by using a water-gas shift reactor and can then be separated. H_2 can be used for pollution-free power generation. The process of gasification combined with syngas production is called Integrated Gasification Combined Cycle (IGCC). Coal gasification plants using IGCC system have higher efficiencies and combined with CCS they are expected to be near-zero-emission plants of the future.

Combustion

Oxyfuel combustion is more common in the glass, cement, and steel industries. In oxyfuel combustion, the fuel is burned in a mixture of O_2 and recycled flue gas, rather than air. The O_2 is produced by an air separation unit (ASU), which removes the atmospheric N_2 from the air. Removing the N_2 at an early stage results in flue gas with a high concentration of CO_2 and water vapor. The water vapor can be removed by condensation, leaving a product stream of relatively high purity CO_2 which, after subsequent purification and dehydration, can be pumped to a geological storage site post-combustion. In India, the Tiruchirapally plant of the Bharat Heavy Electricals Limited (BHEL Trichy) is extensively researching in this field and houses many test facilities (Soundaraj & Raj, 2010).

Post Combustion

Post-combustion capture is the third stage alternative in which CO_2 is separated from the flue gas and is stored away from the atmosphere or utilized in industrial activities. Oxy rich combustion generally eliminates the need for a separate post combustion 'capture' plant. However, the capture of carbon dioxide produced by the combustion of fossil fuels

used in electric generation can be achieved by amine scrubbing of the flue gases. This process is costly and may, in the future, be replaced by options such as membrane separation, molecular sieves, or desiccant adsorption.

The efficiency of post-combustion technology is expected to be 95% while pre-combustion and oxy-combustion capture at an efficient rate of 85% and 87.5% respectively (Thangaraj, 2018).

IV.4 Biological Methods for CCS

As the name suggests, Biological sequestration is mostly due to natural processes. A few artificial strategies are also proposed, which mainly includes ocean sequestration through ocean fertilization and terrestrial sequestration.

IV.4.1 Ocean fertilization is abiotic method of ocean sequestration, meaning enhancing the concentration of the limiting nutrients that would stimulate growth and production of phytoplanktons, and thus will ultimately enhance carbon fixation. Though researchers worldwide have studied various methods of achieving this, e.g. addition of Iron and Ammonium Nitrate, etc., but thus far, this method is still a controversial area because ocean fertilization needs to be done at a huge, level which is practically very challenging and less feasible.

IV.4.2 Terrestrial sequestration involves the net removal of CO_2 from the atmosphere by plants and micro-organisms and its storage in vegetative biomass and soils. Terrestrial sequestration offers many potential advantages (Daniel, Diringer, & Wang, 2004) namely being exceptionally cost-effective, high throughput, protecting or improving soils, water resources, habitat, and biodiversity, generating rural income and promoting more sustainable agriculture and forestry practices. The major components are:-

- **Soil** contains more carbon than is contained in vegetation and the atmosphere combined. Also, Carbon stored in soils oxidizes rapidly. Agricultural carbon sequestration can not only mitigate the global warming impacts substantially, but also improve soil quality. Carbon is stored in the soil as soil organic matter (SOM), which is a complex mixture of carbon compounds, consisting of decomposing plant and animal tissue, microbes (protozoa, nematodes, fungi, and bacteria), and carbon associated with soil minerals. The methods that significantly enhance carbon sequestration in soil (Al Kaisi, 2008) (more widely used in organic farming than in conventional farming) include:
    i. **Conservation Tillage** This refers to minimizing or eliminating manipulation of the soil for crop production. This includes the practice of mulch tillage, which leaves crop residues on the soil surface. These procedures generally reduce soil erosion, improve water use efficiency, and increase carbon concentrations in the top layers of the soil. Conservation tillage can also reduce the amount of fossil fuel consumed by farm operations.

ii. **Cover Cropping -** Cover crops improve carbon sequestration by enhancing soil structure, and adding organic matter to the soil. These can be introduced for protection and soil improvement between periods of regular crop production

iii. **Crop Rotation -** Planting different crops on a rotating pattern of years will reduce the loss of carbon from the soil and with some additions (e.g. manure-lime-phosphorous) will add carbon to soils.

- **Grasslands** Grasslands contribute to soil organic matter, mostly in the form of their extensive fibrous root mats. Since the 1850s, a large proportion of the world's grasslands have been tilled and converted to croplands, allowing the rapid oxidation of large quantities of soil organic carbon. Livestock producers can enhance carbon sequestration on their operations by converting from continuous grazing to rotational grazing. This keeps the plants in an actively growing state and keeps photosynthesis rates high. This improves the quality of the forage and allows the plants to sequester more carbon.
- **Forests** draw out of the atmosphere when they are growing and release it back as the flora decays. India now stands 10th in the world in terms of forest area and eighth in terms of annual forest gain. The total forest and tree cover is 24.56% of the geographical area of the country. The total forest cover is 7,12,249 sq km which is 21.67% of the geographical area of the country. The tree cover is 2.89% of the geographical area of the country (FSI, 2019).
- Algae are one of the most important living resources of the oceans and can be used for CO_2 sequestration efficiently. It has been found that one tonne of algae can fix 0.36 tonnes of Carbon, 0.6 tonnes of Nitrogen, and 0.008 tonnes of Phosphorus. It has been also found that and all carbon fixation by intertidal marine algae in the estuaries exceeds 13500 tonnes per year and accounts for 21% of the total carbon fixed by all primary producers (Sahoo, 2010). India has a long coastline of seven thousand kilometers with 717 species of seaweeds. Recently large scale cultivation of seaweeds such as *Kappaphycus alvarezii* and *Gracilaria verrucosa* has started in different parts of the Indian coastline. Efforts are now being initiated to expand the Seaweed cultivation to several other parts of the Indian coast.

V. Conclusion

India's initiatives to combat climate change have been praiseworthy because the share of renewable power to total power installed capacity is 17.5%. Given India's dependence on coal as a dominant source of energy in thermal power generation, the CO_2 sequestration technology expects to address two most critical problems of the 21st century, namely energy security and climate change. CO_2 sequestration can provide an increase in biomass, enhanced fertilization, and value addition through the production of fuel.

CCS may not be a cost-effective technology with short on medium-term rewards. It may, however, definitely emerge as a long-term solution to the challenge of CO_2 capture. Heavy dependence on coal as the primary source of energy will continue since our power demand is going to grow at an annual rate of 1 to 9% over the next 25 years; despite the technological developments in hydroelectric power, plans to augment the nuclear power capacity, commitment to exploit all other renewable energy sources, etc. Therefore, the power strategy must explore and find solutions to the increasing CO_2 emission problem. CCS Technology appears promising and will need appropriate research investments to make it cost-effective. This is indeed a challenge to scientists and technologists (Shahi, 2009).

VI. Suggestion & Way forward

It is felt that a two-pronged approach to address CCS is the need of the time. The country has to not only invest in biological, chemical and physical means of CCS for mass carbon capture, but at the same time bring in policy interventions to ensure a high degree of carbon capture right at the source, i.e. the industries running on coal. Very recently, it has been made mandatory for thermal power generating industries to install Flue Gas Desulfurisers (FGDs) across all plants, so as to treat the flue gas for its Sulfur content (). Similar interventions would be very welcome for CCS at source.

References

- Al Kaisi, M. (2008). Impact of Tillage and Crop Rotation Systems on Soil Carbon Sequestration.
- Benson, S., & Surles, T. (2006). Carbon Dioxide Capture and Storage: An Overview With Emphasis on Capture and Storage in Deep Geological Formations.
- Daniel, B., Diringer, E., & Wang, X. (2004). Possible Approaches to Advancing International Climate Change Efforts.
- Darrel, P. (2017). Test of Carbon Capture Technology Underway at Iceland Geothermal Plant.
- FSI. (2019). India State of Forest Report.
- Goel, M. (2010). Perspectives in CO_2 Sequestration Technology and an Awareness Programme.
- IEA. (2019). Global Energy & CO_2 Status Report 2019.
- IEC. (2018). Coal 2018: Analysis and Forecasts to 2023.
- IPCC. (2019). Global Warming of 1.5 °C - Special Report.

- Qasim, S. Z. (2010). Corporate Response to Climate Change.
- Sahoo, D. (2010). Role of Algae in Carbon Sequestration.
- Shahi, R. V. (2009). Carbon Capture and Storage Technology: A Possible Long Term Solution to Climate Change Challenge.
- Soundaraj, & Raj, M. (2010). CO_2 Sequestration Technologies for Clean Energy.
- Thangaraj, P. (2018). Factsheet: Bioenergy with Carbon Capture and Storage.

Lessons Learnt and Way Forward

(Source: https://wallpapersafari.com/w/h1cPKf)

Lessons Learnt and Way Forward

Editors

This knowledge compendium has brought out comprehensive knowledge and ideas about Environmental Sustainability and Green Growth. This compendium has covered various aspects of sustainability ranging from ecosystem services, flood disaster vulnerability assessment, potable water issues, protection of mangroves, solid waste management to peri-urban issues. This also highlights the possible ways of bringing resilience in agriculture sector through usage of plant growth promoting bacteria and potential wild edible plants. Disaster resilient construction is an important solution for disaster prone areas and this section gives insights about promoting green growth through green buildings, eco-friendly approach for construction through local available material, climate resilient built structures and also post-disaster housing strategies. The compendium also encompasses strategic issues like embankment safety, implementing circular economy through paper and pulp industry and understanding of disaster management among school teacher to inculcate a right view point about the sustainability and green growth among the students who are the future drivers of the nation. The last section of the compendium also discusses about the ways of reducing the disasters through introducing the green growth approaches and carbon footprint management. Lessons learnt through these sections are highlighted in brief.

A. Sustainability

Single point approaches to disaster risk reduction have been ineffective up until now, Eco-DRR is a comprehensive approach which covers multi-disciplines and looks at ways to increase resilience by addressing one of the main drivers of risk (environmental degradation). The approach considers both spatial and temporal scales in the context of risk reduction (Cohen et al., 2016, Estrella 2013). It also attempts to create synergies between different government departments and empowering grassroot institutions.

Ecosystems support communities by providing essential ecosystem services such as food, fuel, shelter and can strengthen human resilience and security against disasters and reduce socio-economic vulnerability. For example, the establishment of coastal nurseries provide seedlings for fruit, forest or mangrove. Planting these forests can provide food, increase aesthetical effects and provide shelter, which can support tourism activities (MEA 2005).

By using tools such as ESSVA, ecosystem services can be mapped to help planners understand the relationship communities have with their ecosystems-providing essential support before, during and after disaster events. Planners can also use the approach to assessing and responding to risk of upstream and downstream development around ecosystems. Further it will help communities understand the hidden regulating values that can be taken for granted, help develop a common view of ecosystem services and explore restoration options.

While in the short run, infrastructure centric approaches may reduce vulnerability of the communities to this risk, the cost burden of such interventions are rarely factored in decision-making. While the interlinkages of ecosystem services management and disaster management are highlighted, there are limitations to how much protection nature-based solutions can provide depending on the magnitude of the hazard. Exactly how much protection an ecosystem can provide is limited to local conditions. Also, ecosystem-based approaches are often more cost-effective over time and in some cases, grey-green infrastructure combinations may be more ideal (Kumar et al., 2017).

Dams are beneficial to store water and supply during non-rainy season to meet various demands such as drinking water, irrigation and power generation, the damages are high during dam failure as well as dam breaches. When they collapse it can produce irrecoverable losses in terms of life, property, and infrastructure and adversely impact the landscape and environment as well. It thus makes complex processes, accurate estimation of high risk zones and flood travel time are very essential and critical. The assessment of characteristics-such as inundation, travel time, discharge etc. resulting from potential failure of the Neerasagar dam using the HEC-RAS hydraulic model show that considerable losses occur in nearby villages with water level going upto 30 m in the stream depending on the flood intensity and distance from the dam. As ecosystem impacts are huge, proper planning to avoid dam breakage and controlling dam breach are the best options for such eventualities. Proper care and maintenance of structure would reduce chances of dam failures. Protection of water bodies and river banks of through various measures such as release of water on time, afforestation etc. could result in safeguarding the ecosystem. The particular study would be useful in identifying safe zones for expanding residential areas, minimize flood risks in the downstream areas, plan emergency actions in downstream areas of Neerasagar dam which gets flooded either due to dam failure or dam breaching. More importantly, the owner of the structure should make a mandatory reviewing and maintenance of the structure as stipulated in the dam safety bill of 2019. Further, it is also, important to develop an Emergency Action Plan (EAP) for the dam for considering the various dam release scenario and extreme condition such as dam break, which will be handy in operating the dam as well as to provide necessary information to the line department who will be involved in undertaking the evacuation of the people and live stocks during the flood situations.

Despite the knowledge of challenges and solutions to solve the water crisis, the public as well the administration fail to derive and initiate actionable plans. The KAO analysis suggests simple decentralized micro-level supply systems in conjunction with low cost water purification technologies as the most feasible solution. In addition, community needs to be sensitized about their role in protecting and managing their resources and also on the 5 "R" concept of resource conservation namely reduces, reuse, recycle, replenish and finally respect, that can also act as step towards ensuring drinking water scarcity. Adding one more "R" for refuse if we don't want would add to conservation strategies. The pertinent aspect that is evidenced from the above study is that there has to be a scientific method of water collection, storage and distribution. Revisiting the ancient methods of conservation shall add value to solve the issue in otherwise water scarce regions of Kuttanad. Alongside there has to be strong policy which has to be administered through the local administration which shall provide solace to every persistent problem. A sense of Green thinking and notion of sustainability has to be instilled in the minds of the people so that any implementation of the technology or policy will sustain because of the cooperation from the subjects.

Nature Based Solutions (NbS) are the key for saving the resources of earth for the survival of humans. Among all other components of NbS, Mangroves are of prime importance for reducing the risk of disasters and improving the economy of the country. During several disasters in India, Mangroves have proved as saviours for both humans and infrastructures. For example, mangrove forests saved lives in the 2004 tsunami disaster, in 2019 they saved the Sundarbans from the gusty cyclone's impacts and many more. This chapter focuses on the role of Mangroves of east and west coast of India. It was also found that there is a need for implementation of mangrove and other NbS solutions at grassroot level. Awareness programs are required to aware the local communities about the benefits of NbS and how it can help them economically. NbS should be implemented at the landscape scale and, in order to tackle social problems, NbS are part of the overall strategy, plan and intervention design.

The 2015 development agenda gave way to an integrative approach to development focusing on the well-being of all and upheld the scope of sharing co-benefits as well as equitable sharing. This led the global leaders to start visualising development as a holistic manner. Despite substantial increases in the scope and magnitude of biodiversity conservation and ecological restoration, there remains ongoing degradation (Cohen-Shacham et al., 2019). NbS concept is increasingly being referred to in scientific literature (e.g., Kabisch et al., 2016; Raymond et al., 2017a; Keesstra et al., 2018). Given the eight principles, NbS has potential to embrace the conservation norms promoting benefits to the society in an equitable and transparent way. The productivity and capacity of green infrastructure and services in the provision of large ecosystem services was demonstrated

by Liquete et al., (2016). It also stressed the importance of incorporating various value systems and the views of stakeholders to facilitate environmental decision making.

An effective mechanism for planning and management is required to ensure the least damage to the environment and safeguard cultural practices of the peri-urban area. Ceaselessly these areas are under physical, social, economic and environmental changes. These areas hold the utmost importance in spatial planning as they are believed to be the upcoming major urban centers. Thereby, proper management in the transformation of peri-urban areas regulates the economic prosperity and sustainability of the resources. The transformation of peri-urban areas into urban agglomerations is imperative. Metropolitan cities and other urban centers will further expand and invite supplementary workforce and investments. Thus, proliferations of peri-urban areas are bound to happen. Often, these peri-urban areas remain underprivileged and over exploited for their resources benefitting only the adjacent cities. Empirical studies on issues such as sanitation, access to basic amenities, poverty and education in peri-urban areas should be facilitated in order to conceive efficient policies safeguarding social, economic and environment development. Organizations require attaining deeper insights and management strategies to recognize the importance of peri-urban areas and their role in development of a country. Indian government, both central and states need to strengthen their laws and regulations to enable balanced urban growth and promote sustainable economy.

India has the Municipal Solid Waste (Management and Handling) Rules, 2000 where it is mentioned that recycling of construction and demolition waste is essential. Every urban centre should identify the site for recycling of these wastes. However, many Indian cites are yet to demarcate a site and set protocol for management of the demolition waste. It is rightly said, no environmental policy will be successful unless staff understand the need for change and are committed to making it happen. Taking a longer-term perspective, in the context of sustainable development, increases the likelihood that more immediate adaptation actions will also enhance future options and preparedness. Many adaptation and mitigation options can help address climate change, but no single option is sufficient by itself. Effective implementation depends on policies and cooperation at all scales, and can be enhanced through integrated responses that link adaptation and mitigation with other societal objectives.

B. Resilient Agriculture

Pseudomonas putida RA ameliorates drought stress in both *desi* and *kabuli* chickpea varieties. Progression in drought stress significantly affect the physical (phenotypic) parameters of both cultivars by altering root length, shoot length and biomass and modulates physiological and biochemical properties such as EL, photosynthetic pigments content, proline content and antioxidative enzyme activity. These parameters showed

better stress tolerance and survival by *desi* chickpea cultivar and positive effect of RA-treatment on its growth performance. Negative correlation expression pattern of miRNAs and their target genes suggested their involvement in the stress regulatory pathways, and ultimately in drought stress response in chickpea. Our findings thus provided an understanding of the physiological and molecular basis of the chickpea response and adaptation to PGPR-mediated drought stress.

The wild edible plants available in Male Mahadeshwara (MM Hills) Wildlife Sanctuary, their uses and scope of value addition to increase economic benefit and sustainable forest management. A total of 94 wild edible species has been recorded which are either sold in local market or have domestic use. The indigenous communities depend significantly on wild edible plants, which is estimated to be approximately 28.15 tons per annum. Field-based assessment of nine wild edibles has shown that the collection of wild edibles by community is very low as compared to their production, where more than 75% of the resources are left unutilized. Analysis of value-addition process of those wild edibles, and comparison of production costs and market values of value-added products show that the wild edibles have immense potential to increase the income of the farm households, which can go up to two to fourfold. It is suggestive that promotion of value-added wild edibles has the potential to offer a safety-net for households' income where agricultural livelihoods are at risk because of environmental change including changing climate. It can also reduce the pressure on biotic resources and has potential in contributing the ecosystem sustainability and mitigating the threats due to disasters that are driven by variety of factors and aggravated by ecosystem degradation. Therefore, the policies need to be formulated for conservation of these valuable plants in the wild habitats. Also there is need for developing a proper management plan so that the sustainable utilization of these resources can be ensured for contribution in sustaining the local livelihoods. Conservation and sustainable utilization of bio-resources would provide a meaningful solution towards sustainable socio-ecological development.

Wild plant food is an important ecosystem service which has the potential to provide nutrition and economic benefits. The wastage of these locally available nutritious foods is tremendous and can be harvested for sustainable livelihood development and nutritional security. Proper institutional support is required to make it a mainstream livelihood to develop a more resilient community under the circumstances of changing climate. There are also several associated traditional beliefs. In the current times, due to changes in lifestyles, preference towards agricultural crops and so on, the utilization of wild edibles has decreased and the related traditional knowledge is being lost. This has reduced the utilization and collection of wild edibles, which in turn has led to wastage of this valuable natural resource. There is a need to conserve wild edibles and make the human society aware of their importance. Value addition would lead to the sustainable utilization of

wild edibles with better economic incentives to the local societies living in forested landscapes of India

C. Disaster Resilient Construction

Due to increasing climatic change events & various environmental episodes the occurrence of natural disasters has increased. In order to mitigate the loss caused by the extreme events, it is of utmost importance to build a resilient society rather than only a responsive one. One should be aware of all the vulnerabilities and should address the risks associated with the disturbances to make the society resilient. This will result into mitigation of long term disruptions and increased acceptance for design related to sustainable and green infrastructure to enhance resilience. Hence a comprehensive approach of green growth provides a roadmap for sustainable environment, along with fostering economic growth, disaster resilience and socio inclusiveness. Green growth is balanced collaboration of environmental services related to climate change scenarios and at the same time enriching economic benefits for development. Green buildings/infrastructure is one of the way to achieve green growth. It aims to reduce the impact of after effects of disasters through systematic efforts to manage and analyse the causative factors and also encouraging and promoting the use of renewable resources. To increase the socio economic resilience of the society in terms of green growth, green infrastructure provides a way towards sustainable approach. A green building provides a structural stability during disaster as many lives are put in danger due to improper construction.

Environmental change is required to cause more serious and the sky is the limit from there incessant characteristic perils. As our urban communities and coasts develop more powerless, these dangers can lead to debacles that are far more awful than those we have seen until now. We have a good, social and financial commitment to construct flexibility which can be attained by green growth.

Green growth acting as sustainable approach towards disaster resilience includes:

1. Mitigating the side effects of structure on the environment, climate and society by identifying and understanding risk scenarios
2. Providing with better savings and returns to community hence economic development and financial strengthening
3. Sustainable planning and urban development design process resulting into safeguarding of natural ecosystems.

Till date emphasis has been laid on reducing risk of human lives and seldom importance is given to climate, environment and urban planning w.r.t infrastructure during any catastrophic event. Green buildings, energy efficient and water conservation practices

along with environment friendly approach plays an important role towards sustainability in terms of disaster resilience. Resilience comes in practice when buildings are sustainable in true sense of fulfilling their minimum requirements of following building codes.

The proposed framework that concentrates on minimising time and cost towards recovery contributes to minimising the physical and mental agony of the disaster victims. The only option to reduce threats from disasters is to minimize exposure to it. For such devastations, the community faces a dilemma between relocating to a new place to avoid similar threats in the future or rebuild on the same site with additional measures and safeguards. Relocating to a new site depends on extensive community consultation mostly due to its impact on livelihood and sustenance. It is also necessary for the state to source adequate land for rehabilitating the victims. In case the land is not available, appropriate legislative provisions and financial strength of the state and individuals are necessary for land supply. The next challenge for such cases would be to derive an effective land distribution strategy among the effected people for housing and community services. Appropriate policy and financial capacity are necessary to choose whether to distribute land or housing and the methods for such distribution. A state can adopt land swapping based on the land tenure records or monetisation of land based on the land value of the disaster-affected area. A mutually agreed period between the buyer and seller is necessary to determine the land valuation. In case the state supply or subsidise housing to the victims, a housing distribution policy is necessary to determine pre-disaster housing ownership and rental housing ratio. At present, India's post-disaster housing policy is non-existent, which follows a diabolical approach of supplying housing to the victims.

For in-situ rehabilitation, safeguard the community from future disasters are important. It includes both community safety and individual protection. Adequate improvement of building regulations and community protection strategies reduce exposure to future disasters. It also improves a community's resilience to cope with disasters and overcome its consequences in future. The infrastructural improvement needs to accompany with the confidence building measures of the community. Informing about the measures taken by the state and institutions and infrastructural augmentation help to grow confidence among the community members. It is important to develop long time resiliency of the community. A standard operating procedure and regular institutional training help people to be agile and alert during the disasters. The institutional capacity, knowledge and skills also help to lead the rehabilitation process in medium and long term.

The area of habitat and buildings has many crucial linkages to green growth objectives. In the context of mountain regions, the emergence of non-local materials and practices is one of the key issues to be addressed. While at the one hand, it increases the overall carbon intensity of construction, its contribution to disaster-resistance of the building

remains minimal. The environmental damage caused by building construction is fueled by disregard for sustainable harvesting of critical resources like sand. The potential for employment opportunities which are anchored in the local economy is an equally important component of green growth. The currently emerging construction practices, with their focus on greater and inefficient use of non-local industrialized materials and dependence on non-local personnel are inadequate in unlocking this social and economic potential.

There needs to be a government push for these micro-enterprises by facilitating finance for their improved infrastructure. There is an urgent need to strengthen the area of timber-based products for construction in conjunction with the sustainable forest management practices which can ensure long-term supply of timber without negative environmental impact. With the right policy support, supplemented with technical support, the resurgence of timber-based practices can be a strong step in the direction of eco-friendly construction in mountainous regions.

Climate change is going to impact every single existing building and infrastructure across the world. All the future renovations and new infrastructure must have the planning and design for 360 degree sustainable construction including climate change risk mitigation. New built structure should not be approved without plans for disaster risk management as part of the design master plan. To support green growth, climate change adaptation and mitigation measures must be included as a mandatory practice.

D. Strategic Issues

Research and administrative systems should be focused on human recovery, learning and adaptability to the conditions, and develop a strong ability to cope up with disasters. In terms of disaster mitigation, a LCA based approach should be used and it should include the socioeconomic compensations and relief costs provided by the government to the affected communities. The *build-maintain-rebuild* paradigm should be put forth in place of our *build-forget-build* attitude. The implementation of the LCA approach based embankment assessment will be a keystone policy in India's disaster mitigation strategy against floods as the systematic implementation of these studies will have incremental de-risking effects. Along with the iterations of the dynamic LCA approach the initial complicacies of the implementation will have a multi-fold impact on embankment safety as well as sustainability. The accelerated growth in technology and connectivity will facilitate in improvement of the current systems and align the flood risk assessment to ensure maximum safety and minimum losses to the citizens of our country.

Circular Economy can act as a crucial tool in order to mitigate the challenges being faced by the paper and pulp industry. With several mills already taking the initiative, their overall footprint has been significantly reduced. In order to fully analyse the situation, we

can broadly divide it under the banner of sustainability and critically assess each pillar of the Triple Bottom Line Approach.

1. Economic - One of the most major costs handled by the mills is the procurement of raw materials. By recycling their by-products as well as reusing certain material, they can very well have a positive impact on their overall spending. Moreover, several mills sign long-term deals with sugar mills to use their waste (bagasse) as a raw material.
2. Social - By integrating farmers as well as nearby communities, the mills help to generate income - based activity for them. This further helps strengthen the socio-economic climate of their region.
3. Environment - Plantation schemes will help sequester carbon. Moreover, recycling will help reduce the amount of waste being generated. The lower emission will lead to lesser pollution. Overall, having a positive impact on the environment in general.

Circular Economy is the future of doing better business. It can be clearly seen that the current linear model will not be able to derive positive long term results.

Knowledge of environmental hazards and knowing the definition of climate change is not enough, we lack the proactive attitude and therefore, there needs to be a system of assessment for the students in order to assess not only their knowledge about the concept but also their skills and behaviour towards DRR, climate change, and sustainable development (Selby and Kagawa 2012). The view that environmental education should take place outside the classroom, and in the environment, is considered to be an extra activity or project work, instead of an important part of education by the majority of educators. In order to perceive the problems and look for solutions, it is important to fully immerse and understand the environment through first-hand experiences. Though our textbooks provide adequate information and activities for that same, there are no meaningful transaction of information about the climate change and disaster risk reduction. This makes it important to work with the teachers and build their attitudes and values for sustainability through pre-service and in-service training, so that they bring can those values to the students

E. Green Growth and Carbon Management

Greenhouse gas emission dropping is one of the precarious challenges to climate change, which plays an essential role in executing the carbon and climate commitments are implemented by planning for mitigation. Government panel on climate change like to limit the temperature to 2 degrees by 2050 with CO_2 emissions peaking. The setting of bold objective to carbon neutrality often drives deeper cuts in emission beyond to would be achieved with intention to use existing resources wisely and economically. The

effective demonstrations of sustainable policies will help all to bring together as a community around with common action and commitments. The carbon mitigation efforts are often useful to follow a carbon management hierarchy with waste reduction concept of reduce, reuse, recyle (3R's) by various strategies. The efficiency and conservation are often endeavours as first adoptions to involve the technological improvement to equipment and infrastructures. The additional strategies include green revolving fund, renewable energy credits, power purchase agreements etc. will allow the accumulated the revenues and enable the carbon neutrality. Energy production and consumption have high environmental impacts. The air quality remarks the urbanization, which is affecting the community health and environment. The consumption of energy escalates GHG emission levels to be contingent on economic growth. For any GHG emission policies are aimed to accomplish the reduction of greenhouse gases even more. The key components of effective campaign on energy conservation will reduce the energy GHG emission with proper action planning and measurements of cogeneration, deep conservation, alternative to fossil fuels, biomass, landfill gas, renewable energy technologies, solar photovoltaic electric arrays, wind energy, geothermal, transportation solutions and waste minimization.

The government is planning to reduce the GHG emissions the cost-effective economic factors are needed to be identified and addressed. The best available control technologies on 'Energy Conservation' should be prioritized, which will also be a part of sustainable development. By adopting the best practices, the emissions can be controlled and reduced substantially. As we are becoming more conscious of environmental degradation caused by increasing consumption of energy, each entity whether the source of energy or a household or industry, is compelled to take measures for reducing.

Way Forward

A. Sustainability

- Need to establish coastal nurseries for providing seedlings to local people for plantation.
- Need to map ecosystem services to help planners.
- Need to assess the risk of upstream and downstream development around ecosystems to develop a common view of ecosystem services and explore restoration options.
- Ecosystem-based approaches are often more cost-effective over time and in some cases, grey-green infrastructure combinations may be more ideal.
- Proper care and maintenance of structure would reduce chances of dam failures.
- Protection of water bodies and river banks through various measures such as release of water on time, afforestation etc. will safeguard the ecosystem.
- Reviewing and maintenance of the structure should be mandatory.
- Need to develop an Emergency Action Plan.
- 5 "R" namely reduce, reuse, recycle, replenish and respect can help in resource conservation especially water.
- Need a scientific method of water collection, storage and distribution.
- Technology & Policy intervention is needed to solve the water crisis.
- Need to create awareness for the value of water.
- Nature Based Solutions could be implemented into policy and initiatives such as in the climate change strategies, regulations, investment in infrastructure and funding mechanisms to save the green on the Earth.
- Mangroves are the saviours for both humans and infrastructures during several disasters in India, especially tsunami and cyclone.
- Empirical studies on issues such as sanitation, access to basic amenities, poverty and education in peri-urban areas should be facilitated in order to conceive efficient policies safeguarding social, economic and environment development.

- All Indian cites should demarcate a site and set protocol for management of the demolition waste.
- Effective implementation depends on policies and cooperation at all scales, and can be enhanced through integrated responses that link adaptation and mitigation with other societal objectives.
- Research and administrative systems should be focused on human recovery, learning and adaptability to the conditions, and develop a strong ability to cope up with disasters.

B. Resilient Agriculture

- Improved variety of corn and pulses are available which is more drought tolerant. Using such types of seeds will help in saving water as well as increased production during drought and save resource and life.
- 94 wild edible plant species are there which have immense potential to increase the income of the farm households of Male Mahadeshwara (MM Hills) Wildlife Sanctuary, Karnataka.
- It has potential to provide nutrition and economic benefits.
- It can also reduce the pressure on biotic resources and has potential in contributing the ecosystem sustainability and mitigating the threats due to disasters that are driven by variety of factors and aggravated by ecosystem degradation.
- Policies need to be formulated for conservation of these valuable plants in the wild habitats.
- Proper institutional support is required to make it a mainstream livelihood to develop a more resilient community under the circumstances of changing climate.
- There is a need to conserve wild edibles and make the human society aware of their importance.

C. Disaster Resilient Construction

- Green buildings/infrastructure is one of the way to achieve green growth.
- A green building provides a structural stability during disaster as many lives are put in danger due to improper construction.
- Green construction acting as sustainable approach towards mitigating the side effects of structure on the environment, climate and society by identifying and understanding risk scenarios.
- Sustainable planning and urban development design process can help in safeguarding the natural ecosystems.
- State should source adequate land for rehabilitating the disaster victims. In case the land is not available, appropriate legislative provisions and financial strength of the state and individuals are necessary for land supply.
- Post disaster housing policy intervention is needed.
- Informing about the measures taken by the state and institutions and infrastructural augmentation help to grow confidence among the community members.
- A standard operating procedure and regular institutional training help people to be agile and alert during the disasters.
- The institutional capacity, knowledge and skills also help to lead the rehabilitation process in medium and long term.
- In mountain regions, the emergence of non-local materials and practices is one of the key issues to be addressed as it increases the overall carbon intensity of construction, its contribution to disaster-resistance of the building remains minimal.
- Eco-friendly approach for construction in mountainous region also generates revenue for local people including female.
- There is an urgent need to strengthen the area of timber-based products for construction in conjunction with the sustainable forest management practices which can ensure long-term supply of timber without negative environmental impact.
- Right policy support, supplemented with technical support, the resurgence of timber-based practices can be a strong step in the direction of eco-friendly construction in mountainous regions.

D. Strategic Issues

- Tn terms of disaster mitigation, a LCA based approach should be used and it should include the socioeconomic compensations and relief costs provided by the government to the affected communities.
- The build-maintain-rebuild paradigm should be put forth in place of our build-forget-build attitude.
- The accelerated growth in technology and connectivity will facilitate in improvement of the current systems and align the flood risk assessment to ensure maximum safety and minimum losses to the citizens of our country.
- Circular Economy can act as a crucial tool in order to mitigate the challenges being faced by the paper and pulp industry.
- By recycling their by-products as well as reusing certain material, paper mills can very well have a positive impact on their overall spending.
- By integrating farmers as well as nearby communities, the mills help to generate income-based activity for them.
- Recycling will reduce deforestation and plantation schemes will help sequester carbon.
- Recycling will help reduce the amount of waste being generated.
- The lower emission will lead to lesser pollution.
- We need to create proactive attitude towards climate change and environmental hazards among the students is necessary.
- Need to create skills towards DRR and sustainable development among the students.
- Need to mainstream the disaster education.
- Pre-service and in-service teacher's training is also needed in this regard.

E. Green Growth & Carbon Management

- Need to reduce waste following 3R strategy, Reduce, Reuse, Recycle.
- Need to generate green revolving fund, use renewable energy credits, power purchase agreements etc. Which will allow to accumulate the revenues and enable the carbon neutrality.
- Need to reduce the GHG emission with proper action planning and measurements of cogeneration deep conservation, alternative to fossil fuels, biomass, landfill gas, renewable energy technologies, solar photovoltaic electric arrays, wind energy, geothermal, transportation solutions and waste minimization.
- Carbon Capture and Sequestration (CCS) has been recognized as a potential mitigation measure to slow the atmospheric and marine accumulation of greenhouse gases.
- Green growth and flood proofing measures such as water harvesting, rain gardens, blue roofs, green roofs and bioswales can be equally effective in residential and industrial areas.
- Reforestation and preservation of existing forest, open spaces along with planning corridors around lakes and rivers will provide flood proofing and increased infiltration for long term.
- Areas around lakes and rivers have to be protected from further encroachments. Have to regain areas for creating room for rivers and corridors along them.
- Bioretention in storm drains and tree trenches, with permeable pavements along roads will help in draining the excess water.

National Institute of Disaster Management
(Ministry of Home Affairs, Government of India)
Plot No.15, Pocket 3, Block-B, Sector-29, Rohini, Delhi-110042
Email: ed.nidm@nic.in | Website: www.nidm.gov.in
ISBN No.: 978-93-82571-63-6