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Editor-in-Chief

A disaster is a natural or anthropogenic hazard that seriously disrupts a community's or society's ability to function and results in significant material, economic, and environmental losses and impacts that are greater than what the affected community or society can reasonably expect to be able to handle on its own. The intensity and frequency of catastrophes have grown due to climate change and environmental degradation, making important resources—including people—more vulnerable.

One of the most geographically diverse nations in the world, India is susceptible to cyclones, earthquakes, landslides, floods, and droughts. The short- and long-term economic development of many different industries can be significantly harmed by disasters. These extraordinary occurrences continue to have a negative impact on the nation's economy as well as the health and happiness of its citizens.

The National Institute of Disaster Management has consistently worked to build a disaster-resistant India through its trainings, research, documentation, and publishing in accordance with the requirements of the Disaster Management Act of 2005. The Institute produces a biannual journal called "Disaster & Development" with the goal of giving academics, academicians, and others a shared venue for publishing their distinctive and avant-garde research work on all facets of disaster management. The journal's debut issue was published in 2006.

In order to accomplish the aim of zero casualties and a disaster-free and resilient India, I believe that readers will find this issue useful in improving their understanding and knowledge of natural hazards, associated risks, and preparedness, preventative, and mitigation methods.

Shri Rajendra Ratnoo, IAS

Editorial Note

We are delighted to welcome you to the journal "Disaster and Development," Volume 12, Issue 1, January to June 2023. This issue covers a wide range, with case studies on catastrophe risk reduction and resilience with a focus on wide range of geo-hazards and theoretical considerations.

This issue brings together a wide spectrum of viewpoints, firsthand accounts, and research findings from academics, practitioners, and policymakers. We think that this collection of insightful papers will not only add to the body of existing knowledge but also stimulate insightful debate and result in practical solutions for development planning and catastrophe management.

The Disaster and Development Journal is dedicated to encouraging an interdisciplinary and team effort to address the difficult problems presented by catastrophes and their effects on global development initiatives. We would like to express our appreciation to the authors, reviewers, and editorial team whose hard work and knowledge enabled the publication of this issue.

We conclude by expressing our hope that the research and insights presented here will spur new initiatives in the areas of catastrophe risk reduction, sustainable development, and equitable resilience-building. We can create a more sustainable, equitable, and resilient future for everyone if we acknowledge the innate link between disasters and progress.

We appreciate your support and invite you to interact with the special issue's content and give us your feedback.

Surya Parkash, Ph.D.

Development of Climate Vulnerability Index for Bundelkhand Region, India

Surendra Singh Jatav[1], Nathoo Bharati[2]

Abstract

The present study aims to develop a climate vulnerability index for different districts in the Bundelkhand region of India. The indicator approach and the IPCC's AR4 methodology were used to develop potential vulnerability and climate vulnerability indices. According to the calculated vulnerability index, Lalitpur districts is highly vulnerable due to their greater exposure to changing climate. On the contrary, Chitrakoot district is the least vulnerable to climate change. Hence, the current study suggests the following policy recommendations. First, most of the districts are facing a water crisis even in the rainy season due to the continuous decline in monsoon rainfall distribution, while water is the most critical factor for farming. Therefore, water conservation through rainwater harvesting and the construction of new ponds and check dams would be a possible solution for the current crisis. Second, wheat, rice, and sugarcane are highly water-consuming crops and are not suitable for the Bundelkhand region. Hence, shifting from high water-intensive cropping patterns like wheat, rice, and sugarcane to less water-intensive crops such as kharif pulses and minor cereals would be a better adaptation strategy to increase net farm returns.

Keywords: *Exposure Index, Sensitivity Index, Indicator Approach, IPCC, Water Conservation, Climate Vulnerability*

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1. Introduction

Global, regional, and national economies are all being affected by climate change. Impacts threaten the viability of traditional farming, cattle, and forestry businesses, as well as pre-existing community infrastructure (Singh, 2020a). Inadequate precipitation, high temperatures, and the introduction of harmful pests and diseases are just a few of the ways in which climate change has been shown to damage agricultural production across the world (IPCC, 2018). Crop failure and sterile soil are all direct consequences of climate change, as are the declines in water-holding capacity, economic development, income distribution, and agricultural demand (FAO, 2008). Prices of agricultural goods and services will rise because of the global economic crisis, having a ripple effect on the agricultural sector. Because of agricultural productivity declines, it increased food prices, and reduced purchasing capacity, climate changes will have a significant effect on crop production stability and food availability (Singh and Sanatan, 2014; Singh, 2019; Singh, 2020a & b; Singh and Sanatan, 2020; Jatav et al., 2021a & b; Jatav, 2022).

The concept of climate vulnerability has been defined in many different ways and several conceptual frameworks have been developed to categorise vulnerability factors and describe the various vulnerabilities (McCarthy et al., 2001; Fussel, 2006; Kumar et al., 2016; Singh, 2020a & b; Balaganesh et al., 2020; Datta et al., 2022). (Singh, 2020b). McCarthy et al (2001) and Fussel (2006) defines vulnerability as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Climate vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (Fig. 1). The exposure of a system to climate stimuli depends on the level of global climate change and, due to the spatial heterogeneity of anthropogenic climate change, on the system's location. The sensitivity of a system denotes the (generally multi-factorial and dynamic) complex and dynamic link between its exposure to climatic stimuli and the resulting impacts. Adaptation refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Further, Singh, (2020a & b) presents a conceptual framework of vulnerability that combines a nomenclature for describing any vulnerable situation in terms of the vulnerable system, the hazard(s) of concern, the attributes(s) of concern, and a temporal reference; a classification scheme for vulnerability factors according to their sphere and knowledge domain; and a terminology for vulnerability concepts that is based on the vulnerability factors included. The conceptual framework allows to concisely describe any vulnerability in the literature as well as the differences between alternative concepts (Kumar et al., 2016; Balaganesh et al., 2020; Datta et al., 2022).

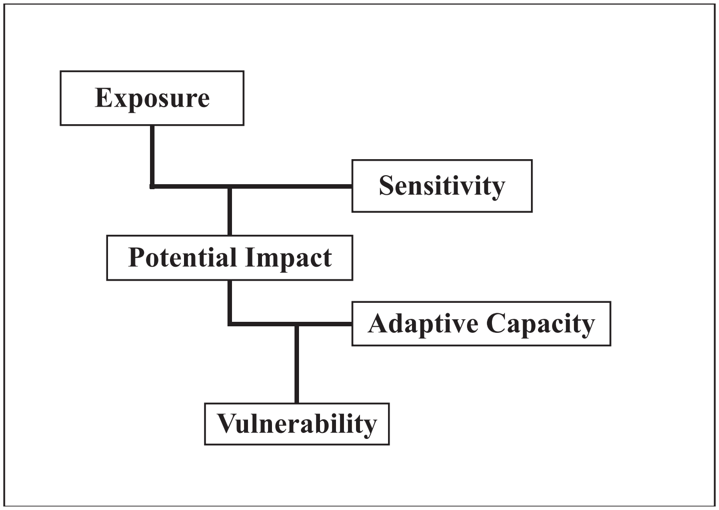

Figure 1 : Conceptual Framework of Climate Vulnerability

Source: IPCC, 2001

The "capacity or inability to be adversely impacted by climatic variability and severe climate events and support them" is a straightforward definition of vulnerability in the context of climate change. Vulnerability assessment is a difficult task because of the complex relationships between many parts of natural systems and human interventions. However, among the many tools necessary for the adaptation of social and biological systems, vulnerability assessment is often regarded as the most crucial.

The current research defines vulnerability as the extent to which climate change threatens food crop output. The idea of vulnerability has emerged as an important tool in the study of climate change in recent years. This is because of the crucial function it plays in helping us comprehend, quantify, and appraise the predicament of communities and individuals in the face of climate-induced catastrophes (Singh, 2020b). In order to better create adaptive measures and build resilience in the face of climate change, the Intergovernmental Panel on Climate Change (IPCC, 2018) stresses the need of conducting a thorough evaluation of the susceptibility of places to climate change.

1.1 Review of Literature

A growing climate vulnerability literature indicates that rural farmers in the Bundelkhand region are particularly at risk. Singh (2020b) looked at the different kinds and levels of susceptibility to economic hardship faced by farming households in the Bundelkhand region. The empirical findings reveal that farmers belonging to Scheduled Tribes (ST) groups were the most susceptible to climate change and the least prepared to respond. In a similar vein, a study by Derbile et al (2022) in Ghana, Africa, found that farmers there were vulnerable to several climatic extremes, with drought being the most often and influential adverse event that considerably impacted agricultural production. As a result, crops were damaged by the subsequent high temperatures and/or plenty of sunshine. All crops investigated, including maize, rice, millet, and soybeans, were very sensitive and susceptible to strong sunshine and temperatures, but the findings showed that rice and corn were the most sensitive and delicate to drought.

In addition, Kumar et al (2016) conducted a study in Karnataka, India, using an indicator approach and a development risk score for several districts. Losses in grain, pulse, and oilseed production were shown to be higher due to climate variability in the Gulbarga and Raichur areas. It is also estimated that over 70% of the farm land is under risk, which is important since it provides food and shelter for 60% and 67% of the state's livestock and rural inhabitants, respectively. Balaganesh et al (2020) did something similar for 30 districts in Tamil Nadu, India, and compiling agricultural and dairy data into a new composite drought vulnerability index (CDVI). The IPCC method was used to determine the index's value; this method took into account the factors of exposure, sensitivity and adaptability. The study found that 12 districts are extremely vulnerable to drought, 8 are moderately vulnerable in the eastern and southern agro-climatic zones, a few districts in Tamil Nadu's Cauvery delta and western zones are extremely vulnerable, and most districts in the north-western, and high rainfall zones are less vulnerable. Likewise, the vulnerability of three smallholder agricultural systems in Telangana, India was also studied by Kuchimanchi et al (2021), (i) crops without livestock (CWL),

(ii) crops with small ruminants (CSR), and (iii) crop with dairy (CD). They found that people's beliefs of their own vulnerability to climate change, the accessibility of resources to support themselves, and the methods they utilised in their farming all had a role in how susceptible their own families households in CWL areas were more susceptible to total precipitation decreases and higher maximum temperatures, whereas those in crop-and-cattle farming areas were more exposed to higher maximum temperatures and more erratic rainfall.

The opinions of farmers are also valuable in determining risk. Datta et al were conducted a (2022) meta-analysis and found that, consistent with meteorological data, many Indian farmers had seen an increase in temperature and an increase in the frequency and/or reduction in rainfall. It seems that Indian farmers have used a broad variety of incremental and systemic adaptation strategies. Farmers are also increasingly adopting radical adjustments such as shifting their land usage, resource and labour allocations, occupational patterns, and agricultural methods. In addition, factors like family income, farm size, gender, and resource endowment, among others, often impact the adoption of adaptation methods.

With the above evidences, the present study aims to develop a climate vulnerability index for all 13 districts of Bundelkhand region using the Assessment Report 4 methodology of Intergovernmental Panel on Climate Change. More specifically, the purpose of the paper is to answer some of the key questions to the extent (how much), causes (why) and spatial distribution (where) of vulnerability.

2. Methods and Materials

2.1 Study Area

The Bundelkhand region comprises of 13 districts in the States of Madhya Pradesh (6 districts) and Uttar Pradesh (7 districts) in central India (Fig. 2). The districts in Madhya Pradesh are Sagar, Damoh, Chhatarpur, Tikamgarh, Panna, and Datia and; the districts in Uttar Pradesh are Jhansi, Lalitpur, Jalaun, Hamirpur, Banda, Mahoba, and Chitrakoot. The Bundelkhand region lies between 23° 08 north to 26°30 north latitude and 78°11 east to 81°30 east longitude, with a total area of 71, 619 km^2. About 82% of the total population of 18.3 million depends on agriculture, the majority of which is rainfed (Census, 2011). About 33% of the territory is covered by degraded forest, grazing pasture, and degraded wasteland. In totality, of the population depends on agricultural and livestock-based industries (Gupta et al., 2014; Singh, 2020b).

The region receives a mean annual rainfall of 750 millimetres, which falls at random intervals throughout the year. More than 85% of the year's precipitation falls during the rainy season (Kharif), which runs from July to September. The remaining 15% is spread out throughout the other nine months (Singh, 2020b). The regional water balance, particularly groundwater recharge, has suffered as a result of this (Singh et al., 2014). The mean temperature is 35°C higher in the rainy season than in the dry season (rabi), which is cooler (10°C). Using long-term data (1971-1990 and 1991-2004), Rao et al. (2013) found that in the Bundelkhand region of of Uttar Pradesh, formerly semi-arid wet climates have transitioned into semi-arid dry and arid climates, affecting around 580,000 hectares.

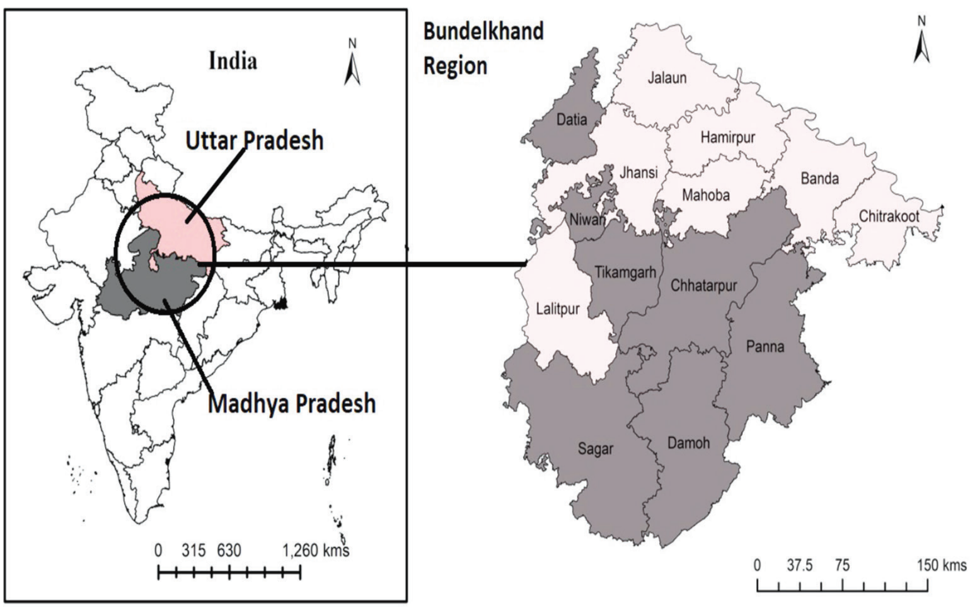

Figure 2 : Study Area Map

Source: Authors Map, 2023. Note: base map was taken from Bhuvan portal, India

2.2 Data Sources, Rationality of Indicators and Descriptive Statistics

The present study uses district-level data collected from differential sources to develop a climate vulnerability index for different districts of the Bundelkhand region. To develop an exposure index, data on temperatures and rainfall was collected from the Indian Meteorological Department, Government of India. Further, seasonal aspects of climate variability were also considered for the robust development of an exposure index. Therefore, exposure index is divided into seasonal temperatures and rainfall indices, i.e., kharif season and rabi season. Mean maximum temperature of Bundelkhand region was 32.41°C, which varies from 28.61°C in rabi season (October- March) to 34.2°C in kharif season (Table 1). Further, mean minimum temperature was 18.74°C, which varies from 12.81°C in rabi season to 25.14°C in kharif season. Mean annual rainfall was 917.36 millimetres, which varies from 78.81 millimetres in rabi season to 825.01 millimetres in kharif season during 1951-2020 (IMD, 2020).

Similarly, data for the sensitivity index were gathered from the Population Census (2011), the Ministry of Agriculture and Farmers Welfare, Government of India (2021-22), and the 76th round of the National Sample Survey organisation (2019-20). Bundelkhand region has reported 11,005 hectares of forest cover, while 3,902 hectares have been reported as not suitable for farming with 10% degraded land (Table 1). Almost half of the region's population lives in poverty, and the gender ratio is lower than in national statistics (i.e., 885). The population density of the region is 278 persons per kilometre. Access to basic amenities is also vital to lowering the climate sensitivity status of households in the region. According to the 2011 census, only half of the population has access to all-season houses, while roughly 40% has access to bathrooms and latrines. However, more than 99% of households have access to safe drinking water.

Although the system may be exposed to or sensitive to climatic stress and shock, it cannot considered to be fragile (Fellmann, 2012). The adaptive capability of a system impacts vulnerability by altering both exposure and sensitivity (Singh, 2020b). Three important factors determine successful and efficient adaptation (i) Timely perception and realisation of climate change and the need to adopt adaptation measures; (ii) incentives to adapt and the ability to adapt; and (iii) the need to change farming practises to maximise returns from the new climate change (Singh, 2020b).

Access to extension services is taken into account when creating an adaptation index for the Bundelkhand region. Table 1 depicts that only 62.67% of households have access to all seasonal roads, while 94.21% of households have access to an electricity connection. Limited financial inclusion is observed. Only 8.81% of rural households are members of an agricultural credit society, while 81.91% of households own livestock. Further, 34.53% of the population works as agricultural labourers. The mean annual per capita income was reported at 27,548 INR. As far as the agricultural training of farmers is concerned, only 1.08% of the population is skilled, while 48.13% of rural households are working in MGNREGA. Moreover, 65.69% of the population is literate, while the mean land size is 1.47 hectares.

Table 1 : Rational Indicators for Vulnerability Assessment

Components	Functional Relationship with targeted component	Mean	Source
Exposure			
Maximum Temperature Variability (1951-2020)			
Kharif Season (June-September)	+	34.21	Singh et al., 2019
Rabi Season (October-March)	+	28.61	Singh et al., 2019
Annual	+	32.41	Singh et al., 2019
Minimum Temperature Variability (1951-2020)			
Kharif Season (June-September)	+	25.14	Singh et al., 2019
Rabi Season (October-March)	+	12.81	Singh et al., 2019
Annual	+	18.74	Singh et al., 2019
Rainfall Variability (1951-2020)			
Kharif Season (June-September)	+	825.01	Singh et al., 2019
Rabi Season (October-March)	+	78.81	Singh et al., 2019
Annual	+	914.36	Singh et al., 2019
Sensitivity			
Forest Area (Hectares)	-	110054	Funk et al. (2019)
Area Not Available for Cultivation (Hectares)	+	39028	Shrestha et al., 2017

Components	Functional Relationship with targeted component	Mean	Source
Net Sown Area (Hectares)	-	312426	Rai et al., 2008
Degraded Land (%)	+	9.76	Rai et al., 2008
BPL Population (%)	+	42.33	Alam et al., 2017
Sex Ratio	+	885.15	Nadeem et al., 2009
Population Density (1000/Km)	+	278.15	Islam et al., 2013
Decadal Population Growth (%)	+	18.65	Islam et al., 2013
Households having all Seasonal House (%)	-	51.00	Alam et al., 2017
Households having Access of Bathroom (%)	-	39.32	Alam et al., 2017
Households having access of Latrine (%)	-	40.57	Alam et al., 2017
Households having Access of Safe Drinking Water (%)	-	99.34	Miranda et al., 2011
Adaptive Capacity			
All Seasonal Approach Road	+	62.67	Masud et al., 2017
Households having access of Power Supply (%)	+	94.21	Masud et al., 2017
Households having membership of Agricultural Credit Society (%)	+	8.81	Singh et al., 2019
Households owning Livestock (%)	+	81.91	Masud et al., 2017
Agricultural labours to total population (%)	+	34.53	Masud et al., 2017
Per Capita Income (₹)	+	27548	Hahn et al., 2009
Households taken formal Training in Agriculture (%)	+	1.08	Singh et al., 2019

Components	Functional Relationship with targeted component	Mean	Source
Households have worked in Mgnrega (%)	+	48.13	Singh et al., 2019
Literacy Rate (%)	+	65.69	Nadeem et al., 2009
Mean Land Size (Hectare)	+	1.47	Abid et al., 2015

Source: Authors estimation, 2023.

2.3 Estimation Method

Conducting a vulnerability assessment is a multistep exercise and requires setting a clear goals and objective that will determine the type of vulnerability assessment as well as the scale, sector, tier, indicators, and methods to be adopted. Because each of the sub-components is measured on a different scale, it was first necessary to standardize each as an index. Hence, equations 1 and 2 (min-max method) was used to normalized the data as follows.

$$Index_{sv} = \frac{S_v - S_{min}}{S_{max} - S_{min}} \quad (1)$$

$$Index_{sv} = \frac{S_{max} - S_v}{S_{max} - S_{min}} \quad (2)$$

Equation 1 was used if the indicator is positively associated with the targeted index, while equation 2 was used if the indicator is negatively associated. In the equations 1 & 2, sv is the original sub-component for the district d, and S_min and S_max are the minimum and maximum values, respectively, for each sub-component determined using the data from all 13 districts. For example, forest area ranged from 110054 to 120154 hectares in all 13 districts. These minimum and maximum values were used to transform this indicator into a standardized index so it could be integrated into the sensitivity component of the vulnerability index. For variables that measure frequencies such as the 'percent of household having access of safe drinking water', the minimum

$$Index_E = \frac{\text{MaxTK+MaxTR+MaxTA+MinTK+MinTR+MinTA+RK+RR+RA}}{9} \quad ...(3)$$

value was set at 0 and maximum value at 100. Moreover, equations 3, 4 & 5 were used to develop exposure, sensitivity, and adaptive capacity indices.

$$Index_s = \frac{\text{F+ANSA+NSA+DL+BPL+SR+PD+DPG+House+Bathroom+Latrine+Safe Water}}{12} \quad ...(4)$$

Where, $index_E$ is an exposure index, while MaxTK, MaxTR, MaxTA, MinTK, MinTR, MinTA, RK, RR and RA are maximum kharif season temperature, maximum temperature rabi season temperature, annual maximum temperature, minimum kharif season temperature, minimum temperature rabi season temperature, annual minimum temperature, kharif season rainfall, rabi season rainfall, and annual rainfall.

Where, *index*.is sensitivity index, while F, ANSA, NSA, DL, BPL, SR, PD, DPG, House, Bathroom, Latrine and Safe water are forest area, area not available for cultivation, net sown area, degraded land, population below poverty line, sex ratio, population density, decadal population growth, access of all seasonal house, access of bathroom, access of latrine, and access of safe drinking water.

$$Index_{aci} = \frac{\text{Road+PS+ACS+Livestock+labour+PCI+Training+MGNREGA+LR+Land}}{10} \quad ...(5)$$

Where, $index_{aci}$ aci is adaptive capacity index, while road, PS, ACS, Livestock, labour, PCI, Training, Mgnrega, LR and Land are all seasonal approach roads, households having access of power supply, membership of agricultural credit society, ownership of livestock, agricultural labourers, per capita income, formal agricultural training, population working in MGNREGA, literacy rate and mean land size.

Once the values of exposure, sensitivity, and adaptive capacity for the district level had been calculated, two contributing factors (exposure and sensitivity) were combined using equation (6) to obtain the district-level potential climate vulnerability index (Tripathi, 2017).

$$PCVI_d = Exposure\ Index_d + Senstivity\ Index_d \text{.........................} (6)$$

Where, $PCVI_d$ is the potential climate vulnerability index for the district d; $Exposureindex_d$ is the calculated exposure index for the district d; and $Senstivityindex_d$ is the sensitivity index for the district d. Adaptive capacity, represented byACI_d (equation 7), was taken into consideration to develop a climate vulnerability index (CVI) for the district das follows.

$$CVI_d = (Exposure\ Index_d - Adaptive\ Capacity\ Index_d) * Senstivity\ Index_d \text{......} (7)$$

PCVI and CVI were scaled so that –1 denotes the least vulnerable and +1 the most vulnerable.

3. Results and Discussion

3.1 Variability in Rainfall and Temperature (1951-2020)

Table 2 depicts the variation in rainfall and temperature from 1951 to 2020. Seasonality of rainfall and temperature was also recorded in order to connect with agriculture. Further, the study period of 1951–2020 is divided into 20–20 sub-periods to capture variability. In India, there are two main cropping seasons, namely kharif (rainy) and rabi (winter). Hence, data on rainfall and temperatures were calculated separately for the kharif, rabi, and annual seasons. The statistics of rainfall revealed that rainfall has declined while variability in temperatures has been observed. Table 2 indicated that annual rainfall during 1951-70 was 999.54 millimetres, while it was only 873.33 millimetres (about 86 millimetres less) during 2011-2020, and similar trends were also observed in the kharif and rabi seasons.

A marginal increase in maximum temperature was also observed. The annual maximum temperature was 32.35°C from 1951 to 1970, and it has risen by 0.19°C from 2011 to 2020. Furthermore, maximum temperatures have risen rapidly during the kharif season while gradually rising during the rabi season. Similar trends in minimum temperatures in the kharif and rabi seasons were also observed. Moreover, diurnal temperature is also important for farm practices. Diurnal temperature range means the variation between the lowest and highest temperatures during a given day at a certain location. It is also reported in Table 2 that the diurnal temperature in all the seasons has increased.

Table 2 : Variability in Minimum & Maximum Temperatures and Rainfall from 1951 to 2020

Indicators	Season	1951-70	1971-90	1991-2010	2011-2020	1951-2020
Rainfall	Kharif	896.89	833.17	785.25	784.71	825.01
	Rabi	95.58	84.02	60.93	74.72	78.81
	Annual	999.54	928.76	855.82	873.33	914.36
Maximum Temperature	Kharif	34.03	33.99	34.34	34.47	34.21
	Rabi	28.65	28.45	28.76	28.59	28.61
	Annual	32.35	32.23	32.56	32.54	32.41
Minimum Temperature	Kharif	25.21	24.96	24.96	25.45	25.14
	Rabi	12.57	12.50	13.03	13.15	12.81
	Annual	18.68	18.53	18.83	19.07	18.74
Diurnal Temperature	Kharif	8.82	9.04	9.39	9.03	9.07
	Rabi	16.08	15.94	15.73	15.44	15.80
	Annual	13.73	13.67	13.69	15.37	13.94

Source: Authors estimation, 2023. Note: Kharif season (June-September) and Rabi season (October-March)

3.2 Exposure Index (EI)

Table 3 depicts exposure indices for different districts in the Bundelkhand region. The calculated exposure indices show that Lalitpur district is highly exposed to changing temperatures and rainfall, while Chitrakoot district is relatively least exposed. In general, temperatures in Lalitpur are higher than in other districts during the kharif and rabi seasons. The statistics revealed that the mean annual temperature during 1951–2020 in Lalitpur was 32.63°C while it was only 32.46°C in Chitrakoot. On the contrary, the mean minimum temperature is relatively higher in Chitrakoot than in Lalitpur. The mean minimum temperature in Lalitpur was reported at 18.40°C, while the corresponding figures for Chitrakoot were 18.81°C. It shows the variability in temperature in the Bundelkand region.

As far as rainfall variability is concerned, the mean annual rainfall in Chitrakoot was 1006 millimetres, while the corresponding figures for Lalitpur were only 971 millimetres during 1951-2020.

Table 3 : District-Wise Exposure Index

Districts	Maximum Temperature			Minimum Temperature			Rainfall			Exposure Index
	Kharif	Rabi	Annual	Kharif	Rabi	Annual	Kharif	Rabi	Annual	
Banda	0.152	0.362	0.235	0.466	0.060	0.092	0.182	0.434	0.073	0.228
Chitrakoot	0.117	0.237	0.000	0.453	0.000	0.017	0.125	0.249	0.077	0.142
Hamirpur	0.020	0.985	0.778	0.000	0.214	0.000	0.540	0.700	0.497	0.415
Jaluan	0.265	0.990	0.489	0.151	0.584	0.380	1.000	1.000	1.000	0.651
Jhansi	0.557	0.961	0.888	0.768	0.759	0.826	0.359	0.724	0.432	0.697
Lalitpur	0.830	0.701	1.000	0.704	1.000	1.000	0.193	0.667	0.249	0.705
Mahoba	0.323	0.871	0.801	0.612	0.342	0.393	0.210	0.338	0.077	0.441
Chhatarpur	0.463	0.485	0.537	0.514	0.292	0.259	0.104	0.189	0.000	0.316
Damoh	0.927	0.001	0.277	1.000	0.433	0.659	0.137	0.000	0.083	0.391
Datia	0.500	0.983	0.570	0.304	0.815	0.623	0.389	0.901	0.501	0.621
Panna	0.541	0.012	0.015	0.595	0.174	0.190	0.263	0.000	0.161	0.217
Sagar	1.000	0.017	0.370	0.607	0.495	0.513	0.000	0.223	0.017	0.360
Tikamgarh	0.632	0.639	0.750	0.626	0.619	0.632	0.234	0.597	0.265	0.555

Source: Authors estimation, 2023.

3.3 Sensitivity Index (SI)

Table 4 depicts district-wise sensitivity indexes for the Bundelkhand region. The calculated sensitivity index shows that Chitrakoot district is relatively highly climate-sensitive, while Hamirpur district is relatively less sensitive. The cross-indicator analysis revealed that the main influencing factors responsible for less higher sensitivity in Chitrakoot district than Hamirpur district are less forest area, net sown area, a higher proportion of the population living below the poverty line, higher population density, higher decadal population growth, and less access to bathrooms and latrines.

It is observed that Chitrakoot district has only 24084 hectares of forest area, while Hamirpur district has 81363 hectares. Further, Chitrakoot district has only 165019 hectares of land under cultivation, while Hamirpur district has 289212 hectares. In Chitrakoot district, approximately 36.35% of the population lives below the poverty line, while only 29.75% of the population lives below the poverty line nationally. Furthermore, only 22.22 and 47.57% of households belonging to the Chitrakoot district have access to bathrooms and latrines, while the corresponding figures for Hamirpur were relatively higher, i.e., 47.92% and 63.54%.

Table 4 : District-Wise Sensitivity Index

Districts	Forest Area	Area Not Available for Cultivation	Net Sown Area	BPL Population	Sex Ratio	Population Density	Decadal Population Growth	All Seasonal House	Access of Bathroom	Access of Latrine	Safe Drinking Water	Degraded Land	Sensitivity Index
Banda	1.000	0.782	0.573	0.272	0.041	1.000	0.475	0.229	0.667	0.688	0.001	0.026	0.479
Chitrakoot	0.747	0.503	1.000	0.364	0.367	0.655	1.000	0.078	0.778	0.521	0.007	0.068	0.507
Hamirpur	0.937	0.520	0.697	0.298	0.000	0.444	0.000	0.468	0.524	0.365	0.000	0.049	0.358
Jaluan	0.924	0.741	0.566	0.494	0.082	0.874	0.441	0.281	0.417	0.569	0.005	0.076	0.456
Jhansi	0.903	0.908	0.629	0.218	0.592	0.981	0.369	0.689	0.719	0.615	0.005	0.107	0.561
Lalitpur	0.762	0.848	0.693	0.510	0.918	0.383	0.811	0.219	0.875	0.798	0.000	0.082	0.575
Mahoba	0.961	0.669	0.834	0.408	0.347	0.621	0.754	0.250	0.708	0.800	0.000	0.026	0.531
Chhatarpur	0.307	0.792	0.242	0.575	0.449	0.234	0.581	0.839	0.667	0.819	0.018	0.136	0.472
Damoh	0.131	0.422	0.616	0.596	1.000	0.119	0.458	0.594	0.719	0.750	0.008	0.131	0.462
Datia	0.920	0.000	0.860	0.394	0.245	0.575	0.538	0.786	0.692	0.708	0.010	0.104	0.486
Panna	0.000	0.743	0.773	0.489	0.898	0.000	0.547	0.625	0.218	0.197	0.010	0.185	0.390
Sagar	0.029	1.000	0.000	0.616	0.653	0.345	0.500	0.406	0.500	0.417	0.010	0.152	0.386
Tikamgarh	0.858	0.247	0.837	0.272	0.816	0.552	0.606	0.906	0.406	0.479	0.011	0.127	0.510

Source: Authors estimation, 2023.

3.4 Adaptive Capacity Index (ACI)

Table 5 depicts district-wise adaptive capacity indexes for different districts in the Bundelkhand region. The calculated adaptive capacity index results show that Hamirpur district has the highest adaptive capacity compared to other districts, while Chitrakoot district has the least adaptive capacity to cope with climate change. The cross-indicator analysis revealed that relatively higher access to electricity, higher membership in agricultural credit societies, a higher working population in agriculture, higher per capita income, a higher population working in MGNREGA, and a higher mean land size were the main contributing indicators for higher adaptive capacity in Hamirpur

It is observed that about 95.95% of households belonging to the Hamirpur districts have access to electricity, while the corresponding figure for Chitrokoot is only 92.43%. About 7.12% of farmers in Hamirpur district are members of an agricultural credit society, compared with only 6.56% of farmers nationwide. Further, more than 40% of the rural population in Hamirpur district works in agriculture, while the corresponding figure for Chitrakoot is 38.23%. There is a wide gap between the per capita income of Chitrakoot and Hamirpur districts. The per capita income of Hamirpur is 60,216 INR, while that of Chitrakoot is only 21,590 INR. MGNREGA provides employment to the unskilled population in the off-cropping season and is a major contributor to livelihood security. The statistics revealed that more than 40% of the rural population was employed in MGNREGA, while the corresponding figure for Chitrakoot was only 9.38%. Lastly, the mean land size of Chitrakoot district was only 1.03 hectares, while the mean land size of Hamirpur is 1.75 hectares.

Table 5 : District-Wise Adaptive Capacity Index

Districts	All Season approach roads	Power Supply	Agricultural Credit societies	Livestock	Agricultural labours	Per Capita Income	Agricultural Training	Mgnrega	Literacy Rate	Mean Land Size	Adaptive Capacity Index
Banda	0.519	0.988	0.061	0.896	0.233	0.348	0.020	0.229	0.559	0.417	0.427
Chitrakoot	0.796	0.924	0.066	0.813	0.382	0.124	0.010	0.094	0.773	0.000	0.398

Districts	All Season approach roads	Power Supply	Agricultural Credit societies	Livestock	Agricultural labours	Per Capita Income	Agricultural Training	Mgnrega	Literacy Rate	Mean Land Size	Adaptive Capacity Index
Hamirpur	0.789	0.960	0.071	0.851	0.409	1.000	0.000	0.426	0.668	1.000	0.617
Jaluan	0.775	0.893	0.099	0.813	0.304	0.098	0.000	0.438	0.725	0.556	0.470
Jhansi	0.755	0.893	0.099	0.867	0.304	0.836	0.004	0.200	0.702	0.611	0.527
Lalitpur	0.838	0.995	0.051	0.906	0.261	0.304	0.000	0.328	0.604	0.528	0.481
Mahoba	0.783	0.888	0.094	0.781	0.373	0.200	0.005	0.313	0.619	0.944	0.500
Chhatarpur	0.462	0.909	0.108	0.807	0.317	0.036	0.000	0.645	0.592	0.833	0.471
Damoh	0.459	0.981	0.072	0.813	0.435	0.099	0.050	0.750	0.661	0.625	0.495
Datia	0.442	0.976	0.108	0.696	0.292	0.166	0.038	0.554	0.706	0.639	0.462
Panna	0.444	0.898	0.088	0.781	0.460	0.018	0.009	0.656	0.626	0.472	0.445
Sagar	0.453	0.958	0.089	0.969	0.376	0.143	0.006	0.750	0.721	0.889	0.535
Tikamgarh	0.633	0.984	0.139	0.656	0.342	0.000	0.000	0.875	0.586	0.486	0.470

Source: Authors estimation, 2023.

3.5 Climate Vulnerability Index (CVI)

By using equations 6 and 7, potential vulnerability and climate vulnerability indices were calculated (Table 6). The potential vulnerability index indicates that if farmers do not adopt recommended adaptations, they will be exposed and sensitive to climate change; on the other hand, the vulnerability index increases farmers' adaptive capacity in the system. In the science of vulnerability assessment, adaptive capacity is always a determining factor. Higher adaptive capacity reduces the intensity of climate vulnerability and makes the system more resilient to climate change. Jhansi district is the most vulnerable, while Panna district is the least vulnerable, according to the calculated potential vulnerability index scores. Now if we include adaptive capacity in the system, the picture changes completely. The calculated vulnerability index shows that Chitrakoot district has the least vulnerable district, while Lalitpur district has the highest vulnerability among the districts.

Table 6 : District-Wise Vulnerability Index

Districts	Exposure Index	Sensitivity Index	Adaptive Capacity Index	Potential Vulnerability Index	Vulnerability Index
Banda	0.228	0.479	0.427	0.707	-0.095
Chitrakoot	0.142	0.507	0.398	0.649	-0.130
Hamirpur	0.415	0.358	0.617	0.773	-0.072
Jaluan	0.651	0.456	0.470	1.107	0.083
Jhansi	0.697	0.561	0.527	1.258	0.095
Lalitpur	0.705	0.575	0.481	1.280	0.129
Mahoba	0.441	0.531	0.500	0.972	-0.031
Chhatarpur	0.316	0.472	0.471	0.788	-0.073
Damoh	0.391	0.462	0.495	0.853	-0.048
Datia	0.621	0.486	0.462	1.107	0.077
Panna	0.217	0.390	0.445	0.607	-0.089
Sagar	0.360	0.386	0.535	0.746	-0.068
Tikamgarh	0.555	0.510	0.470	1.065	0.043

Source: Authors estimation, 2023.

4. Conclusion and Policy Recommendations

This study was conducted in the most backward and vulnerable region of India, i.e., the Bundelkhand region. Using the IPCC's AR4 vulnerability assessment methodology, vulnerability indices for different districts of the Bundelkhand region were calculated. The region is drought-prone, and the rural population is solely dependent on farming, which is highly susceptible to changing climates. The findings from our study can be supplemented with the vulnerability assessment of ICAR-CRIDA. The results of the study also show that livelihood options in the region are limited and primarily based on agriculture and the labour sector. Due to their high reliance on the primary sector for livelihood, the rural population is highly vulnerable to changing climatic conditions. The findings from this study are more suitable for the local rapid vulnerability assessment. Furthermore, the findings aided in the development of sector-specific as well as overall vulnerability assessments and adaptation strategies for dealing with climate change. These can be implemented by the state government and local bodies to reduce the vulnerability and enhance the adaptive capacity of all 13 drought-prone districts.

As a result, the current study suggests the following policy recommendations. First, most of the districts are facing a water crisis even in the rainy season due to the continuous decline in monsoon rainfall distribution, while water is the most critical factor for farming. Therefore, water conservation through rainwater harvesting and the construction of new ponds and check dams would be a possible solution for the current crisis. Second, wheat, rice, and sugarcane are highly water-consuming crops and are not suitable for the Bundelkhand region. Hence, shifting from high water-intensive cropping patterns like wheat, rice, and sugarcane to less water-intensive crops such as kharif pulses and minor cereals would be a better adaptation strategy to increase net farm returns.

The study's findings are critical for assessing regional vulnerability and providing direction for future research. The results of this study, however, need to be interpreted with caution because of certain limitations. First, the present study only used spatial data, while if we want to track the role of climate adaptations introduced to reduce vulnerability in the region, spatial and temporal analysis are prerequisites. Second, crop production loss due to climate change is another important factor responsible for higher vulnerability in the region. Hence, the production loss index (decomposition analysis) also needs to be calculated for robust estimation. Finally, while secondary data is useful for rapid assessment, the case study method is critical for capturing the impact of any adaptation strategy, such as how MGNREGA contributed to reduce climate vulnerability. Hence, a robust and comprehensive case study of climate vulnerability in the region is a prerequisite.

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The Potential use of Thermal Springs in Building Resilience after Disaster: Conceptual Introduction and Outlook

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Abstract

The use and development of thermal springs can provide underestimated potential in relevant cultural and psychosocial resilience-building after traumatic disaster. This paper allows insight on an initial conceptual introduction and provides an outlook of thinkable ideas based on exploratory field research performed within an academic grass-roots framework. It does so by taking a look at examples of various countries under different aspects of the use of thermal springs, considering them in the context of combining disaster management with trauma pedagogy.

Keywords: *Cultural Resilience, Psychosocial Resilience, Trauma Pedagogy, Trauma Therapy, Disaster Relief Management*

1. Conceptual Introduction

In 2021, massive forest fires plagued Evia in Greece, an island some 200km (125 miles) away from Athens. The fire gutted 50,795 hectares of forested land from Ellenika in the island's far north to the east of Istaia and down to Rovies [1], threatening the lives of its inhabitants, of which dozens had to be evacuated [2]. The fire finally burnt out near the seaside resort Ilia, some 10 km (6 miles) away from the thermal springs of the coastal town Loutra Edipsos. Only a short time later, the island was internationally re-introduced and recommended as tourist destination. The maintenance of the island's thermal springs in Loutra Edipsos, "renowned for its mineral-rich therapeutic waters - said to cure everything from gout to heart sickness" [1], did play a role in this

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cultural development of resilience [3]. Further examples of other countries suggest that the use of thermal springs provide potential in both the development of cultural as well as psychosocial resilience-building after traumatic events such as natural or man-made disasters.

While the case of the Greek island of Evia in the aftermath of the forest fires can be seen as display for cultural resilience, examples of the use and re-use of thermal springs in Iraq [4] or mere public sanitation facilities in Syria [5] underline their potential as tool for the development of psychosocial resilience. In a more therapeutical context, when taking a specific look on the Balkans, thermal springs have also been used for the strengthening of mental health as well as for the treatment of nervous diseases as, to give an example, is indicated on the information board of the lye and healing mud near Burgas, Bulgaria [6]. These factors underline the potential use of thermal springs in trauma pedagogy, when considering the important and sometimes overlooked aspect of providing therapeutic treatment for traumatized individuals as part of long-term disaster management, specifically disaster relief management.

2. Use of Thermal Springs Under the Aspect of Cultural Development and Psychosocial Well-Being

In 2021, the cultural importance of thermal springs and the institutional structure that facilitates them was made internationally aware by UNESCO World Heritage Convention by enlisting The Great Spa Towns of Europe: “These ensembles are all integrated into an overall urban context that includes a carefully managed recreational and therapeutic environment in a picturesque landscape. Together, these sites embody the significant interchange of human values and developments in medicine, science and balneology.” Further explanations point out the traditional concept of medical cure meeting both psychosocial well-being and cultural values: “Taking the cure, either externally (by bathing) or internally (by drinking, and inhaling) involved a highly structured and timed daily regime and a combination of medical aspects and leisure, including entertainment and social activities [...] as well as taking physical exercise within an outdoor therapeutic spa landscape.” [7].

The concept of using sanitation facilities and thermal springs for psychosocial well-being and cultural development within the framework of disaster relief management for long-term resilience- building becomes obvious when studying the case of Hammam

Al-Nahhasin in Aleppo, Syria as well as Hammam Al-Alil near Mosul, Iraq. The traditional public bath Hammam Al-Nahhasin had to close its doors as it was located right in the center of deadly battles in Aleppo. When efforts were made to reopen it again, locals were glad to regain a part of their normal weekly family routine contributing to their psychosocial resilience after this man-made disaster. [5]. In Iraq, Hammam Al-Alil is a town near Mosul which is famous throughout the country for its healing hot waters and muddy baths on the banks of the Tigris river. The spa town, once a magnet not only for visitors from Iraq but also from Kuwait, the Gulf countries and Saudi Arabia, but was partly destroyed when the whole Mosul region turned into a terrible battlefield. In 2017, the old spa facilities were able to reopen, very much to the benefit of a severely traumatized local community [4, 8]. As the manager of Hammam Al-Alil spa, Ali Aziz Ahmed, adds, a further progress towards psychosocial resilience and cultural development was achieved as recent as in June 2022 when the thermal water was made accessible in a newly built spa center. The use of this thermal water has become part of a monthly or even weekly routine for both male and female individuals of different ages who still suffer from physical and psychological effects of man-made disaster [9].

3. Potential Use of Thermal Springs Under the Aspect of Resilience after Traumatic Events

Experiencing traumatic events can cause lasting mental affliction and can lead to a range of both mental as well as physical ailments [10]. The definition of trauma is described as event which is experienced as horrifying and threatening, combined with subjective vulnerability to this very threat [11]. The exposure of individuals to these catastrophic moments perceived as life-threatening for them effectively can make trauma pedagogy (or: trauma consultancy, trauma education as used in other professional contexts) an integral part of disaster relief management. While the nature of trauma can differ (caused by either natural or man-made disaster), so can the type of trauma of different individuals vary, including those being secondarily traumatized (such as journalists, aid workers, intercultural mediators, trauma therapists or lawyers that need to cope with stories of traumatized individuals) [12]. While trauma therapy specifically aims at curing a person from post-traumatic stress disorder, trauma pedagogy focuses on giving support to traumatized individuals especially by educating and empowering the people in their surroundings [6]. Therefore, as mentioned above, the thinkable concept of trauma pedagogy and trauma therapy being used as effective tools in resilience-building and disaster relief management appear coherent.

When briefly looking at a therapeutic aspect of thermal waters for individuals traumatized by natural or man-made disasters, medical science outlines that "any improvement in the general condition significantly promotes the abation of mental disorders". Thermal springs bear the potential for both sleep promotion, providing relaxation and calm, as well as supporting a healthy rhythm of life by alternating between activation and relaxation [13].

A consideration of spa towns on the European Balkans show a successful use of thermal water in connection with medical facilities, which is, for example, widely promoted in the countries of Serbia and Bulgaria. The well-known Serbian spa towns Vrnjaka Banja, Sokobanja and Novi Pazarska Banja all host medical facilities using thermal water as part of the therapeutic schedule. It is further notable that in Novi Pazarska Banja a well-established hospital curing nervous diseases is located right next to the very historic thermal water spring of both therapeutical and highly cultural value [14]. In addition to the Serbian case examples, a potential aspect of resilience after traumatic events becomes also evident when considering the possibility of using thermal mud baths near Burgas, Bulgaria as mentioned above. While not only pointing out that positive effects were seen in individuals to improve their mental health it further explains: "The essence of the healing mud treatment is a complex effect on the entire peripheral nervous system. Its thermal features expand the vessels and open new capillaries. Thus reducing swelling and pain, healing and wounding of scars, improving the metabolic and regenerative processes." [6].

4. Conclusion and Outlook: The use of Thermal Springs as Potential Part of Resilience-Building and Disaster Management

This conceptual introduction aimed at highlighting a potential future key awareness factor in the furtherance of resilience-building which could otherwise easily remain overlooked: combining aspects of trauma pedagogy with disaster relief management in using local natural resources that have proven to be of value for cultural, psychosocial resilience-building while bearing a specific therapeutical aspect for individuals suffering from traumatic emotional and physical consequences after disaster. Current observations regarding the use and ongoing maintenance of thermal springs after natural disaster in Greece or man-made disaster in Iraq suggest the high value of such a thinkable concept. In addition, the World Heritage Convention of UNESCO recently positioned the use of thermal springs in spa towns also as a worthwhile and historic cultural issue [7], thus further promoting the idea of thermal springs bearing a vital potential for building resilience in a cultural sense in the actuality of our disaster-stricken time [6]. Thermal springs are a natural resource easily available also in India and its South Asian neighbors, laying the focus on using them within the framework of long-lasting disaster relief management in all its aspects can be very beneficial even if only applied on a grass-route level by a trained mediator. Awareness is key – among the examples of other countries mentioned above (covering the aspect of providing therapeutic treatment for traumatized individuals), the case of Evia in Greece serves as encouragement that promotion and maintenance of thermal springs, either in the sense of cultural or psychosocial resilience, can actively form a part of exemplary long-term disaster relief management on a communal or even international level.

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Programming the Layered Recovery-A Framework for Inclusive and Programmatic Prioritization of Recovery Needs and Investment Planning

Narayanan Edadan[1]

Abstract

Disaster recovery efforts are multifaceted with layered resources and institutions. This paper attempts to synthesize the lessons learned based on an in-depth review of a large number of post-disaster recovery projects to highlight the key challenges and drivers for the successful design and implementation of recovery. Effective and sustainable recovery investments warrant strategies for consensus building and coordination across various levels of governments, spatial and sectoral agencies, and formal and informal partner organizations engaged in recovery program management. A layered approach to disaster recovery management would be efficient to manage these multi-faceted layers of disaster recovery; designed and implemented around disaster needs assessments, residual needs analyses using aid tracking and other project management platforms, prioritization of multi-sectoral recovery needs, converting prioritized recovery needs into strategic investment plans including area-based recovery action plans, and implementation of recovery strategies structured around 'value for money', 'flexibility', 'incremental', 'inclusive', subsidiarity and consultative' principles.

Since the programmatic recovery approach entails functional layers with distinct methodological protocols, their functional integration must be monitored and verified by the disaster management lead agency to ensure that the system protocols and processes are not overloaded. A layered approach will provide modularity, flexibility, and robustness to the recovery implementation processes provided various layers are well defined, and recovery projects and activities are assigned across organizational layers under the oversight of national recovery steering committees for avoiding process overloads and strategic conflicts. The programmatic prioritization of recovery needs through inclusive

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and participatory processes and converting the prioritized and sequenced needs into strategic investment plans based on effective management of institutional and resource layers are essential for the efficient and sustainable implementation of recovery programs. This paper attempts to articulate this recovery management approach based on the lessons learned from a large number of recovery projects.

Keywords: *Recovery Management, Layered Approach, Programmatic Approach, Prioritization, Strategic Investment Planning*

1. Introduction

Disaster recovery efforts are multifaceted with layered resources and institutions. Effective and sustainable recovery investments warrant strategies for consensus building and coordination across various levels of governments, spatial and sectoral agencies, and formal and informal partner organizations engaged in recovery program management. The lessons learned from a review of a large number of disaster recovery programs suggest that a layered approach to disaster recovery management would be efficient to manage these multi-faceted layers of disaster recovery designed and implemented around multi-sectoral needs assessments, prioritization of strategic investments and programmatic implementation of recovery strategies. This approach will provide modularity, flexibility, and robustness to the recovery implementation processes provided various layers are well-defined and recovery projects and activities are assigned across organizational layers involved in the program implementation under the oversight of the national recovery steering committee.

The layered recovery assessments should culminate into multi-sectoral state/ local strategic recovery investment plans based on a programmatic and inclusive prioritization of recovery needs. This paper provides the principles and an analytical framework for prioritizing recovery needs and investment planning based on inclusive and programmatic approaches. The lead recovery agency can break down the recovery prioritized typologies of recovery needs/interventions into operational projects and activities and investment plans and manage their vertical and horizontal consultation and coordination. Since the programmatic recovery approach entails functional layers with distinct methodological protocols for coordinating various layers, the disaster recovery agency should ensure that the system protocols and processes are not overloaded. This paper examines the institutional and strategic requirements for successfully implementing sustainable recovery plans.

2. Methodology and Scope

This paper is based on an in-depth desk review of a large number of disaster recovery programs funded by the World Bank and recovery assessments done by multi-lateral institutions and practitioners. This is supplemented by the lessons learned by the author while working on various typologies of disaster management projects in Asia and Africa regions. The paper is organized into three parts. Part one summarizes the major lessons learned from the desk review and identifies key conceptual and operational challenges and project drivers for the successful management of recovery projects. The second part discusses the institutional layers involved in recovery management and identifies the strengths, weaknesses, and opportunities of existing and emerging institutional arrangements for effective recovery implementation and monitoring. Based on these assessments, the paper presents an operational and integrated recovery investment planning framework based on the multi-sectoral and multi-agency-based inclusive recovery prioritization model for prioritizing and structuring recovery needs into viable projects and activities and converting them into area-based strategic investment plans. It emphasizes balancing the multi-sectoral programmatic framework, sector-based recovery sub-projects and action planning processes for achieving cohesive and sustainable recovery outcomes. It is important to state at the outset that this paper is not an academic paper but a practice note to disaster recovery management practitioners, and the observations and recommendations made in this paper is mainly based on the lessons learned from the review of a large number of recovery projects as well as from the practice insights.

3. Key Lessons Learned

For practical reasons, many recovery projects implemented by governments and partner organizations take sectoral and project management approaches. However, at the conceptual level, disaster recovery frameworks stress a programmatic recovery approach. Programmatic recovery strategies may be similar to project management approaches but with a few key differences. The main difference is that recovery program management is done in complex and uncertain environments with inadequate and layered resources to meet a large number of recovery needs. The urgency to get the disaster-affected families back to homes and restore their livelihoods; to address the political aspirations to create visible recovery impacts on the ground within the immediate term to enable inclusive participation of disaster-affected communities and to foster sustainable partnerships with various government and non-government agencies within the transient and layered institutional structure with transparency and accountability are often challenging.

Some of the strategic and operational challenges experienced across most post-disaster recovery programs are succinctly summarized as follows:- recovery needs are not properly identified through a comprehensive and inclusive needs assessment process, recovery programming is ad-hoc and is not informed by spatial needs, recovery strategies do not take into account vulnerabilities and cultural considerations adequately, recovery is not supported by adequate financial resources, disaster aid is typically provided for immediate humanitarian relief with few resources provided for longer-term recovery needs, recovery favors rebuilding infrastructure over socio-economic and household recovery needs, and recovery efforts often fail to encourage local participation and ownership (UNDP, 2016).

A global review of the recovery projects suggests the following key strategic requirements for successful recovery management (WORLD BANK 2020):

- The resilience and recovery processes are successful and sustainable if they are based on a long-term transformational development approach that links humanitarian support to long-term development processes.
- The recovery strategy should support a strong partnership between donors, UN agencies, and local partners to address the root causes of the high vulnerability to climate change to build resilience and provide a pathway for strengthening adaptive management, learning, and innovative risk financing.
- The recovery process shall be established on information sharing and participatory systems that allows communities to identify innovative solutions for mitigating disaster risks.
- The recovery management approach that relies on resilience building and recovery management practices using innovative risk financing options is required for agile and flexible programming of recovery to respond to environmental changes.

- The recovery strategy based on inclusive prioritization of recovery needs and strategic investment plans integrating various resource layers is more efficient and sustainable.
- The recovery strategy based on multi-sectoral needs assessments with state-of-the-art data analytics makes the recovery programming processes more efficient.
- Social mobilization of vulnerable people, prioritizing their multi-sectoral needs through participatory processes, grievance redressal, and onsite support, is very important to address the collective vulnerability.
- For the sustainability of recovery projects establishing integrated local area-based recovery plans and investment coordination within a decentralized framework are critical.
- Effective institutionalization of recovery requires a legal and policy framework as well as a lead recovery agency to manage various layers of institutions and resources.
- For enabling governments to face recovery challenges it is necessary to establish protocols, minimum standards, procedures, and operational methodologies to ensure that multi-sectoral recovery planning processes are efficient, and include an exit strategy for a seamless transition from recovery to development.

Post-disaster recovery efforts often face challenges when they occur in parallel to electoral processes and changes in government administration and it is critical to sensitize the political dispensations to minimize the risk of politicization of recovery management (UNDP, 2020). While rapid recovery project preparation is important in emergencies, more important is to build community resilience in the nexus environments. The prolonged project implementation is of great concern where the collective fragility overlain by disaster makes it doubly important for the project to deliver on the coping mechanisms. It is also observed that the application of design approaches such as multi-sectoral programmatic approaches; incremental result-oriented and flexible approaches, innovative risk financing, and strategy to address security vulnerability require more attention from recovery planners and government agencies for promoting resilient recovery.

4. Managing the Institutional Layers of Recovery

The institutional arrangement for recovery is reflected in the designated functional assignments within the government to oversee, manage, coordinate and implement the recovery and reconstruction phase (UNDP, 2016).These functions are codified by law. It is however worth noting that governance structures vary across phases in a disaster (Tierney K, 2012), thus, recovery can have a separate institutional arrangement for disaster risk reduction, as compared to distinct institutional dispensations to address recovery planning. While smaller disasters might not change the pre-existing government structure, a low frequency large-scale disaster may challenge the existing government framework of policies and legal arrangements (Srivastava N and Shah R, 2015). How the government machinery is established to respond, recover, and rebuild from a disaster - and the capacity and resources these structures have - play a critical role in whether recovery and reconstruction will succeed or fail. Globally, post-disaster recovery experience reveals a range of institutional arrangements. The government may choose a lead agency after having necessary consultations with key stakeholders and future implementers of programs both within and outside the government (GFDRR, 2015).

Some of the institutional arrangements for recovery management range from the dedicated project implementation unit (PIU) established within the Ministry of Finance or other dedicated Line Ministries, dedicated national or state disaster recovery agencies known commonly as the Hybrid Model, and the emerging Modified Hybrid Model which is based on a partnership between national or state recovery agency and UN agencies such as the UNOPS. The selection of an appropriate implementation arrangement shall also be informed by the institutional layers, their policies, and administrative mandates within the country for undertaking disaster recovery activities under the prevailing disaster management policies, legislative acts, ordinances, and other legal statutes of the government. The nature and local impacts of disasters will determine the structure and form of the lead recovery agency, whether it could be a state-level agency as in the case of Gujarat State Disaster Management Authority in India, a national reconstruction agency as in the case of the National Reconstruction Authority in Nepal, and a national disaster management authority as in the case of National Disaster Management Authority in India and Federal Emergency Management Agency in the USA.

A review of the implementation arrangements suggests that there is an increasing trend to establish dedicated quasi-government recovery agencies. In countries with federal governance structures, the National Disaster Management Authority/ State

Disaster Management Authorities established within the legislative framework of a National Disaster Management Policy/Act address both recovery and resilience building tasks, although, in practice, they are found to be inadequately empowered to design and implement sustainable resilience and other disaster risk mitigation activities. Since a large part of ex-ante disaster risk management activities are built into the functional domains and hierarchies of Line Ministries and Quasi Government Agencies, funding and functional coordination between the layers of institutions responsible for resilience building is often very challenging. For addressing security risk and capacity challenges experienced in conflict environments, particularly in the FCV and DRM nexus environments, a Modified Hybrid Model based on the UN-National/State Recovery Agency partnership is found to be useful.

To appreciate the challenges and drivers for successful management of recovery programs, a detailed assessment of the institutional layers involved in the recovery programming exercises, such as needs assessments, prioritization of recovery needs, structuring recovery sub-programs into projects and sub-projects, converting the prioritized recovery projects into strategic investment plans and preparation of local area based recovery action plans was conducted. A SWOT analysis of the Hybrid Model and Modified Hybrid Model of institutional arrangement was done to know the strengths, weaknesses, and opportunities for scaling up these models. Some of the key lessons learned from the review of these dedicated agencies are briefly summarized below:

5. National/ State Recovery Agency (Hybrid Model)

Strengths

- Dedicated permanent or temporary organization at the National or State levels draws support from the Offices of the Prime Minister/State Chief Minister.
- Derives its institutional strength from the Disaster Management Policy/Act and other legislative statutes.
- Can leverage its institutional status to coordinate with line departments and partner organizations to fund programs/sub-projects more effectively.
- With appropriate policy guidelines and legislative framework, the recovery agency could streamline the recovery to development transition as part of its exit strategy.

Weaknesses

- It takes significant time to establish a dedicated recovery agency soon after the disaster and to obtain the legal and administrative mandates to operationalize its activities, particularly setting up oversight committees, procurement, and contract management systems, and hence may have to depend on partner organizations to address early recovery activities, which could lead to fragmented early recovery programs.
- Due to its quasi-government structure, the Agency is susceptible to the politicization of disaster management processes.
- In many cases, financial resources are passed through the Ministry of Finance and it significantly affects the timing and level of funding.
- The agency is not institutionally structured to address meaningful resilience and risk mitigation activities.

Opportunities

- Formulation of a National Disaster Policy or Legislated Act which specifies the roles and responsibilities of various institutional and resource management layers will enable the establishment of a disaster-specific recovery agency faster.
- The recovery agency with the necessary legislative support will be effective to manage the various recovery layers as well as effect sustainable horizontal coordination of recovery activities.
- An Area-Based Recovery Program Approach will enable effective decentralization of recovery implementation efforts and enhance local and political ownership.

6. Modified Hybrid Model (PIU+UNOPS+UN Agencies)

Strengths

- Due to the security challenges experienced in conflict situations, UNOPS has been increasingly roped in as the technical arm of the PIU to manage the recovery in the Zimbabwe Idai Recovery Project.
- UNOPS aims to provide capacity support out of their regional offices by deploying teams of experts. It manages the engagements and contracts of UN Agencies, INGOs, NGOs, and Private Sector Agencies. Responsibilities of the UNOPS include overall

coordination of project activities and the work plans, consolidated progress and financial reporting, coordination of M&E, and monitoring the project compliances by all partner agencies as per the project operations guidelines

- The PIU will be able to kick start the program soon after the disaster using established protocols of UNOPS.
- The program can be implemented and monitored faster using the internal processes of the UN Agencies, particularly in FCV- DRM environments.
- The Agency can establish effective community participation by leveraging existing community engagement platforms established by the UN agencies.

Weaknesses

- Aligning the project guidelines of the funding agency with the established UNOPS protocols is time-consuming and could lead to compliance issues.
- Since UN agencies contracted by UNOPS follow their internal procedures, it is not easy to agree on common operational procedures to implement the project, particularly during the early recovery phase.
- Based on the existing footprints and strengths each agency could become a Supra Implementing Partner which at times affects coordination and accountability, challenging the functionality and sustainability of collective recovery outcomes.

Opportunities

- The implementation arrangements between the PIU+UNOPS and UN agencies can get tedious because of the overlapping mandates and coordination issues.
- Application of objective and score-based prioritization of multi-sectoral recovery needs with inclusive partnerships will provide the much-required institutional confidence to funding agencies to co-finance recovery projects. This will ensure that projects and recovery activities are cohesive and sustainable.
- Scaling-up of the project activities is possible when partner agencies and local community-based organizations establish win-win partnerships.

7. Monitoring Recovery Outcomes:

At the programmatic level, a good M&E system influences sector assistance strategy formulation-improves project design-incorporates views of stakeholders-encourages the sustainability of project benefits and enables outcome-based midterm review of recovery implementation performance (GFDRR, 2015). Operationally, the 10 steps M&E framework proposed by Jody Zall Kusek & Ray C. Rist (2004) can be successfully applied to disaster recovery programs to create effective recovery results monitoring and evaluation systems. A significant issue often experienced in practice is the high variance between the planned and actual targets observed across recovery projects. While higher actual targets of the project development objective (PDO) indicators can be attributed to the project implementation success, a close examination of some of these numbers may show this may not be the case in all projects, in many instances, the completed standalone projects are not functional and sustainable. Due to these inconsistencies, high variations between planned and actual targets need to trigger 'mandatory self- evaluation' of the project and how to interpret such results.

Theoretically, output (sectoral) indicators are expected to be consumed in the project outcomes for determining project impacts in terms of sustainable socio-economic changes achieved by the project. Since outcomes reflect long-term impacts, the project implementation success and shortcomings are measured by output indicators used for determining the level of targets achieved. A review of some of the project implementation reports indicates that conversion of output indicators into composite outcomes is challenging and in many cases, outcome indicators are not successfully estimated. In a nexus situation, a partnership between World Bank Group, UN, and non-UN agencies and convergences of definitions and determination of “collective outcomes” are critical particularly in the Modified Hybrid Project Implementation Model, wherein UN agencies may focus on their internal policies and procedures rather than the integrity of collective project outcomes to determine project performance.

The pronounced significance given to sectoral outputs/ targets in project monitoring and reporting overlooking their functionality and sustainability is an important issue often observed across a large number of recovery programs. Although issues such as functionality and sustainability of project outputs are often discussed in the project documents, due to the layered organizational and resource management characteristics of some of the project outcomes, they are seldom examined adequately, although, they are important information required for implementing the project exit strategy. It is observed that in a multi-sectoral programmatic recovery project, fixing range-bound targets with lower and upper limits is more effective for enabling flexibility in project implementation. Due to the emergency environment of the recovery projects, the baseline data are not estimated and therefore the results frameworks are calibrated based on absolute numbers. To capture meaningful project outcomes, it is recommended to identify variables/indicators which explain significant variations in the proposed outcomes/impacts and apply them in the results framework and if necessary apply "control group" analysis.

8. Programming the Layered Recovery

Since recovery project management organizations and resources are highly layered; the application of program assignment models, processes, and operational protocols across various institutional layers is critical to productively designing and implementing recovery strategies and action plans. Contrary to a project-based sectoral approach, the multi-sectoral programmatic approach allows effective prioritization and sequencing of the recovery interventions and investments, contributing to sustainable institutional responses. Allowing the progressive allocations and transfer of resources across different components and recovery layers and combining them under verifiable strategic investment plans can help the project deliver better results. Flexibility and modularity in resource allocation are keys to programming a layered recovery approach. The operational component of this process is schematically presented in Figure 1.

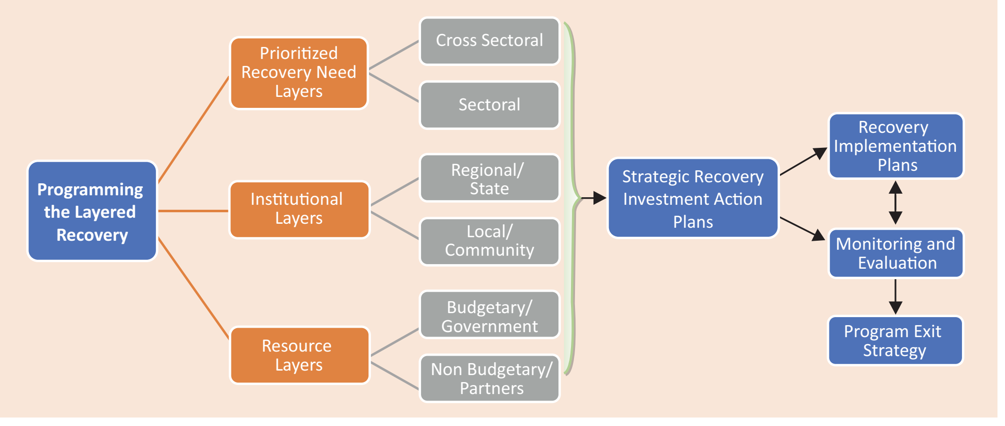

Figure 1: Programming the Recovery Layers

Institutional Management: While designing a multi-sectoral recovery program, institutional challenges arising from the compression of activities in time and space;

speed and deliberation; balancing the creation of new agencies and leveraging the existing ones; coordinating the funding mechanisms; addressing displacements and supporting livelihoods of the vulnerable people; vitalizing the sluggish vertically organized and hierarchical government structure, and to respond to sectoral coordination and inter-agency coordination and information sharing require special attention. The politics of disaster management further complicates recovery implementation complexities. From the political perspective, disaster management strategies are aimed to control political risks (Arjen Boin, 2008). The political economy issues, therefore, become very critical when the political existence of the governments is challenged by the politicization of disaster events in the country, particularly when the country moves from emergency response through the recovery phase, which greatly influences the fragility and vulnerability conditions unless robust safeguards are front-loaded in the implementation process.

Inclusive Participation: Visible and effective community participation with inclusive strategies to partner with community-based organizations should be a critical part of the recovery project strategic framework. Implementation of a decentralized and consultative approach to prioritize needs and sequence recovery investments would ensure community ownership in the recovery processes and enhance the sense of ownership among the layered organizations. Since the recovery project management process entails partnerships with development partners with different emergency perspectives and timelines to enter and exit the recovery program, designing and implementing a flexible, but structured, program focusing more on collective outcomes and range-bound targets without compromising on the critical recovery principles is critical, but this is also challenging.

Sustainable Partnership: An important area in which some disaster recovery programs have experienced challenges during the implementation processes is for building robust and sustainable partnerships between governments, civil society organizations, and the private sector. Although some of the recovery programs have been successful in establishing effective government and community partnerships during the project implementation periods, in general, there seems little institutional aptitude within the government bureaucracy to formalize community engagements during the whole period of program implementation. Support to governments to align non-governmental efforts with government recovery objectives for sustainable recovery outcomes is essential and design considerations such as avoiding unrealistic expectations, maintaining simplicity while implementing and monitoring project outcomes, keeping procurement and disbursement procedures relevant to post-disaster context; and supporting priority areas based on recovery needs (Alcira Kreimer, et al,1998)) are critical.

Structured and Sequenced Recovery Strategy: In general, recovery projects are designed to respond to post-disaster needs assessed during the post-disaster need assessment exercises. These included post-disaster rehabilitation and reconstruction of damaged physical and economic assets, restoration of livelihoods, rebuilding community infrastructure, peace-building, and social cohesion and disaster risk management, social and economic issues emerging from the FCV and DRM nexus environments, economic recovery, local capacity building, etc. Many of these elements are of equal importance when formulating proposals for recovery investment planning and all of them have distinct institutional and resource layers to manage.

The recovery project management challenges such as too many needs and too few resources with layered sources across various recovery actors, expectations of disaster-affected communities to deliver recovery assistance within the shortest time possible, and meeting the high expectations of the political dispensations, particularly when the post-disaster recovery and political election cycles are coinciding, etc., can be addressed only through a decentralized and inclusive process of prioritization of recovery needs and calibrated sequencing of recovery investments. Although the process of investment prioritization and sequencing of project activities are common across conventional project management, they are applied with different principles in recovery management. While financing efficiency is the key principle in the conventional project management process, 'equity', 'inclusiveness', and 'participatory' principles are significant in the prioritization of multi-sectoral recovery needs and investment sequencing processes.

Multi-Sectoral Needs Based Prioritization Process: An important lesson learned from the review of various recovery programs across different disaster typologies is that the inter-sectoral prioritization and sequencing processes applied in most recovery programs are largely driven by the sectoral agencies and they failed to decentralize the prioritization process for developing inclusive strategic investment plans and flexible annual work plans. It is observed that for inclusive and sustainable recovery outcomes, prioritization of recovery needs and investments should be built around an inclusive and objective analytical framework structured around key verifiable indicators that reflect disaster intensities, project development objectives (PDOs), and expected collective recovery outcomes. The prioritized interventions shall be structured into cohesive projects while preparing recovery investment plans in DRM and FCV environments. The programmatic, inclusive, and indicator-based analytical prioritization model implemented in the Multi Crisis Recovery Project (MCRP) in Nigeria, Zimbabwe Idai Recovery Project, and Somalia Crisis Recovery Project in the Africa region provides an analytical framework to develop priority typologies of recovery needs which could be structured into implementable and cohesive projects and sub-projects.

Since most recovery interventions identified during needs assessment exercises are often lumpy, for developing actionable recovery work plans, the prioritized interventions should be broken down into projects and sub-projects for assigning them to the layered institutions, particularly for funding ex-ante disaster risks and resilience-building action plans. The prioritization committees established at the national and state levels shall guide these processes through the effective participation of partner agencies and local civil society organizations. Rationalization and re-prioritization of recovery needs and interventions are necessary for identifying and implementing cohesive recovery projects. This could be done using a four-way matrix analysis to structure prioritized sector interventions based on key strategic questions: a) Where - identify locations of the identified projects; b) Whom - identify project targets/ beneficiaries; c) Who - identify project implementing agency; and d) When -identify the timeline for sequencing/phasing the recovery plan using appropriate filters (Edadan N and Parvez A, 2022).

Converting Prioritized Recovery Needs into Strategic Investment Plans: An important outcome of the multi-sectoral needs-based prioritization model is to develop typologies of prioritized recovery needs for strategic investment plans (SIP). A decentralized recovery investment planning process shall enhance the appreciation among the funding institutions that prioritized needs are done objectively and the strategic investment plans are viable and realistic. For these reasons, the SIP preparatory process shall entail robust consultation with all recovery stakeholders including the functional linkages between projects and sub-projects. The inclusive prioritization model and strategic investment planning processes being implemented in the MCRP, SCRP, and ZIRP recovery projects provide operational templates for dovetailing budgetary and non-budgetary financing mechanisms for realizing a predictable funding strategy and achieving satisfactory recovery outcomes.

9. Conclusion

The main objective of this paper is to identify the key drivers and challenges while implementing layered post-disaster recovery programs based on detailed review of recovery projects and practice insights. It is learned that effective and sustainable recovery program implementation warrants a multi-layered and multi-sectoral programmatic approach, which entails both prioritizations of multi-sectoral recovery needs based on decentralized, inclusive, and participatory frameworks, and converting the prioritized needs into strategic recovery investments plans, both at state and local levels, preferably through a decentralized local area based recovery planning framework. Application of verifiable indicator-based prioritization of multi-sectoral recovery needs with disaster intensity and security risk filters for structuring and sequencing strategic recovery investment plans will not only enhance the acceptability of the recovery programming process among the various layers of institutions and funding partners but also minimizes the project risks entailed in the politicization of the recovery resource management.

Due to the layered structure of the institutions and resources involved in the recovery programs, a multi-layered programmatic management approach should be applied to recovery planning and implementation processes with adequate safeguards for seamless integration and coordination between various program layers. The paper attempts to decipher the various cross-sectoral and sectoral layers of recovery needs involved in the prioritization process as well as the preparation of strategic investment plans, program implementation, and monitoring of collective recovery outcomes. Although, a layered recovery approach will ensure simplicity, modularity, flexibility, robustness, and replicability of the processes while programming a multi-sectoral recovery program, it is critical that the process does not suffer from process and decision overloads which could lead to decision and funding overlaps and uncertainties. This risk could be addressed only if the recovery programming exercises are managed by a lead recovery agency with built-in horizontal program coordination structures guided by the disaster management policy within an enabling disaster management legislative framework.

The paper summarizes the lessons learned from the various institutional and operational layers of recovery program implementation structures including how to build meaningful implementation and monitoring systems that could support program effectiveness and sustainability with feedback for reprioritizing recovery investment plans. An obvious limitation found across a large number of recovery programs is the absence of an explicit and workable exit strategy to ensure that the program achieves the planned collective recovery outcomes, controls time and cost overruns, and the recovery processes enable a seamless transition from recovery to development.

Institutionalization of the best practices developed and implemented during the recovery program within a recovery and development transition framework is critical to ensure that the recovery investments are sustainable post the program completion. An important aspect of this sustainable recovery to development transition process is the calibrated transfer of assets reconstructed and rehabilitated during the recovery program to local communities and departments and agencies. It is also important to structure disaster management mechanisms with ex-ante and ex-post disaster management financing frameworks. More attention should be paid to these aspects to ensure that the assets restored during the recovery remain functional and sustainable post the implementation of the recovery programs, more so in FCV environments, with adequate budgetary allocations and decentralization of functional and financial powers.

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Increasing Frequency Of Urban Floods: Lessons From Bengaluru Floods, 2022

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Abstract

In 2022, Bengaluru was hit by (131.6 mm) intense rainfall causing floods that led to a standstill in the city. This study examines the underlying causes of floods and the impact of urbanisation and poor planning. Secondary data sources, such as government reports and news articles, were used to identify the factors that contributed to the floods. The results indicate that rapid urbanisation and inadequate planning significantly contributed to floods. The city's infrastructure was unable to cope with the volume of rainwater, leading to flooding in low-lying regions. The lack of proper drainage systems in the construction of buildings and roads exacerbated the situation. The study also emphasises the impact of climate change on the frequency and severity of extreme weather events like floods. It suggests that policymakers and urban planners must incorporate climate change predictions when devising and implementing development plans. The study concludes by urging immediate action to address the fundamental causes of the floods, including infrastructure improvements, better land-use policies, and sustainable urban development. By implementing these measures, Bengaluru can decrease the chances of future flooding and ensure a more resilient future for its citizens. The study underscores the need for urban development that is conscious of the changing climate patterns, which can result in safe, sustainable, and prosperous cities.

Keywords: *Drainage, Floods, Planning, Urbanisation, Watershed*

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1. Introduction

Of all natural disasters, floods are the most common. Floods are said to occur when water accumulates over land that is normally dry, causing it to be submerged for a significant amount of time. Although floods are generally classified as natural disasters, most floods today result from a complex interaction between human activities and natural phenomena (Raven et al 2013). A number of factors contribute to flooding. Heavy rainfall is a very common cause of floods. Overflow of coastal waters and dam and levee breaches can also lead to the submergence of land. Based on the cause of submergence, floods may be classified into several types. River floods are said to occur when a body of flowing water, such as a river or stream, overtops its banks and water spills over and inundates adjacent land. This may happen because peak seasonal precipitation or rapid melting of snow due to sudden rise in temperature cause excessive quantities of water to drain into river channels, exceeding their carrying capacity. Such floods are a regular occurrence for many rivers and support many ecosystems that are adapted to such inundation. However, they can cause extensive damage when floodplains are densely populated. Coastal floods occur when storm surges or extreme tides cause a short-term increase in sea level. The rise in sea level because of global warming and the increasing frequency and intensity of cyclones has made more coastal areas vulnerable to this type of flooding. Flash floods are a type of flood that is especially devastating on account of the speed of their occurrence and their unpredictable nature. They occur soon (usually less than 6 hours) after heavy rain. They can also be caused by a dam or levee failure, and also when the flow of a river is suddenly blocked by debris or ice jam. Urban areas can be affected by all the above-mentioned types of floods. However, the term urban flood is used to denote floods that are pluvial, caused by intense and/or prolonged rain, and not by the overflowing of a water body. The process of urbanization involves extensive modification of the natural landscape, including removal of vegetation, draining of wetlands, paving of surfaces and construction of buildings. Rainwater is not absorbed by the mostly impervious urban surfaces that are covered by roads and buildings. Consequently, intense showers of rain generate runoff from roads and other built-up surfaces that easily overwhelm the carrying capacity of stormwater drainage systems, leading to flooding. The problem is made worse by the fact that city growth takes place with total disregard for natural drainage routes. Unlike other types of flooding, pluvial flooding is a direct, quick and localized consequence of rainfall (Ochoa-Rodriguez et. al).

1.1 Urban Floods In India

Floods in India were almost synonymous with riverine floods. Consequently, agencies responsible for the management of flood-related disasters tended to focus on floods caused by overflowing rivers. In the present century, urban floods have been a recurring phenomenon. Hyderabad (2000), Delhi (2002, 2003, 2009 and 2010), Chennai (2004, 2015, 2017), Mumbai (2005, 2020), Surat (2006), Kolkata (2007), Jamshedpur (2008) and Guwahati (2010) experienced severe flooding. The devastation caused by floods in Mumbai in 2005 forced the National Disaster Management Authority (NDMA), the apex body for disaster management in India, to recognize urban floods as a separate type of disaster. The NDMA noted an increase in urban flood disasters in India and issued guidelines for their management in 2010. It also identified several factors which placed Indian cities at greater risk from urban floods. The foremost among them is the highly seasonal character of Indian rainfall. Most of India receives 75 to 80% of its annual rainfall during the summer monsoon season which extends from June to September. Intense spells of rain are also experienced due to other weather systems such as depressions and cyclones which can dump large quantities of water in a very short span of time. Coastal towns and cities are especially vulnerable to flooding from storm surges, a problem made worse by sea level rise (Anshu et.al, 2019). A flood can also occur due to the sudden release of water from dams. Conversely, a failure to ensure the timely release of water from dams can cause the dams to burst, causing sudden and massive flooding in downstream areas. NDMA has observed that the urban heat island effect has led to an increase in rainfall in urban areas. The intensity of rainfall is further exacerbated by changes in weather patterns induced by global climate change. The urban stormwater drainage system (where it exists) is outdated and cannot cope with the increased intensity of rainfall. Most systems were designed for a rainfall intensity of 12 to 20 mm and are unable to handle rainfall of higher intensity. The systems have failed to keep pace with the growth of cities. As cities grew in size, drains should have been widened. The unfortunate reality, however, is that existing drains have been encroached upon. Further, the systems are poorly maintained and do not work even to their designed capacity, either because they are broken or are choked with silt and/or plastic and other solid waste. City growth, whether planned or unplanned, has failed to take into account the natural flow of water (NDMA). Thus, a complex combination of natural and human-made factors is responsible for the problem of urban flooding.

2. Study Area

Bengaluru, also known as Bangalore, is a rapidly growing and diverse city located in the southern part of Karnataka state in India. Located at coordinates 12.97°N 77.56°E, Bengaluru spans across an area of 1741 Km2. While most of the city falls under the jurisdiction of the Bangalore Urban district in the state of Karnataka, the adjoining rural regions are part of the Bangalore Rural district. The city has a rich history, and in recent years has emerged as a global hub for technology and innovation, also the capital city of the state. It is situated on the Deccan Plateau, at an average elevation of 900 meters above sea level. The city is surrounded by several hills, including the Nandi Hills and the Chamundi Hills. The climate in Bengaluru is moderate throughout the year, with temperatures ranging from 15°C to 35°C (Census, 2011). The city is also known for its numerous lakes and parks, including the Lalbagh Botanical Garden and Cubbon Park. Bengaluru is home to several major research institutions, including the Indian Institute of Science, the National Aerospace Laboratories, and the Indian Space Research Organization. The geography of Bengaluru provides a unique setting for research in fields such as ecology, geology, and urban planning.

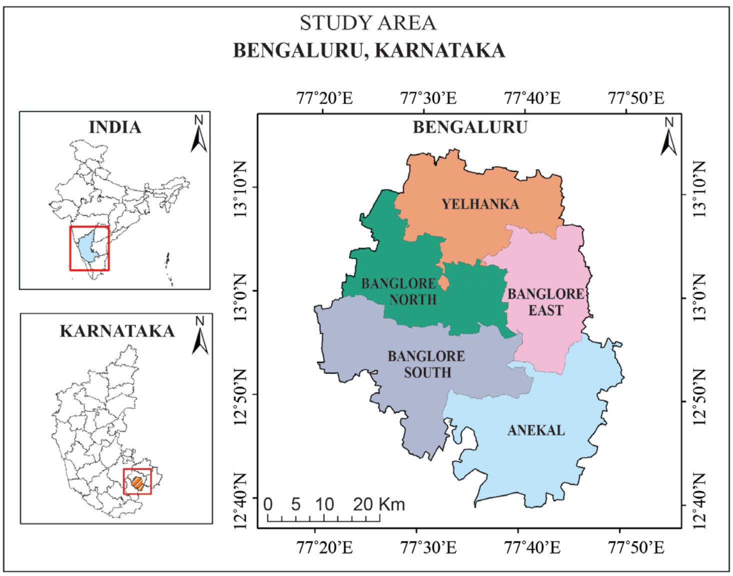

Figure 1 : Study Area - Bengaluru, Karnataka

3. Data & Methods

IMD gridded data with 0.25° × 0.25° spatial resolution spread over Indian land mass has been used as the ground validation in the present study. This study utilized data such as a 30 m resolution Digital Elevation Model (DEM) of the basin obtained from the US Geological Survey website, extracted from the Shuttle Radar Topographic Mission (SRTM).

In ArcGIS, the digital elevation model (DEM) was utilized to demarcate watersheds by converting the raster to the polyline. The process of automatic extraction of the watershed and drainage network was accomplished using ArcGIS 10.2 software. Specifically, the watershed tool within the hydrology toolbox of ArcGIS 10.2 was utilized for delineating the drainage of Bengaluru. The topography of Bengaluru is characterised by an undulating terrain with hills, valleys, and plateaus. Generally, the land surface slopes towards the southeast, resulting in dendritic to sub-dendritic drainage patterns in the area, which are connected to a system of lakes.

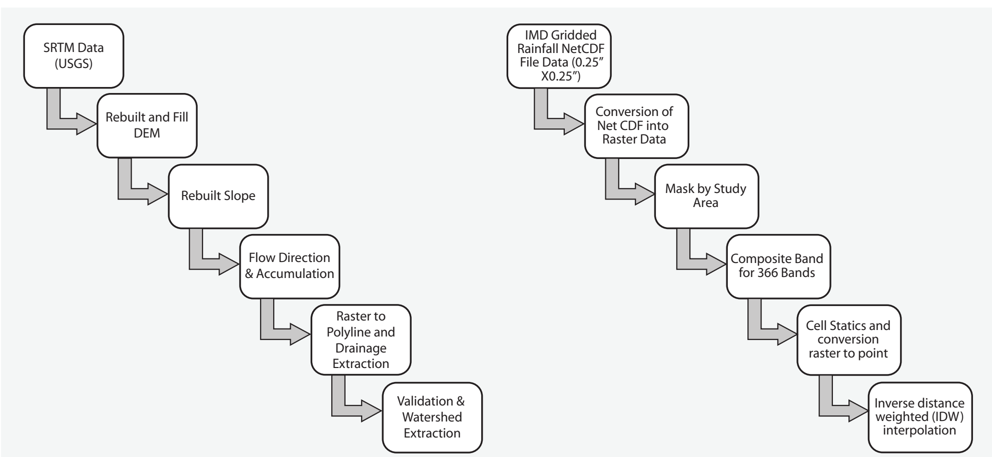

Figure 2 : Stepwise Methodology to Extract Data (a) Elevation and, (b) Rainfall

Bengaluru is situated in the tropics and has a semi-arid climate. The rainfall patterns of Bangalore from 1901 to 2000 exhibited a wide range of variability, with the annual rainfall fluctuating from 500 mm to 1350 mm, whereas the average annual rainfall was

970 mm. The city primarily receives its rainfall during the Southwest monsoon, but the Northeast monsoon can also bring precipitation if cyclonic formations are closer to Bengaluru. Although Bengaluru lies in a rain shadow region, it is not entirely obscured by hill ranges. In the years 2017-2021, the annual rainfall recorded in the capital city of Karnataka was 1,696 mm, 1,050 mm, 950 mm, 1,200 mm, and 1,500 mm, respectively. Data from India Meteorological Department (IMD) shows that in 2022, Bengaluru experienced a total of 1,958.6 mm of rainfall, with more than 2.5mm of rain recorded in 90 days. On September 5, 2022, the city experienced its heaviest rainfall of the year, with 131.6 mm of rainfall inundating a significant portion of the city.

3.1 Urban Floods in Bengaluru, 2022

Bengaluru is one of India's largest cities. Located on the Mysuru Plateau (a part of the Deccan Plateau) at a height of 949m above sea level, the city is known for its pleasant climate. Although it is generally flat, a prominent ridge runs down its centre from NNE to SSW. No major river is found in, or close to, Bengaluru, although the Arkavathi and South Pennar rivers originate in the nearby Nandi Hills. Vrishabhavathi, a minor tributary of Arkavathi, carries much of Bengaluru's sewage.

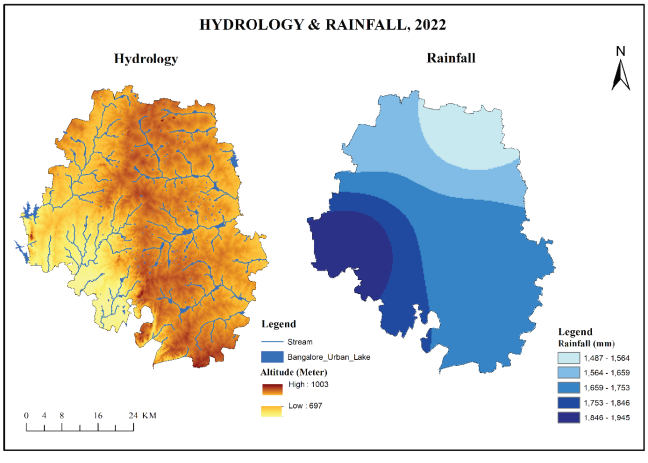

Figure 3 : The intense Rainfall Raised the Water Level in the Urban Lakes.
In other Words, Lake Surface Area must Increase due to Intense Rainfall.
Hint: Author should Analyse Pre and Post-Flood Urban Lake Area.
Hydrology (SRTM 30m) and Annual Rainfall Map of 2022 (0.25X0.25 IMD, Pune)

Bengaluru started as a small settlement around a mud fort built by Kempe Gowda, a local chief, in 1537. It rose to prominence when the British used it as an administrative and military centre from 1831 to 1881. It became the capital of the Indian state of Mysore in 1956, and subsequently of Karnataka in 1973. The location of several public sector manufacturing units in the city in the 1950s created employment opportunities that attracted a stream of migrants. Simultaneously, Bengaluru also emerged as an educational hub. In the post-liberalisation era in the 1990s, the city emerged as the centre of information technology in India with many domestic and multinational companies locating their offices within it, making it famous as the Silicon Valley of India. However, in September 2022, Bengaluru was in the news for totally different reasons. Many portions in the southeast, east and northeast of the city were submerged under water for two days while it was lashed by heavy rains, causing many lakes to overtop their banks. Normal life came to a standstill amidst power outages and traffic disruptions, affecting posh localities and the poorer quarters alike. Areas with higher elevations also experienced flooding as the clogged drains were unable to discharge the rain surge. The water supply came to a halt as pumping stations of the Bengaluru Water Supply and Sewerage Board went underwater in many areas. This resulted in immense suffering people and great financial loss to individuals and the economy as a whole. Among the worst affected areas was Bellandur, Yemalur, Mahadevapura and Manyata Tech Park. State Disaster Relief Forces (SDRF) had to be called in to help and visuals of residents being rescued in boats and tractors flooded social media.

The rain that was too much

Rainfall records from 1901 to 2000 show that the average annual rainfall of **Bengaluru** is 970 mm. The lowest rainfall recorded in a year in this period is 500mm while the highest is 1350mm. **Higher rainfall is recorded in May and then again in September-October and September** is generally the rainiest month. This year Banglore has experienced higher rainfall than the normal usual, with 1466.6mm of rainfall having already been received by September.From June to August 2022, the city received 769 mm of rain, nearly 80% higher than the average for the period. 370mm of rain was received in August 2022, making it the second-wettest August ever recorded. An analysis of weekly rainfall in Bengaluru Urban District in June, July and August showed that rainfall was 60% more than the Long Period Average in as many as 5 weeks within that period (**Sangomla**, 2022). More rain came on the 4th and 5th of September as a wind shear zone was formed between westerlies in the south and easterlies in the north. This created instability in the atmosphere that was laden with moisture from the monsoon winds. The effect of the ongoing La Nina may have also played a part (Sangmola, 2022). 131.6 mm of rain was dumped on the city in just 12 hours, proving too much for the city's infrastructure.

The above data shows that Bengaluru received above-average rainfall in 2022. The distribution of rainfall within the city is shown in Figure 2. Intense rainfall on the 4th and 5th of September triggered the floods. But was flooding an inevitable consequence of the heavy rain? P. Mukhopadhyay, a monsoon modelling expert at the Indian Institute of Tropical Meteorology, Pune (quoted by Ramesh, 2022) maintains that the intense rainfall was predicted and "very much within the accepted range". There are instances when more rain has been received in a single day in September. 180 mm of rain was received on September 12th, 1988 and 132.3 mm was received in a single day in September 2014. However, the rains did not cause flooding to the same extent on both previous occasions.

Did global warming play a role?

The impact of climate change on weather patterns across the world is undeniable. However, its relationship with increased incidences of urban flooding is yet to be conclusively established. Heavy monsoon rains caused devastating floods in Pakistan between June and October 2022. The simultaneous occurrence of floods in parts of America, Africa and Asia and severe drought in Europe and China in 2022 is widely attributed to climate change. A warming atmosphere has a greater capacity to hold moisture which can then be released in the form of intense precipitation. Urban pluvial flood risk is expected to increase significantly in the future as a result of climate change (Ochoa-Rodriguez, et al.). A study of rainfall data from 165 stations across India reveals that the intensity of extreme point rainfall events (highest 24-hour rainfall) has gone up considerably after 1960. Record rainfall events on different time scales, from hourly to annual, have also taken place in recent decades (Khaladkar, et. al., 2009). In the case of Bengaluru, the Long Period Average (LPA) rainfall between 1981 and 2010 is 986.1mm. Rainfall since 2010 has been in excess of the LPA. The average rainfall between 2010 and 2021 was 1146.62 mm, which is 16% over the LPA (Ramesh, 2022).

Currently known as the Silicon Valley of India or the IT capital of the country, Bengaluru (or Bangalore) was once better known as the Garden City or a Pensioners Paradise. Parks and lakes covered a large part of the city area. The population of the city has increased from 745,999 in 1950 to 12, 326,532 in 2020 (population.un.org.wpp). Bengaluru's size increased from 69 square km. in 1901 to 161 sq. km. in 1981, and 221 sq. km. in 2001 (Yashasvini et. al., 2019). In 2006, 741 sq. km. was denoted as Greater Bengaluru after merging the area of Bengaluru city with 8 neighbouring urban local bodies and 111 villages. The growing population has been accommodated at the cost of the city's lakes and green cover. Between 1973 and 2017, Bengaluru has seen a 1028% increase in paved surfaces, an 88% decline in vegetation cover and a 79% decline in wetlands (Ramachandra et.al., 2017) In 1800, Bengaluru had 1452 water bodies with a storage capacity of 35 thousand million cubic feet (TMC) of water. Rainwater is collected in these water bodies, reducing the possibility of floods. In 2016, only 194 of these lakes remained and their storage capacity had been reduced to 5 TMC (CAG Report, 2021).

What makes the situation worse is the lack of interconnectivity between the lakes. The rajakaluves (a clear path that allowed stormwater to flow from one waterbody to another) that connected these lakes are blocked due to encroachment by land grabbers and also the accumulation of solid waste. A study of floods in the city (Sanganal) identifies an increase in the built-up area, paved surfaces, encroachment of natural water courses and low-lying areas, inadequate capacity and encroachment of storm water drains and increasing density of population as the major causes of floods in Bengaluru. The study found that streets lacked sufficient rainwater outlets and that existing outlets were choked with dirt and debris. In some cases, rainwater outlets had been rendered non-functional after road widening had been undertaken. Another study by Ramachandra and Majumdar (2009) similarly blames the siltation of tanks and encroachment of nalas and lake bodies and the choking of steams and stormwater drains for floods in Bengaluru.

The 2021 Audit Report by the Comptroller and Auditor General (CAG) raised serious concerns over the increase in the frequency of flooding in the city of Bengaluru while the city also suffered from the depletion of groundwater table levels. The Performance Audit (PA) "revealed that Bengaluru witnessed large-scale encroachment of lakes/ drains and depletion of natural drainage systems. The changes in land use such as the decrease in vegetation cover and open spaces and increase in the built-up area resulted in the loss of interconnectivity between water bodies impacting the effective recharge of groundwater and increase in runoff of stormwater" (CAG Report, 2021). The report also expressed concern over the decline in the storage capacity of existing water bodies due to siltation to only 1.2 TMC. Several lakes under the jurisdiction of the Municipal authorities had been identified as disused lakes which were now vulnerable to encroachment. The failure to recognise surface runoff as a water resource and formulation a policy for its management was also highlighted as a major lapse on the part of governing agencies.

The highly fractured governance system in Bengaluru makes the problem of flood management even worse. While Bengaluru Development Authority is the principal planning authority, Bengaluru Metropolitan Management Authority is responsible for planning in the Bengaluru metropolitan region. There are separate agencies for the management of water and wastewater (Bengaluru Water Supply and Sewerage Board), and transport (Bengaluru Metropolitan Transport Corporation), while fire services are the responsibility of the Karnataka Fire Emergency services (Jha, 2022). Professionals working with each agency have a narrow, sectoral approach. Coordination between these multiple agencies is a challenge in the best of times, and more so in times of crisis.

4. Results and Discussion

It is obvious from the above that floods in Bengaluru resulted from a combination of higher than normal rain and poor land management that prevented the city landscape from absorbing or draining the rainwater. The city had already received above average rain from June to August in 2022 and an intense spell of rain on 4th and 5th September finally triggered the flood. This spell of rain may have been heavy, but it was not unprecedented. Clearly, the city was not prepared to meet such an eventuality. Heavy precipitation events are likely to become more common in the near future and city planners and administrators would do well to gear up to meet them.

Flooding results from almost every above-average rainfall event due to unplanned urbanization. Increase in paved surfaces, reduction in green cover and reclamation of wetlands for urban development means that even small amounts of rain can overwhelm the inadequate rainwater infrastructure. In the case of Bengaluru, many of the numerous lakes that dotted the city had either disappeared or greatly reduced in size. The catchment area of the remaining lakes had been greatly altered, leading to silting of the waterbodies. Ramachandra's study (2009) shows that the storm water drains connecting the lakes are blocked by encroachments and solid waste accumulation.

5. Conclusions and Suggestions

The above discussions reveal that the immediate cause of devastating floods in Bengaluru (and in other urban areas) was an extreme point rainfall event. The frequency of such events is increasing due to global warming and climate change. However, while the floods may have been triggered by high-intensity rainfall, the underlying cause is poor urban planning and a total lack of preparedness for urban flood disasters. Urban areas are planned and developed without due consideration for the various components of the hydrological cycle and water infrastructure. Impermeability of surfaces and obstruction of water flow in urban areas increases peak flows in cities to up to 7 times that of rural areas (Tucci, 2006). In the pre-urbanised scenario, 40% of precipitation reenters the atmosphere through evapotranspiration, 50% infiltrates into the soil and runoff accounts for a mere 10%. Post-urbanisation, evapotranspiration returns only 25% of the precipitation to the atmosphere. Another 30% infiltrates into the soil while the remaining 45% becomes part of rainwater drainage (Tucci, 2006). The complex nature of urban flooding is summarized in Figure 4.

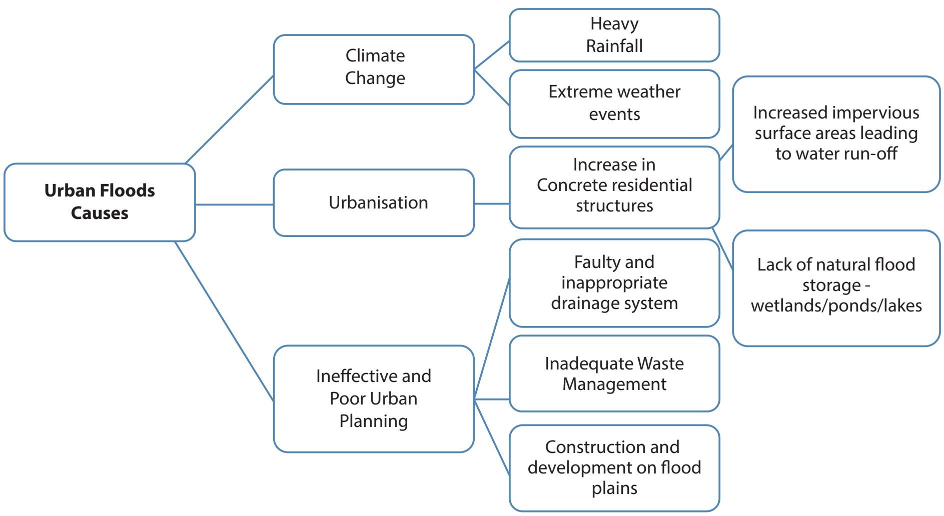

Figure 4 : Urban Flooding in Bengaluru

Bengaluru requires an integrated approach to flood management. A combination of watershed management, land use planning and developmental planning is the need of the hour. The following steps can be taken to mitigate the problem of urban floods:

- The first step towards mitigation of urban floods is flood vulnerability and risk mapping. Areas most vulnerable to floods must be identified and factors enhancing flood risk must be addressed.
- Once areas prone to flooding are identified, land use planning must be undertaken at the micro-level. Parks can be developed in high flood-risk areas. This will help in enhancing urban amenities while also ensuring protection from floods.
- The natural flow of water must be taken into account when plans for the development of the city are drawn up.
- Green infrastructure should be developed for absorbing and storing stormwater. This is more cost-effective and efficient than grey infrastructure in controlling floods.
- Preservation of natural vegetation will help in reducing runoff and increasing groundwater recharge. This will help in mitigating floods while also raising the water table.
- Rainwater harvesting must be made mandatory. Soakaways can be built to collect water from rooftops and let it seep into the ground. This should be made a part of building codes.
- Infiltration trenches can be constructed along streets and highways and in housing complexes so that rainwater can drain into them, reducing the intensity of the rain surge.
- Pervious paving should be carried out in areas of low traffic.
- Lakes, wetlands and other waterbodies, including rajakaluves, must be preserved (or rejuvenated) as they help in storing excess stormwater. Areas around them should be well vegetated to reduce siltation. The flow of water into these bodies must be free and unobstructed. They must be protected from encroachment by the enactment of strict laws that are seriously enforced.

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Impact of MGNREGA in Building Climate Change Resilience in Western Dry Region, Rajasthan

Dr. Babasaheb Kazi[1] **Satish Macwan**[2]

Abstract

The Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) works towards providing guaranteed employment to rural communities for creating critical rural assets. It is aimed at improving socio-economic and ecological conditions in rural areas, which can potentially help build resilience to climate change. This study assesses the impact of MGNREGA on building resilience to climatic change in the Western Dry Region of Rajasthan, a climate-vulnerable area. Eight blocks were studied, with two from each of the four districts, based on the highest and lowest MGNREGA expenditures. The study found that MGNREGA implementation has helped in improving soil, water, irrigation, and cultivation areas in the study region. It has significantly reduced migration by improving agriculture, livestock, and local employment opportunities. The study showed a significant difference in the income increase from agriculture in high-performing MGNREGA blocks compared to those with minimum expenditure. Overall, the results indicate that MGNREGA has helped rural communities in Western Rajasthan adapt and absorb the impacts of climate change and build resilience by improving local natural resources and sustaining household income.

Keywords: *MGNREGA, Climate Change, Resilience*

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1. Introduction

Enacted in 2005, the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) is a significant legislation that aims to provide 100 days of guaranteed wage employment to every rural household in a financial year. The program has a multifaceted approach to addressing poverty in rural India. It seeks to ensure livelihood security for the poor by creating durable assets and improving water security, soil conservation, and land productivity. Since its inception in 2005, the program has expanded its objectives to include improving the durability and sustainability of assets created under the program, enhancing local governance, and promoting skills development at the local level (MoRD 2021).

Almost during the same period of the last two decades, climate change and its implications on vulnerable communities have raised up the global development agenda. Climate change poses a significant challenge to development and there is evidence that the rural poor in developing countries will be most adversely affected by climate change (Sen 1999; IPCC 2014). For the poorest households and communities, it can reverse development gains made in recent decades and reinforce the underlying drivers of poverty and inequality that keep millions of people below the poverty line (IPCC 2014).

MGNREGA provides a safety net to help the poor and marginalized communities during difficult times. The programme can play a central role in helping households and the local economy absorb the effects of climate risk, adapt to climate impacts and transform their ability to address escalating and future climate stresses (Agrawal et al., 2017). However, the role of MGNREGA has not been sufficiently researched for its climate role. But the fact that it provides wages and assets to millions of rural people, most of whose livelihoods depend on climate-sensitive sectors such as natural resources, means that the programme has inherent characteristics that respond to climate change vulnerability. Few studies have attempted to explore how MGNREGA can help communities build resilience to climate change by developing durable infrastructure, increasing household wages during climate shocks, and strengthening communal assets (Tiwari et al. 2011; Adam 2015; Steinbach et al. 2016). It is also observed that conceptually, the MGNREGA meets basic normative requirements for mainstreamed adaptation action but that functional methodological limitation prevents it from taking on a more purposeful role. (Adam 2015)

A large number of studies have looked into the impact of MGNREGA on socio-economic conditions, finances, and administration and implementation (for instance, Shah 2007; Ambasta et al. 2008; Kareemulla et al. 2009). Studies to assess the impact of MGNRGA on the environment have shown positive impacts and have also shown that environmental benefits generated by programme have increased the adaptive capacities of beneficiary households reducing their vulnerability to climate risks. Previous studies have also suggested to view the programme in light of its role in enhancing resilience to long-term climate change. (IIS 2013). However, previous studies have kept a limited understanding of climate resilience not taking the systems view or the socio-ecological systems perspective on how MGNREGA can improve climate resilience.

In light of the above, a study was undertaken with the objective of exploring the role of MGNREGA in building climate resilience, measured in three resilience capacities of absorptive, adaptive, and transformative changes, in one of the highly vulnerable agro-climatic regions of India i.e. Western Dry Region in the state of Rajasthan.

1.1 Research Setting

The selection of the study region was guided by two primary factors. Firstly, since the study aims to assess the impact of MGNREGA, Rajasthan was chosen due to its outstanding performance in providing the highest number of employment days under the program (MGNREGA MIS, 2022). Secondly, the study targeted the Western Dry Region in Rajasthan, which is highly vulnerable to the impacts of climate change. (Pathak 2014) This selection was made deliberately to align with the study's objective of evaluating the effectiveness of MGNREGA in enhancing climate change resilience.

The study used the Analytical Framework (Figure 1) to explore the response of the community towards climate change in three categories of climate resilience. (International Institute for Environment and Development, 2017).

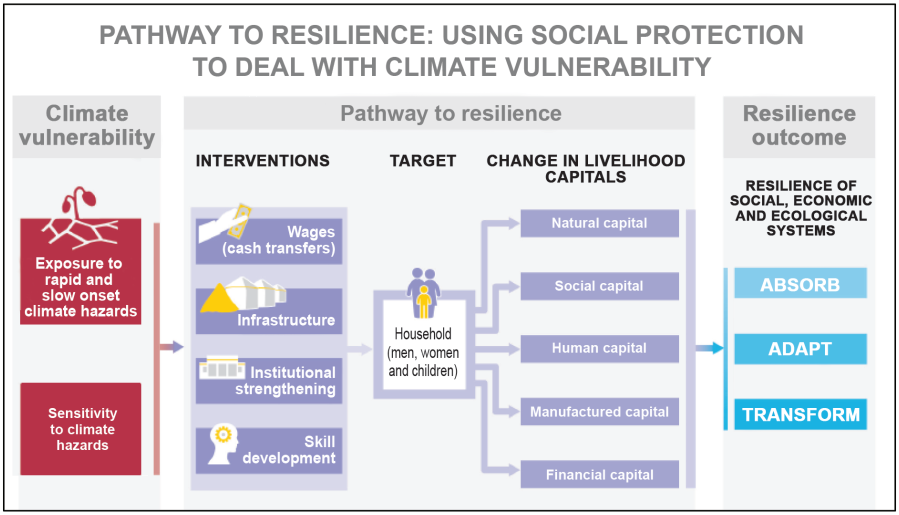

Figure 1 : Analytical Framework on how MGNREGA Contributes to Resilience

Source: Working paper on Climate change resilience, Institute for Environment and Development, 2017

Absorptive resilience: the ability of social, economic, and ecological systems to maintain their original structure by preparing for, mitigating or recovering from the impacts in order to preserve and restore essential basic structures and functions. (Béné et al. 2012; Cutter et al. 2008).

Adaptive resilience: the ability of social, economic, and ecological systems to improve their original structure by adjusting, modifying or changing its characteristics and actions in order to better respond to existing and anticipated future climatic shocks and stresses and to take advantage of opportunities (Béné et al. 2012; Brooks, 2003; IPCC 2012).

Transformative resilience: the ability of social, economic and ecological systems to fundamentally change their structure, characteristics and actions when the existing conditions become untenable in the face of climatic shocks and stresses to move beyond vulnerability thresholds (Béné et al., 2012, Walker et al., 2004).

2. Climate Change Variability in Western Dry Region, Rajasthan

In India, Climate change has affected a number of states and regions through climate change induced risks such as drought, flood, rising temperature etc. Rajasthan is one of the most vulnerable states owing to the frequent occurrence of droughts, extremely low and erratic rainfall and limited surface water sources. Apart from the water scarcity issues in the state, the resource base for productive agriculture is also not adequate in most places. (ICAR 2014)

The soil organic content stands at 70.08 tonnes per hectare, which is one of the lowest amongst all Indian states (Singh et al., 2010). It also ranks among the states where proportion of land undergoing degradation is highest (Ajai et al., 2009). Studies show Rajasthan as part of the group that are major food grain-producing states according to the level of groundwater development and suggest that groundwater is overexploited to the tune of 109%–145% (Sharma, 2009). In spite of having the highest share of land area among all other Indian states, the state is not as agriculturally productive as most of the state falls under the semi-arid agro-climatic zones while the Western Dry Region is totally arid region. Moreover, more than 5.02 million hectare of land is cultivable wasteland. The yield of food grains in the State is only 803 kg per hectare and is the lowest for any state in India (Kakade et al., 2003). Droughts are ubiquitous to Rajasthan, with erratic rainfall and extreme temperatures being common features in many areas (Kakade et al., 2003).

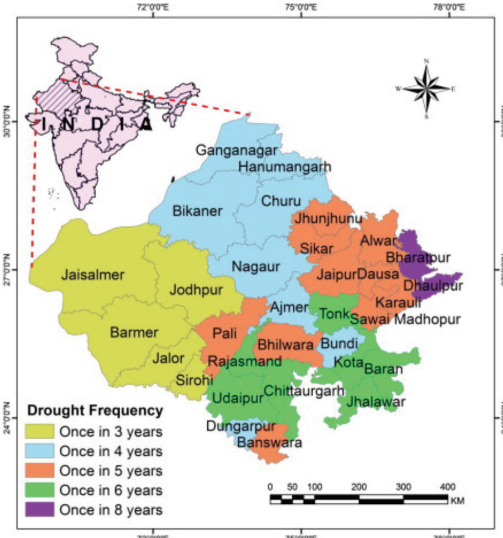

Figure 2 : Drought Frequency Map of Rajasthan

Source: Disaster management and Relief Department, Rajasthan 2015

The 11 districts which fall on the western and north-western side of the ranges constitute a part of the great Thar Desert. These are Barmer, Bikaner, Churu, Ganganagar, Hanumangarh, Jaisalmer, Jalor, Jhunjhunun, Jodhpur, Nagaur and Sikar. Two of the 11 districts have overcome the problem of aridity through extensive irrigation (Pathak, 2014). The remaining nine districts, viz. Barmer, Bikaner, Churu, Jaisalmer, Jalor, Jhunjhunun, Jodhpur, Nagaur and Sikar constitute the western dry region of Rajasthan.

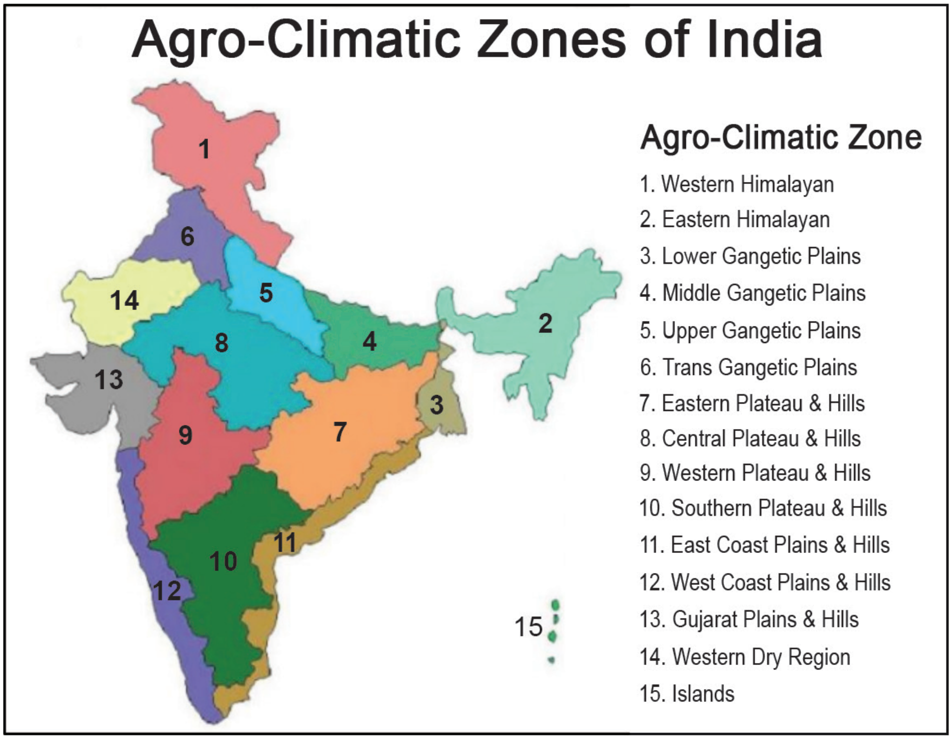

Figure 3 : Agro-Climatic Zones of India

Source: ICAR (Indian Council of Agriculture Research) and Planning commission of India, 1974

Climate: The climate of the region ranges from semi-arid to arid. The region has harsh climate with great extremes of temperatures, long periods of severe drought, high wind velocities and low humidity. The normal annual rainfall in the Western most district of Jaisalmer is 185.5 mm and it increases to 400 or more as one move towards east. About 85% of the rainfall is received during the period June to September. Jaisalmer and Jodhpur have the highest average wind velocity. Evaporation in the region greatly exceeds the total annual precipitation. The variation in the annual rainfall is very high and in drought years, it is not sufficient to grow even crops like Bajra without some irrigation (ICAR, 2000).

The zone has all the characteristics of a hot desert. Rains are scanty and erratic, rate of evaporation is high, there are no perennial rivers, and ground water table is very deep and is often brackish. Vegetation is sparse. The average rainfall is about 400 mm but with very high year to year variations. The average temperature varies from about 45°C in May–June to less than 2°C in December–January. High wind velocity, scorching heat and sand storms are common features during summer months. The soil is mostly sandy, loamy sand and sandy loam. About 28% of the land is tilled; 11% of the cultivated area is irrigated. Productivity is among the lowest in the country. (ICAR, 2000).

Recurring drought is a common phenomenon in the Western Dry Region owing to the factors mentioned above. The droughts cause devastating effects on the lives of people and adversely impact the environment for the long term.

Several studies expound on the seriousness of recurring droughts in the region. They also examine the long term impacts of droughts on people's assets, livestock in particular and recognize that despite being a single occurrence, the effects are far reaching and deep. A study of the impacts of droughts in Shergarh tehsil in western dry region from 1899–1976 revealed that out of the 78 years studied, 43 were mild drought years where 50% of the crops reached maturity, 19 were drought years where 25% of the crops reached maturity and 8 were severe drought years where no crops matured. Analysis of land use changes revealed a positive correlation between the intensity of drought and the extent of the area damaged. Mean annual yield of kharif crops decreased from 90%–100% in a drought year and 30%- 66% in a moderately deficit year. Livestock losses ranged from 17% for goats to 50% for cattle during drought years (Bharara, 1980).

Villages in Western Dry Region have also experienced decline in area and deterioration in quality of common property resources over three decades. Disruption in traditional management of resources caused farmers to adjust to shrinking common property resources by reducing herd size, by changing its composition, and by relying more on private resources to rear animals (Kazi et al., 2022)

The impact of climate change would be the most severe for the poor communities, with limited options for livelihood and high level of dependence on the natural resources as the case in Western Dry Region. The impacts increase the food insecurity, water stress and extreme weather events which would affect the livelihood security of these communities and increase their vulnerability. MGNREGA addresses these issues by undertaking diverse activities aimed towards water harvesting, drought proofing, flood protection and plantations (Kazi et al., 2022).

3. Methodology

A total of 310 households in 8 Panchayats of 8 blocks of Western Dry Region in Rajasthan are taken as sample for the study, in each district, one block with maximum expenditure and another block with lowest expenditure in MGNREGA were selected. From each block, few villages were selected where there is a significant work under MGNREGA to be able to study the impact of the program. The maximum expenditure block is classified as Group A block while the lowest expenditure block is categorized as Group B block. The expenditure of the last 7 years (2014-2021) from these blocks was considered to identify the blocks as well as the Panchayats in these blocks.

A structured interview schedule was used to collect the major part of the data. The schedule was prepared based on the data required on main categories of demographic, climate change impact, livelihoods and income, MGNREGA contribution, etc. Interviews were conducted with the head of the households of the sample households. Majority of the head of households were male out of the total sample of 310 (282 males, 28 females).

The study also used Focused Group Discussion (FGD) with a homogenous group of wage seekers of MGNREGA and community leaders of village institutions/Panchayats. The FGD Guide included discussion points on how MGNREGA was used to avail employment and work on the natural resources in the villages, how these works helped in agriculture and livestock and meeting the livelihoods needs of the community.

Secondary data on climate variables were collected from the India Meteorological Department, land use and land cover data from Bhuvan, NRSC, and demographic data from Census 2011. Data on MGNREGA's performance was collected from the official website of MGNREGA, data from various reports on MGNREGA such the impact of Mission Jalshakti works under MGNREGA, and the Ministry of Rural Development (MoRD).

4. Results and Discussions

4.1 Climate Change Risks

Climate change poses a great risk to agriculture and livestock, major livelihood sources in the western dry region.

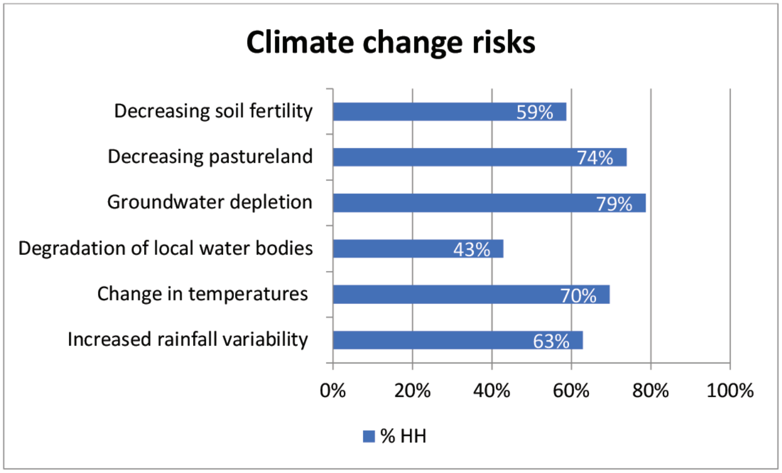

Figure 4 : Climate Change Risks Perceived by the Community

Source: Kazi et al., 2022, Households Survey The perceived climate change risks among communities are largely linked to extreme weather conditions, such as rising temperatures and increased summer days, as well as changing monsoon patterns with variable rainfall. According to a survey, a significant majority of respondents (70%) reported changes in temperature, specifically an upward trend in the number of summer days, which is highly pertinent to the climatic conditions of the arid western region. The survey also indicated that groundwater depletion was viewed as a major climate change risk by 79% of respondents, while 43% recognized water body degradation, including ponds and check dams, as a concern. The rise in temperature not only reduces water volume in resources but also curtails the number of water-staying days, resulting in direct impacts on crop patterns and drinking water availability for cattle, a crucial source of livelihoods for local communities.

Table 1 : Yearly Average Rainfall

District	Block	Yearly average rainfall in mm					CV (Coefficient of variation)
		2016	2017	2018	2019	2020	
Bikaner	Bikaner	348	308	355	388	353	8.14
	Dungarpur	328	285	254	292	302	9.20
Barmer	Dhorimana	204	709	107	314	290	70.78
	Samdadhi	296	550	152	380	348	41.67
Churu	Rajgadh	562	375	332	369	421	21.80
	Birasar	445	354	332	484	359	16.70
Jalore	Raniwada	536	1287	176	729	755	57.86
	Dayalpura	753	729	230	645	548	36.46

Source: India Meteorological Department, 2021 (www.imdpune.gov.in) The findings of community perception on climate change risks is validated by the rainfall data. It clearly shows high rainfall variability across the blocks except two blocks of Bikaner. Though Bikaner rainfall is consistent, the precipitation is consistently lower throughout the last five years compared to other blocks with mean rainfall data around 350 mm.

In the rest of the blocks except Bikaner, the year 2018 is low rainfall year and marked with drought like condition. While in the year 2017, most blocks show highest rainfall variability as much as from the lowest 107 mm to 1287 mm indicating greater erratic nature of rain. Other risks perceived by the community like ground water depletion, change in temperature, soil fertility etc. are indirectly related to this kind of rainfall pattern.

4.2 Impact of Climate Change

The biggest climate change impact experienced by the community is about the adverse impact on livestock and agriculture. More than 80 % of the households responded the impact of climate change in crop loss and livestock disease. The crop loss is due to pest attack and crop disease as well as severe climatic conditions such as extreme temperature.

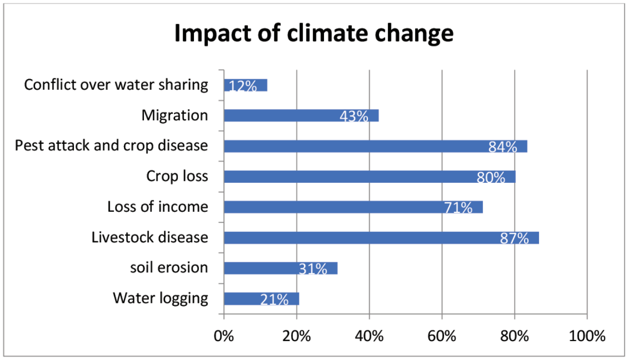

Figure 5 : Impact of Climate Change

Source: Kazi et al., 2022, Households Survey The survey results indicated that over 70% of the respondents reported the loss of income as another significant impact of climate change.Furthermore, agriculture and livestock have been adversely affected, leading to migration as an associated impact of climate change. With no alternative livelihood options, people are compelled to migrate in search of work. About 43% of households viewed migration as a direct result of changing climate conditions. In this context, the role of the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) becomes crucial in preventing migration as it aims to provide 100 days of guaranteed employment within the village Panchayat.

4.3 Impact of MGNREGA

The impact of MGNREGA was evaluated to understand the effectiveness of the programme in addressing the climate change risks as mentioned above.

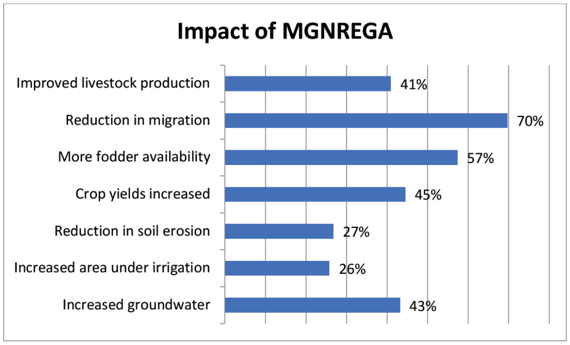

Figure 6 : Impact of MGNREGA

Source: Kazi et al., 2022, Households Survey The most significant impact of MGNREGA was its role in reducing migration, indicating that the program has effectively met its objective. Approximately 70% of respondents recognized the positive impact of MGNREGA on increasing employment opportunities and reducing migration. The impact was slightly higher in the group A blocks, with respondents clearly attributing the impact to the program. Improvement in fodder availability and water are also key factors contributing to preventing migration especially for the livestock keepers.

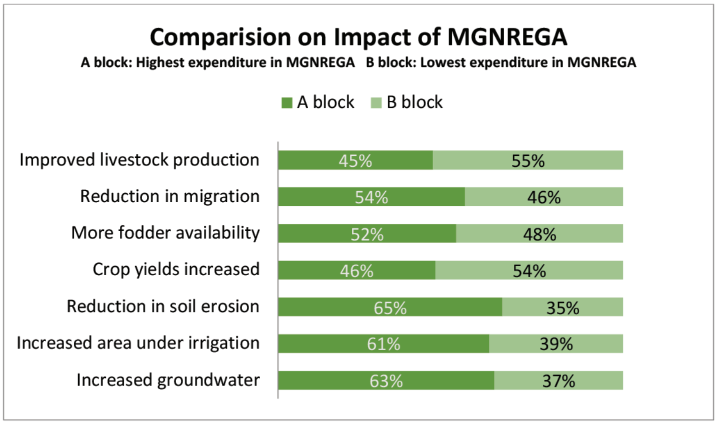

Figure 7 : Impact of Climate Change

Source: Kazi et al., 2022, Households Survey

MGNREGA has had a significant impact in terms of increasing groundwater levels, ground and surface water availability, and reducing soil erosion. This impact is reflected in the increased area under irrigation, number of irrigations, and overall improvement in soil health. The difference made by MGNREGA is particularly significant, with a higher impact ranging from 23 to 32% in these parameters observed in group A Panchayats.

However, this impact has not necessarily translated into a significant increase in livestock production and agriculture yields, as there is not much difference in these parameters between both groups of blocks. Nevertheless, the income from agriculture and livestock is higher in group A blocks, indicating a higher productivity of the livestock and agriculture systems in these areas. Overall, the positive impact of MGNREGA on the environment and livelihoods in rural areas is evident, but more research is needed to understand the complex relationships between various parameters and the sustainability of these improvements over time.

Table 2 : Change in Income

	Agriculture			Livestock		
Change Category	**Total %**	**Group A blocks**	**Group B blocks**	**Total %**	**Group A blocks**	**Group B blocks**
Decreased	3%	50%	50%	8%	76%	24%
Increased	24%	84%	16%	20%	70%	30%
No change	72%	51%	49%	68%	53%	47%
No income	0	0 %	0%	4%	38%	63%

Source: Kazi et al., 2022, Households Survey The impact of MGNREGA on household income from agriculture and livestock is significant, with high performing Group A blocks showing a clear increase compared to the minimum expenditure Group B blocks. In Group A blocks, 84% of households reported an increase in income from agriculture compared to only 16% in Group B blocks. Similarly, for income from livestock, 70% of households in Group A blocks reported an increase compared to only 30% in Group B blocks.

However, it is noteworthy that despite the clear increase in income for some households, around 72% of households in both groups did not experience any change in income from agriculture and 68 % from livestock. These results, when coupled with the climate change conditions in the region, suggest that MGNREGA has helped the community in absorbing the shocks of climate change and adapting to the situation. The program has thus played a crucial role in improving the resilience of rural households to climate change-induced challenges.

4.4 Change in Drinking Water Availability

MGNREGA works are specifically designed to enhance water conservation and water harvesting structures, such as check dams, ani-cuts, ponds, drains, and nadis. These works are expected to increase the availability of water for multiple purposes, including agriculture, livestock, and drinking water. The expenditure data of MGNREGA suggests that the category of "water conservation and water harvesting" had the highest expenditure, which highlights the importance of water conservation in the region.

Table 3 : Change in Drinking Water Availability

Change Category	Total %	Group A	Group B
Decreased	5%	55%	45%
Increased	32%	74%	26%
No change	62%	49%	51%

Source: Kazi et al., 2022, Households Survey The household survey data shows that 32% of the respondents reported an increase in drinking water availability. Interestingly, 74% of these respondents were from group A blocks, which indicates the positive impact of MGNREGA in increasing water availability. However, 62% of the respondents reported no change in water availability, and there was no significant difference in responses from both groups.

4.5 Change in he Availability of Minor Forest Produce

Table 4 : Change in Availability of Minor Forest Produce

Change Category	Total %	Group A	Group B
Decreased	8%	50%	50%
Increased	20%	74%	26%
No change	66%	46%	54%
Don’t know	5%	94%	6%

Source: Kazi et al., 2022, Households Survey Common land such as pastures, forests, water bodies are crucial for sustaining the eco systems and meeting firewood, fodder, food, medicine and other needs of the poor households of the villages. Minor forest produce from common land acts as safety nets for the poor in times of crisis. The results on change in Minor Forest Produce (MFP) from common land show similar results as other parameters of availability of drinking water for cattle. In the Group A blocks, the availability of MFP is significantly higher than the group B blocks suggesting impact of MGNREGA. However, for more than 65% there is no change in the availability of MFP and it remained same. This also indicates that there is no degradation or deterioration of natural resources as a result of climate condition and anthropogenic pressure.

4.6 MGNREGA Expenditure (2014-2021)

In order to understand the MGNREGA expenditure pattern in terms of work wise category-wise utilization and implications on the impact as discussed earlier, details on two sample Panchayats of Jalore district is given to understand the difference in works under MGNREGA in high-performing MGNREGA blocks (Group A) and low performing MGNREGA Panchayats (Group B).

Table 5 : MGNREGA Expenditure of Two Sample Panchayats of Jalore **District (2014-2021)**

(Amount in INR lakhs)

	Group A		Group B	
Work category	**Expenditure**	**%**	**Expenditure**	**%**
Anganwadi/ Other Rural Infrastructure	2.40	0%	8.80	3%
Bharat Nirman Sewa Kendra	0	0%	12.26	4%
Drought Proofing	27.53	3%	1.73	1%
Flood Control and Protection	45.05	5%	16.61	6%
Land Development	0	0%	14.33	5%
Other Works	0	0%	48.54	17%
Renovation of Traditional Water Bodies	10.72	1%	6.66	2%
Rural Connectivity	119.44	14%	35.06	12%
Water Conservation and Water Harvesting	568.69	67%	120.30	41%
Works on Individuals Land (Category IV)	712	0	26.38	9%
Grand Total	**290.68**	**100%**	**845.03**	**100%**

Source: MGNREGA MIS, 2022

In Group A - Raniwara gram panchayat, total expenditure during the year 2014 to 2021 is almost three times higher than in Group B-Dayalpura Panchayat which represents the low MGNREGA expenditure block. Expenditure in NRM works altogether in group A Panchayat is significantly higher at 86% while its 64% in Group B Panchayat.

In both the groups, expenditure on water conservation and water harvesting is the highest with 41% and 67% respectively. Raniwara which is group A Gram Panchayat also has much higher expenditure in the works on water conservation and harvesting (67%). It can be inferred that the Panchayats which have taken up these works are likely to fair better in MGNREGA performance. It can be also attributed to the introduction of the Jal Shakti Mission programme where the focus was mostly on these kind of works.

4.7 Landuse /Land Cover

The analysis of land use land cover (LULC) data provides evidence of the positive impact of MGNREGA on building climate resilience. The available LULC data from 2013 and 2018 of both group A and group B Panchayats for one of the blocks shows a significant increase in the area under Rabi crop. In Group A, the area under Rabi crop increased by 27%, while in group B it increased by 12%, from almost nil area under Rabi cropping in the year 2014 in both locations.

The increase in the area under Rabi crop indicates improved water and moisture availability after the monsoon season, which is crucial for agriculture and helps to mitigate the impacts of climate change. This increase in Rabi crop area can be attributed to the water conservation and water harvesting structures developed under MGNREGA, which have helped in improving the water availability and soil moisture, thereby enhancing the agricultural productivity and resilience of the region.

Table 6 : Land use Land Cover (2013-18)

	Group A		Group B	
	2013	2018	2013	2018
LULC category	Area in %	Area in %	Area in %	Area in %
Kharif only	41%	4%	82%	3%
Rabi only	1%	27%	0%	12%

	Group A		Group B	
	2013	**2018**	**2013**	**2018**
LULC category	**Area in %**	**Area in %**	**Area in %**	**Area in %**
Double/Tripple	38%	17%	9%	2%
Current fallow	11%	40%	5%	76%
Other wasteland	5%	4%	3%	1%
Scrubland	4%	0%	1%	1%

Data Source: Bhuvan, NRSC, 2021

However, there was a decrease in Kharif cropping area in both locations due to significantly low rainfall in the monsoon of 2018, which was almost drought-like. This led to an increase in the current fallow area in both locations. Nevertheless, the increase in current fallow area was significantly lower in Group A Panchayats compared to Group B Panchayats, which can be attributed to the higher number of works and investments for improving soil and water conservation under MGNREGA. Similarly, there was a reduction in double/triple crop area in both locations, but the impact was much lower in Group A Panchayats due to the works carried out for improving natural resources.

Therefore, it can be inferred that MGNREGA's performance is directly correlated with an increase in second cropping area, higher double/triple crop area, and a reduction in fallow land.

5. Conclusion

The Western Dry Region in Rajasthan is facing significant climate change risks, such as increasing temperature, rainfall variability, and depleting water resources, as reported by the respondents as well as evidenced by scientific data on temperature and rainfall patterns. In this context, the implementation of the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) has played a crucial role in mitigating the impact of climate change and sustaining the livelihoods of the local community.

The study results show that the implementation of MGNREGA has a positive impact on the soil, water, irrigation, and cultivation areas, leading to an increase in income from both agriculture and livestock production systems. The study highlights that rural households have been able to sustain their income levels and that, in cases of higher MGNREGA investment Panchayats, reported an increase in income, despite the challenges posed by climate variability. Moreover, it has significantly reduced migration from rural to urban areas as a result of improved agriculture, livestock, pastures, and local employment opportunities.

In conclusion, the study provides substantial evidence to support the positive impact of MGNREGA in enhancing the absorbing and adaptive capacities of communities to combat the impacts of climate change in the Western Dry Region.

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Examining Research on Disasters In India-
A Bibliometric Study (1969-2022)

Dr. Priyanka Puri[1]

Abstract

Disasters as a mishap are discussed in multiple forms in theory and practice. Within these multiple dimensions, works can be observed as being related to mitigation, management, rehabilitation, recovery, policy making, governance and others. These works enrich the literature on disaster management aspects and also provide a direction to studies in the field. Numerous practical outcomes can be seen in the discipline of disaster management as an outcome of addition of contributions. In this context, the outcomes in the form of publications tend to provide content to the discipline for practices and policies. The studies on disaster management have gained pace rapidly in explanatory as well as critical forms. In India, the discipline of disaster studies and concerned dimensions have seen immense growth. Besides this, India is also prone to disasters with regards to natural and anthropogenic factors. The focus of the current paper is to visualise the nature of published national and international academic works on the topic of 'India and Disasters' through the well acknowledged Scopus and Web of Science databases, with a bibliometric study of a total of 6,554 (3,072 +3,482 documents respectively) documents. Results highlight an increasing number of publications on the topic 'India and Disasters' but in a very diversified form, geographies, affiliations and institutions in the two databases.

Keywords: *India, Disaster, Research, Bibliometric*

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1. Introduction and Literature Review

Disasters are considered as a calamity which can be either natural or human induced (Britannica, 2023). It can cause a grave disturbance of natural functioning of individuals, societies, economies and all other systems when they are exposed to it. This is due to their vulnerability to such happenings (UNDRR, 2023). India is observed to be in the list of world's most disaster prone countries. In the light of climate change and an ever increasing population, these issues have now become more problematic (UNICEF, 2023). India has also gone through an increased intensity of disasters due to all such concerns (Kumar, Walia, & Chaturvedi, 2011).

Disaster studies are seen to be as an emerging and a distinctly recognised discipline. Further, along with this, disaster management can be seen as a practice. However, it is difficult to mark any boundary between these two (Andharia, 2020). Therefore, works on disasters also have an academic and policy based orientation leading to disaster studies and related works in the field. But there is no single analysis of works which can show what kind of studies are actually taking place in the field. Thus, introspection of research needs to be of multiple kinds (Andharia, 2020). A research based perspective can be helpful in bridging the gaps. This is also required to remove the observed dominance of the Western nations in this academic aspect (Gaillard, 2019).

Bibliometric studies use and provide both qualitative and quantitative information on multiple kinds of publications (Pai & Alathur, 2021). Bibliometric examination can also be of help as it can cover the missing information, help in studying the topic and in assisting academic and research works (Rayner, 1957). This also provides a critical insight into the studies which have been conducted over a period of time and helps in clearly observing the contemporary events such as COVID-19 (Horowitz & Remes, 2021). Examples of bibliometric studies on disasters and related concerns can be seen in literature, although not in plenty, and whatsoever works are visible are basically either conceptual or thematic in nature.

Natural hazards and disaster management have been studied through a bibliometric examination through the Web of Science, Scopus and Google Scholar databases. Rana (2020) has conducted a bibliometric examination on the topics of 'disaster resilience' and 'climate change resilience'. The outcomes indicated a growing field of research with climate change resilience overtaking the number of works on disaster resilience

(Rana, 2020). Chumky, Basu, Onitsuka and Hoshino (2022) have discussed disasters through Web of Science data based bibliometric study in the light of migration. They have suggested that studies on migration due to slow onset type of disasters is lesser as compared to fast setting disasters (Chumky, Basu, Onitsuka and Hoshino, 2022). Sweileh (2019) has examined health concerns related to natural disasters from the Scopus database for publications from 1900-2017. Results indicated that a limited information was available on the evolution of the topic and it is only after 2004 that a surge in the works can be observed (Sweileh, 2019). This information is very essential for reaching out for Sustainable Development Goals and reduce the negative impacts of natural disasters (Sweileh, 2019). Another example can be given as that of work on the scientific and technological aspects of international cooperation through bibliometric analysis. It highlighted that the maximum input is coming from the USA and that there was a strong geographical dissimilarity between the actual location of the disaster and the research conducted (Fan, et al., 2020).

In India, bibliometric studies on disasters are observed in specific fields related to disasters although a broad study on these in bibliometric analysis is not visible in publications. For instance, Pai and Alathur have conducted a bibliometric examination on mobile health services in India through the Scopus database and have indicated an importance of the concept in health services in India (Pai & Alathur, 2021). However, bibliometric analysis for literature on 'India and Disasters' in India is extremely limited and context specific in nature rather than a broad one. The current study is an attempt to get an overview of works on disasters in India through a bibliometric perspective from the well-known Scopus and Web of Science databases.

2. Methodology

2.1 Data Source

Bibliometric information is derived from the Web of Science (WoS) and Scopus e-data sources. The Web of Knowledge database is called Web of Science since 2004. Along with Scopus, it stands as one of the two largest databases for generating bibliographic and bibliometric information on numerous disciplines. Considered as the 'gold standard' for citation (Harzing & Satu, 2016), WoS is provided by Thomson Reuters with records from 1900 to the present and includes several databases on sciences and social sciences (Annie, Haralstad, & Christophersen, 2015). It is one of the most trusted global citation data sources and has 1.9 billion cited works from 171 million records of more than 115 years of highest quality research works (Clarivate, 2022). Along with multiple kinds of bibliometric information, citation searches with diagrammatic retrieval of data are also feasible through WoS (Annie, Haralstad, & Christophersen, 2015). This makes citation search detailed through indexing, citations, journals, author, country and other related bibliographic content (Ramlal, Ahmad, Kumar, Khan, & Chongtham, 2021). A commercial license is required to do analysis (Ramlal, Ahmad, Kumar, Khan, & Chongtham, 2021). The WoS Core Collection includes three indices- The Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI) and Arts and Humanities Citation Index (AHCI); all containing databases from 1989 to present (Clarivate, 2022).

As per Harzing and Satu, Elsevier's 'Scopus has evolved after the WoS and provides an alternative to Scopus database', although Scopus is defined as a new entrant in the field. It is currently an indicator of publication standards and even University rankings (Harzing & Satu, 2016). Both are observed as fore runners in databases and even competing in nature and are widely used for such analysis (Zhu & Liu, 2020). Besides, both databases are commercial and based on subscription for bibliometric information and its generation. This has also increased their demand (Pranckute, 2021). Scopus and WoS have differences in coverage and also seem to hold a bias in certain respects. Yet, all these databases have a lot of similarity in terms of bibliometric information generated (Mongeon & Hus, 2016).

2.2 Data Collection

The analysis conducted in this paper is based upon data derived from the Scopus and Web of Science databases for the exact phrase 'India and Disasters'. For both the databases, results for the year 2023 were excluded. The data is extracted from WoS Core Collection from WoS website including the following criteria- Author, Title and Source with details extracted on Author(s), Title, Source, Times Cited Count; Abstract, Keyword, Addresses with details extracted for Abstract, Addresses, Affiliations, Document Type, Keywords, WoS Categories and Research Areas and; Cited References and Use with details extracted for Cited References, Cited References Count, Usage Count and, Highly Cited Publications (Clarivate, 2022). The information extracted from Scopus included- Citation Information with details extracted on Author (s), Document Title, Year, Citation Count, Source and Document Type; Bibliographical Information with details extracted on Publisher; Abstract and Keywords with details extracted on Abstract, Author Keywords, and Index Keywords. The WoS generated 3,482 published research works on the topic while the Scopus database gave 4,672 documents through search from which only 3,072 works could be exported from the Scopus database. Scopus provided data from 1969-2022 while WoS gave data from 1989-2022.

2.3 Data Analytics

Data generated from the both the databases is analysed in the VOS viewer software. It acts as a tool for generating and analysing bibliometric information (Viewer, 2022). The software provides help in observing bibliometric networks, geographies and subsequent mapping of bibliometric information for authors, keywords, languages and linkages of bibliometric information. Analytical diagrams have been generated from Scopus, WoS, as well as VOS viewer to conduct bibliometric analysis.

3. Results

The search on the topic 'India and Disasters' through the Scopus database generated 3,072 results and for the Web of Science database generated 3,482 results. Following analysis was derived from this information:

3.1 Scopus Database

3.1.1 Publication Overview

The number of publications on the topic 'India and Disasters' have steadily increased 2003 onwards in the database. In this category, maximum documents in the subject were observed by Social Sciences at about 17% followed by Environmental Science at 15%. Publications from India had the maximum share followed by publications from the USA. Articles and conference papers had the highest share of publication types as can be seen in Fig.1.

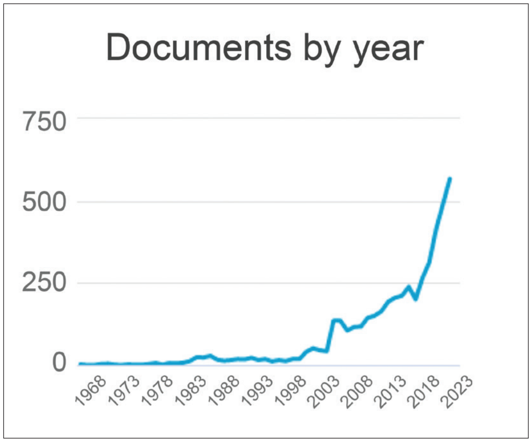

Figure 1 : Publications on Theme 'India and Disasters'- 1969-2022

Source- Scopus, 2022 (Scopus, 2022)

3.1.2 Co-occurrence of Keywords and Terms

In this category were observed 6,883 keywords used by authors with the criteria of analysis set at least occurrence of once. This was done on the basis of full counting which implies that the co- authorship of weight of the link is fractionalized by the software and 5,847 terms met the criteria. The results were generated by the software from 2016-2022. As can be seen in Fig. 2. and 3, India, climate change, and COVID-19 terms dominate the text of publications. This clearly implies the nature of research is focusing around these topics. In terms of the concentration co-occurrence analysis was also conducted to check co-occurrence of text from the abstracts of the publications. Binary counting method was used which counts this information by considering the presence or absence of terms in the publication. Of the 57,195 terms recognized by the software, a limit of occurrence of the term at least twice is set as the criteria which was seen to be met by 11,645 terms. When subjected to analysis to identify the clustering of these terms, it was observed that the term India, COVID-19, landslides and Himalayas were the dominant themes.

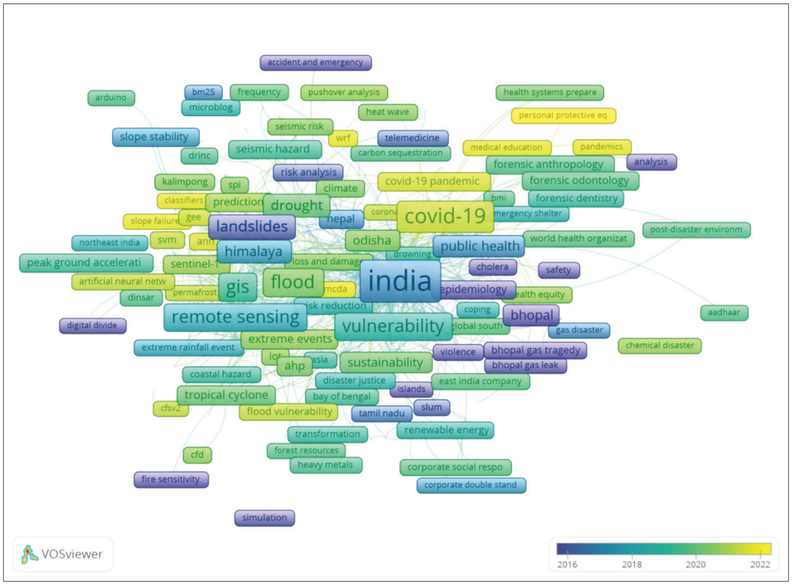

Figure 2 : Co-occurrence of Keywords in Abstract

Source- Author, 2022

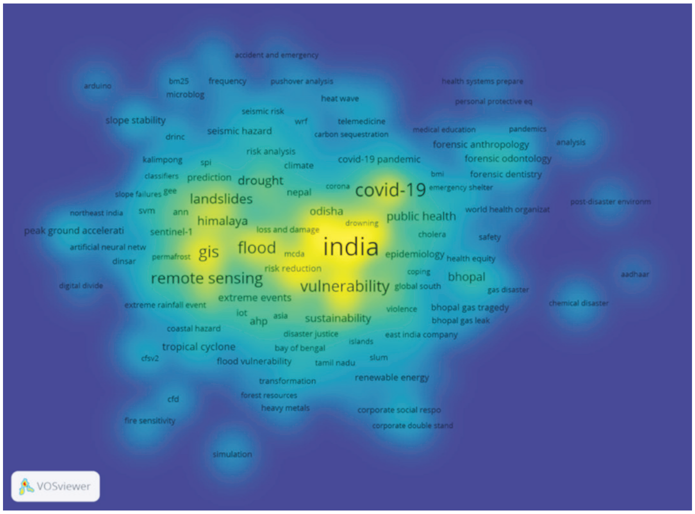

Figure 3 : Clustering of Abstract Keywords

Source- Author, 2022

The works can be seen to be clustered around the themes of vulnerability in India as can be seen form Fig.3. Besides, floods and GIS and Remote Sensing seem to depict a distinct cluster along with landslides in Himalayas. The pandemic of COVID-19 reflects a notable impact on research in this short span of time with a distinct clustering observed near to the dominant theme of vulnerability and India.

3.2. Web of Science Database

3.2.1 Publication Overview

The data indicates that the number of publications and citations have increased constantly since 2012. In these publications, from 'Geosciences Multidisciplinary' with 653 publications as can be seen in Fig. 4.

Figure 4 : Publication Record- WoS

Source- Clarivate, 2022

Table 1 : Publication Record from WoS Satabase

Publication Years	Record Count	% of 3,482
2022	556	15.968
2021	550	15.796
2020	422	12.119
2019	296	8.501
2018	203	5.83
2017	184	5.284
2016	148	4.25
2015	147	4.222
2014	122	3.504
2013	105	3.016
2012	98	2.814
2008	80	2.298
2010	79	2.269
2011	72	2.068
2007	56	1.608
2009	56	1.608
2005	51	1.465
2006	47	1.35

Publication Years	Record Count	% of 3,482
2004	26	0.747
2002	24	0.689
2003	20	0.574
2023	18	0.517
2000	16	0.46
2001	14	0.402
1994	13	0.373
1996	12	0.345
1995	10	0.287
1997	10	0.287
1999	10	0.287
1991	9	0.258
1992	9	0.258
1993	8	0.23
1998	7	0.201
1990	3	0.086
1989	1	0.029

Source- Author, 2022 from Clarivate (2022)

3.2.2 Citation Report

Of the 3,466 publications, 2,833 documents were cited at least one. For citations as per the institution, with a criteria of at least one document and at least one citation, 1,931 documents met the criteria. Fig.4. indicates that the IIT's got the maximum citations for the period while the National Institute of Technology had the maximum citations in the last two years. With regards to the number of citations, the average citations were 17.86 per item. (WoS, 2023). Citations of published works have rapidly increased from 2012 onwards which indicates the emergence and development of the field. This can be seen in Fig. below. Further, the citation report on meso topics highlights that 'Climate Change' dominated the theme as can be seen in Fig.5.

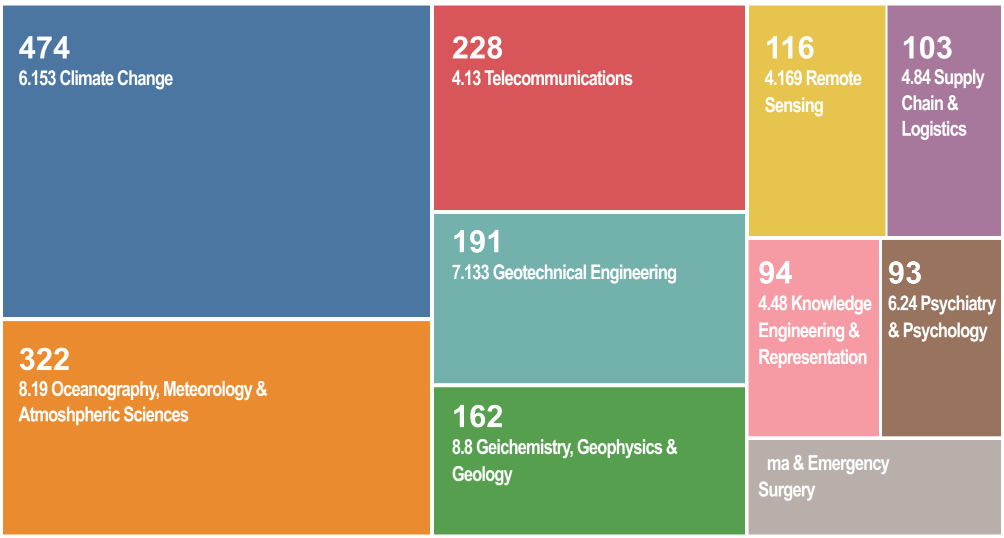

Figure 5 : Themes of Publications

Source- Clarivate, 2022

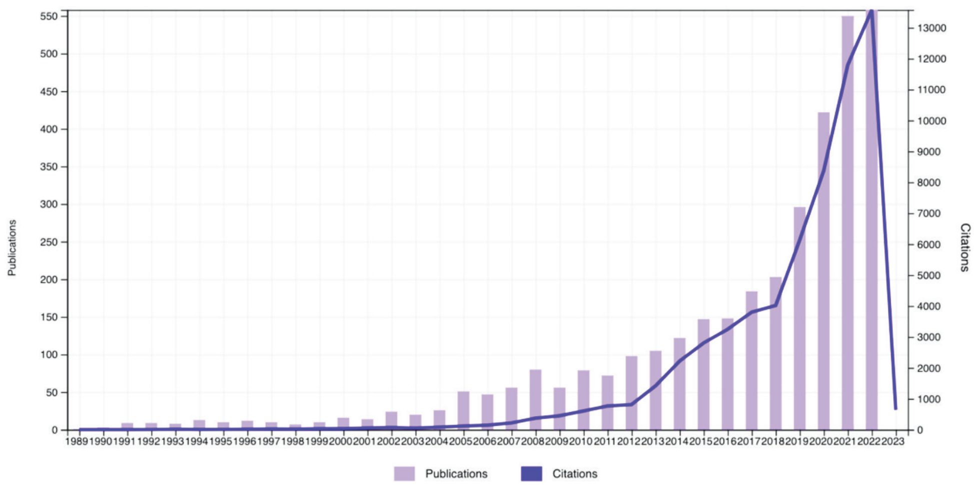

Figure 6 : Citations and Publications Record

Source- Clarivate, 2022

With regards to publishers, Springer Nature did the maximum number of publications on the topic; the details of first fifteen publishers can be seen in Table2.

Table 2. Top 15 Publishers on the Topic 'India and Disasters'

Publishers	Record Count	% of 3,468
Springer Nature	812	23.414
Elsevier	716	20.646
Taylor & Francis	282	8.131
Wiley	202	5.825
Mdpi	137	3.95
IEEE	122	3.518
Indian Academy of Sciences	119	3.431
Sage	87	2.509
Cambridge University Press	69	1.99
Emerald Group Publishing	50	1.442

Publishers	Record Count	% of 3,468
Disaster Advances	33	0.952
Oxford University Press	30	0.865
Amer Geophysical Union	26	0.75
Hindawi Publishing Group	25	0.721
India Meteorological Dept.	24	0.692

Source- Author, 2022 from Clarivate (2022)

3.3 Details on Co-authorship

This information was derived on co-authorship as per countries, authors and organisations. Information on co-authorship as per the number of documents in an organization was derived on the basis of at least two documents per organization criteria. For 3,795 works generated, there were 2,926 documents with co-authorship as per organizations. The maximum co-authored works were observed from the IIT's in India as can be seen from Fig.7. In fact, a dense clustering of works gets absorbed around the IIT's followed by NIT's. Findings on co-authorship as per authors aimed at deriving data for a minimum of two publications per author. The results generated 1,442 number of authors whose works had a co-authorship. The number of countries with co-authorship were found to be 133 and details are depicted in Fig.8. Here, the works within the country dominate the publications. This is followed by PRC and USA.

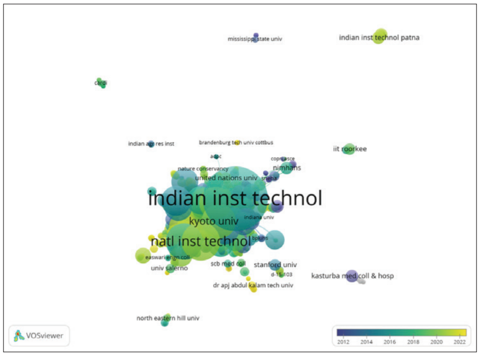

Figure 7 : Co-authorship as per Organisations

Source- Author, 2022

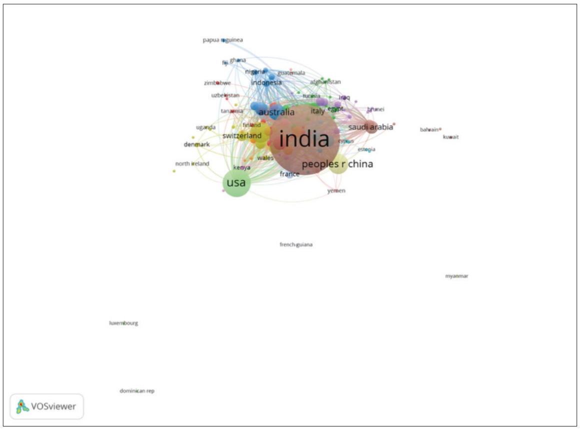

Figure 8 : Co-authorship as per Countries

Source- Author, 2022

3.4 Co-occurrence of Keywords

The keywords are indicative of the focus of publications on the topic for the country. The published research on the topic 'India and Disasters' with regards to Co-occurrence of keywords in these works indicates that at the chosen aspect of a repetition of a keyword twice, 3142 keywords find a repetition. This is visualized in Fig.9

Figure 9 : Co-occurrence of Keywords

Source- Author, 2022

For publication titles, ‘Natural Hazards’ journal had 156 publication titles followed by ‘International Journal of Disaster Risk Reduction’ with 142 publications.

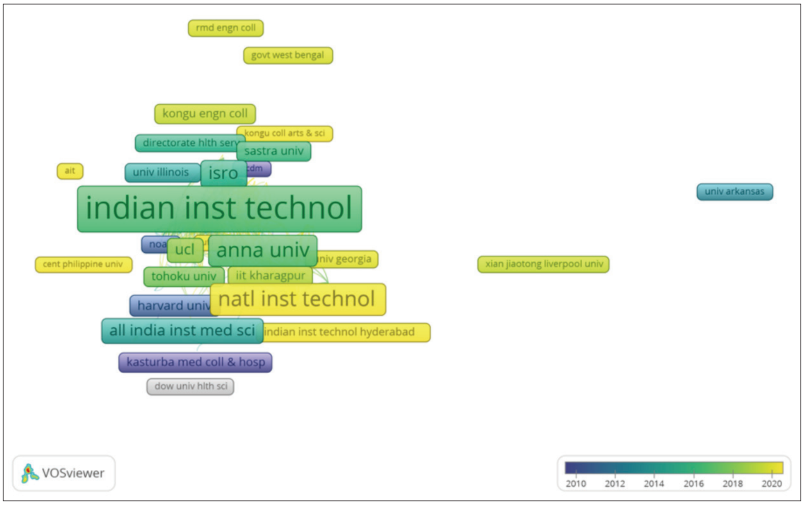

Figure 10 : Citations as per Institute

Source- Author, 2022

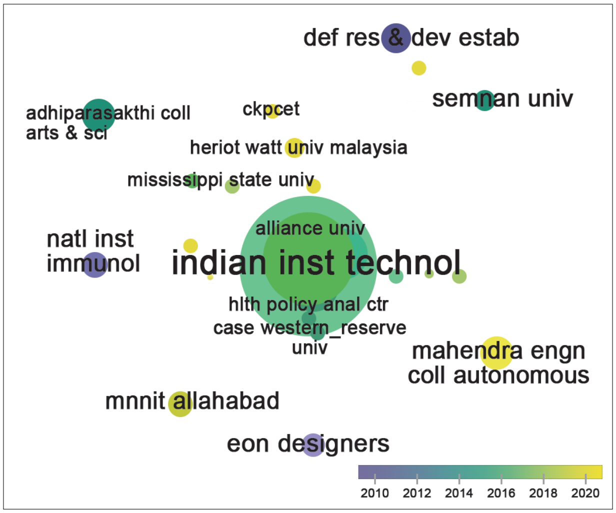

Figure 11 : Bibliographic Coupling as per Organisations

Source- Author, 2022

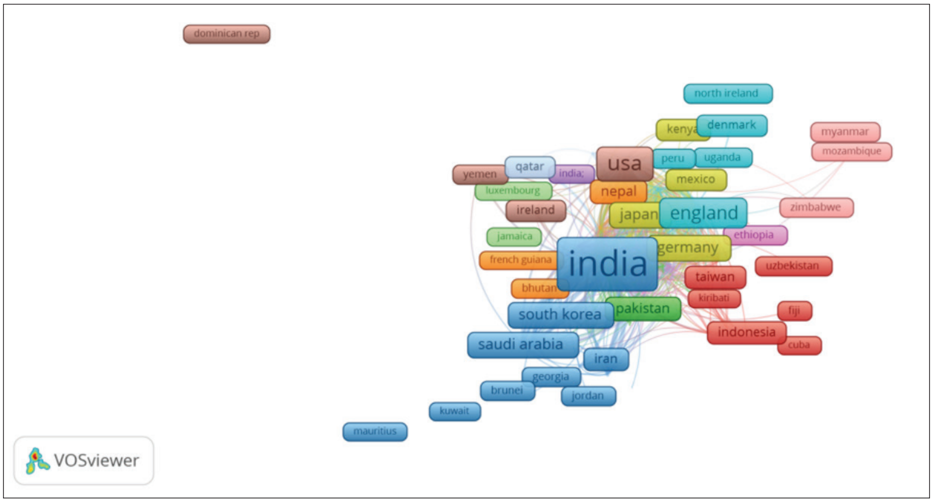

Figure 12 : Bibliographic Coupling as per Countries

Source- Author, 2022

Observing citations as per countries, it can be observed that Indian publications dominated the citations followed by USA and England. This data is available from 2016-22. Bibliographic coupling information also indicated the dominance of IITs as is visible in Fig.10.IIT Delhi also had the maximum bibliographic contribution in coupling as is observed in Fig.11. From 2010 to 2020, the number of documents observed were 3,795 with one document per organisation. Bibliographic coupling for countries is indicative of India being the dominant contributor for the same.

4. Conclusions

It is clearly visible from the attempt that the number of publications on disasters in India have seen a spurt in the 21st century. This was visible earlier in Scopus as compared to the Web of Science. Besides, the citations have also increased. However, there are certain themes around which this research revolves and clusters. In this context, the COVID-19 pandemic has indicated a significant influence on research and that too within a span of about three years in the Scopus database. This is not much visible in the WoS database. The analysis further indicates that research on the topic 'India and Disasters' is dominated by science and technology oriented publications. This also leads to the suggestion that social science based studies can augment their contributions in the field. This is observant in the keyword search also as more pure science oriented keywords are visible in the database. The contribution of other countries in the field is also notable besides that of India.

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Environment and Public Heath Disaster from the lens of Sludge Management in India

Vishakha Jain[1]

Abstract

The goal of any sanitation policy is to eliminate direct or indirect contact with feces. To ensure this objective, UNDP has framed sanitation ladder so that all member countries can design their sanitation policy to attain SustainableDevelopment Goal (SDG) 6.2. Developed counties have invested on offsite sanitation system but Low Middle IncomeCountries (LMIC) have opted for mix of offsite and onsite sanitation methods. Onsite sanitation can be considered as safe sanitation, if the partially digested sludge is disposed in safe manner. 'Swach Bharat Mission (SBM)', the recent public policy on sanitation has motivated households for the construction of toilet. The toilets constructed through SBM are improved toilets which mean the risk of fecal contamination is lower. Rural India is predominated with Onsite sanitation methods; it can be considered safe only if thesufficient provisions for fecal sludge management are provided. If the waste from septic tank is disposed in the open/ponds/rivers then the end result would beenvironment and health disaster. The present sewage treatment plants are run by the government and they donot accept the sludge from the septic tanks. The state run provisions for transportation and treatment of sludge generated from septic tanks are not sufficiently available. The current study examines the facilities of sludge management in India and the risk with present sludge management facilities.

Keywords: *On-Site Sanitation, Offsite Sanitation, Sludge Management, Safe Sanitation, SDG 6.2*

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1. Introduction

The concept of sanitation starts from providing access to toilet and ends with safe disposal of toilet waste. This means sanitation is not just providing safe options to defecate but if the waste from the toilet is added to natural resources, the objective sanitation can't be fulfilled. Public health has high close association with Personal hygiene and environment hygiene(PEARSON, JOANNA, 2008),(WaterAid, 2016). To maintain the personal hygiene, it is necessary to eliminate fecal-oral contamination and to maintain environment hygiene, it is necessary that the human/animal waste is disposed in such manner that it will not create any pressure either on natural water bodies or soil or air (through emissions). The global importance for sanitation was started with Millennium Development Goals (MDG) in 2000. The seventh goal, third section (7C) of the MDG highlighted the significance of environmental sustainability through fixing the target of reducing the percentage of population without sustainable access to safe drinking water and sanitation by fifty percent by the year 2015 (United Nations, 2000). The member countries of United Nations worked in this direction and by 2015, open defecation has reduced significantly at global level hence the concept of sanitation has further enhanced while framing goal 6 of SDG(UNDP, 2019). The SDG 6.2 is focused to provide sanitation facilities to all without any discrimination. The concept of sanitation is monitoredthrough sanitation ladder (framed by UNDP and WHO). The first target in this hierarchy is giving access to improved toilet and ends with safe disposal of toilet waste(Dasgupta et al., 2021). The objective of safe sanitation is to protect human health by breaking the cycle of disease and protecting the environment. This can be achieved by ensuring that everyone is using the toilet and the waste from the toilet is disposed in a safe manner. If the toilet waste is not disposed in safe manner (toilet waste is ended up in the natural water bodies or barren land), then the true objective of sanitation can't be achieved. It is necessary to provide safeguard to environment, human and aquatic life. Theway it will be helpful to achieve climate mitigation and adaptation. Climate change is a bigger challenger for the entire world. Lack of sanitation and wastewater management has direct association with emissions. With a planned approach climate change policies should be associated with sanitation policy(Dickin et al., 2020). With sharp increase in population and urbanization, the problem of waste disposal (including solid waste) is becoming a challenge. Unsafe disposal of toilet waste can be a major source of various community infection spread. To tackle the problem of toilet waste, developed countries have invested heavily on the development of sewage lines and sewage treatment plants, but developing countries can not invest heavily on sludge management. They are still struggling in providing safer options for defecation.As a result, Globally around 80 percent of untreated wastewater returns to the environment (UnitedNations, 2016). The larger proportion of world population is living in developing or LMIC, hence it is necessary to develop some cost-effectivemethods to solve the problem of safe disposal of toilet waste so that LMIC can adopt these. Presently in most of the LMIC, sludge is collected manually from the latrines;this sludge is then transported to central collection points and then to STPs for the treatment. This process of sludge management requiresmany stakeholders so standardization and monitoring isdifficult. After collecting sludge at central collection point, it has to be treated. For treatment some of the countries have developed sufficient capacity through decentralized sewage treatment plants but most of the developing countries are lacking this facility.In this entire process, there are high chances of leakagese.g, for cleaning of septic tank and transportation of sludge, safety gears and training to sanitation workers is necessary. After transportation, there should be sufficient capacity in the treatment plant for safe disposal of this waste.In case of India, STPs do not have sufficient capacity to treat sludge generated from septic tanks.

2. Objective

The study is focused to examine the health and environmental impact of unsafe disposal of toilet waste in South-Asian countries, and how can these impact be mitigated. The study will further examine the different methods of toilet waste disposal among Indian householdsbased on location (Rural vs urban).

2.1 Comparative Position of India with other South Asian Economies for Toilet Waste Management

The toilet waste management is not yet received attention from the policy makers. The impact of MDG 7c and SDG 6.2 is mainly focused to provide improved toilets but to make sanitation policy sustainable, it is necessary to provide options for better use of toilet waste. There are two methods for fecal sludge management; onsite sanitation and offsite sanitation (WSP & GoI, 2008). Offsite sanitation requires huge investment and for the LMIC, it is not possible to invest heavily on centralized sewage lines. Construction and maintenance of STPs/sewer pipeline is practically difficult in shorter span of time for any LMIC (Sljbesma, 2008). Hence, septic tanks are considered as safe method for sludge management (Dasgupta et al., 2021). But septic tank has its limited capacity and these have to be cleaned after some interval. The problem arises if the provisions for treatment of sludge from septic tank are sparsely available. Let's first understand how the South Asian LMIC are planning for provision for safely managed sanitation. World Health Organization (WHO) and United Nations International Children's Emergency Fund (UNICEF) collaborate to develop a platform which helps nation to compare and analyze their progress on SDG 6. This portal provides a comparativeanalysis with the data provided by the government of member nations like National Family Healthcare Surveyin India and international agencies. The comparative progress at regional and global levels helps nation toimprove. This data base is known as Joint Monitoring Program (JMP) which publishes global updates on water and sanitation since 1990.

Table 1: Sanitation Facility Type: India and its Neighboring Countries (%)

	Improved latrine and other	Septic tank	Sewer	Sewage Treated	Faecal Sludge treated
India	34.63	36.16	12.58	3.96	0
Nepal	29	53.76	4.95	2.05	0
Pakistan	21	30.41	27.28	NA	NA
Bangladesh	49	20.08	9.35	2.92	0
Afghanistan	49	8.82	3.15	NA	NA

Source: JMP (2020)

India, Nepal and Bangladesh have data on treatment of wastewater generated through toilets connected with sewers (Offsite sanitation). However all the countries don't have data on fecal sludge treated (waste generated through toilets connected with septic tank/pit latrines or on-site sanitation) or they do not have any such facility. Pakistan has 27 percent toilets connected with the sewers but the information for sewage treatment is either missing or the STPs do not have sufficient capacity to treat the sewage collected. The dependency on septic tank toilets is highest in Nepal followed by India and Pakistan but the information on sludge treatment from septic tank is totally missing. This shows that these LMIC are still focusing on providing safe defecation options. Along with the availability of toilets, there is need to develop the awareness/ options or capacity for fecal sludge management. Due to low government revenue, constructing sewage lines can be challenging, it is still necessary to provide safe options for sludge/sewage disposal. This can be possible with the combined efforts by government and private sector.

2.2 Sewage and Fecal Sludge Management in India

It is overambitious to construct the sewage lines in the villages for any LMIC. Hence it is a wise decision of GOI to choose onsite sanitation system (toilets with septic tanks). To provide a sustainable solution to developing countries, on-site sanitation system has emerged. Onsite sanitation methods are considered safe and hence these are considered for highest level in sanitation ladder (safely managed sanitation). Onsite sanitation system can be possible with different toilet designs, but only few of them are sustainable in themselves and capable enough to decompose the human waste naturally. With the constant technology intervention, there are few toilets construction designs which don't require any external method for waste disposal. But others require regular cleaning and the waste from these toilets needs proper disposal mechanism. Let's understand the type of toilet design opted by Indian households.

Table 2 : Household Peferences for Toilet Design, NFHS-V (2019-21)

	Rural (%)	Urban (%)	All India (%)
Flush to piped sewer system	2.9	25.6	10.4
Flush to septic tank	40.2	53.2	44.5
Flush to pit latrine	14.9	7	12.3
Flush to somewhere else	0.6	1.4	0.9
Flush, don't know where	0.1	0.4	0.2
Ventilated Improved Pit latrine (VIP)	0.8	0.5	0.7
Pit latrine with slab	6.2	3.5	5.3
Composting toilet/twin pit	5.9	1.1	4.3

Source: (NFHS 5, 2021)

The above table shows the toilet construction design by the Indian households based on waste disposal method. Just 1 percent households have toilets with soak pit. These pits are connected with open drains. These open drains are connected withmain drain and transport the septic to STPs, but sometime these open drains are ending in disposal of sludge in unsafe manner. The basic difference between improved and unimproved toilets is of drainage facility from the toilet. Unimproved toilets either have soak pit or connected with open drains so the toilet waste is either seeped in the ground water or it is routed to low-lying areas or some to natural water bodies. The situation becomes worse in those areas where households have flush/pour flush toilets connected with open drains or open fields. Hence unimproved toilets have high negative health and environment externalities. It is appreciable effort of GOI that most of the toilet constructed under SBM is of improved toilet construction design. Majority of rural as well as urban households have toilets connected with septic tanks. The improved toilets can be categorized into two; toilets connected with onsite sanitation system and toilets with offsite sanitation system.

2.3 Onsite Sludge Management

On-site sludge management can be defined as a system where latrine is connected with a deep pit/ septic tank which has storage facilities of fecal matter. It is constructed within the dwelling or its immediate surroundings. The idea of on-site sanitation system is more suitable for developing countries as it does not require the grid of sewage lines in the entire area so even a remote village or a small cluster of houses can have safer option for sanitation. Another benefit of this method is it does not create pressure at one area(WSP & GoI, 2008). The treatment of fecal material is done into a comparatively smaller scale so it will increase the efficiency. Onsite sanitation system can be categorized into two; self-sustain toilet where there is no need to empty the pit (for example composting toilet or twin pit toilets) and other category is the toilet which is connected to one pit with limited capacity.

The self-sustain toilet design under onsite sanitation is twin leach pit/composting latrines/ Ventilated improved toilets. But these toilet designs are not popular among Indian households and only 11 percent choose twin pit (NSS 76 round, 2018) which has reduced to 5 percent (NFHS-V, 2019-21). The reason could be space as it requires more land and planning from the starting. If a new toilet is going to be constructed then such method can be adopted but it is difficult to alter the existing toilet to become self-sustain toilet. Twin pit toilets are such toilets which are self-sustainable toilets in nature. Fecal sludge can be converted into manure and extracted by the household himself (without any technical help). This manure is highly useful for plants. This solution is best if the household has some extra space and toilet construction is planned from the scratch. The existing toilet is difficult to be converted in this design. These are the improved pit latrines with two pits, interlinked through Y-junction to pour flush toilet(Verma et al., 2020). Fecal sludge or popularly known as Septage can be understood as slurry that contains both solid human waste and liquid waste (black water). This Septage is collected in one pit for some months and when this pit gets filled, another pit is used to collect the fecal matter. Meanwhile, the collected Septage in the first pit can be decomposed to have manure through the natural process. This toilet design requires more water as the waste has to move through one pit to another. GOI has also motivated households, particularly rural households to adopt this toilet design but due to its requirement of space and water, it is not a popular choice. Besides twin-pit toilets, the other option for on-site disposal is in-situ containment systems. In this design, the human waste is segregated in two columns/ compartments. The liquid from raw sewage will be evaporated with time and the solid waste will be decomposed to a greater extent. This does not require emptying of sludge. Hence, no fecal sludge management (FSM) services will be required in the area (Department of Drinking Water and Sanitation, Ministry of Jal Shakti, 2021).

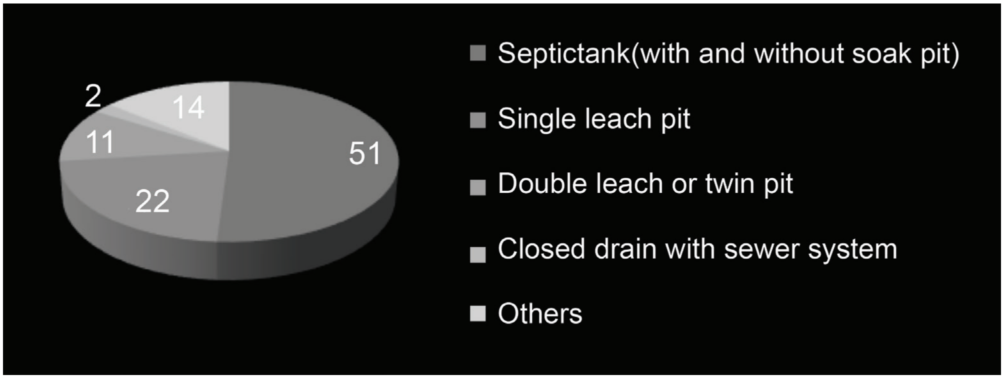

Figure 1 : Methods of Toilet Drainage System in India (In %)

Source: NSS 76 Round (2018-19)

Most of the toilets constructed under SBM has septic toilets. 44 percent of rural and 53 percent of urban households have toilet connected with septic tank. Majority of the households have access to toilets connected to septic tank which is a part of onsite sanitation toilet design. The toilets with the single pit need de-sludging after a certain time interval. The time required to clean the septic tanks depends on number of people using toilet and the depth of the septic tank. These septic tanks have limited capacity, after the filling of the septic tank; sludge has to be removed to make these septic tanks reusable (Department of Drinking Water and Sanitation, Ministry of Jal Shakti, 2021). This way, the onsite sanitation system has total three steps: collection of sludge from the septic tanks, transportation of this sludge safely to the treatment site and finally disposal of sludge in safe manner. The third step can be extended to reuse of the residual of this sludge. From the perspective of sanitation ladder, it is considered as safer option for sludge management but this requires regular cleaning. If the country has infrastructure for transportation and disposal of sludge then septic tank can be proven as most cost friendly method for safe sanitation.

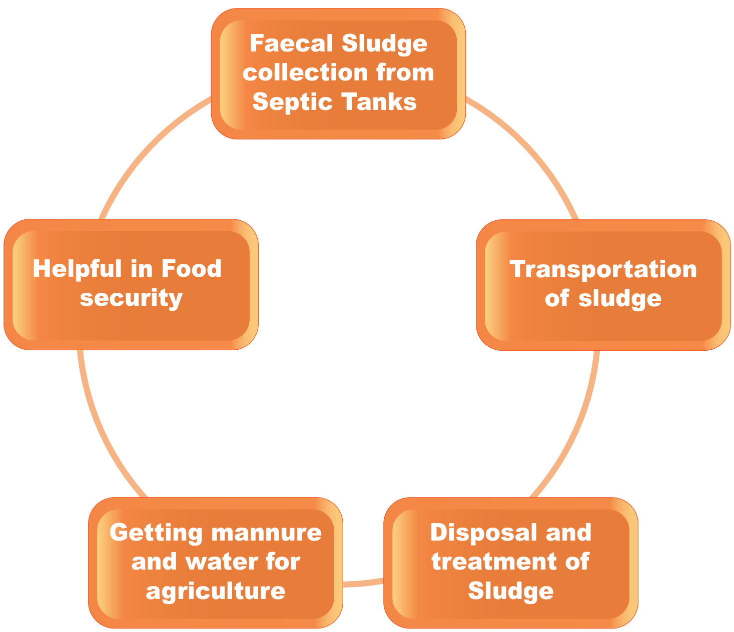

Figure 2 : Steps for Sludge Management in Onsite Sanitation System (Septic Tanks)

For any low-middle income country, on-site sanitation solutions are the most practical way to deal with sludge management. The onsite sanitation system can only be considered safe and free from externalities when this sludge can be collected through suction trucks, transported safely to sewage treatment sites. Ideally, a septic tank system should be cleaned every one and half year with the flexibility of up to three years as per the Central Public Health and Environmental Engineering Organization guidelines(Ministry of Urban development Governmnet of India, 2013). If the STPs are not accepting the sludge transported by private companies, then they also have to dispose of it in an unsafe manner. Most of the on-site sanitation systems are emptied manually without any safety gears(Ingole, 2016). In the year 2018, Dalberg advisors (supported by Bill and Melinda gates foundation) conducted a survey on the different challenges faced by sanitation workers in India. As per their estimate 5 million workers are working in this industry, although their definition of sanitary workers has different nine categories but directly or indirectly this was the estimates of people associated in this profession. In the year 2019 Ministry of Social Justice and Empowerment, Government of India (GOI) has estimated that total 54,130 people working in manual scavenging work. Although manual scavenging is banned by Supreme court of India under Prohibition of Employment as Manual Scavengers and their Rehabilitation Act, 2013 (MS Act, 2013) but the workforce who is engage in cleaning the septic tanks without proper training and safety gear are no better than manual scavengers. After the collection of sludge, it is importance to know where these private contractors dispose of the sludge.

Table 3 : Place of Disposal of Sludge from the Septic Tank

S.No	Area of disposal for sludge	Rural (%)	Urban (%)	All India (%)
1	treatment plant	2.8	6	4.5
2	buried in a covered twin leach pit/single pit	7.6	6.3	7.0
3	uncovered pit/open land/ pond/river etc.	20.1	10.1	15.0
4	not known	39	64.1	51.8
5	other places	30.4	13.4	21.8
	Total	100	100	100.0

Source: NSS 76 round (2018)

If the toilet waste travels through open drains and finally dumped in pond or river, then there will be deeper health and environment issues. 20 percent of rural households have accepted that their toilet waste is ended in either to barren/open land or river or ponds. Such access and use toilet can only be beneficial for social security but these toilets are as dangerous as open defecation and do not create any positive externalities. More than 50 percent of the households are not aware about the area where the desludging of their septic tank has been taken place. The probable reason for that most of the households has got their toilet constructed recently under SBM. The newly constructed toilets have not yet reached the capacity of the septic tank. Till now, the government has not drafted any solution for cleaning of the septic tanks. Out of the remaining households, just 11.5 percent of households are opting for safe options for disposal of the sludge. These households who have transported their sludge to a sewage treatment plant and have twin pits can be considered as safe disposal. 15 percent of households are opting for desludging in the barren land or in the freshwater source, which is extremely harmful and has high negative externalities. Such kind of measure creates complex obstacles for grey-water management as well. Rural India is majorly dependent on on-site sanitation methods, which require cleaning of septic tanks/ desludging at a regular interval. Most of the toilets constructed under SBM are flush toilets with small pit which means these toilets have limited capacity to store the sludge and needs to be cleaned after small interval of time.

Table 4 : Frequency of Cleaning of Septic Tank

	once or more in a year	once in 2 years	once in 5 years	once in 10 years	not known	others
Rural	12.6	20.1	33.0	21.0	7.3	6.1
Urban	18.1	18.0	27.7	21.9	8.8	5.6
Total	15.4	19.0	30.3	21.4	8.1	5.8

Source: NSS 76 round (2018)

The frequency to clean of the pit depends on different factors like; number of members using the latrines, depth of the pit and the ground water level. In case the ground water level is high then pit needs to be cleaned more frequently. If the toilet is shared and a greater number of people are using it then also it need to be cleaned more frequently. If the pit is around 3 feet, then it has to be cleaned frequently. From the data, it has been observed that there are high number of households who need to get the pit cleaned once in five years. Even if the frequency of Cleaning of septic tank is high then also it is equally safe if the cleaning is done by some responsible agency.

To understand the deeper understanding of impact of septic tank on environment, a question is asked in NSSO 76 round on the pace of disposal of sewage from the household toilet. Although the total sample size become small as most of the toilets constructed through SBM will not require cleaning till now.

Table 5 : Agencies Hired for Emptyingthe Septic Tank (in %)

	Panchayat/ municipality / corporation	Private agency	Privately hired labor	By household members	others	Not Known
Rural	5.4	35.8	49.2	5.7	0.7	3.2
Urban	23.2	43.7	27.3	1.5	1.7	2.5
Total	14.5	39.9	38	3.6	1.2	2.8

Source: (NSS 76 round, 2018)

Majority of the households either have to depend on private agency or the hired labour for the cleaning of the septic tank. Though in the urban area, municipality is responsible for this work and in rural area panchayat has the responsibility. (WaterAid, 2020)But due to a limited capacity of the civic agency or low technical expertise among the local government bodies, the household have to choose private agencies for this work. These private agencies mostly belong to the unorganized sector which doesn't have suction trucks or the option to dispose sludge in STPs. They don't provide sufficient safety gears to the sanitation workers and hence there are high chances of the health hazards to these workers.

Due to these insufficient options for sewage management, there are high chances of getting fecal matter in the grey-water(NITI AYOG, 2021). Currently there is no monitoring system by the local government or any government department on these private agencies. Even the local governments hire these private agencies when there is need for emptying/desludging septic tanks by local government. If some Public-private partnership model can be developed where government can provide their own standards for transportation and disposal of sludge, then there is possibility that safely managed sanitation can be achieved even with on-site sanitation system. Sustainable Sanitation a Catalyst for any human settlement, to break the vicious cycle of disease, it is necessary to save the fresh water resources from the waste water/ sludge. If this is backed with potential to transform waste into resource, then the entire system can become finically viable as well.

2.4 Offsite Sanitation System

To treat the sewage at a central point, human waste needs to be transported to this central point. For this purpose, underground sewage pipelines have to be installed. These pipelines are connected to each house so that the sewerage of entire area can be accumulating at point for its safe treatment. The pipelines have to high maintenance, sometime choked due to plastic waste, low efficiency of STPs is another problem. Centralized sewage system is a challenge for all low-middle income countries. For a low- middle-income country, it is difficult to construct sewage pipelines for all regions because of high fixed cost. Which result in low coverage of central sewage lines; for example, India has just 4% central sewage lines . GOI has adopted the National Policy on Fecal Sludge and Septage Management (2017) to improve sludge treatment opportunities. This policy is specifically focused on on-site sanitation facilities, so it covers the areas which are not covered with sewers. For better connectivity of sewers, their maintenance 'Atal Mission for Rejuvenation and Urban Transformation (AMRUT 2.0)', was launched on 1 October 2021. The objective of this program is to provide Sewerage management in the cities with the population more than one lakh, but the problem can't be solved by providing the drainage solution only to cities. If he sewage treatment plants can become financially independent, then only it is possible to make sanitation a sustainable policy. In the previous chapter, it was observed that at all India level, only 11 percent sewage is treated in urban India, while this sewage treated is as low as 0.3 percent among rural India (JMP, 2020).

2.5 Making Sewage Treatment Cost Effective

Human waste is totally bio-degradable and thus can be decomposed in a natural way with small interventions. But with increase in population and usage of acid as toilet cleaner, need for waste management become highly important, particularly for cities and town(Sundaravadivel & Vigneswaran, 2001). If this human waste is not tackled in a planned way, it can become a root cause behind water pollution, methane emissions or different health problems to the human and animals. The same wastewater and excreta can also be utilized as a raw material to generate energy/ biogas/ manure(Yeasmin et al., 2017). With the systematic planning, it can be converted as a valuable resource; it can add nutrition to the plant or provide electricity with cost efficiency. Bio-organic waste has tremendous potential to produce green energy in the form of bio-gas which can be converted into heat/ commercial electricity. This can be particularly efficient in public toilets or community toilets(Pickford et al., 1998). The energy produced can be supplied to the grid or used in the vicinity. This will promote food security through organic manure as well. This is a renewable source so it will reduce the dependence on fossil fuel(Dickin et al., 2020). This holistic approach which considers human excreta and wastewater as a valuable resource is known as sustainable sanitation. The objective of sustainable sanitation is to provide a futuristic solution which is economically viable and socially acceptable. To ensure the safe disposal of toilet waste, the SDG target has stretched to SDG 6.3, with the aims to save water resources from the discharge of untreated wastewater(World Health Organization and UNICEF, 2021). Natural water bodies are necessary for the human and animal survival and if untreated wastewater discharges into that, it disturbs the entire eco-system. Sustainable sanitation approach focuses to overcome the drawbacks of conventional approaches. This way Sustainable sanitation can help in mitigate the effects of climate change.For villages in LMIC, Decentralized wastewater treatment systems can be highly usueful. These are small-scale water treatment facilities, designed to treat and dispose of wastewater on-site, rather than relying on a centralized sewer system. These small machines can be installed for a small cluster. These is a cost-effective method which require less energy compared to centralized wastewater treatment plants. The chances of errors will be less.for example, if a centralized STP become dysfunctional due to some technical glitch, the city managementgot hampared. Small digestor/treatment machine is easy to manage. These decentralized sludge treatment plants uses natural processes such as aerobic and anaerobic digestion,and sand filters to treat wastewater. Other Simple and low-cost treatment technologies such as constructed wetlands, bio-filters, and vermin-filters can also be used to treat wastewater in villages.Treated wastewater can be used for agriculture, which reduces the demand for freshwater for farms.However, it is important to ensure that the treated wastewater meets the necessary standards and does not pose a health risk to consumers. This treated water can be discharged into nearby water bodiesto recharge groundwater recharge. These small scale technologiescan be used in the urban resident societies, which can supply treated water back to toilets in the flush. To make these technology popular, these can be installed with public private partnership. Private companies bring in their expertise and investment, while the government provides the necessary regulatory framework and infrastructure support. PPPs can help in reducing the financial burden on the government and ensure better project management. All such methods can be popular when people have sufficient awareness about health problems due to lack of sludge management. Awareness among users can be created through awareness campaigns, regulatory measures, and financial incentives. Bigger institutions like industries or group housing societies can be motivated through strict policies to install on-site treatment systems and dispose their wastewater independently, but along with strong policy, it is important to make sewage treatment cost-effective through innovation. This way, a holistic approach is required which involveinnovative technologies, partnerships, and incentives. It is important to move towards sustainable sanitation practices that not only ensure proper waste disposal but also utilize the potential of wastewater as a valuable resource.

3. Conclusion

Accessibility to toilet is definitely an important factor to reduce open defecation and visible faeces but just access to toilet is not likely to eliminate the health and environment externalities.Swachh Bharat Mission has made significant progress in improving sanitation coverage in India, still there is a long way to go in terms of achieving universal access to safely managed sanitation. Ongoing investment in sanitation infrastructure, behavior change campaigns, monitoring and evaluation will be critical to sustaining the gains made till now.

If the capacity/ provisions for sewage treatment/fecal sludge management are not development then in the coming years, there will be huge dependency on the private agencies to clean the septic tanks. At present there is no monitoring how these private agencies are disposing the sludge. There is need to create/ train sanitation entrepreneurs who can use the organic waste to generate energy. This way sludge can be used as a resource instead of polluting the natural water bodies/soil or create emissions. Waste disposal is a complex problem for any developing country. For India, it can become more dangerous due to high density of the population. If electricity or energy can be produced from this waste then the entire sewage treatment process can become cost effective andself sustainable. The country can gradually switch from public owned sewage treatment plants to PPP model in sewage treatment so that the capacity of sewage treatment can be increasedThis dimension of sanitation needs technological interventions, few provisions are made in the Budget of 2023-24 but still developing sludge treatment infrastructure is neglected. Safe disposal of toilet waste needs immediate attention otherwise fecal-oral diseases can't be reduced. Stable and long-term financing and planning is essential for sustaining ODF status. Short-term and one-time planning, without a future roadmap will result in high health expenditure and incomplete shield from the sanitation benefits. Poor sanitation has the potential to undo most of the positive impacts generated so far in achieving the targets of SDG6 as well as all other SDGs. Safe sanitation implies that the entire sanitation chain needs to function in a safe and sustainable manner. If there is any loose point in one part of this chain, the entire investment will be waste. There are high chances of market failures in this chain. PPP model in sewage treatment can be helpful in increasing the capacity and coverage of decentralized sewage/sludge treatment in villages and cities, however there are chances of market failures which need to be addressed to ensure sustained private and public sector involvement in fecal sludge management facilities. In lack of monitoring it would be difficult to increase the efficiency of decentralized treatment plants.Private agencies usually work only for profits. They are not concerned for environment or public health. Hence they should be monitored regularly. To increase the efficiency of these companies, there is need to develop options for resource generation from toilet waste.. Otherwise the organized sector will not show interest in this sector. Public sector options require huge funds so the time to develop fecal sludge management methods will be long . There is need to address these market failures to develop a sustained and long-term involvement of the public and private sector which implies a significant development for fecal sludge management facilities.

4. Limitation of the Study

India has recently increased the access to toilet. Most of the toilets constructed in villages during SBM are improved toilets with septic tank. These septic tanks will take

3 years (on average) to fill itscapacity. Most of the households have not yet require the cleaning of septic tank and those who have done through private agencies are not aware about the disposal of sludge by the agency. There is no official data availableon sludge disposal methods by these private agencies. Another study is required to investigate the methods of sludge disposal by professional agencies in different states.

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Morphometric Analysis on Tectonic Events Based on Geomorphological Indices Using Remote Sensing and GIS-a Case Study of Andaman Island

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Abstract

An important component of neotectonics is tectonic geomorphology, which is considered to be the backbone of the study. Aside from being tectonically active, the Andaman and Nicobar Islands comprise one of the most active groups globally due to the collision of the Indian and Eurasia plates. Tectonic geomorphology of the South-Andaman Island is primarily addressed in the present study by incorporating geomorphological indices in order to analyze the tectonic activity and landscape evolution of 13 sub-basins. For the purposes of this study, the following indices were used: Asymmetry Factor (AF), Hypsometric Index (HI), Mountain Front Sinuosity (SMF), Longitudinal Profile (L), Transverse Topography Symmetry (T), and Basin Elongation Ratio (Bs). There has never been a study of this kind conducted in this region before. Tectonically active subbasins were observed in all the sub-basins with SMF values < 1.4. The Bs values indicate that basins are most often elongated and have trellis drainage patterns, indicating tectonic control. It can be concluded that the sub-basins are tilted at either end of the plane, as both Af values are < 50 and > 50 as well as T values approaching one (1). HI greater than 0.60 is indicative of tectonically unstable and actively raising subbasins such as Colinpur and Miletilek. The subbasins of Beodnabad, Burmanallah, Dhanikhari and West Jarawa showed HI values > 0.30 and < 0.50, indicating relatively stable landscapes, however still under development. According to longitudinal profiles of all streams, disequilibrium

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conditions were responsible for uplift along the active fault. Burmanallah sub-basin was the only one without much irregularity in slope because the rock types were homogenous.

Keywords: *Geomorphic Indices, Neotectonics, ASTER-DEM, Basin Analysis, GIS, South Andaman Islands*

1. Introduction

According to Keller and Pinter (2002), tectonic geomorphology studies the origin and the shape of landforms that have been formed as a result of tectonic processes or uses the principles of geomorphology to determine the magnitude, history, and degree of the process. In this article, the emphasis is placed on the difference between geomorphological features and topography that has been formed as a result of tectonic forces and erosion resulting from surface processes (Burbank and Anderson, 2001). There is a wide spectrum of effects that tectonics can have on a landscape's geomorphology, ranging from minutes to thousands of years. It is important to note that these effects are largely determined by the type of bedrock underneath. Andaman and Nicobar Islands have a very complicated tectonic setup, because they are located at the center of the Burma-Sunda- Java subduction belt, a 5000 km long belt (Allen et al., 2007). The north of the 90° E ridge is connected in a north-south arc that separates the Sunda and Indian plates (Curray 2005; Dasgupta and Mukhopadhyay 1993) (Figure-1). A study by Malik et al. (2006) concluded that the Andaman spreading zone, which lies between the latitudes of 10° N and 12° N, is enclosed by the Sunda fault system in the eastern part of the archipelago. It has been often referred to as the Burma micro plate since it plays an important role in the evolution of minor tectonic plates (Dasgupta and Mukhopadhyay, 1993; Ortiz and Bilham, 2003; Kayal et al., 2004). There have been various active strike-slip and thrust faults formed since the Cretaceous period due to deformations caused by subduction along trenches either irregularly or continuously (Tapan pal, 2003; Malik et al. 2006 and Chakraborthy, 2009). In Northern Sumatra-Andaman, an oblique subduction was created, which resulted in a strike-slip movement, which also caused the development of a sliver plate between the right-lateral fault system and the subduction zone (Chakraborthy, 2009). During the late Paleocene, the collision between Asia and greater India had a more or less normal convergence, which caused the Northern and Western Sunda arc to rotate and bend in a clockwise direction.

In the Eocene period, a sliver fault may have been initiated offshore of Sumatra and may have spread up to the present regional extent of the Sagaing fault within the Andaman Sea.

Since the strike-slip motion and back-arc extension were united due to oblique convergence, the rate of strike-slip motion was amplified by rotation. This resulted in the oblique opening of an array of extensional basins. An oblique motion between the Burma-Sunda plate and the Indo- Autralian plate appears to have been initiated with the help of existing strike-slip motions in the Andaman Sea, thrust motions in the Sumatra-Andaman trench, ridge-arc systems in the Sumatra faults, and back-arc movements in the southern region (McCaffrey, 1992; Sieh and Natawidjaja, 2000). A section of the Andaman-Sumatra trench lies at the western end of the Andaman-Nicobar ridge and is filled with sediment flowing from the Bengal fan. The Andaman-Nicobar Ridge is believed to have formed during the Late Eocene or Oligocene period and is composed of either seabed ophiolites or sediments from the Indian plate covered by sediments from the shallow water forearc region (Allen et al., 2007; Curry, 2005). This region has been classified as zone V in the recent seismic map of India, as a result of its complex tectonic setup and frequent earthquakes of a mild to moderate severity. Furthermore, this entire chain of islands is also susceptible to other natural disasters, such as tsunamis resulting from both large earthquakes and massive shock waves from afar. This is due to the fact that the earthquake database in India is still incomplete, particularly for earthquakes that occurred prior to the historical period (prior to 1800 AD) (Figure 1.1).

The objective of this study is to morphometrically analyze South Andaman Island in order to address landform evolution and tectonic intensity. This is the first study to apply geomorphic indices, namely mountain front sinuosity (SMF), transverse topography symmetry, asymmetry factor, basin elongation ratio, longitudinal profile, and hypsometric index. All measurements have been determined by manually calculating the values of the above indices, since they are the benchmark for any seismic activity (Bull and McFadden, 1977 and Silva et al. 2003). A topographic map was used to measure the valley height, and then these values were compared with the values from the field in order to evaluate their consistency and accuracy (Bull, 1968, 1977a, 1978, and Bull and McFadden, 1977).

Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) imagery was the primary source of Digital Elevation Models (DEMs) as well as an input for the analysis of other digital data. Various interpretations of DEM images are very popular for assessing motion within tectonically active regions (Grygar and Jelnek, 2003; Wojewoda, 2004, 2005b, 2006b, 2007b; Jordan et al. 2005; Kervyn et al. 2006 and Grohmann et al. 2007). An important method for morphotectonic analysis is the DEM analysis. In the present study, a new approach has been employed in order to confirm movement within the areas of tectonic activity by using a digital method combining multiple layers of geographic data, satellite imagery, and digitized calculations of a number of geomorphological indices. To determine tectonic activity along the mountain fronts of the South Andaman Island, this study aims to transition from traditional morphometric analysis to digital morphometric analysis. In the present study, six basins have been named after nearby localities: Beodnabad, Burmanallah, Colinpur, Dhanikhari, Miletilek and West Jarawa.

2. Study Area

The current study examines six sub-basins of South Andaman Island (Figure 2), which is part of the southern group of the Andaman Islands, namely Beodnabad, Burmanallah, Colinpur, Dhanikhari, Miletilek and West Jarawa. This study area comprises Andaman Flysch, Mithakhari, and Ophiolite rock types, as illustrated in Figure 3, and is characterized by a number of trench parallel and trench perpendicular structures. Further, a number of faults in compressional, tensional, and shear regimes run through it in the N-S, NE-SW, and E-W directions. There are mainly trellis and dendritic drainage systems in the study area, which are governed by local faults and fractures.

3. Methods

3.1 Mountain Front Sinuosity Index (SMF)

The Mountain Fronts are the foremost fault-bounded topographic ridges that have measurable relief, surpassing one contour interval of 20 meters. A measure of SMF is the extent at which erosion has modified the tectonic structures (Bull, 1977a, 1978; Bull and McFadden, 1977; Rockwell et al. 1984; Wells et al. 1988; Keller and Pinter, 2002; Silva et al. 2003). The method is used to assess tectonic activity along mountain fronts (Keller and Pinter, 2002; Silva et al., 2003). Using the following formula, it can be calculated.

SMF = LMF / Ls

Specifically, SMF represents the mountain front sinuosity, Ls represents the length of the mountain front along the top of the mountain, and LMF represents the length of the mountain front along the bottom (Bull and McFadden, 1977; Keller and Pinter, 2002).

3.2 Basin Shape Index (Bs)

Geotectonically active mountain ranges typically have elongated basins that are parallel to their slopes on a topographical level. A reduced amount of tectonic activity and topographical uplift over time result in the elongated structures being replaced with rounded basins (Bull and McFadden, 1977). As tectonically active regions have narrower drainage basins along the mountain front, the force of the stream is directed primarily in the direction of downcutting. It is usually possible to determine the planimetric or horizontal shape of a basin using the elongation ratio or basin shape index, Bs (Ramirez-Herrera, 1998), which is calculated a†s follows:

$$B_s = \frac{Bl}{Bw}$$

Where, Bl is the length of a basin measured from the headwaters point to the mouth, and Bw is the width of a basin measured at its widest point. Higher values of Bs indicates elongated shape of the basin which can be associated to comparatively higher tectonic activity. Lower values of Bs indicate a more of a rounded-shaped basin representing relatively lower tectonic activity. Thus, it can be concluded that the Bs value signifies the rate of tectonic activity.

3.3 Drainage Basin Asymmetry (AF)

An index such as this can determine tilting from basin scales to larger areas as a result of tectonic activity, and is particularly sensitive to tilting which occurs perpendicular to the trunk stream. The calculation can be expressed as follows:

$$AF = 100\ (Ar|At)$$

Here, AF represents the asymmetry factor, Ar represents the area of the basin on the right side of the stream trunk, and At represents the total basin area. In stable conditions, most networks of streams have an AF of 50. When a value exceeds 50 by a significant amount, it indicates the influence of tectonic activities, such as the slipping of bedding plains by streams in the course of time (El Hamdouni et al. 2008). In the case of relatively few or slight tilts that are perpendicular to the stream trunk, a value near 50 can be inferred. Considering that active tectonics has tilted the drainage basin to the left, tributaries adjacent to the left side of the main stream will be shorter than those adjacent to the right side by an asymmetry factor greater than 50 and vice versa (Hare and Gardner, 1985; Keller and Pinter, 2002).

3.4 Transverse Topographic Symmetry Factor (T)

The Transverse Topographic Symmetry Factor (T) is calculated by using the formula below

$$T = {}^{Da}/_{Dd}$$

Here, Da indicates the proximity between the midpoint of drainage basin and the midpoint of active meander belt, while Dd indicates the proximity between the midpoint of drainage basin and the basin divide. Consequently, the T value indicates the direction in which the streams migrate perpendicular to the drainage basin axis. Therefore, this index provides a medium for calculating the magnitude and direction of change that may be found between 0 and 1 (T = 0 to 1), which corresponds to a perfectly asymmetrical basin or a tilted basin (Cox, 1994; Cox et al. 2001; Burbank and Anderson, 2001; Keller and Pinter, 2002). It is evident that T values increase and approach 1 as the streams migrate laterally away from the basin center and toward either of the two margins. The main stream of the subbasin was segmented into 1 km long stretches for the calculation of the T index in this study. Then, a two-dimensional vector was created based on the T value calculated for each segment. There is a proportional relationship between vector length and the ratio Da / Dd, and the direction of migration is perpendicular to the segment of the stream. Vector direction reflects the direction in which a segment moves with respect to the midpoint of the basin. The AF index as well as the T index can be used quantitatively to identify tilting of the ground (Cox, 1994; Cox et al. 2001; Keller and Pinter, 2002).

3.5 Hypsometric Integral (HI)

In general, the Hypsometric Integral index is calculated for a specific drainage basin, and its composition is unaffected by the basin's size. An elevation index illustrates the pattern of elevation distribution in a landscape, particularly in drainage basins (Strahler, 1952). It is defined as the area below the hypsometric curve, which is a measure of the volume of the basin that has not been eroded. Calculating HI is done by directly obtaining the minimum and maximum elevations of the topographic map (Mayer, 1990; Keller and Pinter, 2002). Using a point sampling method on a grid, the mean elevation value of the basin is determined by taking into account at least fifty values of elevation (Pike and Wilson, 1971; Keller and Pinter, 2002; Luo, 2002; Luo and Howard, 2005). According to Davis W.M. (1899), a value of less than 30 indicates "tectonically stable", "mature", and "denuded" basins, whereas a value above 60 indicates "unstable", "young", and "actively uplifting" basins. Higher values of HI usually indicate that very little of the landscape has been eroded, which suggests that the landscape may be young or immature as a result of active tectonic activity. It is generally accepted that lower values are associated with mature landscapes that have undergone more erosion and have a smaller impact from active tectonic movements.

$$H_i = \frac{Mean\ elevation - Minimum\ Elevation}{Maximum\ Elevation - Minimum\ Elevation}$$

3.6 Longitudinal Profile

It is widely accepted that longitudinal profile analysis is an effective method of identifying how rivers respond to active tectonic activity (Sinha, 2001). As it shows distance on the x-axis and elevation on the y-axis, its effectiveness is determined by the fact that irregularities in channel slope can be seen in disequilibrium conditions, which indicate uplift along active faults. A profile that is upwardly concave indicates mature basins and channel degradation resulting from a longer period of time since the basement was lowered, whereas an upwardly convex profile indicates less down-cutting of channels and continuous lowering of the base level and/or shorter time since the base level fell (Wells et al. 1988).

4. Results

4.1 Mountain Front Sinuosity Index (Smf)

For each of the six sub-basins, mountain front sinuosity was calculated (Figure 5). After evaluating all mountain fronts, the average of all values obtained was calculated (Figure 5.1). Based on SMF values of Colinpur, Dhanikhari, Miletilek, and West Jarawa, all are classified as Class One (SMF 1.0 -1.4, Tables 1 c, d, e, and f, respectively), indicating that all mountain fronts are tectonically active. As the SMFs for the remaining two subbasins, Beodnabad and Burmanallah, were > 1.4 (Tables 1 a and b, respectively), they were classified under Class Two, indicating a relatively low tectonic activity.

4.2 Basin Shape Index (Bs)

Using the drainage basin shape equation, each sub-basin was calculated (Figure 4). An increase in the ratio of Basin shape index (Bs) indicates tectonically active basins (Cannon, 1976), and similarly, in this study, the Bs of three sub-basins (Colinpur, Dhanikhari, and Miletilek) indicate elongation (Figure 6 c, d, and e, respectively), whereas an increased ratio of Bs (Figure 6.1; Table 2) indicates that these basins are tectonically active. Beodnabad, Burmanallah, and West Jarawa were found to have circular shapes (Figures 6 a, b, f), suggesting they are tectonically less active (Figure 6.1; Table 2).

4.3 Drainage Basin Asymmetry (AF)

The Asymmetry Factor (AF) calculated for each of the six sub-basins and the ratio are shown in Table 3. Colinpur, Dhanikhari, and Miletilek subbasins are tilted towards the right (Figure 7 c, d, and e, respectively) as the ratio is less than 50 (AF < 50), whereas Beodnabad, Burmanallah, and West Jarawa subbasins are tilted towards the left (Figure 7 a, b, and f, respectively), as the ratio is greater than 50 (Table 3).

4.4 Transverse Topographic Symmetry Factor (T)

For each of the six sub-basins, the Transverse Topography Factor was calculated. Table 4 shows the ratio of transverse topography symmetry. Transverse topography ratios were calculated for all segments at 1 km intervals transversely for each subbasin, as shown in Figure 8, and the values were averaged (Table 4). As a result, the ratios of the sub-basins - Beodnabad, Colinpur, Dhanikhari, and Miletilek - have been calculated to be approximately one (1), suggesting that these sub-basins are tilted. Burmanallah and West Jarawa have T values approaching 0, thus they are not considered tilted in the sense shown in Figure 8.

4.5 Hypsometric Integral (HI)

For all six selected sub-basins, the elevation/relief ratio factor (HI) was also calculated. Table 5 shows the ratios of the hypsometric index for all the subbasins. In the Colinpur and Miletilek subbasins, the HI is greater than 0.60, indicating that they are tectonically unstable and actively uplifting. As a result, the sub-basins namely Beodnabad, Burmanallah, Dhanikhari and West Jarawa, exhibit HI values > 0.30 and < 0.50, indicating that these sub-basins are relatively less stable tectonically, but still undergoing development. Landscapes or sub-basins with HI less than 0.30 are considered stable. The HIs of all the sub-basins in the study area, however, were greater than 0.30, indicating their tectonic instability.

4.6 Longitudinal Profile (L)

Stream profiles were plotted along the longitudinal axis for each sub-basin in order to identify irregularities in channel slope in the form of Knick points, which are ascribed to active tectonics. As seen in Figure 9, Beodnabad, Colinpur, Dhanikhari, Miletilek, and West Jarawa show irregular slopes indicating disequilibrium conditions along the fault line. The Burmanallah subbasin, however, did not exhibit much irregularity in slope due to its homogeneous rock type. There is evidence of upward concavity in the longitudinal profiles of the sub-basin streams, indicating that the headwater area is highly active tectonically (Figure 9).

5. Field Evidences on Active Faults and Interpretation

In the current study, field investigations have been conducted on selected and possible sites. There are several major faults in the South Andaman region, including Jarawa Fault, Bathubasti Fault, Beodnabad Fault, Jogger's Park Fault, Carbyn Fault and South Point Fault (Figure 10). A field investigation was conducted at the Beodnabad and Burmanallah sites in order to collect geological and geomorphological evidence that confirmed the active nature of the faults (Figure 11). As an initial step, the tectanogeomorphic landforms in Quaternary deposits are mapped, including fault scarps, pressure ridges, shutter ridges, sag ponds, river deflections, compressed meanders, and Knick points. It is challenging to conduct field investigations and validations at the other sites in the current study because they are in a reserve forest area.

6. Discussion

subbasins were examined based on geomorphic indices (SMF, Bs, Af, T, HI, and L). As shown in Table 1, Colinpur, Dhanikhari, Miletilek, and West Jarawa sub-basins have Mountain Front Sinuosity (Smf) values between 1 and 1.4, which indicates they are tectonically active (Figure 5). Beodnabad and Burmanallah are slightly tectonically active, with Smf values greater than 1.5 (Figure 5.1). Colinpur, Dhanikhari, and Miletilek have elongated drainage basin shapes and an increased ratio of Bs, which indicates tectonically active drainage basins (Figure 6 c, d, and e, respectively; Table 2). On the other hand, the sub-basins Beodnabad, Burmanallah, and West Jarawa, which are circular in shape, have a low Bs ratio, indicating that they are less tectonically active (Figures 6 a, b, and f, respectively; Table 2). It can be seen from Figure 7 that the Drainage Basin Asymmetry (AF) for Colinpur, Dhanikhari, and Miletilek sub-basins is less than 50 (Table 3), which indicates that there is active tectonic activity (Figure 7 c, d, and e, respectively). There is an AF ratio greater than 50 in the sub-basins of Beodnabad, Burmanallah, and West Jarawa (Table 3), indicating that these basins are also tectonically active (Figure 7 a, b, and f) and due to tilting, the drainage system changed direction and course. According to Table 4, Beodnabad, Dhanikhari, Colinpur, and Miletilek exhibit a close to 1 Transverse Topography Factor (TTF), indicating they are tilted and tectonically active (Figure 8). On the other hand, Burmanallah and West Jarawa had nearly zero TTF values (Table 4), indicating that they were moderately tilted and slightly active (Figure 8). Colinpur and Miletilek have a Hypsometry Index (HI) greater than 0.6 ($HI > 0.6$), indicating that they are tectonically unstable and are actively rising (Table 5). Beodnabad, Burmanallah, West Jarawa, and Dhanikhari have $HI > 0.3$ and 0.5, which indicates a relatively less stable tectonic environment (Table 5). Figure 9 depicts disequilibrium conditions that suggest uplift along active faults at Beodnabad, Colinpur, Dhanikhari, West Jarawa, and Miletilek. The Knick point in the river profile is clearly visible as a result of faulting. Burmanallah sub-basin (Figure 9) is the only exception, which shows no irregularities in slope due to the homogenous nature of the rocks. By analyzing current river/stream patterns and drainage basins, we can gain insight into past deformations (Friend et al., 1999).

7. Conclusion

In this study, morphometric analyses of drainage subbasins in Bumanallah, Colinpur, Dhanikhari, Miletilek and West Jarawa were conducted based on the following geomorphic indices: Mountain Front Sinuosity (Smf), Drainage Basin shape (Bs), Drainage Basin Asymmetry (AF), Transverse Topography Factor (T), Hypsometry Index (HI) and the longitudinal profile of the faulted fronts. As a result of the study, it has been concluded that landscapes have continuously evolved under the influence of tectonic activity throughout the sub basin region of South Andaman. While the bulk of the topography seems to have developed under compressional tectonics, the analysis provides ample evidence about how the landscape has evolved along active faults within the region.

Table 1 (a) Mountain Front Sinuosity (Smf) of Beodnabad. BEODNABAD

No.	Lmf	Ls	Smf = Lmf/Ls	INFERENCE
1	0.904	0.799	1.13	Tectonically Active
2	1.444	0.792	1.82	Slightly Active
3	1.713	1.106	1.54	Slightly Active

Table 1 (b) Mountain Front Sinuosity (Smf) of Burmanallah

BURMANALLAH				
No.	Lmf	Ls	Smf = Lmf/Ls	INFERENCE
1	1.248	1.018	1.22	Tectonically Active
2	0.553	0.480	1.15	Tectonically Active
3	0.660	0.474	1.39	Tectonically Active
4	1.004	0.787	1.27	Tectonically Active
5	1.962	1.022	1.91	Slightly Active

6	1.693	0.988	1.71	Slightly Active
7	1.235	0.740	1.66	Slightly Active
8	1.261	0.765	1.64	Slightly Active

Table 1 (c) Mountain Front Sinuosity (Smf) of Colinpur. COLINPUR

No.	Lmf	Ls	Smf = Lmf/Ls	INFERENCE
1	0.913	0.866	1.05	Tectonically Active
2	1.114	1.077	1.03	Tectonically Active
3	1.276	1.181	1.08	Tectonically Active
4	0.848	0.782	1.08	Tectonically Active
5	1.779	1.742	1.02	Tectonically Active
6	1.743	1.674	1.04	Tectonically Active
7	1.585	1.549	1.02	Tectonically Active
8	1.155	1.123	1.38	Tectonically Active
9	1.376	1.349	1.02	Tectonically Active
10	1.617	1.466	1.10	Tectonically Active
11	0.687	0.671	1.02	Tectonically Active
12	1.448	1.389	1.04	Tectonically Active
13	1.197	1.164	1.02	Tectonically Active
14	1.175	1.156	1.01	Tectonically Active
15	0.845	0.816	1.03	Tectonically Active
16	1.650	1.577	1.04	Tectonically Active
17	1.640	1.385	1.18	Tectonically Active
18	1.000	0.995	1.00	Tectonically Active
19	0.784	0.768	1.02	Tectonically Active

20	1.586	1.493	1.06	Tectonically Active
21	1.136	1.069	1.06	Tectonically Active
22	2.009	1.965	1.01	Tectonically Active
23	1.170	1.137	1.02	Tectonically Active

Table 1 (d) Mountain Front Sinuosity (Smf) of Dhanikhari

DHANIKHARI				
No.	**Lmf**	**Ls**	**Smf = Lmf/Ls**	**INFERENCE**
1	3.004	2.916	1.03	Tectonically Active
2	1.046	0.970	1.07	Tectonically Active
3	1.378	1.291	1.06	Tectonically Active
4	0.824	0.791	1.04	Tectonically Active
5	1.120	1.112	1.00	Tectonically Active
6	1.492	1.338	1.11	Tectonically Active
7	1.623	1.552	1.04	Tectonically Active
8	1.540	1.437	1.07	Tectonically Active
9	1.218	1.074	1.13	Tectonically Active
10	1.195	1.134	1.05	Tectonically Active

Table 1 (e) Mountain Front Sinuosity (Smf) of Miletilek

MILETILEK				
No.	**Lmf**	**Ls**	**Smf = Lmf/Ls**	**INFERENCE**
1	1.730	1.655	1.04	Tectonically Active
2	1.430	1.314	1.08	Tectonically Active
3	1.765	1.510	1.16	Tectonically Active

4	1.793	1.588	1.12	Tectonically Active
5	1.139	1.040	1.09	Tectonically Active

Table 1 (f) Mountain Front Sinuosity (Smf) of West Jarawa

WEST JARAWA				
No.	Lmf	Ls	Smf = Lmf/Ls	INFERENCE
1	1.426	1.422	1.00	Tectonically Active
2	0.977	0.954	1.02	Tectonically Active
3	0.999	0.857	1.16	Tectonically Active
4	1.283	1.102	1.16	Tectonically Active
5	0.988	0.828	1.19	Tectonically Active
6	0.847	0.844	1.00	Tectonically Active
7	1.745	1.597	1.09	Tectonically Active
8	0.905	0.812	1.11	Tectonically Active

Table. 2 Basin Shape Ratio of all the six sub-basins of South Andaman

BASIN SHAPE RATIO					
NAME	LENGTH	WIDTH	RATIO	SHAPE	INFERENCE
BEODNABAD	5.2	3.5	1.48	Circular	Tectonically Less Active
BURMANALLAH	4.7	5.17	0.92	Circular	Tectonically Less Active
COLINPUR	15.3	2.9	5.27	Elongation	Tectonically Active
DHANIKHARI	14.2	2.9	4.89	Elongation	Tectonically Active

MILETILEK	6.9	2.1	3.28	Elongation	Tectonically Active
WEST JARAWA	8.2	6.5	1.2	Circular	Tectonically Less Active

Table 3. Asymmetry Factor Ratio of all the six sub-Basins of South Andaman

NAME	Ar	At	RESULT	INFERENCE
BEODNABAD	3.65	5.85	57.54	LEFT SIDE
BURMANALLAH	6.77	11.05	61.26	LEFT SIDE
COLINPUR	10.28	29.25	35.14	RIGHT SIDE
DHANIKHARI	7.80	24.88	31.35	RIGHT SIDE
MILETILEK	3.00	12.11	24.77	RIGHT SIDE
WEST JARAWA	11.35	19.56	58.02	LEFT SIDE

Table 4. Transverse Topography Ratio of all the six sub-basins of South Andaman

NAME	RESULT	INFERENCE
BEODNABAD	0.29	Tilted
BURMANALLAH	0.15	Less Tilted
COLINPUR	0.39	Tilted
DHANIKHARI	0.40	Tilted
MILETILEK	0.51	Tilted
WEST JARAWA	0.07	Less Tilted

Table 5. Hypsometric Index of all the six sub-basins of South Andaman.

BASIN	HYPSOMETRIC INDEX	INFERENCE
BEODNABAD	0.38	Tectonically Less Stable
BURMANALLAH	0.35	Tectonically Less Stable
COLINPUR	0.60	Tectonically Unstable
DHANIKHARI	0.56	Tectonically Less Stable
MILETILEK	0.68	Tectonically Unstable
WEST JARAWA	0.49	Tectonically Less Stable

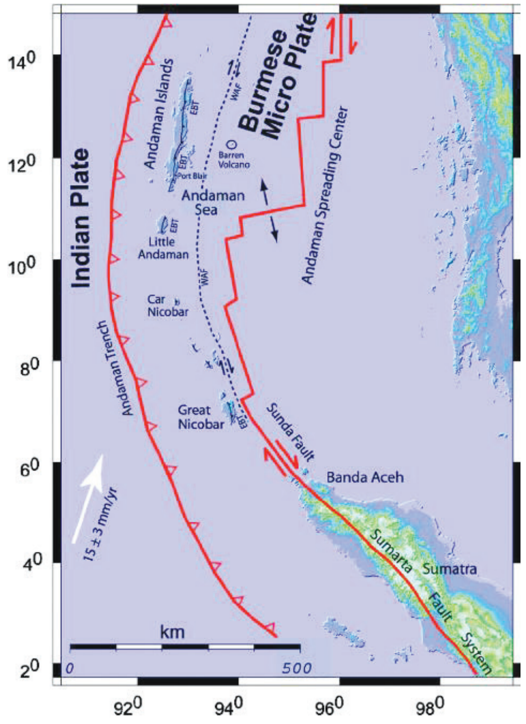

Figure 1: Tectonic setting of Andaman and Nicobar Islands (modified after Malik. 2006) shows very complex tectonic regime with both compression (subduction), expansion and strike-slip movements along Sunda Fault (Sumatra Fault System)

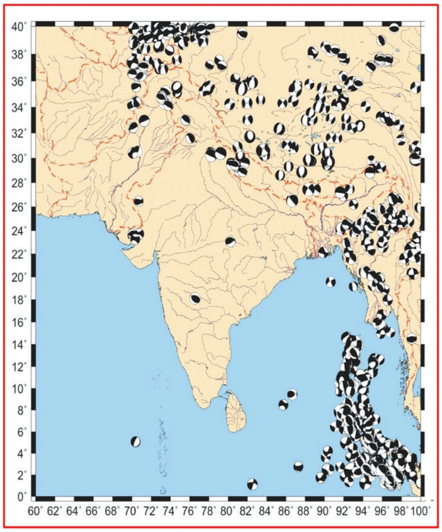

Figure 1.1: Seismotectonic setting of the Indian and Burmese micro Plate and focal mechanism solutions of almost 700 interplate and intraplate earthquakes derived from Harvard CMT solutions from 1/1/1997 – 1/1/2014 and processed in GMT. Dark and blank quadrants show compressional and dilatational fields respectively.

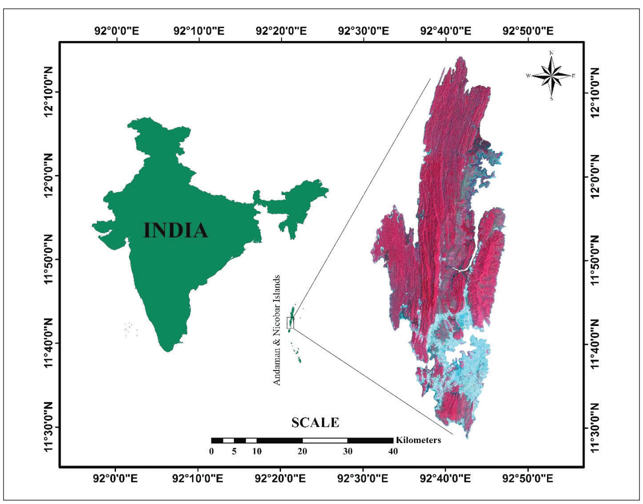

Figure 2 : Map showing the location of South Andaman, India

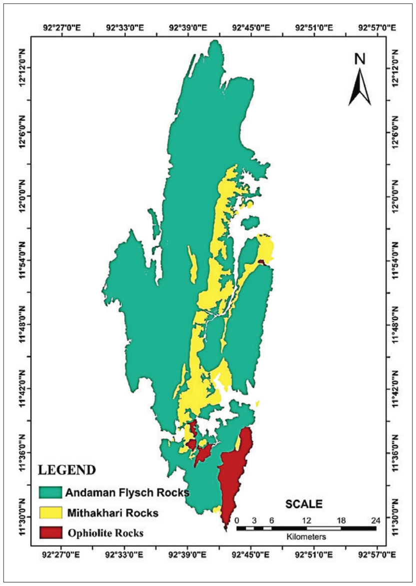

Figure 3 : Lithostratigraphy map of South Andaman, India

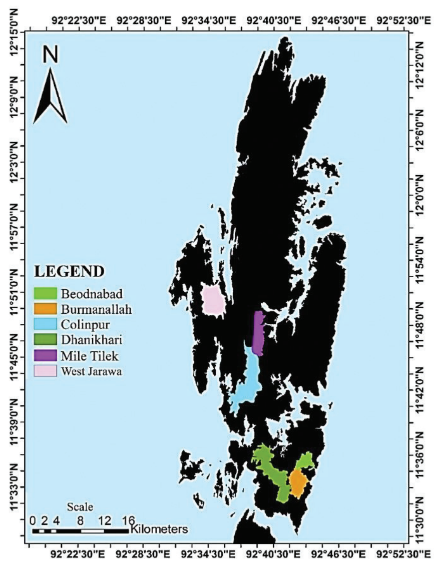

Figure 4 : Six Sub-basins of South Andaman Island were used for current study

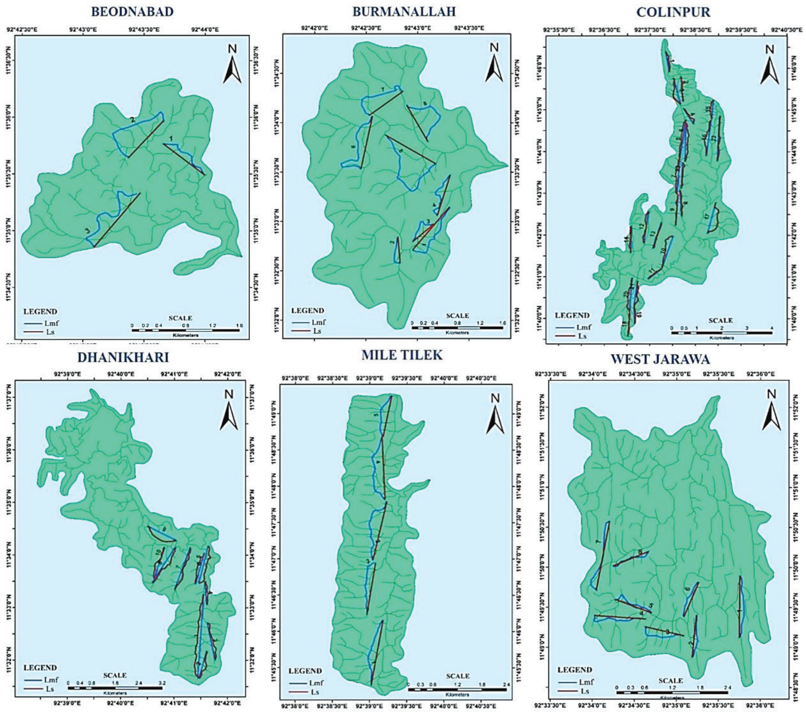

Figure 5 : Mountain Front Sinuosity (Smf) of Six Sub-Basins

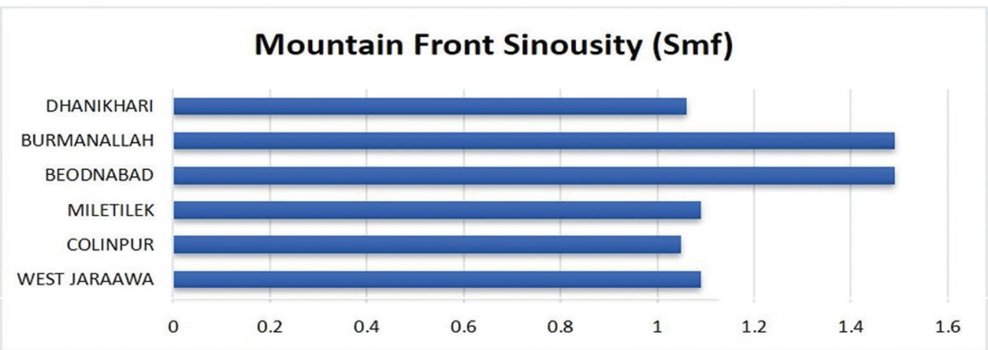

Figure 5.1: Average Mountain Front Sinuosity (Smf) of all the Six Sub-Sasins

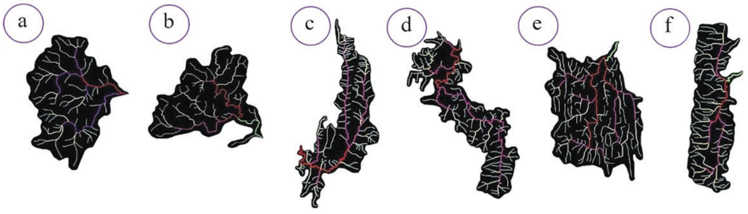

Figure 6 : Drainage Basins Shape (Bs) of six Sub-basins; (a) Beodnabad, (b) Burmanallah, (c) Colinpur, (d) Dhanikhari, (e) Miletilek, and (f) West Jarawa

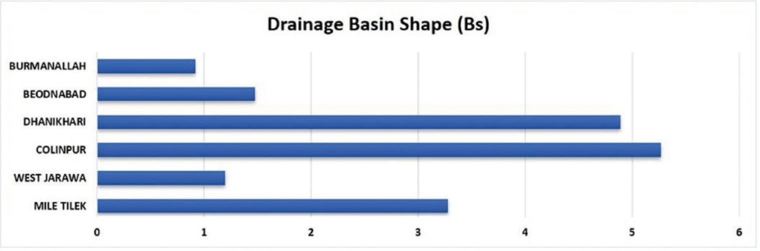

Figure 6.1. Drainage Basin Shape Ratio of Six Sub-Basins

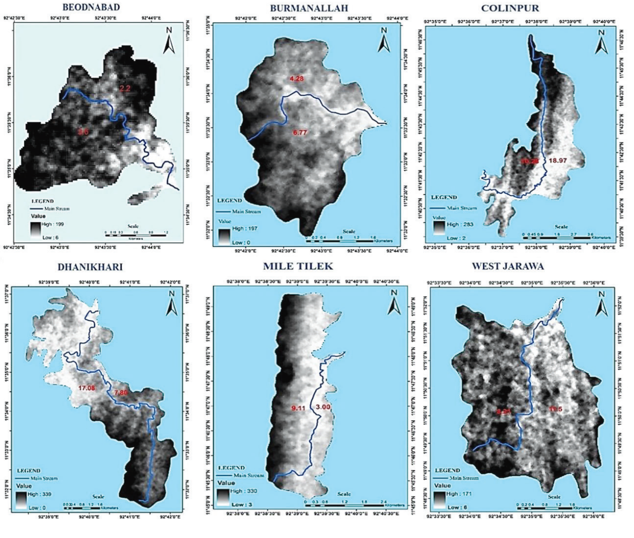

Figure 7. Drainage Basin Asymmetry (AF) of all the Six Sub-Basins

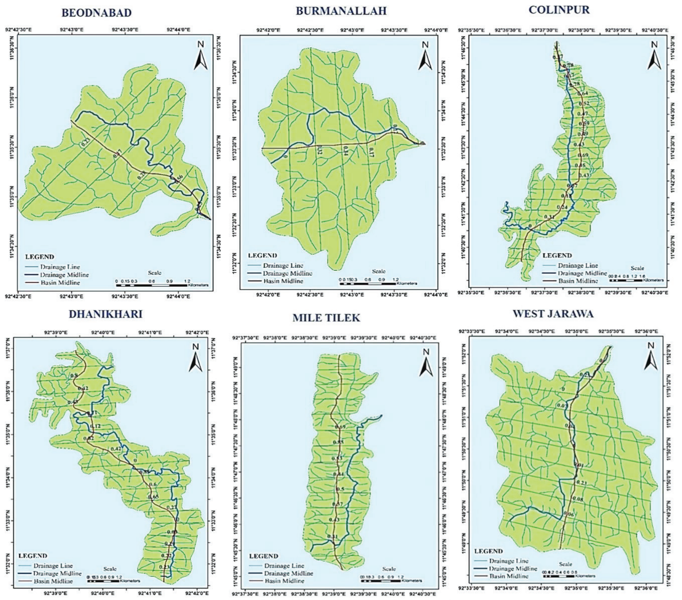

Figure 8. Transverse Topography Factor (T) of all the Six Sub-Basins

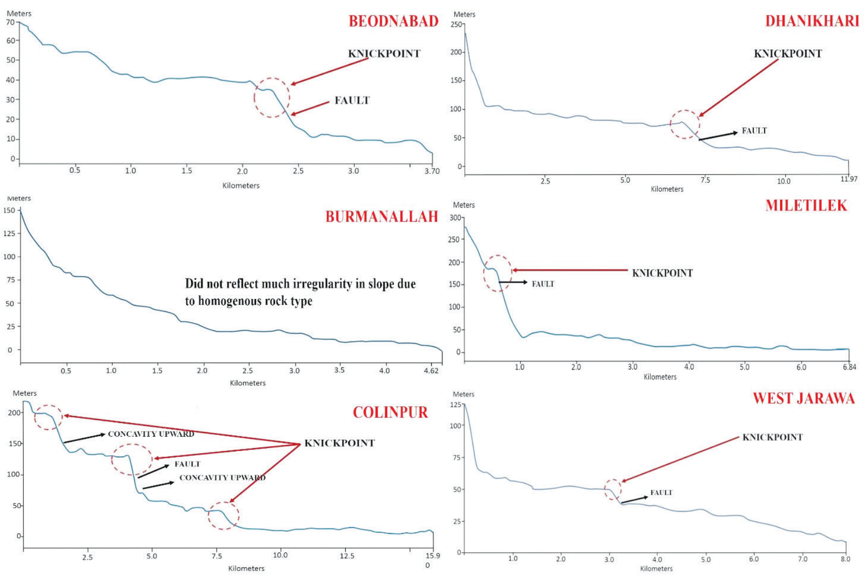

Figure 9. Longitudinal Profile of all the Six Sub-Basins

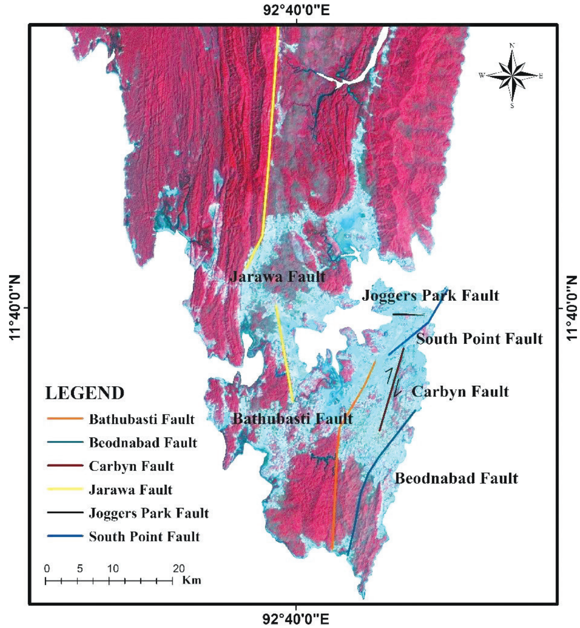

Figure 10. Major active faults of South Andaman Island

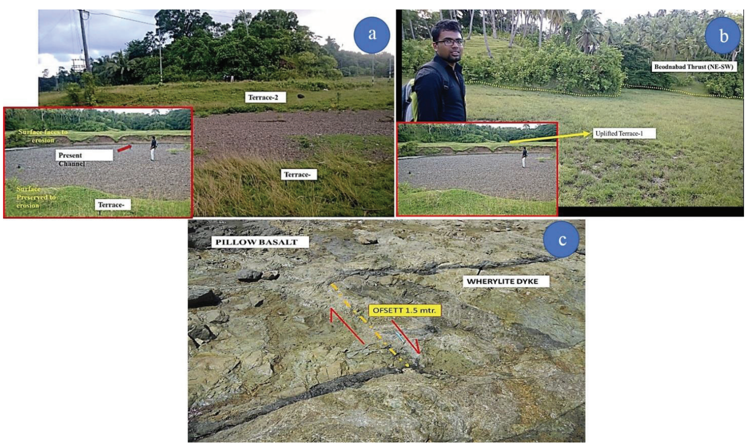

Figure 11. Field investigations in selected sites. (a) Showing river terraces and present channel at Beodnabad (b) Showing uplifted terrace and pressure ridge at Beodnabad (c) Showing offset of Wherylite dyke in Pillow Basalt at Burmanallah.

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Public Health Emergency Preparedness, Response and Resilience in India: Vision 2047

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Abstract

The consequences of public health impacts of recent infectious disease outbreaks and other disasters have tremendously increased over time and recognized the importance of strengthening public health systems to prevent, detect and respond to these threats more effectively. Public health emergency management (PHEM) is a growing field of practice that combines specific knowledge, techniques, and organizing principles necessary to manage health emergencies and disasters effectively. The first step for developing preparedness is measuring the risk or risk assessment to identify the notable threats. Risk assessment helps to determine essential resource requirements to develop plans, procedures, and protocols to enable health systems to function better and prepare communities. Developing public health preparedness response using evidence-informed information is need of an hour as learnings from recent decades emergencies. India has taken the lead in developing the response capabilities learnings from the COVID-19 pandemic by developing an electronic COVID-19 vaccine intelligence network (CoWIN) platform, which is globally recognized. An open platform such as the Integrated Health Information Platform (IHIP), which can connect with eHospital Systems and the new National Health Management Information System, plays a crucial role in strengthening health systems. Unitized and unified real-time surveillance that is not based on traditional systems of data entry and upload, but one that allows interoperability and data sharing mechanisms, capitalizing on technological and digital advances, aligns with the National Digital Health Mission. In addition to the current systems and electronic health records for case-based surveillance

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linked through the best use of unique health identifiers, the vision suggests utilizing new situation-aware real-time signals from social media, mobile/sensor networks, and citizen-participatory surveillance systems for event-based epidemic intelligence. The vision also emphasizes risk communication with residents as the main stakeholders, the execution of prevention measures at all levels, and practical support collaboration of interdisciplinary teams for prompt and efficient public health responses. The chance that the COVID-19 pandemic has given us must not be wasted. Our public health surveillance tools, services, and infrastructure must be strengthened. We must tackle the root causes of illness and disease, refocus health systems on primary care and universal health coverage, and immediately improve the global infrastructure for health disaster preparation and reaction. This manuscript suggests how we can all work together to strengthen Public Health Emergency Preparedness and Response in India by the year 2047.

Keywords: *Public Health Emergency Management (PHEM); Vision 2047; Preparedness, Response; Resilience; India*

1. Introduction

Public health emergencies are primarily unpredictable. They can hit communities at any time, causing massive human suffering and loss of life. They can also have grave economic repercussions. If health systems are not well prepared to cope with emergencies, affected communities will be more severely impacted and more vulnerable to continuing health threats in the aftermath of a crisis.

Dealing effectively with the multiplying complex and multi-dimensional threats of the 21st century requires a strengthened and agile approach to preparing for and responding to public health emergencies and disasters (WHO 2022). Since the incursion of the COVID-19 pandemic, the Asia-Pacific region has been hit by multiple natural and biological disasters. In contrast, climate change has continued to warm the world, exacerbating the impacts. This has reshaped and expanded the Asia-Pacific riskscape. The risk of new public health emergencies and disasters continues to increase, driven by the escalating climate crisis, environmental degradation, and increasing geopolitical instability, disproportionately impacting the poor and most vulnerable. In an increasingly risky world, all these hazards need to be considered not just as individual threats but also in relation to the larger systems they are likely to disrupt.

The pandemic has revealed gaps in the global capacity to anticipate, avoid, identify, and quickly react to outbreaks, pandemics, and other health emergencies. COVID-19 reminded even the most privileged that infectious diseases still have the power to devastate health systems, communities, and economies. COVID-19 mainly affected the poor and vulnerable. The danger of new health crises is constantly rising due to the worsening climate crisis, environmental degradation, and rising geopolitical unrest, disproportionately affecting the most vulnerable and underprivileged. In 2022, 300 million people were impacted by humanitarian crises, increasing their vulnerability to the ensuing health crises (WHO 2022). The healthcare system needs to be the top priority of all countries, and focus should be made on the following points:

- **Better health outcomes:** One of the primary reasons to improve health systems is to achieve better health outcomes for individuals and populations. This includes reducing morbidity and mortality rates, improving life expectancy, and reducing the disease burden.
- **Increased access to healthcare:** Improving health systems can help increase access to healthcare services for everyone, regardless of income or social status. This includes improving the availability of healthcare facilities, equipment, and healthcare workers.
- **Improved quality of care:** Health system improvements can also help to improve the quality of care provided to patients. This includes ensuring that healthcare workers have the necessary skills and training, that healthcare facilities are well-equipped and maintained, and that patients are treated with respect and dignity.
- **Better management of health resources:** Improving health systems can also help to ensure that health resources are managed effectively and efficiently. This includes ensuring that medicines and medical supplies are available when needed, that healthcare facilities are adequately staffed, and that health services are delivered cost-effectively.
- **Preparedness for emergencies:** A well-functioning health system is essential for responding to emergencies like disease outbreaks or natural disasters. Improving health systems can help to ensure that healthcare facilities are prepared to respond to emergencies and that resources are available to respond quickly and effectively.

Overall, improving health systems is essential for achieving better health outcomes, increasing access to healthcare, improving the quality of care, managing health resources, and responding to emergencies.

Public health emergency preparedness, response, and resilience refer to the ability of public health systems to respond to and recover from emergencies, including natural disasters, infectious disease outbreaks, and acts of bioterrorism. It involves a coordinated effort among various government agencies, healthcare providers, emergency responders, and the general public to identify potential risks, develop plans, and take appropriate actions to minimize the impact of emergencies on public health.

Preparedness involves developing and maintaining systems, plans, and capacities to respond to emergencies. This includes conducting risk assessments, developing emergency response plans, establishing communication systems, stockpiling necessary medical supplies and equipment, and training personnel. The response involves implementing these plans and capacities during an actual emergency, such as providing medical care, distributing medications, and conducting disease surveillance.

Resilience involves the ability of communities and systems to recover from the effects of an emergency and adapt to new challenges. This may involve implementing changes to prevent future emergencies or improve their response, such as improving communication systems or increasing public health awareness.

Effective public health emergency preparedness, response, and resilience require ongoing collaboration and coordination among various stakeholders, including government agencies, healthcare providers, emergency responders, and the general public. It also requires a commitment to ongoing training, planning, and evaluation to identify areas for improvement and adapt to changing circumstances.

The Government of India is working towards India@2047- a vision plan for a 'future-ready India' that befits the 100^{th} year of Indian Independence. The Prime minister of India emphasized that in the Amrit period of Independence (2022 - 2047), India is marching ahead rapidly to create a transparent system, efficient process and smooth governance to make development all-round and all-inclusive. The government is committed to strengthening good governance, that is, pro-people and pro-active governance (DARPG, 2023). With Prime Minister Shri Narendra Modi's vision to make India a developed Nation by 2047, the government is deliberating on preparing the Action Plan and Vision Document of India@2047.

India has achieved significant success in preventing, managing, and eradicating main communicable diseases. Smallpox was eradicated worldwide, and Polio has been eliminated in India. In the past two decades, India has significantly decreased the frequency of HIV cases by more than half. The COVID-19 and Nipah viruses, among other recent epidemics, have been successfully confined or under control.

Without effective Public Health Emergency Management systems in existence, none of these efforts would have been feasible. In accordance with the National Digital Health Mission, it is the need of the hour to improve Public Health Emergency Preparedness, Response and Resilience in India with more modern digital health and technological advancements. Furthermore, making public health emergency management more people-centric is crucial, expanding on the 2017 National Health Policy's recommendations. Additionally, the PM - Ayushman Bharat Health infrastructure Mission (PM-ABHIM) established Health and Wellness Centers that offer a framework to improve community-based monitoring for both infectious and non-communicable illnesses.

More significant interaction between humans, animals, and the environment has allowed us to review emerging diseases, as evident during the covid-19 pandemic. Early identification of such an interface is crucial to break the transmission chain and building a robust monitoring system. This manuscript on Public Health Emergency Preparedness, Response and Resilience in India: vision 2047 is a move in towards holistically transforming the delivery of health care services across the public and private sectors in compliance with International Health Regulations (2005); Sustainable Development Goals (2015-2030) and other international agreement. Some of the critical priorities for vision@2047 are discussed in this manuscript.

2. Priority Action Points for Vision@2047

2.1 Public Health Surveillance

India has made significate progress in Public Health Surveillance (PHS). A National

Apical Advisory Committee (NAAC) was established by the Government of India (GoI) in 1995 due to the 1988 Cholera epidemic in Delhi and the 1994 plague breakout in Surat. The National Monitoring Initiative for Communicable Diseases was implemented in 1997. One of the first national disease surveillance systems, HIV Sentinel Surveillance (HSS), started in 1992 and was expanded nationwide a decade later. In 2004, the World Bank provided a ten-year grant to the Government of India for the "Integrated Disease Monitoring Project" (IDSP). This was later converted into a programme funded under the 12th plan (2012-17) within the National Health Mission (NITI Aayog 2020).

Surveillance is 'Information for Action'. Primary, secondary, and tertiary levels of healthcare are all impacted by public health surveillance, which is an essential public health function. The integrated solution envisioned in this paper includes a "One-Health" strategy combining health information from various sources, including human, plant, and animal monitoring, and improving current isolated systems. To march towards achieving India's vision by 2047, we need to prioritize the following points:

- A predictive, responsive, integrated, and tier-based system of disease and health monitoring that includes priority, emerging and re-emerging infectious and non-communicable illnesses and conditions are required for India.
- De-identified individual-level patient data obtained from hospitals, labs, and other sources must serve as the main foundation for surveillance.
- Public health surveillance may be controlled by an efficient managerial and technological framework with sufficient resources, but it must be careful to act in the interests of the general public.
- In order to manage situations that form a Public Health Emergency of International Importance, India will need to exercise regional and worldwide leadership.

For an effective public health surveillance system in India, it is crucial to envision integration, enhanced citizen-centric and community-based surveillance, strengthened laboratory capacity, expanded referral networks, and a unified Surveillance Information Platform to provide data for decision-making and action.

The IHIP is an open platform that can connect with eHospital Systems and the new National Health Management Information System. It can thus connect with public and private hospitals, laboratories, and research centres under one platform to securely facilitate the exchange of health data.

Initiatives such as National Digital Health Mission (NDHM) aiming to make India Atmanirbhar or Self-reliant in providing universal health coverage to all the country's citizens will play a crucial role in strengthening the health sector.

2.2 Leveraging Science and Technology for Health

Our strategy should prioritize and promote the appropriate use of digital technologies as digital public goods adaptable to different countries and contexts to help address critical health system challenges to support equity in access to digital resources so that no one is left behind. We need to promote the protection of people, populations, health care professionals and systems against misinformation and the misuse of information, malicious cyber activities, fraud and exploitation, inappropriate use of health data, racism and human rights violations within the framework established by national and international treaties (WHO 2021). The appropriate use of digital health considers the following dimensions: health promotion and disease prevention, patient safety, ethics, interoperability, intellectual property, data security (confidentiality, integrity, and availability), privacy, cost-effectiveness, patient engagement, and affordability. It should be people-centred, trust-based, evidence-based, effective, efficient, sustainable, inclusive, equitable and contextualized. The growing global challenge of digital waste on health and the environment must also be appropriately managed (WHO 2021).

Advancement in Science and Technology brings interventions to make healthcare accessible and affordable, like low-cost vaccines for disease prevention, diagnostic kits for detection and medicines for treating diseases. For instance, The Ministry of Health and Family Welfare in India owns and runs CoWIN (Covid Vaccine Intelligence Network), an online government site for COVID-19 vaccination enrollment. It shows COVID-19 booking slots that are open in the vicinity, and that can be reserved on the website. Users can use laptops, smartphones, and mobile devices to access the app.

2.3 Leadership and Governance

Effective governance is essential to bring more significant equity, inclusivity and coherence to the architecture of Public Health Emergency Management, enabling our country to work collectively around a shared plan galvanized by political will and with the resources to sustain positive changes (WHO 2022). In order to ensure sustained political commitment and end the cycle of panic and neglect that has characterized the response to prior global health emergencies, public health emergency preparedness and response must be elevated to the level of heads of state in coordination, collaboration, and corporation with the central government. Establishing a high-level body on public health emergencies comprising heads of state, critical stakeholders from central governments, ministries, and other international leaders will be crucial. With the following responsibilities, but not limited to, the high-level bodies/committees would (WHO, 2022):

- Address health emergencies as well as their broader context and social and economic impact;
- Encourage compliance with and adherence to global health agreements, norms, and policies;
- Address obstacles to equitable and effective Public Health Emergency Preparedness and Response, ensuring collective, whole-of-government and whole-of-society action aligned with global health emergency goals, priorities, and policies;
- Identify needs and gaps, quickly mobilize resources and ensure effective deployment and stewardship of these resources for Public Health Emergency Preparedness and Response.

2.4 Amendments to the International Health Regulations (2005)

The International Health Regulations (IHR) (2005) are an international legally enforceable structure specifying the rights and duties of its 196 States Parties and the WHO Secretariat in cross-border public health crises. The IHR is still a crucial legal instrument for responding to and preparing for public health crises. The COVID-19 pandemic has highlighted flaws in the IHR's interpretation, implementation, and conformance.

Further strengthening of IHR implementation compliance will require some targeted amendments. Improved accountability may be achieved by establishing a conference of State Parties and the responsible national authority for the IHR's overall implementation; greater specificity with regard to notification, verification, and information sharing; capacity building and technical support for surveillance, laboratory capacity, and public health rapid response; and streamlining the procedure for enacting IHR amendments. The IHR's ongoing relevance and efficacy as a global health law tool depends on their ability to be quickly and effectively reinforced to meet changing global health requirements (WHO, 2022).

2.5 Strengthening Public Health Emergency Response Teams (PHERT)

The COVID-19 epidemic revealed shortcomings at the national level in the fundamental skills needed for efficient public health emergency preparedness and response. The basic global health security building blocks are national capabilities, so these deficits pose severe systemic risks. Building and bolstering professionalized multidisciplinary health emergency teams that are completely incorporated into national resilient health systems and other pertinent sectors under the One Health strategy will require significant expenditures in order to mitigate these risks.

The scale and nature of workforce requirements vary by country, but the most significant and pervasive gaps identified by COVID-19 are in the fields of epidemiology and surveillance, including laboratories; the health system workforce needed to scale up safe emergency clinical care quickly and maintain essential services during an emergency; the non-clinical aspects of protection, like working conditions and fair compensation; and community engagement (WHO 2022).

The development of globally available health emergency warning and response teams will be facilitated by wise investments in building up national capabilities, increasing regional and global preparation, detection, and response. Strengthened national warning and response teams, in conjunction with emergency coordination mechanisms to support training, certification, and deployment, can develop a national workforce for global health emergencies that is deployable internationally.

2.6 Strengthen Public Health Emergency Coordination

The operational success of the various components of the public health emergency system depends on how well they cooperate. COVID-19 showed that the nation's public health preparation and response management systems were frequently disjointed. The pandemic brought to light regional and global issues such as inconsistent national approaches, a lack of efficient means of coordinating and communicating action among nations, and difficulties in effectively directing international assistance to the areas where it was most required.

Resolving this fragmentation will take further intervention in assuring greater consistency and standardization in emergency planning at national/sub-national levels. An improved workforce, infrastructure, and leadership must be resourced and empowered to strengthen operational readiness through risk and vulnerability assessment, prioritization of key functions across all core subsystems, development of context-specific preparedness, prevention, readiness, and response strategies and plans, mobilization of the required resources, and monitoring and evaluating results. The public health emergency management should be embedded in broader whole-of-government national disaster management systems.

In addition to connecting international and regional technical, financial, and operational support to national emergency management systems, a strengthened and redesigned network of public health emergency operations centres can enhance coordination between nations and international partners throughout the public health emergency management cycle (WHO, 2022).

2.7 Interconnected Core Subsystems

The operational readiness and capacities in five key areas determine the ability to successfully plan for, avoid, identify, and react to national, regional, and international public health emergencies. The core subsystems for health emergency preparedness, response and resilience are as follows:

- Collaborative surveillance and public health intelligence through enhanced multisectoral disease, threat, and vulnerability surveillance; expanded laboratory capacity for pathogen and genomic surveillance; and joint methods for risk assessment, event detection, and response monitoring.
- Community protection through two-way information exchange to educate, inform, and foster trust; community involvement in developing public health and social measures based on local contexts and customs; a multisectoral approach to social welfare and livelihood protection to support communities during health

emergencies; and procedures to ensure that people are protected from sexual exploitation, abuse, and harassment.

- Safe and adaptable clinical care; efficient illness prevention and control that safeguards patients, healthcare professionals, and communities; and robust health systems that can maintain.
- A seamless linkage between research and development and scalable manufacturing platforms and agreements for technology transfer, coordinated procurement and emergency supply chains, strengthened population-based services for immunization and other public health measures, and fast-track research and development are all ways to gain access to counter measures.
- Emergency coordination with a trained health emergency workforce that is interoperable, scalable, and ready to rapidly deploy; coherent national action plans for health security to drive preparedness and prevention; operational readiness through risk assessment and reduction and prioritization of critical functions; and rapid detection of and scalable response to threats using a standardized emergency response framework.

Figure : Interconnected Core Subsystems for Health Emergency Preparedness, Response and Resilience

(Source: WHO 2022)

The five core subsystems must be well integrated within nations and have strong ties to structures for support, coordination, and collaboration across all health emergency cycle phases of preparing, preventing, detecting, responding, and recovering, given these interdependencies and the diversity of actors involved.

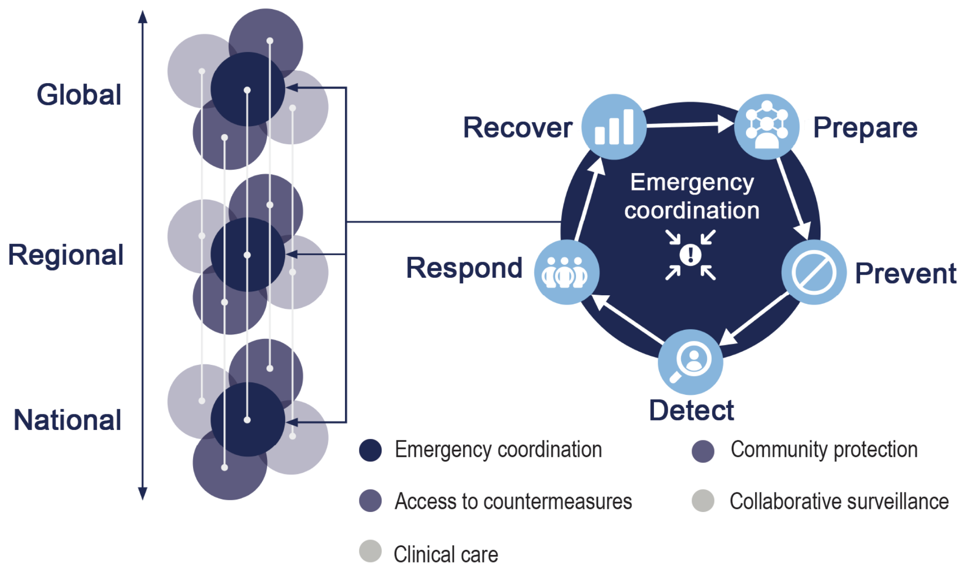

Figure : Interlinkages Between Five Core Subsystems for Health Emergency Preparedness, Response and Resilience Across

(Source: WHO 2022)

2.8 Expand Partnerships and Strengthen Networks for a Whole-of-Society Approach

COVID-19 has demonstrated that organizations and institutions at the national, regional, and global levels can work more closely together to improve resistance to health crises in critical areas. Before a health emergency occurs For, collaborative surveillance, clinical treatment, community protection, and access to remedies will necessitate the bolstering and, where necessary, the creation of whole-society, multidisciplinary, multi-partner networks.

COVID-19 has also drawn attention to how teamwork can help communities become more resilient to health emergencies. After every significant health disaster over the past 20 years, the need to engage in cooperative arrangements that unite communities of practise and communities of circumstance to create reaction and resilience measures has been emphasized: COVID-19 makes these calls impossible to disregard.

2.9 Create/Strengthen an Independent Health Informatics Institute

Data collection, collation, analysis, and transmission for public health surveillance and associated activities are all crucial tasks for public health informatics. A specialized Independent Health Informatics Centre will need to be established to support and direct innovations and analytical activities, including the use of Internet of Things (IoT) surveillance activities. Recognizing the significance of Public Health Information for Action and allocating resources and suitable technology to handle it are imperative for both the centre and the states.

2.10 Prioritise Diseases/Conditions for Surveillance/ Disease Elimination

India can prioritize diseases and conditions under the five broad categories according to the Department of Disease Control, Ministry of Health, and Thailand classification using various criteria based on available information. The country should concentrate on the five main disease categories that were prioritized for health surveillance:

a. Acute Communicable Disease,

b. HIV and TB,

c. Non-communicable disease,

d. Injury,

e. Occupational and environmental disease.

India could create its own list of diseases slated for elimination by 2030. India could adopt/design the prioritization criteria based on the context of each state or district, given its diversity.

2.11 Streamline Data Sharing, Analysis, Dissemination and use for Action

A unique health identifier (UHID) for each person is the most important prerequisite for a uniform surveillance system. In addition to assisting in the existing Syndromic, Presumptive, and Laboratory record links, this may also be used to connect morbidity and mortality data. Additionally, it makes it possible to monitor NCDs better in order to comprehend health effects, estimate incidence and prevalence, and guide resource distribution. To guarantee that every person has a UHID, it is possible to use UID or a comparable system. This will give the patient and the healthcare practitioner full knowledge of the person's health and illness state. One-time passwords can be used to limit who has access to this data. One will need to be aware of the judiciary's rulings regarding the appropriate application of the UID for social and health security.

2.12 Encourage Innovations

India is renowned for its innovative approaches in health and other fields. For instance, Public Health Surveillance needs to identify steps where innovation can be explored within the public health surveillance loop, such as new techniques for data collection, new case definitions or new risk factors/groups, new point-of-care diagnostics and screening tools/devices, new analytical tools, new dissemination techniques, new stakeholders, and new evidence/research findings. In order to successfully build up and integrate these innovations into the Public Health system, it would be essential to find chances for their implementation within districts and states so that lessons could be learned from them.

2.13 Align with PM- Ayushman Bharat Health Infrastructure Mission (PM-ABHIM)

By preparing front-line healthcare workers to perform syndromic reporting for infectious diseases and screening for risk factors or disease markers for common NCD and communicable diseases using simple verbal screening tools or point of care diagnostics and devices, the Health and Wellness centres offer a unique opportunity to strengthen community-based surveillance at the primary health care level. For disease surveillance during hospitalization episodes, information obtained under the Pradhan Mantri Jan Arogya Yojana (PM-JAY) assurance scheme and the Government of India realizes the need for a sustainable, resilient public health infrastructure and programme. The PM- ABHIM focuses on strengthening national public health institutions, expanding the Integrated Health Information Portal, or IHIP, operationalizing several public health units, and establishing Public Health Emergency Operations Centers, or PHEOCs.

2.14 Strengthen Laboratory Infrastructure

To create a successful disease surveillance programme, various levels of healthcare require a strong and well-functioning laboratory system. States may have decentralized diagnosis centres to monitor diseases prone to epidemics. The IDSP-created district public health labs are being reinforced as part of the National Health Mission. These initiatives might be sped up and expanded. We need diagnostics that are quick, precise, cheap, and reliable.

2.15 Focus on Preventive Healthcare

Preventive healthcare should be focused on implementing effective measures to prevent diseases, rather than simply treating them after they occur. This can be achieved through a number of steps, such as promoting healthy lifestyle choices, early disease detection through screening programs and regular check-ups, promoting vaccination programs, developing and implementing health policies that promote health and prevent diseases, and increasing public awareness and education about the importance of preventive healthcare measures. By adopting these measures, the burden of preventable diseases and improving the overall health and wellbeing of its citizens can be reduced.

2.16 Emphasis on Mental Health

Mental health as an essential component of overall health and wellbeing should be prioritize and emphasised. This can be achieved through a number of steps, such as promoting mental health awareness, increasing access to mental healthcare, integrating mental health into primary healthcare, implementing mental health policies and regulations, and addressing social determinants of mental health. Public awareness campaigns can educate people about mental health issues, reduce stigma and discrimination, and encourage people to seek help. There is a need to invest in mental healthcare infrastructure to ensure everyone has access to quality mental health services. Integrating mental health services into primary healthcare can improve early detection and treatment of mental health issues, while developing and implementing policies and regulations can help reduce the risk of mental illness. Addressing social determinants of mental health, such as poverty and discrimination, can also improve mental health outcomes.

2.17 Public-Private Partnership

There is a need to strive towards establishing a robust public-private partnership in the health sector that improves the accessibility and quality of healthcare services for all its citizens. To achieve this vision, several key steps, such as encouraging private sector investment in healthcare infrastructure, creating a supportive regulatory environment, implementing innovative funding models, developing public-private partnerships for research and development, and promoting public-private partnerships in healthcare delivery needs to be taken. Providing incentives and tax benefits can encourage private sector investment in healthcare, while creating a supportive regulatory environment can ensure quality healthcare services. Innovative funding models can be implemented to attract private sector investment in healthcare, while collaborative research and development partnerships between the public and private sectors can lead to the development of new and innovative healthcare technologies. Additionally, public-private partnerships can be established to improve healthcare delivery in underserved areas and address healthcare workforce shortages. By establishing a strong and effective public-private partnership in the health sector, the accessibility and quality of healthcare services for all citizens, while also stimulating economic growth and development can be improved.

2.18 Health Education and Awareness

Health education and awareness should be prioritised as a key strategy to improve the overall health and wellbeing of its citizens. To achieve this vision, several key steps, such as promoting health education in schools, increasing public health awareness campaigns, leveraging digital technologies, collaborating with community organizations, and empowering healthcare professionals may be considered. Including health education in the school curriculum can teach children about healthy lifestyle choices, disease prevention, and the importance of physical activity and nutrition. Public health awareness campaigns can educate people about the importance of disease prevention, early detection, and treatment, while digital technologies can be used to promote health education and awareness and to facilitate access to healthcare services. Community organizations can be engaged in health education and awareness campaigns, and in the development of culturally sensitive healthcare programs. Healthcare professionals should also be trained in health education and communication skills to effectively educate and empower patients to make informed healthcare decisions. By prioritizing health education and awareness, the health literacy of its citizens, encouraging healthy lifestyle choices, reduce the burden of preventable diseases, and building a healthier, more productive society can be improved.

2.19 Strengthen Community-Based Surveillance

In order to promote barriers to disease transmission, such as social/physical segregation, hand-washing, cough hygiene, use of toilets and safe drinking water, etc., as appropriate, primary health care centres would need to strengthen the capacity of front-line workers. These workers would be responsible for community-based surveillance for presumptive and active cases, active case-finding, contact tracing, and other related tasks. In order to screen for or confirm diseases that may be endemic or novel within local geographic contexts, primary care laboratories can be reinforced with point of care, community-based, or self-testing tools.

Block-level labs may be strengthened to improve the effectiveness of public health initiatives and lessen the burden on district and state-level laboratories. In block/district-level laboratories, it is possible to precisely diagnose the prevalent endemic illnesses in the area based on common symptoms (for example, Acute Febrile Illness). Block-level laboratories can support the right decisions regarding action and intervention in a timely manner by verifying the diagnostic early, during disease outbreaks, and after the outbreak.

2.20 Tiered Institutional PHEDM-CDC-PDP Capacity-Building Model

In the twenty-first century, Public Health Emergency and Disaster Management-Capacity Development Programme to Professional Development Programme (PHEDM-CDP-PDP) cannot be understood just in terms of local, national, or public management challenges; an integrated framework including all stakeholders is necessary. Public Health Emergency and Disaster management have a wide range of facets and levels. A tiered hierarchical restructuring becomes necessary while planning the public health emergency and disaster management system. A multi-tier approach creates a new system by bringing together the public sector, private sector and voluntary organization's value systems and ensuring management activities and common services. This five-tier approach will pave the way for acquiring, strengthening, adapting, and sustaining the capacities of people, institutions, and societies to reduce vulnerabilities to public health emergencies and disaster risks, to avoid (prevent), or to prevent (mitigate and prepare for), the impacts of hazards. The five-tier approach is shaped as a triangle where the vertical axis represents increased capability.

Figure : Five-Tiered institutional PHEDM Capacity-Building Model

Conclusion

With the help of advanced technologies, policymakers must consider more complex and varied future scenarios. We need to make intelligent, evidence-based investments that deliver the best possible return in terms of lives saved, sustainable development, global economic stability and long-term growth which means recognizing that strengthening the public health emergency and disaster management must be part of the broader effort towards the 2030 Sustainable Development Goals and Sendai Framework for Disaster Risk Reduction.

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Characterization of Site-Specific Landslide in Port Blair, Andaman and Nicobar Islands using Total Station and 2D Electrical Resistivity Tomography

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Abstract

The Andaman and Nicobar Islands (ANI) of India is well known for its strategic location in the Bay of Bengal, compressional tectonics and is a part of the Southeast Asian plate with frequent seasonal cyclones and rainfall-induced landslides. Rainfall-induced landslides are a natural phenomenon and have become more significant in recent times due to the rapid growth of the population and the development of settlements in and around the steep hillslopes. In addition, these islands are also vulnerable to other natural hazards, i.e., tsunami, storm surges, coastal floods etc. In such cases, the complete reduction of risk is difficult and co-existence with landslides is to be accepted. The capital city, Port Blair, received heavy rainfall and witnessed numerous landslides in and around the city during the great cyclone "Vardha" of 2016. The landslides that occurred during cyclone "Vardha" ranged between minor to moderate, these landslides are yet not to be neglected due to the immense loss caused to properties. Therefore, in our current study, we made a small attempt to characterize and understand a site-specific landslide using ground-based techniques, i.e. Total Station and 2-Dimensional Electrical Resistivity Tomography (2D-ERT), and with field validation. The outcome of the total station survey is presented

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in the form of a topographic profile that revealed the slope angle of the landslide i.e. 30°and the resistivity tomogram shows the presence of a slip surface at 6 meters (approx.) depth along with different lithological structure of the sub-surface, which are very crucial information for landslide hazard assessment on a wider scale.

1. Introduction

Landslides are frequently triggered by various factors, i.e., geological, geotechnical, and climatic (rainfall) (Bogoslovsky and Ogilvy, 1977; Champati Ray and Lakhera, 2004; Aleotti and Chowdhury, 1999; Kannaujiya et al., 2019). The rapid increase in the frequency of landslides has drawn global attention mainly due to their unpredictable nature of damage to human lives and enormous socio-economic impacts throughout the world, especially in developing countries like India. This phenomenon is mostly triggered by earthquakes and heavy rainfall in vulnerable seismic zones and tropical regions respectively (Champati Ray and Lakhera, 2004; Aleotti and Chowdhury, 1999; Kannaujiya et al., 2019). It is pertinent to mention that globally rainfall-induced landslides which occur during a long period of rainfall occupy the top place due to their uncountable damage to lives, the economy, and society. In India, landslides are one of the major destructive natural disasters due to its fragile geo-climatic and topographical arrangements and are covered by ~15% of the geographical area under the landslide hazard-prone area (Sarkar and Kanungo, 2004; Champati Ray and Lakhera,2004; Aleotti and Chowdhury, 1999; Kannaujiya et al., 2019;). The distribution of landslides varies from high to low scale in India i.e., the Himalayan regions, and the Eastern and Western Ghats respectively (Aleotti and Chowdhury, 1999; Kannaujiya et al., 2019; Sarkar and Kanungo, 2004). Besides, the Andaman Islands (ANI) experience frequent landslides due to continuous heavy rainfall for long periods (majorly caused by cyclones) and nonstop deformation due to its geological setup, which needs to be addressed. On 7th December 2016, India witnessed a devastating cyclone called “Vardha”. During this cyclone, Port Blair received continuous heavy rainfall for three to four days and triggered minor to moderate landslides, resulting in a huge socio-economic loss. In addition, the rapid growth in population and continuous changes in land use for development activities like tourist hubs and National Security (Defence) dragged more importance and demand to the current study.

In recent decades, several landslides studies have been carried out through a multidisciplinary approach based on various significant parameters like geological, geophysical, geodetic, and meteorological data analysis, including satellite remote sensing to understand landslides characteristics (Kannaujiya et al., 2019; Sarkar and Kanungo, 2004; Yoshimatsu and Abe, 2006; Yalcin et al., 2011; Chandrasekaran et al., 2013; Suzen and Doyuran, 2004; Kritikos and Davies, 2015; Cogan and Gratchev, 2019; Chang and Chiang, 2009; Castellanos and Westen, 2008; Nourani et al., 2014; El Jazouli et al., 2019; Lee et al., 2012). Noteworthy, technological developments in subsurface studies i.e., the geophysical method using Electrical Resistivity Tomography (ERT) (Lapenna et al., 2005; Perrone et al., 2006) and geodetic survey i.e., topography profiling using Total Station (Heritage and Hetherington, 2007; Keaton and Degraff, 1996) were well established and the integration of these techniques play a crucial role in understanding and characterizing the landslides. ERT is the most common, non-invasive and cost-effective method used to study the subsurface characterization through its capability of reading the electrical properties of the subsurface and helps us to identify the slip surface of the site-specific landslide (Kannaujiya et al., 2019; Lapenna et al., 2005). On the other hand, the Total Station survey, which is a combination of theodolite and an Electronic Distance Meter, is a fundamental instrument and is frequently utilized in monitoring landslides due to its accuracy, speed, and minimal human efforts (Heritage and Hetherington, 2007; Keaton and Degraff, 1996). Both these techniques are fundamental and crucial in understanding and characterizing landslides.

In this context, the integration of total station survey and electrical resistivity tomography proved useful to acquire parameters for this study. In our current site-specific study, we employed the ERT and Total Station survey at Kamaraj landslide, to understand and map the topography and to determine the depth cum geometry of the slip surface of the landslide.

2. Study Area and Geology

“Kamaraj landslide” (named after the Kamaraj School), the present investigating site, is located at Brookshabad, Port Blair, in South Andaman. It is bounded by 11°38’15.33” N latitude and 92°44’23.08” E longitude (Figure.1) and is surrounded by human settlements. This area is also situated within the vicinity of several active faults, such as the Carbyn thrust and Bathubasti fault (Dasgupta and Mukhopadhyay, 1993; Curray, 2005; Ortiz and Bilham, 2003; Malik et al., 2006; Bhat et al., 2019) and also receives an annual rainfall of >3000 mm. Most of the landslides in this area took place owing to the steep slopes, which consist of weak materials and high rainfall during the monsoon season. The eastern section of the South Andaman Islands is comprised of extremely distorted rocks (ophiolites from the oceanic floor) which are made up of Cretaceous-early Eocene ultrabasic/pelagic/volcanic deposits together with metamorphic and the western section is covered by Eocene-Oligocene siltstone/flysch-sandstone with conglomerates in combination with Mio-Pliocene calcareous sediments (Dasgupta and Mukhopadhyay,1993; Curray, 2005; Ortiz and Bilham, 2003; Malik et al., 2006).

3. Materials and Methods

In our current study, we employed two techniques i.e., total station and electrical resistivity tomography, for site-specific landslide investigation.

Total station instrument PENTAX-V321 was used for generating the 2D and 3D Topographic profiling (scarp profiling) across the landslide site to measure the slope elevation and angle of the Kamaraj landslide. We generated several profiles across the site and selected the most accurate profiles for further processing. The selected profile of total station data is systematically processed by following standard processing techniques in Surfer software (version 11). In addition, the data is carried through several procedures to generate 2D and 3D topographic sections (Figure.2a & 2b).

Consequently, we also performed the Electrical Resistivity Tomography (ERT) survey along (M- M1) and across (P-P1) the landslide to obtain the subsurface geometry based on their electrical resistivity values (Figure.3). The ERT technique allows us to acquire two dimensional high- resolution images of the subsurface earth materials having inhomogeneous resistivity by combining the capacities of profiling and sounding prospecting procedures for data inversion with the help of cutting-edge algorithms based on the electrical resistivity properties of the subsurface material (Sharma, 1997; Bichler et al., 2004; Meric et al., 2005). In the current study, we adopted the Wenner array configuration for 2D imaging using Aquameter CRM 500 coupled with a multicore cable to obtain information from different depths of landslide subsurface for two profiles. The first profile (M-M1) is parallel and the second (P-P1) is perpendicular to the landslide. The acquired data is methodically processed using Res2D.INV software to produce the

2D resistivity pseudo-section. The Res2D.INV software generates the pseudo section for the calculated model from the inverted model and then utilizes the least square algorithms to decrease the Root Mean Square Error (RMS) (Godio et al., 2006; Loke and Barker, 1996). Then, the resultant ERT images were used to characterize the lithological features and to trace the possible slip surface of the landslide. In addition to that, we also collected field evidence during the cyclone "Vardha" which helped us while interpreting the data (Figure.6).

4. Results and Discussion

4.1 Total Station

The large-scale topographic map has a contour value that varies between 5 meters to 27 meters from the mean sea level across the Kamaraj Landslide (Figure.2a & 2b). Similarly, the slope length and slope angle of the landslide surface are also found from the obtained value of the total station i.e. 47 meters and 30°, respectively (Table.1). These resultant parameters have an important connection with the landslides.

4.2 2D-ERT Profile M-M1

The acquired Electrical Resistivity Tomography (ERT) with a covered distance of 57 meters along the profile M-M1, which is parallel to the landslide from head (M) to toe (M1) in the North-South direction (Figure.4) usually has a resistivity range that varies from 10.8 to > 133 Ωm. Different colors demarcate the inhomogeneity of the resistivity as per the in situ true resistivity value of subsurface materials. A layer of very low resistivity in the range of 10 to 30 Ωm is detected in the upper and middle part of the profile that extended to a shallow depth of 6 meters from the top of the surface indicating the clay and very loose saturated sediments (layer 'A'). Similarly, another layer having a resistivity range of 30 to 65 Ωm can be noticed on the middle and lower part of the profile that extends up to 4 meters depth from the top of the surface is a possible indication of the depleted landslide masses of unconsolidated sediments and rock fragments with high water content (layer 'B'). In the same way, one more layer (layer 'C') in the deeper part is spotted that shows fractured or weathered ophiolite formation displays increasing values of electrical resistivity (>133 Ωm) which is the potential sign of the parent rock of this site. This profile (M-M1) revealed that the thickness of the overburden material is quite thin (up to 6 meters) and it needs less amount of water to get saturated easily leading to landslides. The vertical extension of overburdened materials at the landslide scarp is having highly saturated unconsolidated sediments that allow water seepage which causes landslides to occur.

4.3 2D-ERT Profile P-P1

The ERT along the P-P1 (Figure.5) that is perpendicular to the landslide direction was conducted on the toe region and it provides better insight into lithology variation with respect to depth and actually, it has a resistivity range from 0.264 to 353 Ωm. Like profile M-M1, a very low resistivity zone is also observed here. In P-P1, the zone of low resistivity is at a greater depth than the M-M1 profile and the thickness of the same is also higher here. There are four lithological layers (i.e. A, B, C, & D) have been demarcated in P-P1 as per their respective resistivity range. Layer "A" is having resistivity value ranging between 0.264 and 40 Ωm that extends from 4 meters to -2 meters downwards, which possibly would be high clay content with water saturated zone due to the influence of heavy leaching activity in this area. Similarly, layer "B" has a resistivity range between 40 and 120 Ωm indicating the presence of loose saturated unconsolidated sediments with sand, which extends from the surface top to around 4.5 meters depth. A small and isolated pocket layer of "C" and "D" with resistivity greater than 120 to ~353Ωm indicates the concrete structure and hard rock block, respectively, which occur from the surface to 2 meters depth.

The Electrical Resistivity Tomography models revealed that in the first profile, M-M1 resistivity generally increases with depth, i.e. over burden clay < loose unconsolidated sediment < fractured or weathered ophiolite formation. In the case of second profile P-P1, the resistivity is decreasing with increasing depth except at isolated and small pockets, which show higher resistivity because of the presence of hard rock and the proximity to a concrete structure that is hard rock > concrete structure > unconsolidated sediment > high clay content. In both profiles, a major part is having clay and loose unconsolidated sediment with sand which is influenced by the heavy leaching condition. During heavy rainfalls, the top soils (loose and unconsolidated sediments) of this area might be highly saturated with water thus the unit weight of the soil might also increase (eg. Vardha cyclone) (Figure.4). As the moisture content simultaneously increases, the weight of the overburdened material would also increase. It increases the shear stress on the weak zone and loose materials, increasing hydrostatic pressure and leading to landslides. In addition to the major Kamaraj Landslide, a few more minor landslides were also triggered by the heavy rainfalls during the cyclone "Vardha" in and around Brookshabad, Port Blair (Figure.7).

5. Conclusion

The integration of 2D Electrical Resistivity Tomography and Total Station survey has utilized on a fresh landslide in Kamaraj Hill, Brookshabad, Port Blair that occurred during cyclone 'Vardha' on 7th December 2016. The key emphasis of this study was on topographical mapping and subsurface characterization along with the identification of possible slip surface by analyzing the data products of total station and electrical resistivity tomography. The total station survey helped collect the topographical information of the Kamaraj landslide on a finer scale where the slope angle was found as 30°. Consequently, the ERT has allowed subsurface characterization and supported the identification of the possible slip surface of the Kamaraj landslide. Multiple ERT profiles were taken but the best one is used to determine the approximate depth of the slip surface, which is expected to be around 6 meters depth. The ERT with a thorough field survey has confirmed the presence of clay in the overburdened materials, which is presumed as the chief contributing factor to the initiation of this landslide. The 2D Electrical Resistivity Tomography integrated with Total Station survey and field observation has proved to be an effective tool for investigating landslides in this area.

Acknowledgments

We are very thankful to Pondicherry University, Port Blair Campus for providing instrumental and institutional support to carry out this study.

Table.1: Slope Information of Kamaraj Landslide acquired by Total Station Survey

Distance in Length (l)	47m
Distance in Height (h)	27m
Slope in Degrees (°)	30°
Slope in Percentage (%)	55%
Total Distance (t)	57m

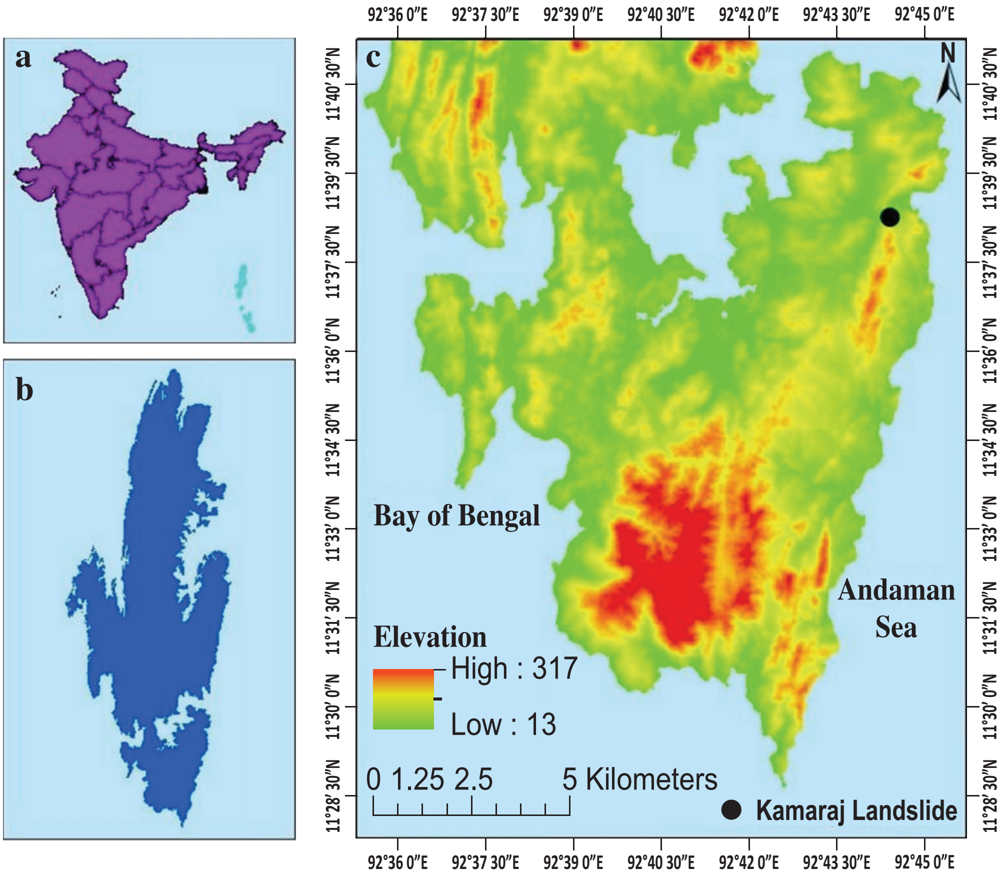

Figure 1 : (a) India (b) Andaman Islands (c) South Andaman Island and the location of Kamaraj Landslide

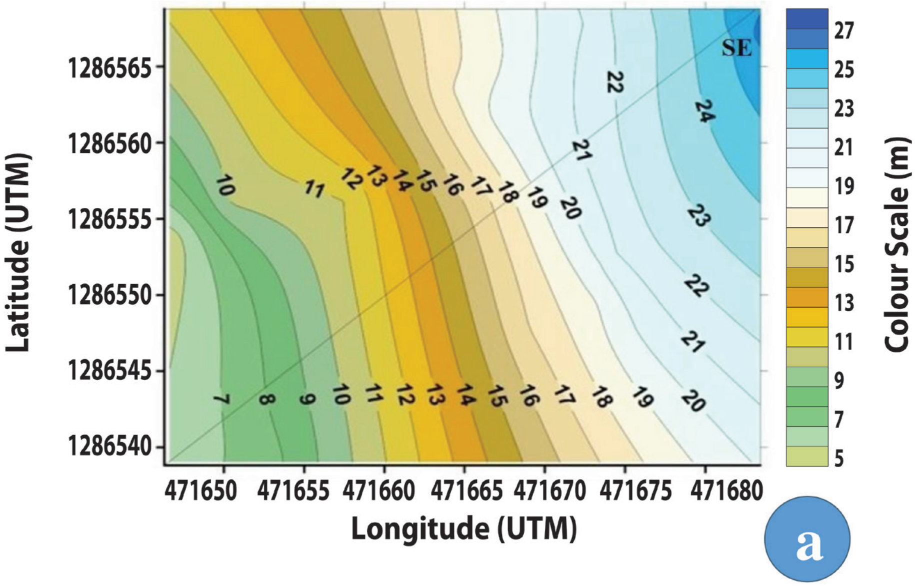

Figure 2 : Large-Scale 3D Topographic Model of the Kamaraj Landslide Surface.

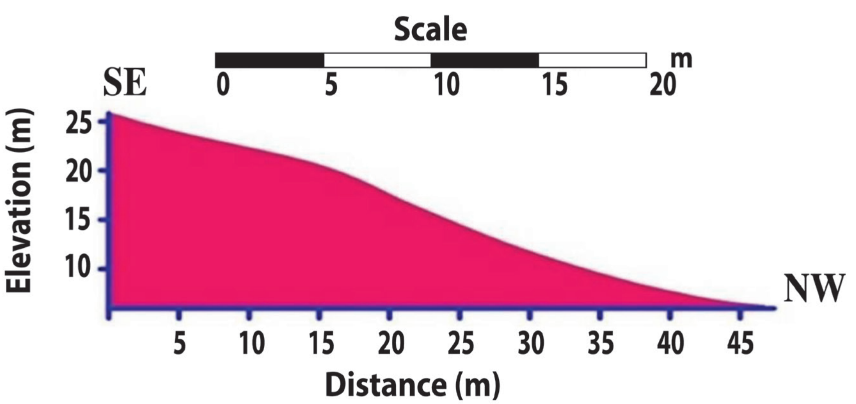

Figure 3 : (a) Large-Scale Topographic Map Prepared using Total Station Measurements with the help of Surfer Software Showing Topography on Large Scale. Identified Elevation of the Kamaraj Landslide Body Varies from 5 to 27 Meters.

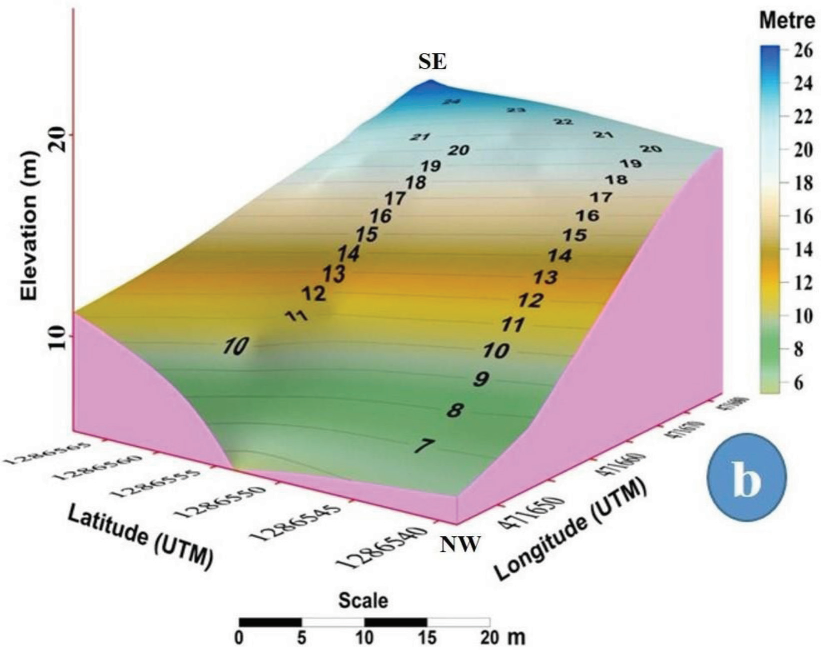

Figure 3 : (b) Large-Scale 3D Topographic Model of the Kamaraj Landslide Surface.

Figure 4 : Kamaraj Landslide at Brookshabad, Port Blair

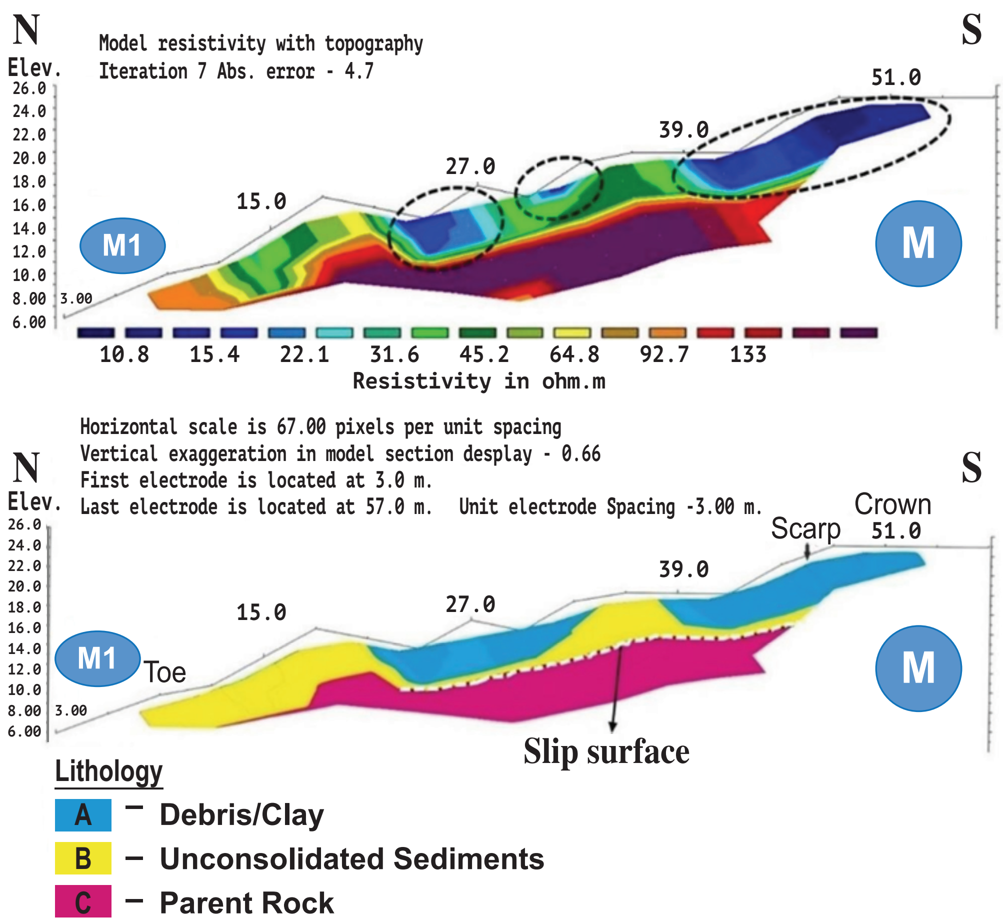

Figure 5 : Depth Section Presenting True Resistivity Values of Subsurface Parallel to the Longitudinal Axis of the Landslide (M-M1 section), Derived through Wenner Array Configuration and produced in Res2D.INV Software. The names have been given to the different layers of Lithology using Corel draw. The Clay/ High Water Saturation was marked by Black Dotted Circles and the Possible Slip Surface was marked by a Dotted White Line.

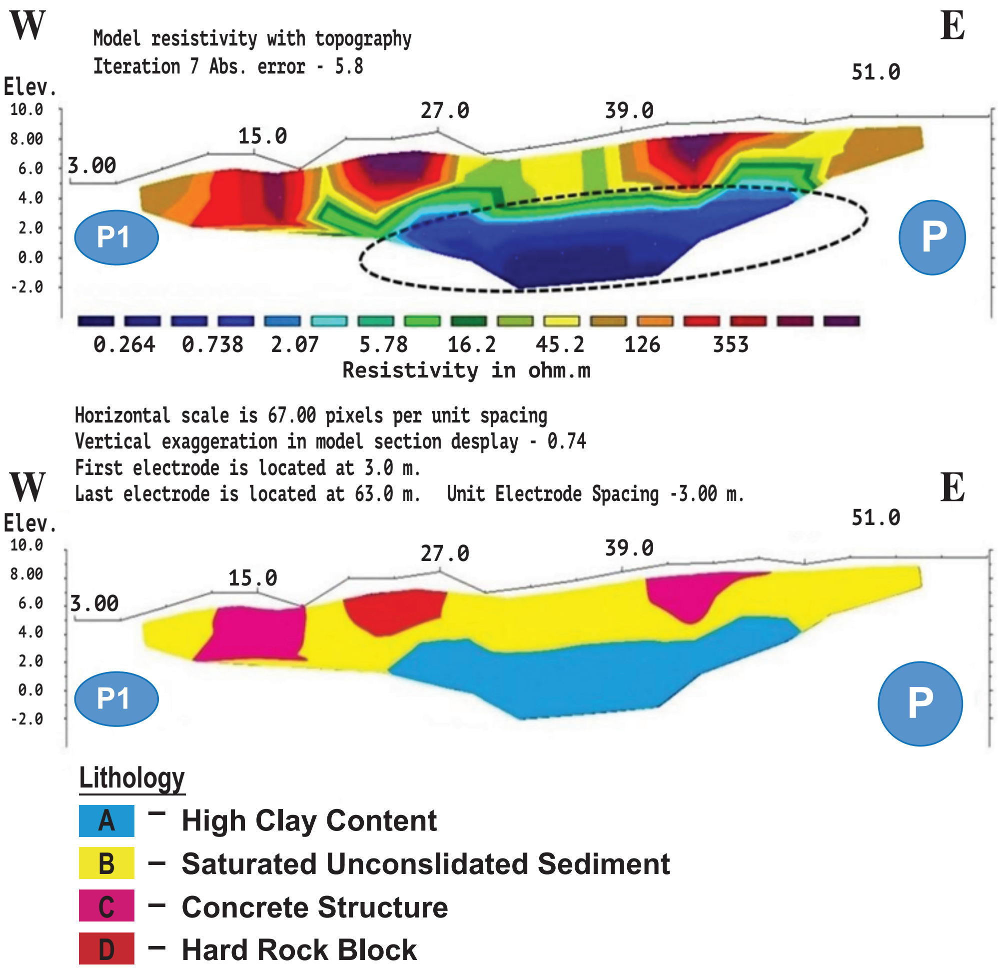

Figure 6 : Depth Section Presenting True Resistivity Values of Subsurface Perpendicular to the Longitudinal Axis of the Landslide (P-P1 Section), Derived through Wenner Array Configuration and Produced in Res2D.INV Software. Corel draw is used for naming the different Lithological Layers. The High Clay content is marked by a Black Dotted Circle.

Figure 7 : Field photo after heavy rain during cyclone 'Vardha'
(Photo- Gunda Goutham Krishna Teja)

Figure 8 : Landslide Damage in some other Sites of Brookshabad, Port Blair after Cyclone 'Vardha'

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Assessment of Active Tectonics of Giri Valley, NW Himalaya: Insights from Geomorphic Signature Using Remote Sensing and GIS

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Abstract

The landforms in the tectonically active region are regulated and modified by both external (climatic) and internal dynamic (tectonic) processes. The imprints of active deformation are stored in the form of geomorphic features such as fossils valley, sag ponds, narrow and wide valleys, pools and rapids, etc. We studied 12 geomorphic indices that have a direct relationship with tectonics using an SRTM-30m (1-arc second) spatial resolution Digital Elevation Model (DEM) coupled with Geographic Information System (GIS) tools. For detailed analysis, we have selected 19 sub-watershed (SW) of the Giri river basin. The geomorphic signatures of active tectonics are quantified in the present study to assess the active tectonics in the Giri valley. The current study suggests 15 SW are highly active and the remaining 4 SW are comparatively less active.

Keywords: *Active Tectonics, Geomorphology, Longitudinal Profile, Giriwatershed, SL and SI Index*

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1. Introduction

The collision of the Indian and Eurasian plates has initiated Himalaya orogeny. The continuous plate movement has shaped the present-day Himalayas. As a consequence of continuous tectonic plate interaction, the Himalayan Mountains are tectonically active and steadily rising (Dewey and Bird, 1970; Burey and Dewey, 1973; DeMets et al., 1994; Singh et al., 2002; Yin, 2006; Puniya et al., 2019). The convergence rate may vary from place to place along the Himalayan mountain belt (Jayangondaperumal et al., 2020). Nakata (1972) was the first to study active tectonics in the Himalayas along the Sub-Himalaya foothill in Pinjor, Dehradun, and Bengal (Jayangondaperumal et al., 2020). The Global Positioning System (GPS) observation suggested a convergence rate of 18±1 mm/ year in the N213°E (Yadav et al., 2019; Gautam et al., 2017; Jayangondaperumal et al., 2020). Tectonics plays a crucial role in the deformation of rocks and landforms in the tectonically active terrain. The deformation leads to the fragile and weak nature of rocks resulting in a higher rate of denudation which eventually changes the topography and accelerates the landslide activities in the Himalayas (Kumar et al., 2017; Sah et al., 2018; Thakur et al., 2023). The geomorphic agents like rivers and glaciers are primary sources of denudation processes in the region (Kumar et al., 2017; Sah et al., 2018; Negi et al., 2021). The landform developed as a result of tectonics can be quantified to assess the active tectonics prevalent in the region.

Geological and geomorphological tools have constantly been used to assess the sensitivity and expressions of active tectonics in the Himalayan Mountain region in the past (Yin, 2006; Webb et al., 2007; Sati et al., 2008; Webb et al., 2011; Jain et al., 2016; Lone, 2017; Jayangondaperumal et al., 2020; Kothyari et al., 2019, 2022). The geomorphic indices are used in the present study as they are widely used to understand the development of geomorphic landforms and to delineate the tectonically active region in mountainous terrain (Keller and Pinter, 1996; Mesa, 2006; Pérez-Peña et al., 2009; Ozdemir and Bird, 2009; Sharma et al., 2018; Vijith et al., 2018). The geomorphic study includes a quantitative assessment of the watersheds (Strahler, 1964). The geomorphic indices used in the present study are effective tools in assessing the changes in landform owing to folding and faulting of litho-tectonic unit. Geomorphic indicators of tectonic activity in such terrain includes varying river course or drainage network set-up, variability in valley incision, basin asymmetry, basin tilt, basin shape, etc. (Cox, 1994; Sharma et al., 2018; Rawat et al., 2021; Biswas et al., 2021; Dasgupta et al., 2022). In the present work, an approach using a combination of tools viz. topographic map, aerial photograph, and satellite data in a Geographic information system (GIS) platform is done to decipher the active tectonics in the Giri river Watershed (Kothyari and Juyal 2013; Kothyari et al., 2017; Biswas and Paul, 2021; Biswas et al., 2021; Dasgupta et al., 2022). The salient objective of the present work is to assess the tectonic activities in GW and examine the role of local or regional tectonics in shaping the present-day landforms.

2. Geological Setup

The Giri Watershed (GW) lies between latitude 30° 26' 29" N to 31° 15' 9" N and longitude 77° 0' 0" E to 77° 50' 55 "E (Fig 1) covering approximately an area of 2628 km². The Giri River originates from the Kupper of Simla district and flows through three districts

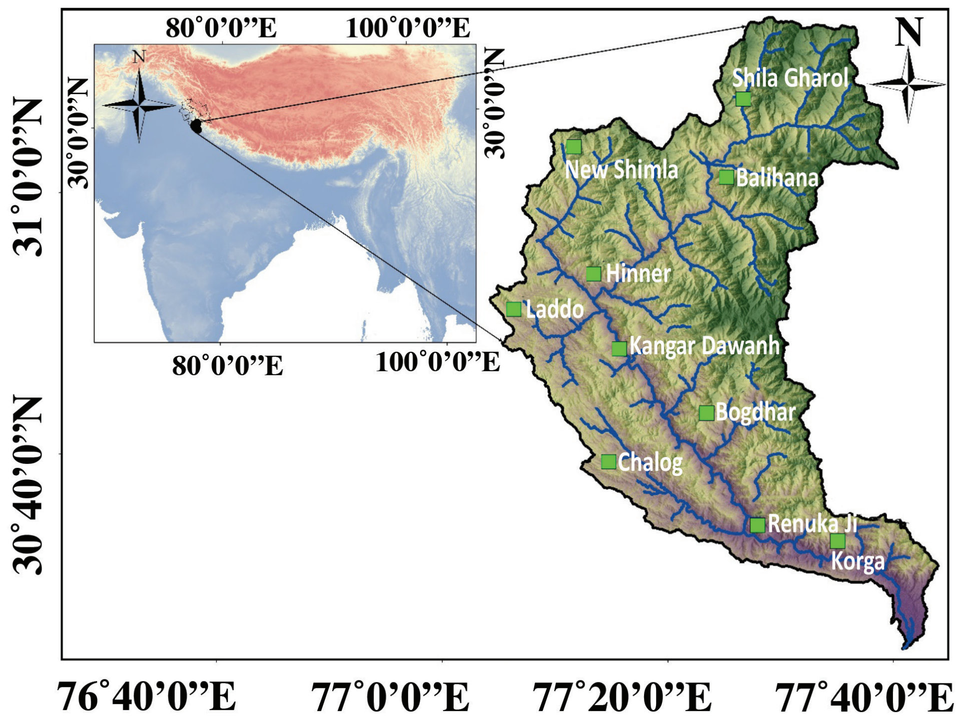

Figure 1 : Location for the Giri Watershed, Himachal Pradesh, Northwest Himalaya, India.

viz. Solan, Simla, and Sirmour, before joining the Yamuna River near Paonta Sahib. The major tributaries of Giri River are Jalal, Assani, Kwali, Ghamber, Satana, Pervi, Chakhred, Bhajetu, Baseri, etc. The altitude in GW varies from 395 m to 3623 m while mean elevation is 1686 m above mean sea level.

Geologically GW constitutes the part of Northwest Himalaya and is composed of Quaternary alluvium, Cenozoic Sedimentary rocks sequence of Sub-Himalaya Sedimentary (SHS) and Meta Sedimentary rocks sequence of Lesser Himalaya (LHS), and Metamorphic and crystalline rocks rock of the Higher Himalaya (HHS) (Fig 2a). The SHS comprises Siwalik and Sirmour Group (Srikantia and Bhargava, 1998; Biyani, 2007; Mishra and Mukhopadhyay, 2012; Srikantia and Bhargava, 2021). The Siwalik group in GW is composed of the Lower Siwalik (Kamlial Formation) rocks that are delimited in the north by the Main Boundary Fault (MBT). Sirmour group is divided into Subathu, Dagashai, and Kasauli formations (Srikantia and Bhargava, 1998; Mishra and Mukhopadhyay, 2012; Srikantia and Bhargava, 2021) (Fig 2a).

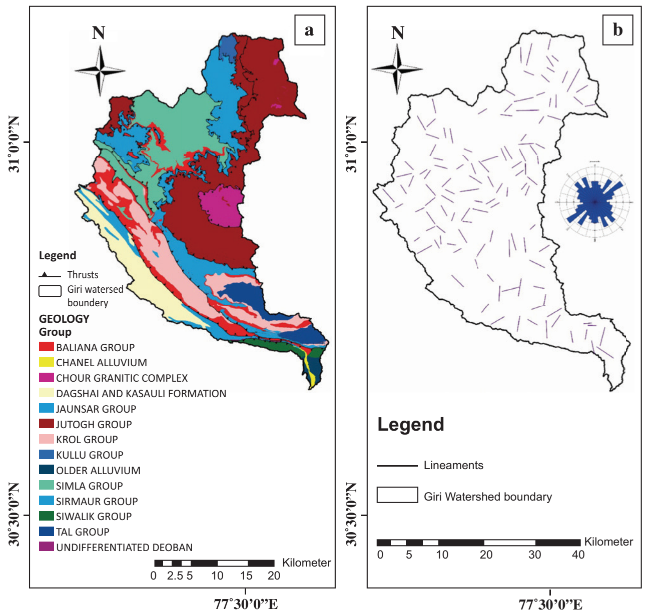

Figure 2 : Fig showing (a) Geological Map (Mukhopadhyay et al., 1996; GSI, 2019) and Major (b) Lineament for the Giri Watershed, NW Himalaya, India.

The LHS includes the rocks of the Deoban group, Jaunsar group (Nagthat, Mandhali, and Chandpur formations), Simla group (Sanjauli, Chhoasa, and Basanatpur Formations), Baliana group (Blaini, and Infrakrol Formations), Krol Group (Kauriyala, Jarassi, Mahi and Chambaghat Formations), and Tal group (Kotidhiman, Sankholi, and Shaliyan Formations) that are delimited by the Jutogh thrust and MBT in North and South respectively (Fig 2a). The old Proterozoic rocks of the Simla and Jaunsar group are separated from the younger rocks of Cenozoic (Sirmour group) by two folded thrust planes (i.e. Krol Thrust and Giri thrust) that are possibly two traces of single thrust (Srikantia and Bharagava, 1998; Singh et al., 2020; Srikantia and Bhargava, 2021). The rocks of the Baliana group overlie the Simla group rocks uncomfortably in GW along with the Jaunsar thrust (Fig 2a) (Srikantia and Bharagava, 2021).

The Higher Himalaya sequence in GW includes the Rocks of the Kullu group (Kokhan Formation), Jutogh group (Naura, Kanda, Taradevi, Khirkhi, Bhotli, Manal, and Panjreli Formations), and Chaur Granitic Complex (Fig 2a). The Kokhan Formation rocks are separated by Jaunsar thrust and Kullu thrust in GW (Fig 2a). The Rocks of the Chaur Granitic Complex are separated by the Chaur thrust from the rocks of the Jutogh group. The rocks of The Bhotli formation and Khirki formation of the Jutogh group is separated by the Khirkhi thrust (Srikantia and Bhargava, 1998; Hughes et al., 2005; Jamwal and Wangu, 2012; Mishra and Mukhopadhyay, 2012; Bhargava and Srikantia, 2014; Dhital, 2015; Mukherjee, 2015; Singh et al., 2020; Srikantia and Bhargava, 2021).

3. Data And Methodology

Morphometric analysis of the GW has been evaluated using remote sensing data and GIS techniques. The Shuttle Radar Topographic Mission-Digital elevation model (SRTM-DEM) (downloaded from https://earthexplorer.usgs.gov) with a spatial resolution of 30 meters has been used for extractions of drainage and delineations of watershed boundary and sub-watersheds (SW) boundary (Fig 3). The drainage extracted from the SRTM DEM have been further referenced and rectified with Survey of India (SOI) toposheet (53E/4,7,8,11,12, and 53F/1,2,5,6,7,9,10,11) in 1:50,000 scale. The watershed and sub-watershed boundary have been delineated using the pour point method in the GIS. The Geological map (Fig 2a) of Geological Survey of India (GSI) in 1:50000 scale (https://bhukosh.gsi.gov.in/Bhukosh/MapViewer.aspx) and Mukhopadhyay et al., (1996) has been modified and digitized in GIS platform. The lineaments are extracted and a lineaments map of the study area is prepared from Sentinel-2 and SRTM-DEM satellite data.

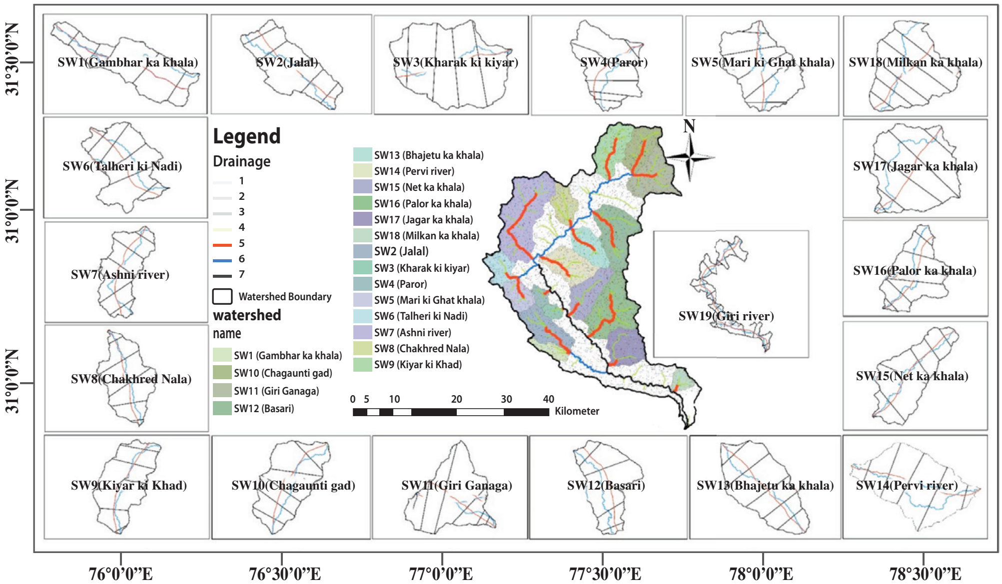

Figure 3 : Showing Drainage Map, Sub-Watershed Map, T and Vf Calculation Section Map for Giriwatershed, Himachal Pradesh, Northwest Himalaya, India.

The GW has been divided into 19 SW based on 5^{th} order stream (except SW19 with 7^{th} order basin) (Fig 3). The morphometric indices have been divided into two broad categories i.e. Spatial Aspects, and Linear Aspects. The Spatial aspects include parameters like *Drainage density* (D_d), *Circulatory ratio* (R_c), *Form factor* (F_f), *Basin shape index* (B_s), *Lemniscate Coefficients (K), Asymmetry factors* (A_f), *Transverse topographic symmetrical factor (T), Valley floor to width to the height ratio (Vf), Hypsometric Curve (HC), and Hypsometric Integral (HI), while Linear Aspects includes Sinuosity Index* (S_I), *Stream Length Gradient Index* (S_L), *Longitudinal river profile, and major Lineaments* (Table 1)

Table 1 : Formulae used for the Evaluation of Morpho-Tectonic Parameter of Giriwatershed Himachal Pradesh, Northwest Himalaya India.

Aspects	Parameter	Formula	Descriptions	References
Spatial Aspects	Drainage density (D_d)	$D_d = \frac{L\mu}{A}$	L_μ is total stream length, A is area of watershed.	Horton (1945)
	Circularity ratio (R_c)	$F_f = \frac{A}{Lb^2}$	A is the area of the watershed, Lb^2 is the square of the basin length.	Horton (1945)
	Ruggedness Number (R_n)	$R_c = \frac{4\pi A}{p^2}$	4 is constant, ϖ is constant i.e. 3.14, and P is the perimeter of the basin or watershed.	Miller (1953)
	Basin shape Index (B_s)	$R_n = R \times D_d$	R is the relief of the basin or watershed and D_d is the drainage density.	Ramırez-Herrera, 1998)
	Transverse topographic Symmetrical factor (T)	$B_s = \frac{L_b}{vfw}$	V_{fw} is the valley floor width and L_b is the length of the valley.	Cox (1994); Keller and Pinter (1996)
	Asymmetrical Factor (A_f)	$T = \frac{D_a}{D_d}$	Da is the distance of the drainage to the mid channel, and Dd is the distance of the stream from the drainage divide.	Hare and Gardner (1985); Keller and Pinter (1996)
	Valley floor width to the Height ratio (V_f)	$A_f = \frac{A_r}{A} \times 100$	A_r is the area in the right-side sides of the stream in the watershed, A total area of the watershed or basin.	Bull and McFadden (1977); Keller and Pinter (1996)
	Lemniscat's Cofficient (K)	$V_f = \frac{2vfw}{(H1-H3)+(H2-H3)}$	2 is the constant and V_{fw} is the valley floor width, H1 and H2 are left and right-side elevation of the valley divides respectively, and H3 is the elevation of the valley floor.	Chorley et al., 1957

Aspects	Parameter	Formula	Descriptions	References
	Lemniscat's Cofficient (K)	$K = \frac{Lb^2}{A}$	Lb^2 is the square of the basin length, and A is the total area of the basin or watershed.	
	Hypsometric Integral (HI)	$E \approx HI = \frac{Elev_{Mean} - Elev_{Min}}{Elev_{Max} - Elev_{Min}}$	Elevmean is the mean elevation, Elevmin and Elevmax is the lowest and highest elevations of the watershed or basin.	Pike and Wilson (1971)
Linear Aspects	Stream Length Gradient Index (SL)	$S_L = \frac{\wedge H}{\wedge L} \times L$	Where, ΔH is the elevation difference of the stream segment, ΔL length of the stream segment, and L is the horizontal length from the midpoint of the stream segment to the watershed divide.	Hack (1973)
	Sinuosity Index (SI)	$S_I = \frac{A_L}{S_L}$	AL is the actual stream length of main stream, SL is the straight stream length of the main stream	Mueller (1968); Haggett and Chorley (1969)

The parameter like S_I, S_L, V_f, and T have been calculated segment-wise (Fig 3). The segment of the river for S_I and S_L have been divided according to the natural break (Jenks) in GIS (Fig 4; 5, 6), while T and V_f have been calculated segment-wise for each SW. The value of spatial and linear aspects is divided into the four classes of active tectonics, where Class-1 (Very high), Class-2 (High), Class-3 (Moderate), and Class-4 (Low) respectively suggests comparative activeness of tectonics in SW. The coefficient of determination (R^2) for the longitudinal profile has been calculated using the following equation:

The linear function: $y=ax+b$. (1)

The exponential function: $y=ae^{bx}$. (2)

The logarithmic function: $y=a\ln x+b$. (3)

The power function: $y=ax^b$. (4)

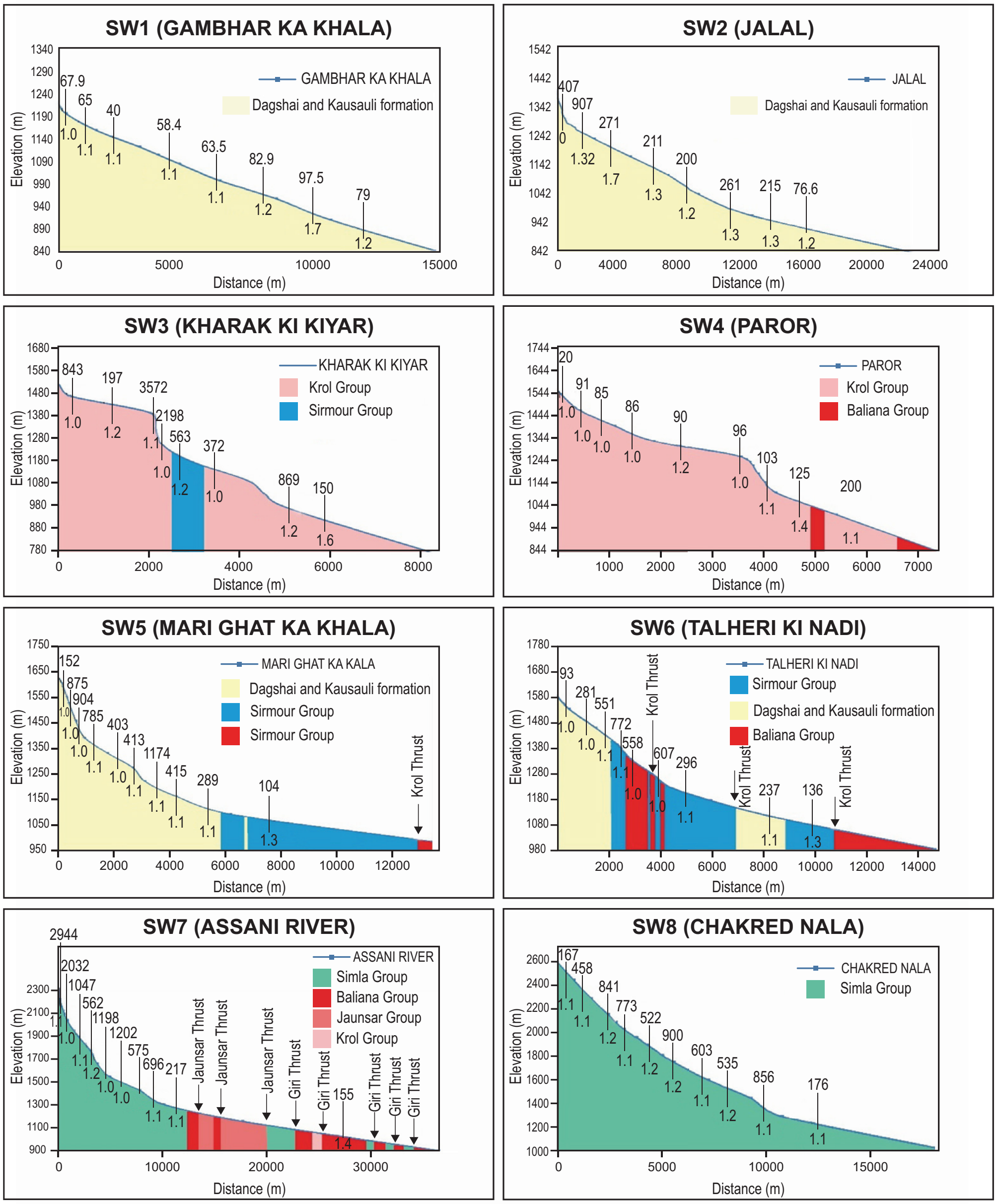

Figure 4 : Showing Examples of the Longitudinal Profile of the River SW1 to SW8. Numerical Value Inset in the Diagram above River SL and Below S_I

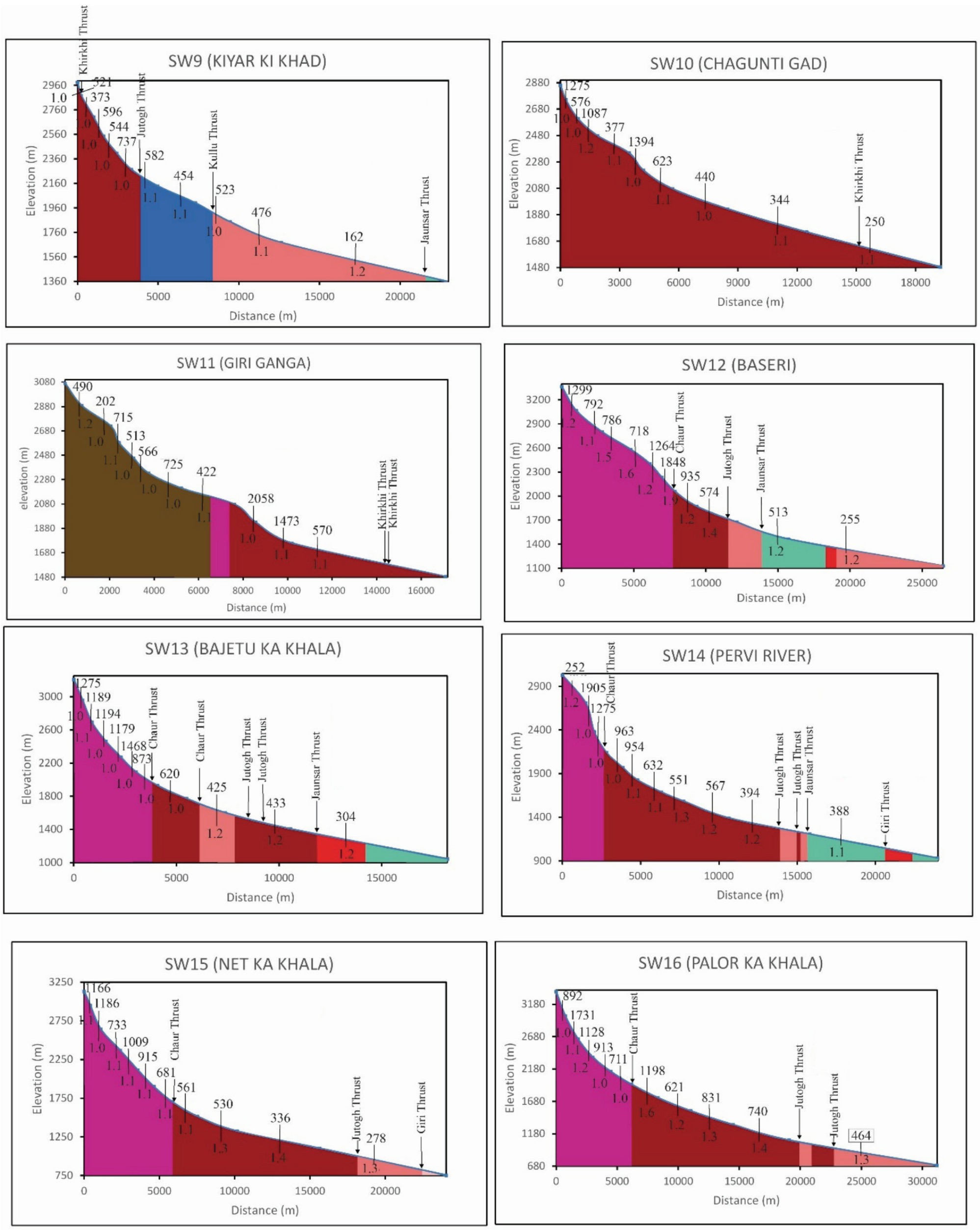

Figure 5 : Showing examples of the longitudinal profile of the River SW9 to SW16. Numerical value inset in the diagram above River SL and Below SI.

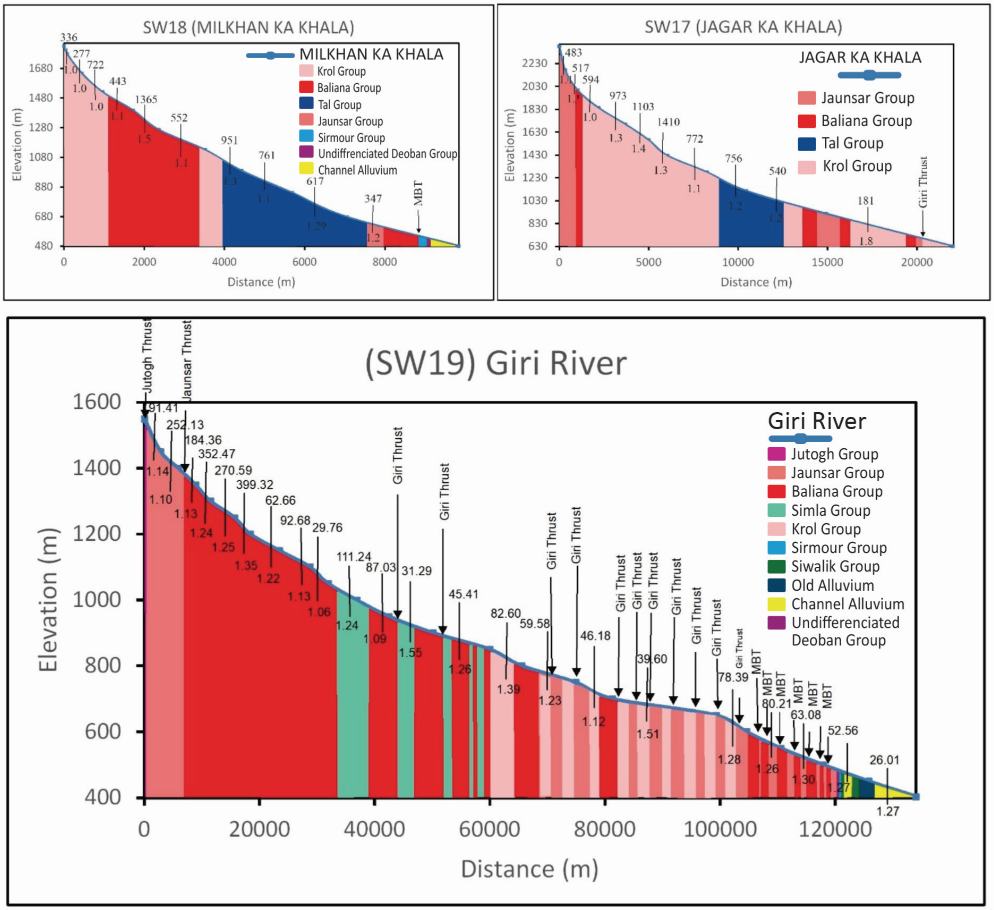

Figure 6 : Showing examples of the longitudinal profile of the River SW17 to SW19. Numerical value inset in the diagram above River SL and Below SI.

RESULTS

3.1. Spatial Aspects

3.1.1. Drainage Density (Dd)

The Dd is obtained as the ratio of Lμ of all stream networks to the area of the watershed, which is an expression of stream in a unit area (Horton, 1945; Strahler, 1964). The D_d is an indicator of dissected and linear topography formed as a result of erosional and fluvial processes and D_d depends on the nature of the rocks, soil strength, and the relief of the area (Singh, 2002; Das and Gupta, 2019). In tectonically active terrains, the D_d signifies the intense deformation and fragile nature of rocks and its value increases with higher rate of deformation and uplift (Rawat et al., 2021). The value of D_d for 19 SW ranges from 2.17 to 2.66 (Table 2) in present study. Based on activeness of tectonics the value of Dd has been divided into Class-1 (> 2.54), Class-2 (2.42-2.53), Class-3 (2.30-2.41), and Class-4 (< 2.29) for the GW (Table 3).

Table 2 : Table Showing Morpho-Tectonic Parameter (where Al –Alluvium, Sw-Siwalik group, Sb-Subathu Formation, Dk- Dagshai and Kasauli Formation, De- Deoban Group, Ja- Jaunsar Group, Sm- Simla Group, Ch- Chaur Granitic Complex, Ju- Jutogh Group, Kl-Kullu Group, Ba-Baliana group, Kr- Krol Group, Tl- Tal Group)

Subwatershed	A_f	B_s	F_f	R_c	K	D_d	R_n	HI	T avg	V_f avg	Geology	Thrusts
SW1 (Gambhar ka khala)	65.54	4.09	0.13	0.37	7.63	2.23	1.56	0.49	0.39	0.14	Dk	
SW2 (Jalal)	41.67	3.00	0.18	0.45	5.62	2.41	2.90	0.47	0.38	0.18	Dk, Sb, Ba, Kr	KrT
SW3 (Kharak ki kiyar)	74.73	1.28	0.38	0.68	2.60	2.17	2.53	0.54	0.18	0.23	Sb, Kr	
SW4 (Paror)	37.70	1.05	0.40	0.54	2.47	2.26	2.69	0.51	0.23	0.33	Kr, Ba	
SW5 (Mari ki ghat khala)	39.75	1.92	0.30	0.62	3.29	2.45	2.17	0.48	0.24	0.14	Sb, Dk, Ba	KrT
SW6 (Talheri ki Nadi)	63.76	1.66	0.33	0.42	3.04	2.63	2.67	0.48	0.19	0.13	Sb, Dk, Ba, Kr	KrT
SW7 (Ashni river)	56.62	2.99	0.19	0.42	5.17	2.52	4.46	0.48	0.21	0.15	Ba, Kr, Ja, Ju, Sm,	GrT, JaT, JuT
SW8 (Chakhred Nala)	54.33	2.27	0.24	0.52	4.21	2.43	4.15	0.51	0.22	0.13	Sm, Ba, Ja	JaT

Subwatershed	A_f	B_s	F_f	R_c	K	D_d	R_n	HI	T avg	V_f avg	Geology	Thrusts
SW9 (Kiyar ki Khad)	57.96	2.48	0.23	0.54	4.39	2.40	4.39	0.50	0.20	0.07	Ja, Kl, Ju	JaT, KuT, JuT
SW10 (Chagaunti gad)	64.09	2.37	0.23	0.58	4.28	2.66	4.53	0.50	0.25	0.04	Ju	KhT
SW11 (Giri Ganaga)	55.00	0.96	0.65	0.53	1.53	2.39	4.11	0.49	0.40	0.12	Ju	KhT
SW12 (Basari)	68.99	2.14	0.23	0.51	4.39	2.35	5.87	0.46	0.34	0.16	Ju, Ch, Sm, Ja, Ba	ChT, JaT, JuT
SW13 (Bhajetu ka khala)	50.60	2.37	0.25	0.65	4.01	2.37	5.57	0.47	0.27	0.21	Ju, Ch, Sm, Ja, Ba	ChT, JaT, JuT
SW14 (Pervi river)	62.70	2.47	0.19	0.56	5.24	2.50	5.58	0.44	0.30	0.16	Ju, Ch, Sm, Ja, Ba	ChT, JaT, JuT,GrT
SW15 (Net ka khala)	47.47	2.95	0.18	0.47	5.63	2.48	6.52	0.46	0.19	0.19	Ch, Ju, Ja, Kr,	ChT, JuT, GrT
SW16 (Palor ka khala)	40.20	2.00	0.19	0.48	5.13	2.50	7.27	0.45	0.37	0.12	Ch, Ju, Ja, Kr, Ba	JuT, GrT
SW17 (Jagar ka khala)	32.93	1.83	0.21	0.64	4.72	2.23	4.00	0.50	0.34	0.10	Ja, Ba, Kr, Tl	GrT
SW18 (Milkan ka khala)	36.42	1.50	0.33	0.62	2.99	2.35	3.59	0.50	0.36	0.25	Kr, Ba, Tl, Ja, De, Sb	MBT
SW19 (Giri river)	54.57	6.03	0.05	0.07	21.95	2.50	6.48	0.43	0.38	0.87	Sw, Dk, Kr, Ba, Tl, Ja, De, Sb Ch, Ju, Sm, Tl, Al	MBT, JaT, JuT, GrT, KrT, KhT,

Table 3 : Active Tectonic Classification Based on Value of Geomorphic Indices for GW.

Aspects	Parameter	Active tectonics classes			
		Class I	Class II	Class III	Class IV
Spatial Aspects	Drainage density (D_d)	> 2.54	2.53 – 2.42	2.41 – 2.30	< 2.29
	Form factor (F_f)	< 0.20	0.21 – 0.35	0.36 – 0.50	> 0.51
	Circularity ratio (R_c)	< 0.44	0.45 – 0.52	0.53 – 0.60	> 0.61
	Ruggedness Number (R_n)	> 5.85	5.84 – 4.41	4.40 – 2.98	< 2.97
	Basin shape Index (B_s)	> 3.31	3.30 – 2.53	2.52 - 1.75	< 1.74
	Transverse topographic Symmetrical factor (T)	> 0.62	0.61 – 0.42	0.41 – 0.22	< 0.21
	Asymmetrical Factor (A_f)	> 68.1	68 – 60, and 31 - 37	37 – 42, and 57 - 60	45 - 60
	Valley floor width to the Height ratio (V_f)	< 0.24	0.25 – 0.45	0.46 – 0.66	> 0.67
	Lemniscat's Cofficient (K)	> 6.11	6.10 – 4.59	4.58 – 3.06	< 3.05
	Hypsometric Integral (HI)	> 0.51	0.50 – 0.48	0.47 – 0.45	< 0.44
Linear Aspects	Stream Length Gradient Index (S_L)	> 2689	2688 - 1797	1796 - 909	< 908
	Sinuosity Index (S_I)	> 1.64	1.63 – 1.43	1.42 – 1.22	< 1.21

3.1.2 Form Factor (F_f)

The Ff is a shape parameter and is the ratio of the area of the watershed to the square of the basin or watershed length (L_b) (Horton, 1945). The shape of the basin is influenced by active tectonics, as the regional structures like faults or thrust influence the surface processes in the watershed which shapes the topography of a watershed. The F_f value ranges between 0 (Elongated shape) to 1 (Circular shape) where the values close to 0 are associated with higher rate of tectonic activity and values close to 1 suggest weak influence of tectonic activity (Wołosiewicz, 2018). The F_f values for 19 SW range from

0.05 to 0.65 (Table 2) in GW. The Ff values obtained have been divided into the Class-1 (< 0.20), Class-2 (0.21 – 0.35), Class-3 (0.36 – 0.50), Class-4 (> 0.51) based on the influence of tectonic activity (Table 3).

3.1.3 Circularity Ratio (R_c)

The R_c is also a shape factor that determines the influence of tectonics on the development of shape of a watershed. The R_c value close to 1 is associated with a circular shape and low influence of lithology, regional or local structures; while values close to 0 indicates elongated shape and tectonically active terrain (Miller, 1953, Rawat et al., 2021). The values of R_c ranges between 0.07 to 0.68 (Table 2), which are divided accordingly into Class-1 (< 0.44), Class-2 (0.45 – 0.52), Class-3 (0.53 – 0.60), and Class-4 (> 0.61) based on tectonic behavior of the terrain (Table 3).

3.1.4 Basin Shape Index (Bs)

The B_s can be calculated as the ratio of basin length to the width (calculated at the widest point) within the watershed or basin (Ramírez-Herrera, 1998). The shape of the drainage basin or watershed is a significant indicator of tectonic control (Sharma et al., 2018). In addition to the contrast, the stable and senile drainage basins are characterized by the widening of the basin (Ramírez-Herrera, 1998; Mahmood and Gloaguen, 2012). The B_s value for 19 SW varies from 0.96 to 6.03 (Table 2). The values of B_s have been divided into Class-4 (< 1.74), Class-3 (1.75 – 2.52), Class-2 (2.53 – 3.30), and Class-1 (> 3.31) based on the influence of tectonics (Table 3).

3.1.5 Lemniscate Coefficients (K)

The K is used as a measurement of the gradient of the Basin or watershed (Chorley et al., 1957). The *K* value ranges from 1.53 to 21.95 (Table 2) for 19 SW in GW. The higher values of *K* indicate a higher rate of tectonic activity in the basin while the lower values are associated with stable structures (Wołosiewicz, 2018). Wołosiewicz and Chybiorz (2015) suggested that drainage basin is considered tectonically active if K > 3, slightly active if the values of *K* are between 2 and 3, and tectonically inactive if K < 2. The K values are higher in all SW except for three SW (Giri Ganga, Paror, and Kharak ki Kiyar) (Table 2). The value of the K has been divided into Class-1 (> 6.11), Class-2 (4.59-6.10), Class-3 (3.06-4.58), and Class-4 (< 3.05) for GW based on tectonic activity (Table 3).

3.1.6 Ruggedness Number (R_n)

The Rn is the product of Dd and basin relief (Strahler, 1952). The Rn is the measure of the surface roughness or undulations which has direct correlation with geology, structure, and topography of the basin (Asthana et al., 2015). The Rn value ranges from 1.56 to 7.27, while the value of all other watersheds is listed in Table 2. The value of Rn has been divided based on influence of structure into Class-1 (> 5.85), Class-2 (4.41 – 5.84), Class-3 (2.98 – 4.40), and Class-4 (> 2.97) for GW (Table 3).

3.1.7 Asymmetry Factor (A_f)

The Asymmetry factor (A_f) reveals the tilt-block tectonics of the drainage basin (Cox, 1994; Keller and Pinter, 1996, Rawat et al., 2021). The A_f value also deciphers the possible directions of the differential tectonics or basin tilt (Pinter et al., 2006; Prakash et al., 2016). The A_f values equal to 50 suggests a symmetrical basin with no tectonic influence, while values more or less than 50 indicate an asymmetrical basin with possible tilting facilitated by local or regional tectonics and lithological variations (Sharma et al., 2018). The A_f values greater than 50 reveal left side tilting, while the A_f values less than 50 reveal right side tilting, in the direction of drainage (Molin et al., 2004; Prakash et al., 2016). The A_f value for 19 SW varies from 32.93 to 68.99 (Table 2). The value of A_f has been divided into Class-1 (> 68.1), Class-2 (60 – 68 and 31 – 37), Class-3 (37 – 42 and 57 - 60), and Class-4 (45 – 56) (Table 3).

3.1.8 Valley Floor Width to the Height Ratio (V_f)

The V_f is used to classify the river valleys into V-shaped, U-shaped, and flat valleys (Bull and McFadden, 1977; Keller and Pinter, 1996; Sharma et al, 2018). The deep V-shaped valley and long linear valley with active incision are generally associated with the active tectonic in the area; while U or flat-shaped valleys are indicators of less impact of tectonics; while flat valleys are associated with old stage of landform development, less activeness and base level attainment in the area (Keller, 1986; Keller and Pinter, 1996; Sharma et al, 2018). In Himalayan river basins, the valley is narrower in the headwaters due to a higher rate of tectonic activity and base level erosion which gradually gets lower towards the south showing wider valleys and river bank erosion (Bull and McFadden, 1977). The average V_f value for 19 SW ranges from 0.04 to 0.87 (Table 2). The V_f values has been divided into the Class-1 (> 0.24), Class-2 (0.25 – 0.45), Class-3 (0.46 – 0.66), and Class-4 (> 0.67) for GW (Table 3).

3.1.9 Transverse Topography Symmetry Factor (*T*)

The *T* is also a symmetry parameter that interprets the lateral tilting or disturbances due to tectonic activities (Cox, 1994; Cox et al., 2001). The value of *T*=0 represents the symmetrical basin, while an increasing value of T or *T* > 0 is associated with an asymmetrical basin, the higher the value of *T* more will be the influence of tectonics on the basin (Cox, 1994; Keller and Pinter, 1996). The values *T* has been calculated for the different segments (Fig 3) in each sub-watershed and the values for 19 SW range from 0.01 to 0.81 (Table 2). The average T value ranges from 0.18 to 0.40 for 19 SW that has been divided into the Class-4 (> 0.21), Class-3 (0.22 – 0.41), Class-2 (0.42 – 0.61), and Class-1 (> 0.62) (Table 3).

3.1.10 Hypsometric Curve (HC) and Hypsometric Integral (*HI*)

The *hypsometric analysis* is an area-elevation analysis that is an important aspect to ascertain the erosional stage, degree of dissection, and influence of tectonics (Strahler, 1952; Horton, 1945; Ritter et al, 1995; Shukla et al, 2014). It is used to differentiate between the erosion of landforms at their different development stages i.e. youth, mature and old (Strahler, 1952; Horton, 1945; Ritter et al., 1995; Singh et al., 2008; Shukla et al., 2014; Yousaf et al., 2018). Strahler (1952) observed different types of hypsometric curves and categorized them for different stages of development of landforms. Hypsometric curves concave upwards with a low *HI* value suggests the old stage and lower rate of tectonic activity, whereas an S-shaped curve indicates the mature stage of landforms development with a moderate influence of tectonics, while a convex upwards curve with high *HI* value shows the youth stage of landforms development and high rate of tectonic activity in the basin (Strahler, 1952; Ritter et al., 1995; Keller and Pinter, 1996; Yousaf et al., 2018). The *HI* Value for 19 SW in GW ranges from 0.43 to 0.54 (Table 2). The HC for 19 SW for GW has shown a mature stage of development or S-shaped curve in most of the SW (Fig. 7). The *HI* values have been classified under Class-1 (> 0.51), Class-2 (0.48 – 0.50), Class-3 (0.45 – 0.47), and Class-4 < 0.45) for GW (Table 3).

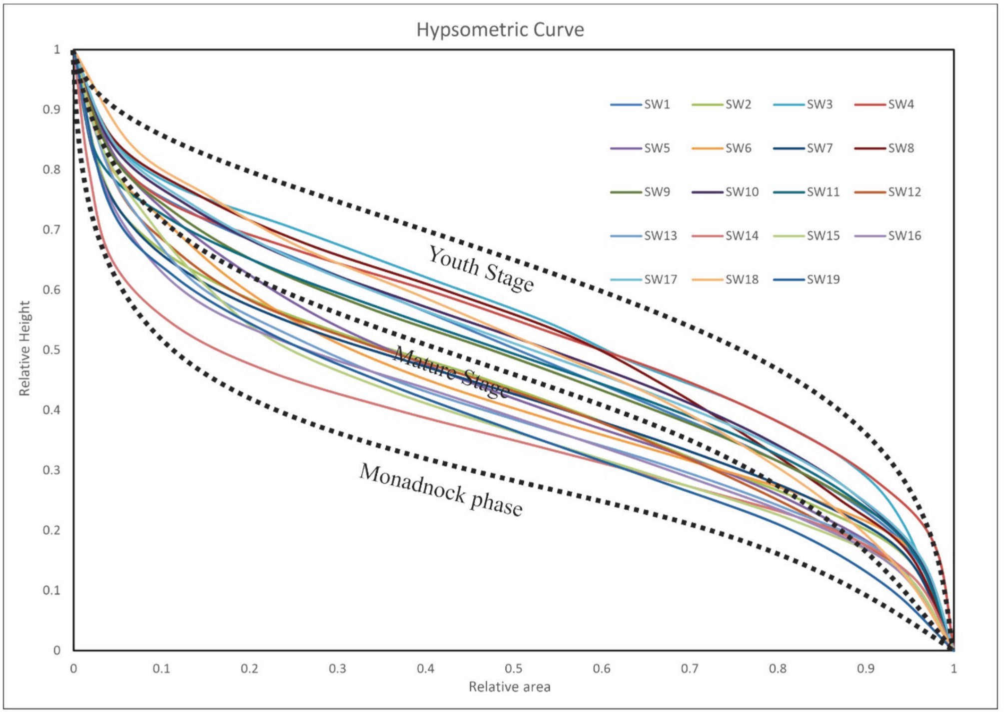

Figure 7 : Showing combined *Hypsometric Curve* (Vertical axes showing elative heights and horizontal axes as relative area) of SW of Giriwatershed, Himachal Pradesh, Northwest Himalaya.

3.2. Linear Aspects

3.2.1 Stream Length Gradient Index (S_L)

The SL is used in understanding the degree to which river systems have adapted to the region's landform evolution and tectonic activities. An S_L also accounts for the geological structure and climatic conditions, which may vary throughout the river's length. It is the relationship between the climatic variability and the *longitudinal profile* of the river to see the state of the equilibrium in the watershed or basin (Hack, 1973; Kotyari et al., 2017; Sharma et al, 2018). The S_L has been calculated along the main channel after being divided into segments (Fig 4; 5; 6) using natural break (Jenks) in the GIS environment.

The SL value for 19 SW ranges from 20 to 3572 (Fig 4; 5; 6), which has been divided into Class-1 (>2689), Class-2 (2688 - 1797), Class-3 (1796 - 909), and Class-4 (< 908) for GW based on the response of channel to climatic variability and active tectonics (Table 3).

3.2.2 Sinuosity Index (S_I)

The S_I is the ratio of the actual river path to the straight path of the river, which defines the degree of meandering. The S_I of a river is influenced by factors like geological structures, lithology, sediment load, etc. (Haggett and Chorley, 1969; Kothiyari et al., 2017; Das and Gupta, 2019). The S_I for the main channel of all 19 SW has been calculated by dividing the main channel into equal segments (Fig 4; 5; 6) based on natural break (Jenks) method in GIS. The SI value for 19 SW varies from 1.00 to 1.84 (Fig 4; 5; 6). Based on the results the SI values have been divided into Class-1 (>1.64), Class-2 (1.43 – 1.63), Class-3 (1.22 – 1.42), and Class-4 (< 1.21) suggesting the degree of tectonic control on main channel flow path (Table 3).

3.2.3 Longitudinal Profile Analysis

The *longitudinal profile* is a curve derived from the relationship between channel height and distance downstream, indicating the influence of gradient on the channel (Hack, 1973). *longitudinal profiles* have been obtained along main the channel as a plot between elevations and the distance of the river from head to mouth. The *longitudinal profile* helps in interpreting active tectonics, palaeo-climate, river discharge, sediment load, etc. (Hack, 1973; Leopold et al., 1964; Kothyari et al., 2017). In the GW, 15 SW have well-developed knick points along the main channel, indicating the influence of lithology and tectonics; while the remaining 4 SW have smoother profiles (Fig 4; 5; 6), indicating homogeneous lithology and minimal tectonic influence. The coefficient of determination (R^2) also has been calculated for the longitudinal profile of all river (Table 4), for linear, exponential, logarithmic, and power curves. The R2 is a crucial aspect for understanding the tectonic vulnerability of the basin, a higher value of R^2 is associated with highly active tectonic or vice-versa (Lee and Tsai, 2010).

Table 4 : Showing the Coefficient of Determination (R^2) for Longitudinal River Profile.

Subwatersheds	Coefficient of determination (R^2)			
	Linear	Exponential	Logarithmic	Power
SW1	0.9876	0.9972	0.5699	0.5219
SW2	0.9163	0.9603	0.6805	0.6093
SW3	0.964	0.9779	0.495	0.4165
SW4	0.9832	0.9731	0.5892	0.5123
SW5	0.7499	0.8151	0.7188	0.6733
SW6	0.8764	0.9278	0.5878	0.5878
SW7	0.734	0.8518	0.6494	0.74
SW8	0.9143	0.9727	0.5865	0.4984
SW9	0.8559	0.9284	0.6948	0.6177
SW10	0.9075	0.9553	0.6711	0.6043
SW11	0.9092	0.9584	0.5968	0.5228
SW12	0.8665	0.9497	0.6769	0.5645
SW13	0.8	0.9162	0.6919	0.5836
SW14	0.7771	0.9053	0.6557	0.5415
SW15	0.8149	0.9434	0.6664	0.5408
SW16	0.8262	0.9636	0.6894	0.5283
SW17	0.9031	0.9848	0.6674	0.525
SW18	0.9578	0.9979	0.6502	0.5232
SW19	0.9581	0.9909	0.5311	0.4263

3.2.4 Lineament and Drainage Interaction with Tectonics

The Himalayas are subjected to enormous stresses, which have resulted in the formation of numerous faults, *lineaments*, and shear zones, etc. (Singh et al., 2002; Yin, 2006). The lineaments are frequently interpreted as the visible surface of weak geologic zones at tectonic boundaries, as well as faults and rock fractures (Thakur et al., 2007; Malik et al., 2010; Prakash et al., 2016). *Lineament* may be identified as the axis of the folds, a plane of the faults, long and narrow linear surface features, and linear tonal and textural contrast, etc. delineated from the satellite imageries, DEM, and Geological map (Parizek, 1976; Sander, 2007; Das and Gupta, 2019; Pant et al., 2020). *Lineaments* can be assessed to detect the role of the structure in shaping the topography or landforms in a river basin (Nur and Ban, 1982). The drainage channels passively follow faults or zones of weakness which is a common spatial relationship between rivers and geologic structures in the Himalayas (Sahoo et al., 2000). A total of 121 Major lineaments (Fig 2b; Fig 8) have been identified from satellite data. The majority of lineaments follow two directions predominantly, one is trending in the NE-SW and the second one is trending in the NW-SE (Fig. 8). The lower hemisphere equal-area net has been prepared for 3rd, 4th, and 5th order drainages which shows the majority of drainages flowing in N-S and E-W, N-S and E-W, S-W, and NW-SE directions respectively (Fig 9). The azimuth of drainages of the 3rd, 4th, and 5th have shown congruence with *lineament* azimuth suggesting structural control over the drainage channel (Fig 8).

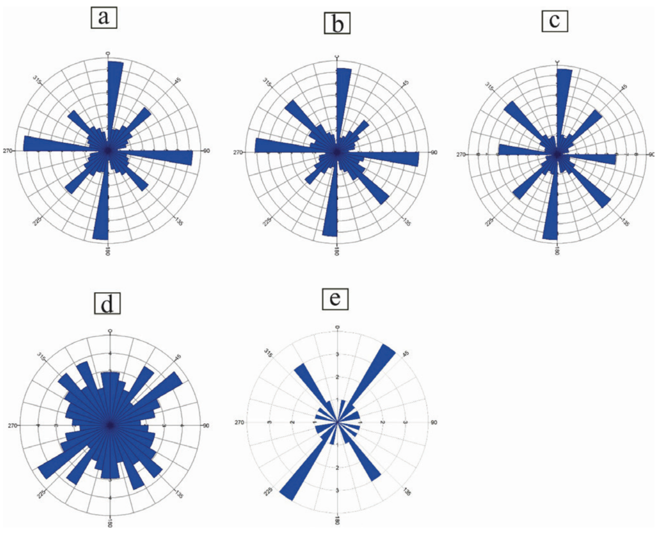

Figure 8 : Showing Rose diagram for Drainage (a, b, and c for 3rd, 4th, and 5th order drainage networks respectively), lineaments (d), and A_f parameter (e) for GW, Northwest Himalaya.

DISCUSSIONS

3.3 Spatial Aspects

The D_d gives an insight to spatial configuration and characteristics of the drainage network. The SW of Class-1 and Class-2 suggest the highly deformed and fragile nature of rocks in tectonically active terrain. The high D_d values are associated with rocks of incompetent nature, and are controlled by Krol, Khirkhi, Chaur, Jaunsar, Jutogh, and Giri thrusts (Fig 2a; Table 2) in GW. The higher Dd values are also supported by presence of knick points (Fig. 4; 5; 6), and high R^2 values in exponential curves for each sub-watershed (Table 4). The K and R_n reveal the gradient and undulation of the terrain (Chorley et al., 1957; Asthana et al., 2015). The SW classified in Class-1 and Class-2 suggest high K and R_n values inferring a higher incision rate, the presence of a narrow valley, and highly deformed terrain (Vijith and Satheesh, 2006). The results infer that the SW in Class-1 and Class-2 are influenced by the major structural discontinuity like Jaunsar, Giri, Jutogh, and Chaur thrusts (Fig 2a; Table 2).

The shape parameters viz. F_f, R_c, and B_s suggests that elongated basin shape and straight drainages are associated with high tectonic activity and structural control (Philip and Sah, 1999). The SW with lower F_f values (Class-1 and Class-2) are associated with active tectonics (Wołosiewicz, 2018) and are either lithologically or structurally controlled. The SW with lower Ff values in GW is possibly influenced by the Chaur, Jutogh, Jaunsar, and Giri thrusts (Fig 2a). The lower value of R_c is associated with tectonically active watersheds in comparison to the watersheds with a higher value. The SW with lower Rc values (Class-1 and Class-2) are associated with late youth to early mature stage of landform development, while watersheds with higher values are associated with mature to late mature stage of landform development that are also supported by HI values (Table 2). The SW with high B_s values suggests the region is tectonically active and is influenced by local and regional structures. The influence of regional structures on SW is also supported by availability of knick points in the *longitudinal profile* (Fig 4; 5; 6), F_f and R^2 values (Table 4). The results from shape parameters of 19 SW has suggested that majority of SW are elongated and their tributaries join the mainstream more or less at a right angle, suggesting significant role of tectonics in the SW (Fig 3).

The *HI* value deciphers the erosional and tectonic activity i.e. higher *HI* value shows the development of the juvenile stage landforms and higher tectonic activities (El Hamdouni et al, 2008). The SW in Class-1 and Class-2 (Table 2; Fig 2a) are comparatively regions of high tectonic activities with highly deformed and lose rocks accompanied by major geological structure (Fig 2a). The *HI* values are also validated by the upward convex *HC* (Fig 7), exponential R2 value (Table 4), and the presence of knick points in *longitudinal profile* (Fig 4; 5; 6).

The A_f are crucial parameters that give insight to understand the possible tilting direction of the watershed or basin (Hare and Gardner, 1985; Cox, 1994; Keller and Pinter, 1996). The A_f values suggests that SW1, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, and SW19 are tilted towards left (i.e. in NE, and SW directions) of the main stream (Table 2). The Af values in these SW are influenced by geological structures like Krol, M.B.T., Giri, Jaunsar, Kullu, Jutogh, Khirkhi, and Chaur thrusts in these SW (Fig 4; 5; 6). While the Af value in SW2, 4, 5, 15, 16, 17, and SW18 show tilting on the right side (i.e. in NW and SE directions) of the main stream (Table 2) and are mainly influenced by M.B.T, Giri, Jutogh, and Chaur Thrusts (Fig 4; 5; 6). The major sub-watershed in the GW are showing tilting in the NE-SW direction which suggests, geological structure is controlling basin tilting and are still active (Fig 9).

The symmetry factor like *T* is also used for the assessment of the symmetry of the GW. The *T* show the possible tilt or symmetry in watershed or basin based upon the topographic symmetry along the main channel (Hare and Gardner, 1985; Keller and Pinter, 1996). The *T* values calculated for the 19 SW, which shows that all the SW are asymmetric in nature. The asymmetric behavior of all the SW in GW suggests that the watersheds are influenced by the ongoing tectonic processes. The SW with higher *T* suggests higher asymmetry and tilting of the basin due to active tectonics and higher rate of deformation (Cox, 1994) (Table 2), (Fig 2a). All SW show V_f values of less than one (Table 2) suggesting deep and narrow valleys and the significant influence of active tectonics (Table 2) (Sharma et al., 2018).

3.4 Linear Aspect

The values of the S_L from the results suggest that, it increase at places where the river flows over the structurally deformed or tectonically uplifted area (Keller and Pinter, 1996). The higher values of S_L in GW are associated with the segment of the river where major thrust, local fault, and knick points encountered. In the GW, majority of SW show disequilibrium due to variable lithology and geological structure. In GW 18 SW has shown high exponential R^2 value except Paror watershed where it R^2 curve is linear suggesting very intense tectonic activity (Table 4).

The SI values from 19 SW suggest that in headwater regions or at higher elevations the main stream is flowing in more or less a straight path without any interference. The behavior of stream of flowing in straighter course suggests that the lithology in the region is homogenous with absence of geological structures or dormant tectonic activity, whereas the value of SI in the dispersing system or at lower elevation is comparatively higher which determines that there is heterogeneity in rock sequence and availability geological structure or active tectonics. The S_I value variation along the main stream is evidenced in the form of intense sinuosity and abrupt change in elevation (observed in the form of rapids) along the river course which clearly suggests the influence of tectonic and lithology over the drainage (Fig 4; 5; 6).

The azimuth of the 3rd, 4th, and 5th order drainage from 19 SW is drawn in lower hemisphere equal area stereonet which shows that the majority of streams has shown NE-SW and NW-SE trend. The 3rd drainage orders are used as they show the influence of geological structure and tectonics on drainage network development and arrangement. The trend of azimuths is correlated with lineament azimuths which shows that the trends from both parameters are consistent with each other suggesting geological structure and active tectonics is prevalent and crucial in the development of landforms.

3.5 Geomorphic Evidence of Neotectonics Activity

The geomorphic evidence of neotectonics activities like traces of fossil valley (Fig 9), Landslides, Denudational hills, Sag pond (Sirmouri Tal), triangular facets, displaced terraces, slope breaks, benches, and exceptionally wide and narrow valleys (Fig 10) are important active tectonic features in the GW (Philip and Sah, 1999; Kothyari et al., 2017; Thakur et al., 2021).

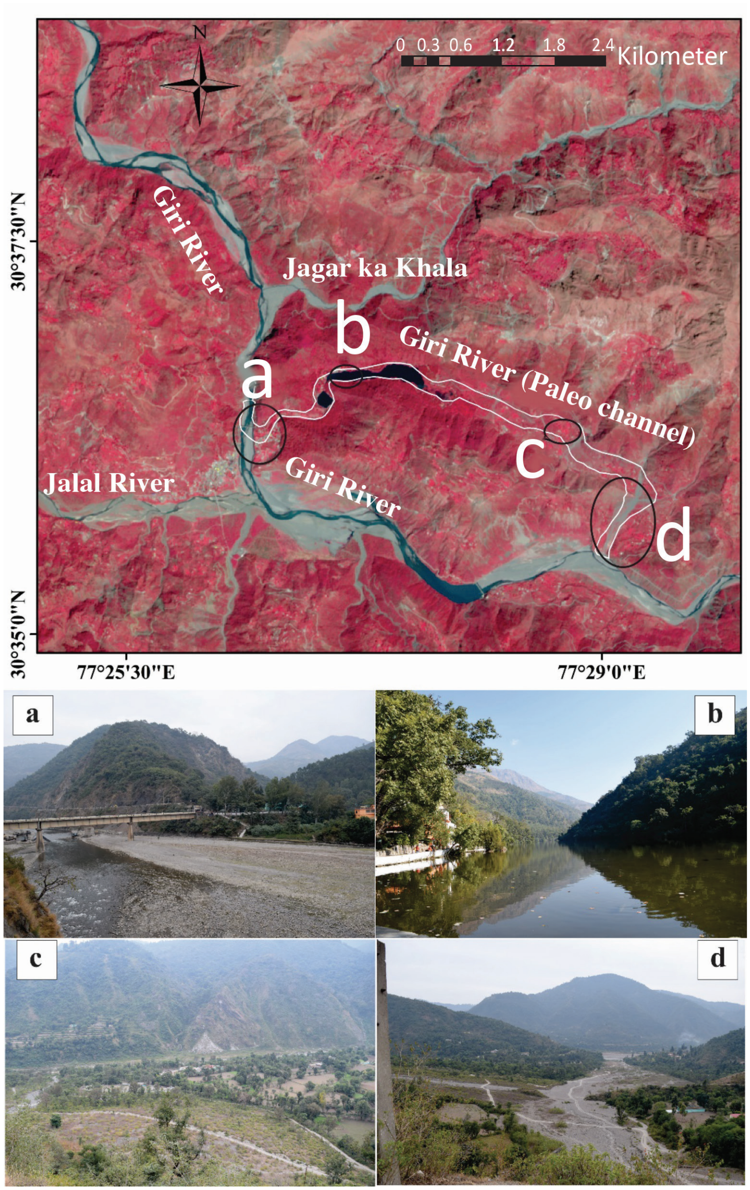

Figure 9 : Figure showing the different parts of the fossil valley including the Renuka Lake, near Renuka Ji area, Sirmour, Himachal Pradesh, northwest Himalaya, India.

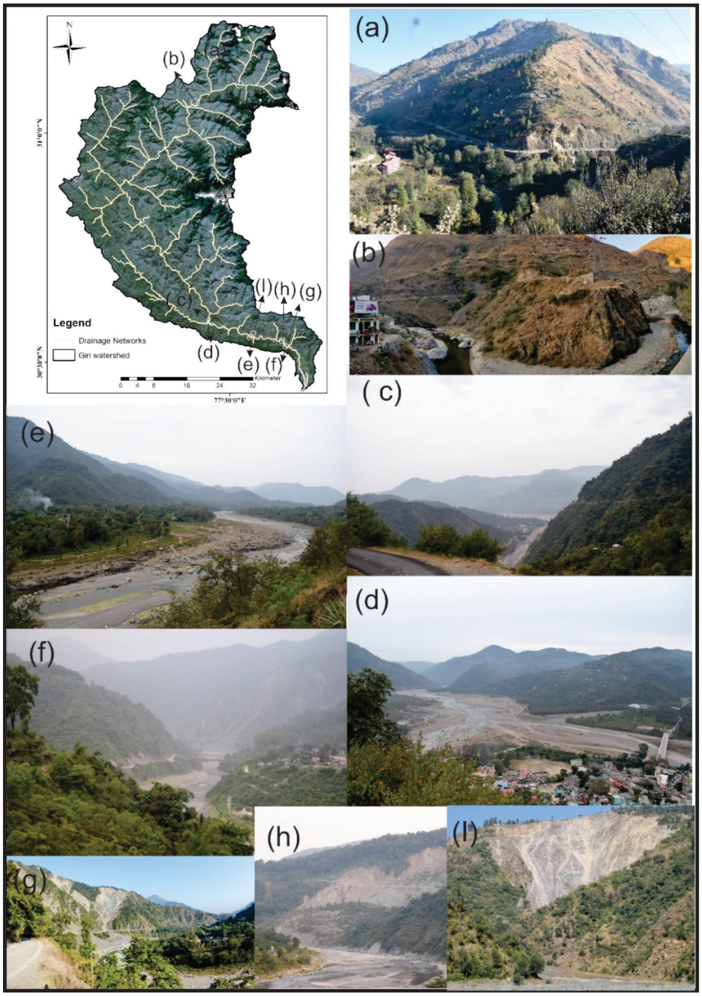

Figure 10 : Showing major consecutive wider and narrow segments in the mainstream, where (a) is a narrow valley and confluence of Giriganga and Chagunti Gad; (b) is meandering in upper segments of Giri river near, Chhailla, Gumma; (c) show upstream narrow segment; (d) show downstream very wide River segments near Dadhau; (e) show rock exposer in the River bed, and wide valley near Ambaun village; (f) show narrow downstream (g) show wide upstream River segments and major landslides near Sataun; (h) and (i) are major landslide near Sirmour Tal and Ambaun, Himachal Pradesh.

The fossil valleys are the results of the climate–tectonic interaction (Kothiyari and Juyal, 2013. The Giri River has changed its path in history which is observed with presence of about 7 km long fossil valley (Fig 9) (Rao, 1975; Raina, 1967). This event of changing of course can be attributed to a regional scale phenomenon aided by the upliftment and tilting (Rao, 1975). The main Giri river has deflected towards right (NE) about 1 km to 2.5 km from its current path after possible tilting of basin (Fig 9). The alteration in river valley profile (viz. narrow and wide valleys) in course of the Giri river (Fig 10) suggests significant role of the Giri thrust and MBT (Fig 2a; Fig 6) on the mainstream. Parenthetically, discontinuity developed by local and regional tectonic is attributing to formation of highly fragile, jointed, fractured, folded and faulted rock masses (Fig 11) in the GW, and making valley more susceptible in terms of disaster associated with active tectonics i.e. landslides, flooding, etc.

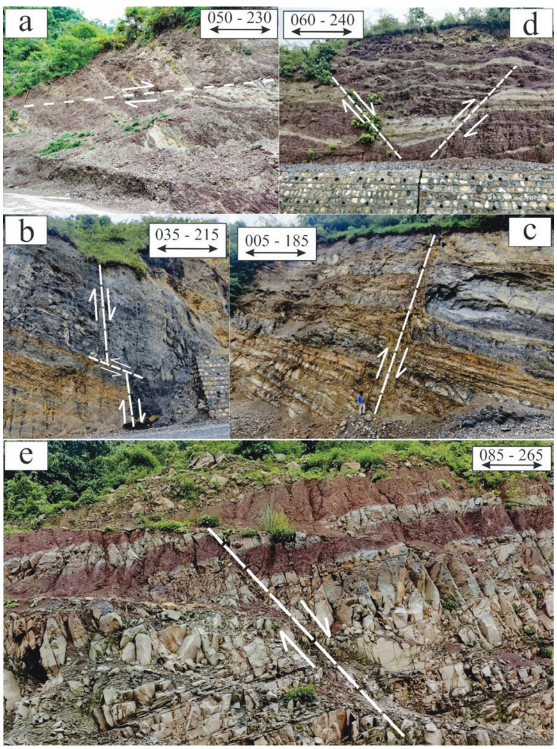

Figure 11 : Field photograph showing important faulted strata in the Giriwatershed, where (a), (c), and (c) are near Barwas, and (d) is near Kamrau village, and (e) is near Sirmouri Tal.

4. CONCLUSIONS

The GW is tectonically active and the activeness of the watershed is inferred by studying geomorphic indices for 19 SW, that are also convinced by the several geomorphic signatures in the GW. From the above study, the following assertion can be drawn:

- Geomorphic indices, river profile, drainages orientations, major lineaments, and field study suggests GW is tectonically active and is controlled by ongoing tectonic activities.
- The local and regional tectonics, lithological, and geomorphological factors play crucial role in shaping the landforms.
- The majority of SW suggested a NE-SW migration of litho-tectonic units in GW.
- Main Giri river around Renuka Ji have shifted around 1 – 2.5 km from its previous path, and have abandoned long stretch of paleo channel of about 7 km.
- The lower GW is tectonically more active in comparison to another part due to the complex geological structures and highly deformed rock mass, which is evidenced in the form of landslides, and other geomorphic signatures.
- Active tectonics activities are accelerating the rate of the geomorphic process like landslides, erosion, rock deformation, etc. in GW.

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Kudumbashree Members' Attitude, Skills and Knowledge of the Psychosocial Care of the Disaster Affected

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Abstract

This study is conducted in the context of concerns over global climate change and related disasters. The psychological after-effects of a disaster may persist for extended periods, sometimes even decades, because of the intensity and magnitude of loss associated with it. In a country like India, where there is a severe shortage of mental health professionals, providing psychosocial care to disaster-affected may be arduous. This emphasises the need for culturally sensitive and community-based psychosocial care to cater to the needs of different sectors of the community. Trained members in a community can play a crucial role in the psychosocial care of the disaster affected. This study was conducted among the members of Kudumbashree, the women empowerment programme by the Government of Kerala, with a membership of 43,93,579, with an aim of understanding their attitude, knowledge and skills in providing psychosocial care to the disaster affected. Findings indicate that Kudumbashree members have a favourable attitude, and possess skills and an average level of knowledge in providing psychosocial care to the disaster affected. The findings have policy implications in the identification, organisation and training of people within a community to provide effective psychosocial care.

Keywords: *Climate Change, Disasters, Psychosocial Care, Kudumbashree*

1. Introduction

Climate change is one of the most alarming crises humankind is facing. This issue is of paramount importance because it concerns the survival and existence of human beings on this planet. It has its own socio-political, psychosocial, emotional, and economic

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repercussions too. Climate change and related problems are not only the concerns of governments or developing nations; it is the concern of everyone. The Intergovernmental Panel on Climate Change (IPCC) states that "Climate change is a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period typically decades or longer" (IPCC, 2007). One of the significant after-effects of climate change is the increasing number of more intense disasters.

The last few decades have witnessed many deadly natural disasters that might have occurred due to the changing climate. The range of disasters varies from the deadliest tsunamis to hurricanes and cyclones in some parts of the globe, and heat waves and wildfires to increased rainfall and flooding in some other regions. (Cacciotti et al., 2021; Sauerborn & Ebi, 2012; Thomas et al., 2013; Van Aalst, 2006). Climate change is not only affecting individuals; societies are also tremendously impacted by climate change and related disasters, crises and emergencies (Arcaya et al., 2020; Collenteur, 2015; Davey et al., 2013; Di Baldassarre, 2014; Dubash, 2012; Duerden, 2004; Healey et al., 2011; Kron, 2015; Van Bavel, 2020).

All communities are susceptible to disasters, and it has a substantial impact on psychological well-being through direct and indirect linkages (Alexander, 2012; Bourque & Willox, 2014; Chen et al., 2020; Cianconi et al., 2020; Fatemi et al., 2017; Hayes et al., 2018; Palinkas & Wong, 2020; Simpson et al., 2011; Singh et al., 2014; Thomas et al., 2009; Wolkin et al., 2015). The psychological after-effects of a disaster may persist for more extended periods, sometimes even decades, because of the intensity and magnitude of various types of loss (Canino et al., 1990; Goldmann & Galea, 2014; Lindell & Prater,2003; Morganstein & Ursano, 2020; Stanke et al., 2012). Most of the psychological, emotional and psychosocial problems that occur due to climate change and associated disasters are likely to proceed gradually (Chan & Wong, 2020; Clayton, 2019; Lawrance et al., 2021; Lorenzoni et al., 2020; Newnham et al., 2020; Paxson et al., 2012; Zhong et al., 2018). Moreover, the impact may vary by the social, historical, political and cultural contexts of the affected people and communities (Ahern et al., 2005; Fernandez et al., 2015; Gaillard et al., 2008; Galea et al., 2006; James & Paton,2015; Kirmayer et al., 2010; Ozer et al., 2003; Perilla et al., 2002).

Previously it was widely thought that mental health after-effects of disasters are limited only to immediate trauma and Post-traumatic Stress Disorder (Friedman et al., 2007; Fullerton & Ursano, 2005; Norris, 2006; North et al., 2021; Raphael & Maguire, 2012; Roudini et al., 2017; Southwick et al., 2016; Vernberg et al., 2008; Yehuda, 2003). This led to a mismatch between the needs of the affected, the resources they have and the services provided to them (Augusterfer et al., 2020; Halpern & Vermeulen, 2017; Kagee, 2018; Keim, 2018; Khorram-Manesh, 2020). An alternative to resolve this reductionist tendency is to have a broader psychosocial support plan for the disaster affected. Fortunately, now almost all the governments and agencies working in the field of disaster mental health recognise the importance of psychosocial care (PSC) as an essential component of disaster management (Bulling& Abdel-Monem, 2012; Diaz et al., 2006; Diaz, 2018; Manzoor & Ali, 2018; Raphael & Maguire, 2012).

According to the National Disaster Management Authority's (NDMA) National Disaster Management Guideline of India for Psychosocial Support and Mental Health Services (PSSMH) in Disasters,

> Psychosocial support in the context of disasters refers to “comprehensive interventions aimed at addressing a wide range of psychosocial and mental health problems arising in the aftermath of disasters. These interventions help individuals, families and groups to build human capacities, restore social cohesion and infrastructure along with maintaining their independence, dignity and cultural integrity. Psychosocial support helps in reducing the level of actual and perceived stress and in preventing adverse psychological and social consequences amongst disaster-affected communities” (NDMA, 2009).

In a country like India, where there is a severe shortage of mental health professionals to cater to common mental health challenges, providing effective psychosocial care to disaster-affected individuals may be arduous. This emphasises the need for culturally sensitive and community-based psychosocial care to cater to the needs of different sectors and vulnerable groups of the community. Trained members in a community can play crucial roles during the recovery, rehabilitation, and reconstruction phases of a disaster. If adequately organised, the community resources can be mobilised effectively to provide psychosocial care during and after a disaster (Aldrich, 2012; Eisenman et al., 2007; Mathbor, 2007; Tierney, 2014). Since the community members may know each other and have a good connection with the families of the affected people, they can provide essential psychosocial care to the affected individuals in the unfortunate event of a disaster. Since they are from the same community, cultural differences, a significant concern and drawback of psychosocial care by outside experts, may not occur. Several studies identified the vital role a community could play in the provision of psychosocial care (e.g., Amaratunga & O'Sullivan, 2006; Bhadra, 2017; Gailits et al., 2019; Gray et al., 2020; Hechanova & Waelde, 2017; Nahar et al., 2014; O'Hanlon & Budosan, 2015; Pfefferbaum & Klomp, 2013; Rao, 2006; Reyes, 2006; Satapathy & Bhadra, 2009; Weissbecker et al., 2019; Wessells, 2009; WHO, 1992).

This study is conducted in the context of the 2018 and 2019 floods in Kerala, one of the southernmost states in India. Kerala experienced heavy rainfall from 1st June to 19th August 2018, resulting in flooding and/or landslides in almost all the districts of the state. As per the report of the Kerala State Disaster Management Authority (KSDMA),

> Flooding has affected hundreds of villages, destroyed several roads, and thousands of homes have been damaged. 1,259 out of 1,664 villages spread across its 14 districts were affected. The devastating floods and landslides affected 5.4 million people, displaced 1.4 million, and took 433 lives (268 men, 98 women and 67 children). Several relief camps were opened to save the people from the vagaries of the flood (KSDMA, 2018).

Interviews at relief camps revealed that families in Kerala were paying an enormous non-quantifiable emotional price in the aftermath of the floods. Emotional trauma was visible in the form of shock, psychosocial damage, distress, trauma, and insecurity from the loss of home, livelihood, assets, possessions, and most importantly, the death of close friends and relatives (Ravi et al., 2019). Volunteers and workers from different community-based organisations and groups like Kudumbashree were actively involved in public health interventions. They visited the disaster-affected houses and relief camps and gave psychosocial support to those in need. Even though they had not undergone any training, or had minimal training in psychosocial care, they could easily connect with the affected individuals since most of these volunteers were from the affected community.

Kudumbashree is the poverty eradication and women empowerment programme implemented by the Government of Kerala. It has a three-tier structure for its women's community network with Neighbourhood Groups (NHGs) as primary level units, Area Development Societies (ADS) at the ward level, and Community Development Societies (CDS) at the local government level. It is arguably one of the largest women's networks in the world. The Kudumbashree network has 2,91,507 NHGs affiliated with 19,489 ADSs and 1064 CDSs with a total membership of 43,93,579 women.

Since Kudumbashree members are from the same community/neighbourhood and are well-connected and informed about the people in the community, they have a crucial role in providing culturally sensitive psychosocial care to disaster survivors. During a disaster, they act as frontline workers, visit families and communities, especially women, the elderly, and children affected, and ensure their well-being. They have proven it through their multifaceted efforts during and after Kerala's 2018 and 2019 floods. During the 2018 and 2019 floods, some Kudumbashree members were trained to provide psychosocial care to people with symptoms of withdrawal and isolation after the trauma due to loss incurred in the floods. Also, the community counsellors of Kudumbashree made timely interventions in the flood-affected districts during the 2018 floods. Their primary role was to provide mental health services to different populations and help them recover from the trauma. They visited rehabilitation camps and houses of the affected and provided individual and group counselling. Community counsellors of Kudumbashree offered counselling to 39,444 persons during and after the disaster (Kudumbashree, 2021).

Since Kudumbashree members are not well-trained mental health professionals, their attitude towards psychosocial care, knowledge about psychosocial care and the skills to provide psychosocial care have a significant impact on the quality and effectiveness of the psychosocial care services they provide. Thus, this study aimed to identify Kudumbashree members' attitudes towards, knowledge about, and skills to provide psychosocial care for the disaster affected.

2. Materials and Methods

2.1. Objectives

1. To identify the nature and extent of Kudumbashree members' attitude towards

knowledge about and skills to provide psychosocial care to disaster-affected individuals and communities.

2. To find out whether trained and untrained Kudumbashree members differ in their attitude towards, attitude towards knowledge about and skills to provide psychosocial care to disaster-affected.

2.2. Hypotheses

1. Kudumbashree members will have a favourable attitude towards the psychosocial care of the disaster affected.
2. Kudumbashree members will have a high level of knowledge about the psychosocial care of the disaster affected.
3. Kudumbashree members will be highly skilled in providing psychosocial care to the disaster affected.
4. There will be no significant difference in the attitude of trained and untrained Kudumbashree members towards the psychosocial care of the disaster affected.
5. There will be no significant difference in the knowledge of trained and untrained Kudumbashree members' knowledge about psychosocial care of the disaster affected.
6. There will be no significant difference in the skills of trained and untrained Kudumbashree members to provide psychosocial care to the disaster affected.

3. Research Design

Since the study investigated the Kudumbashree members' attitude towards, knowledge about and skills to provide psychosocial care to the disaster affected, a descriptive cross-sectional design is chosen as the research design.

3.1. Sample

449 Kudumbashree members with an average age of 41, randomly selected through multistage sampling, from 60 panchayats of the five flood-affected districts of Kerala: Pathanamthitta, Alappuzha, Kottayam, Idukki and Ernakulam, constituted the sample

of the study. Out of the 449 respondents, 86 got basic psychosocial care training, 277 were affected by a disaster, and 204 stayed in a relief camp due to a disaster. Randomly selected 600 Kudumbashree members were approached for data collection, out of which 498 responded proactively (response rate is 0.83) and gave their consent to participate in the study. Among the 498 respondents, 49 were removed because of incomplete data, incomplete responses to the items in the survey instrument, multiple answers to the items and lack of reliability of responses.

3.2. Method of Data Collection

Since the study aimed to identify the nature and extent of attitude, knowledge and skills of the Kudumbashree members about the psychosocial care of the disaster affected, an offline in-person face-to-face survey method was used to collect data.

3.2.1. Instruments for Data Collection

This study employed a specially developed survey instrument to collect data from the respondents about their attitude toward, knowledge about and skills for the psychosocial care of the disaster affected. The survey instrument has five parts: Part-I to elicit socio-demographic details of the respondents; Part-II to understand the respondent's experience and exposure to various aspects of disasters and psychosocial care; Part –III to identify the attitude of the respondent towards the psychosocial care of the disaster affected; Part-IV to understand the respondent's knowledge about psychosocial care and Part-V to identify the skills of the respondent to provide psychosocial care.

3.2.2. The Procedure of Data Collection

During their visit to the selected Panchayats, the investigator met the Chairpersons of the Kudumbashree Community Development Society (CDS) to get the details of the Area Development Society (ADS) and Neighbourhood Groups (NHGs). After randomly selecting the ADS and NHGs in the panchayats, the field investigator directly met the members of the ADS and NHGs after taking prior appointments. Usually, the NHGs have regular meetings on Saturdays and Sundays. The field investigator approached the NHG during their weekly meeting, explained the details of the investigation, and answered their queries. Once they had given their consent to participate in the study, the survey instrument was given to them, and after completion, it was collected back.

During the monthly meeting of the ADS, with a prior appointment, the field investigator met them and explained the details of the study. After obtaining the consent, data were collected from them.

4. Results

Table 1 : Kudumbashree Members' Attitude Towards, Knowledge about and Skills to Provide Psychosocial Support to the Disaster Affected

Variable	n	M	SD	Nature of Attitude/ Knowledge/Skill
Attitude	449	55.03	10.10	Favourable
Knowledge	449	13.12	2.39	Average
Skills	449	69.87	13.31	High

Attitude scale: Less than 28-Highly Unfavourable; 28-45 – Unfavourable; 46-54 – 55-72 –Favourable; More than 72- Highly Favourable

Knowledge scale: Below 9 – Poor; 9-14- Average; above 14- Good

Skills scale: Less than 28-Very Low; 28-45 – Low; 46-54 – Average; 55-72 – High; More than 72-Very High

Table 2 : The difference in Attitude, Knowledge and Skills of Trained and Untrained Kudumbashree Members to Provide Psychosocial Care

Variable	Trained	N	Mean	SD	df	t
Attitude	No	363	54.67	9.83	447	1.51
	Yes	86	56.50	11.09		
Knowledge	No	363	13.17	2.40	447	0.97
	Yes	86	12.90	2.38		
Skills	No	363	68.93	13.58	447	3.09**
	Yes	86	73.83	11.33		

** Significant at 0.01 level

5. Discussion

One of the major findings of the study was that the overall attitude of the Kudumbashree members towards psychosocial care of the disaster affected is favourable. This may be due to their general humanitarian concern, increased awareness about PSC, more exposure to print and visual media, their own experiences during a disaster and/or the training they received as part of their routine job. This is a promising finding since a favourable attitude of the Kudumbashree members is important in providing PSC during and after a disaster. Since they have a favourable attitude, it is expected that they will show interest in various activities related to the PSC, and they may have a genuine interest and involvement in getting trained for the PSC of the disaster-affected. In general, all these may contribute to the enhancement of the quality of the PSC provided by the Kudumbashree members and thereby increase its effectiveness. Moreover, the availability of Kudumbashree members with a favourable attitude may help the local authorities to create a well-equipped team who can respond rapidly in case of an unfortunate event of a disaster. Furthermore, this will make the community more resilient.

It was also found that Kudumbashree members have only an average level of knowledge about the PSC of the disaster affected. This suggests the need for further knowledge enhancement programmes, maybe in the form of workshops or other forms of training. This also reveals that some lacuna exists in the awareness and knowledge-imparting programmes. More detailed and in-depth investigations are required to identify the reasons behind this. The effectiveness of the training provided to the Kudumbashree members must be investigated thoroughly.

Another important finding of the study was that Kudumbashree members are highly skilled in providing psychosocial care. This is yet another positive finding in terms of PSC. Usually, most training programmes related to PSC focus on imparting skills to the trainees. Here the Kudumbashree members reported that they possess a high level of skills to provide PSC. Since the Kudumbashree members are from the same community and know the culture, language, and local dialect, and have a very good connection with individuals and families in that community, they may have better skills to provide PSC. The fact that even without undergoing any of the training programmes related to PSC, many of the respondents reported being highly skilled, is something noteworthy. Almost all of the Kudumbashree members are, in one way or another, engaged in providing services to the people of their community. This might have helped the Kudumbashree members to develop effective skills to provide PSC. However, this finding has to be considered carefully. Kudumbashree members' responses to the skill subtest might be biased by their inaccurate perception of their own ability. Sometimes the tendency to project oneself as good in front of others (social desirability) may play in an unconscious level and alter our subjective evaluations and judgement. Further exploration by experts is required to cross-validate this finding.

Findings illustrate that there is no significant difference in the attitude and knowledge of Kudumbashree members who have got training in PSC and those who have not undergone any training in PSC. However, there is a significant difference in the skills to provide PSC. The trained group have a better skill set than the untrained group. Absence of significant difference in the attitude and knowledge of those who have undergone training and those who have not undergone training questions the effectiveness of the PSC training they have undergone. This finding is an eye-opener as it points out that mere conduction of the training programmes in PSC is not enough; assessing its efficacy is also important.

5.1. Implications

Government and other agencies conducting training in PSC may consider the findings of the study to take necessary steps to revise and modify the existing training programmes to enhance their effectiveness, develop a sophisticated assessment plan to assess the effectiveness of the training programme, and modify the modality of conducting the training. Also, the training module has to give due importance to the attitude and knowledge parts along with the skill-related aspects. It is better to complete the training programmes of PSC in homogeneous groups of optimum numbers. This may facilitate more involvement and interaction of the participants during and after the programmes. Also, after the training, networks of groups can be formed with a mentor in the group so that it will act as a discussion forum where members can clarify their doubts. The group may also serve as a platform for sharing updated and new information related to psychosocial care. This could further make it easy to coordinate the functioning of the Kudumbashree members during a crisis.

6. Conclusion

This study was one of its kind to identify the attitude, knowledge and skills to provide effective psychosocial care for the disaster affected. The findings underline the importance of developing community-based trained teams to provide psychosocial care during a disaster. Also, the findings indicate the need to reframe the existing training programmes in psychosocial care for the disaster affected by the inclusion of attitude and knowledge components. In addition, the findings indicate the need to develop effective assessment strategies to evaluate the training programmes for the psychosocial care of the disaster affected.

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The Role of NGO in Disaster Management-
A Case Study of Young Mizo Association, Mizoram

Lalremruati[1] and Dr. Laldinpuia[2]

Abstract

The NGOs' contribution to Disaster Management and their significant roles have been observed and experienced globally. Meanwhile, there are substantial variations in the strategies adopted and implemented due to the diversity in socio-economic conditions, cultural practices, and indigenous knowledge of a society. A study was carried out to identify the roles rendered by the Young Mizo Association during different phases of Disaster Management, i.e., pre-, during- and post-disaster. Data were collected from Primary and Secondary sources, and interviews were conducted among leaders of the Association. The Young Mizo Association (YMA) is the largest Non- Governmental Organization in Mizoram, established in 1935. YMA has been the hand and foot of the Mizo people ever since its establishment. YMA, a Non- Governmental Organization, is constituted for the Mizos and the state of Mizoram. It acts as a model discipline keeper and stands as a pillar that society cannot do without at times of adversity. Administered by the 'Central YMA' at the Centre, a separate Committee- 'Central YMA Disaster Management sub-committee was set up to deal with an event of a catastrophe in the state. Collaboration with the Government and other agencies often organized disaster mitigation and preventive measures like awareness campaigns, training, mock drills, etc. CYMA Disaster Response Team was constituted under the Central YMA Executive Committee, where the team members were selectively trained by experts in which emphasis was laid upon 'Search and Rescue Training.' The team has provided a handful of equipment, mainly acquired from a donation made by the Government and private sector. Hard times such as the

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pandemic have also proved the immense importance of the organization. Members of YMA volunteer in the Local/ Village Task Force, risking their safety day and night and feeding those without food due to the absence of daily income, providing medical and personal needs to those kept in isolation.

Keywords: *Mizo, Young Mizo Association (YMA), Disaster Management*

1. Introduction

Management strategies for disasters vary across the globe. The recurrence time interval of a catastrophe, the potentiality of risk, its magnitude, or the degree of vulnerability of the population dictates the diverse approach toward disaster risk reduction. Therefore, the roles of various stakeholders in disaster management also differ subsequently. The voluntary humanitarian services rendered by Non- governmental organizations (NGOs) in hard- times emerge as one of the most significant measures of disaster management. The inclusion of community-based disaster management portrayed its immense importance in achieving a comprehensive approach. The NGOs, primarily decentralized organizations boundless by strict regulations and their state of proximity to the local community, could cost-efficiently implement timely actions in an emergency (Behera, 2002). The quality of activities out of voluntarism is appreciably welcoming, especially during hard- times. The NGO rendering such quality and continued being the first responder to disaster became an integral part of the concept of Disaster management.

In the situation of a drastic increase in disaster cases and their impacts globally, it has become possible for the government to operate and drive the needs management process with the contributions of NGOs (Park & Yoon, 2022). The linkages NGOs could build with the government with the varied multi- specialty they possess, encompassing every individual aid and relived for the public sector. The chief role of NGOs towards disaster risk reduction is to perform timely actions effectively and efficiently in pre, during, and post-disaster phases. Focuses were laid on minimizing the impact and enhancing quick recovery by aiding the government and other agencies with the same visions. The services and assistances rendered by different NGOs vary according to the stipulated focus, mission, and targets (Coppola, 2021). Community-based disaster management has emerged as the primary objective of NGOs supported and supplemented by various international organizations in building resilient communities. However, those external agencies usually have a time and financial bond in their project for a specific region. It is, therefore, a pre-requisite for the NGOs to involve the participation of local people in decision-making and strategies adopted for their development and risk reduction. (Kafle &Murshed, 2006).

A natural disaster event's impending or actual occurrence has neither favouritism nor preference. No place can be declared risk-free; instead, every area is prone to one or multiple types of disaster. Consequently, no man's states or positions inevitably determine one's safety in a disaster and like situations. Therefore, profound disaster management strategies reaching every level of society are the need of the hour.

Disaster Management (DM), as mentioned in DM Act 2005, obliges a cross-sectoral public-private collaboration. It can draw sensible disaster management procedures from the outcome of interchange ideas and experience between government and NGOs. It is also crucial for both parties to frequently train as many abled persons encompassing every corner of society. NGOs' flexibility and everyday actions can adversely create a wrongful act, intensifying the impact of a disaster on both victims and novice volunteers (Zubir et al., 2011). The NGO must synergize the government program and initiatives toward disaster management (NDMA, 2010). GO- NGO could build disaster resilience by incorporating community-based Disaster Management awareness and training in government developmental programs.

2. Young Mizo Association

The Young Mizo Association, renowned by its acronym YMA is the largest Non-Governmental Organization in the state of Mizoram in India. YMA is registered under the Societies Registration Act (XII of 1860), founded on 15th June 1935. It is a voluntary, non-profit-making, and secular organization administered and functions without any indulgence of politics. Administered by the Central Young Mizo Association (CYMA) at the centre, the headquarters is located in the capital city- Aizawl. There are 8 sub-headquarters, mainly in district headquarters, 50 groups, and 811 branches (CYMA Statistic 2022). As per their convenience, the YMA branch usually segments its branch into different sections to strengthen it (Fig. 1).

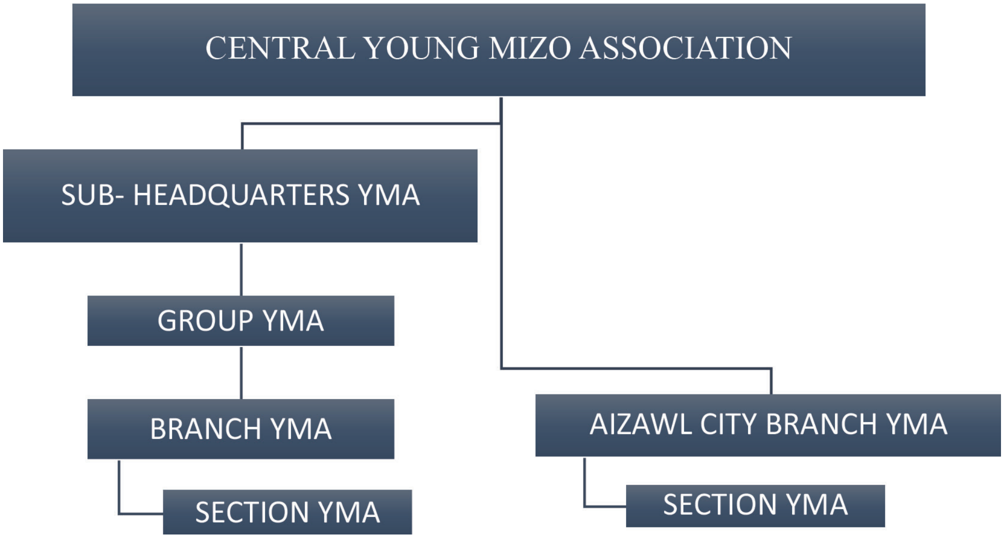

Figure 1 : Organizational Structure of Young Mizo Association

An individual with a Mizo identity, attaining the age of 14 years, is eligible to become a member of the Young Mizo Association. Sometimes, it becomes a matter of course or formality for the Mizos to enrol in the association. Owing to that, it holds many members within and outside Mizoram, which subsequently consolidate the strength of YMA. The members enrolled numbered over 4.4 lakh in 2022, wherein the male comprises 2.6 lakh members while the female member accounts for more than 1.8 lakh.

Act following the three aims and objectives, i.e., i) Effective utilization of leisure, ii) Developing the way progress for the Mizos, and iii) Admiration of Christian ethics, it becomes the hand and foot for the Mizo society (Vanlallawma, C., 1998). Since its inception, YMA has engaged in humanitarian actions, assisting the poor and alleviating those in need from difficult circumstances (Singh, 2017). They often act as a watchdog for society by conserving and enhancing the cultural and traditional practices of the Mizo tribe. It is an NGO that society heavily relies on, especially in times of woes and other adversity, like a disaster (Malsawmliana, 2019). The convention of YMA in times of grave occurrence among the Mizo society is a unique yet significant feature of the association. To aid and accommodate the dead relatives, the YMA made all arrangements.

From digging the grave to burying the dead body, it followed up by gathering, aiming to console the dead relatives. The sound practices rendered by YMA to flatten the curve of the society emerged from the quality of altruism, which is named- ‘Tlawmngaihna’ in the local language; that is claimed to be an instinct among every inner core of the Mizos.

3. Methodology

This study was conducted to understand the services extended by the Young Mizo Association towards Disaster Management in Mizoram.

The present study adopted a qualitative Descriptive Research design to carry out the research. Data are collected from both Primary and secondary data. Studies are based on analysis of activities record files of YMA. Interviews conducted and observations also form the central part of the study. Data were analysed using the thematic inductive analysis technique. The measures and activities of YMA for Disaster Management are categorized into three themes- Pre, during, and Post Disaster phase. The complexities in nature of activities are broadly classified into 5 segments. The yearly program organized from 2006-2020 was evaluated and merged every three consecutive years into one group which was then interpreted using the Frequency polygon.

4. Administrativemechanism of Young Mizo Association- Towards Disaster Management

Because of building a holistic approach for the advancement of Mizo society and the state of Mizoram, the Young Mizo Association has forward enormous initiatives. In accordance with society, the Central Young Mizo Association needs to establish Sub-Committees to facilitate and implement different developmental aspects. The CYMA Disaster Management Sub-Committee is formed to deal with matters relating to disasters and the management thereof. Meanwhile, a committee to precisely manage the relief measures- ‘CYMA Relief Committee’ was formed in 2017 by the Executive Committee of CYMA. Forging ahead, the CYMA Disaster Management Sub- Committee constantly strives to build community-based disaster management, synergizing the local community through its groups and branches of YMA across the state (Fig. 2). With the consent of Central YMA, the CYMA Disaster Management Sub- Committee formulate CYMA Disaster Response Force in 15th January 2016. The force with strength of appointed 20 male members from different branch came into function from 1st October 2016. To enhance co-operation and to link every corner, the YMA Groups and Branch were advice and consent to formulate Disaster Management Sub- Committee in each respective coverage area.

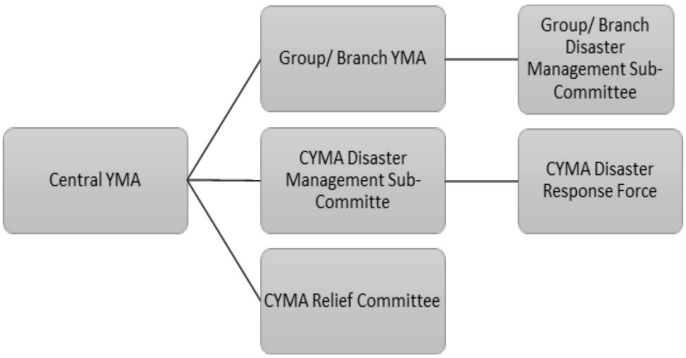

Figure 2 : Disaster Management Mechanism of Central Young Mizo Association

5. Role of YMA in Pre- Disaster Phase

The incorporation of local people in Disaster risk reduction strategies facilitates the

Figure 3 : Nature and Amount of Activities Organised by YMA

process of policymaking and implementation (Azad et al. 2020). Mainstreaming the community-based Disaster awareness, the CYMA, through the encouragement of the CYMA DM Sub- committee strives to build a disaster-resilient community by adopting pro- active mitigation strategies.

5.1 Disaster Management Training

Basic DM Training for volunteers was frequently conducted mainly for members representing each branch YMA (Fig. 4). The group/ branch representative trainees of 'YMA Trainer's Training' was expected and projected to further propagate the gained knowledge and expertise to the community in their respective localities. The devoted 'CYMA Disaster Response Force' was persistently strengthened and reinforced to respond promptly to an emergency through 'Training on Disaster Response' and 'Equipment Operator Training' (Fig. 5). Instructors and trainers were meant from the 'National Disaster Response Force' (NDRF), 'State Disaster Response Force' (SDRF), professionals from government agencies and academic institutions, medical practitioners, and experts from the association simultaneously.

Figure 4 : Disaster Management Training Branch YMA Members

Figure 5 : Training of CYMA Disaster Response Force

5.2 Community Disaster Awareness Campaign

Imparting and extending disaster awareness to the local community emerged as the priority of the CYMA approach to disaster management (Fig 3). They mainly organised community awareness campaigns in the different local branches through a collaboration of several outside agencies (Fig. 6). The 'State Disaster Management Authority' (SDMA), Mizoram, and 'Department of Disaster Management and Rehabilitation' (DM&R), Govt. of Mizoram were the persistent partners from which resources person are mostly arranged. However, the group or branch YMA has also organised campaigns in their respective localities. Trainees from the activities mentioned above played a significant role in this aspect.

Figure 6 : Community-Based Disaster Awareness Programme

5.3 Mock Drills

YMA members supplement the Government initiatives by primarily engaging themselves in multi-hazard mock drills (Fig. 7). As per the request and invitation; CYMA has dispatched the 'CYMA DM Response Force' to exercise the crucial role of a prompt response. Mock drills are one of the most vital exercises by the CYMA to identify the room for improvement and examine the strength and effectiveness of the force. As more players could be attained through YMA, the members of a particular incident area are usually the leading player, thereby enormously contributing to the success of the drills.

Figure 7 : Mock Drill in Aizawl

5.4 Information dissemination

Acknowledge the vulnerability of Mizoram to several types of disaster, and the CYMA circulates a notice to their branch when a potential threat is felt in critical times. The leaders of branch YMA are requested to enquire about the community's safety and direct the CYMA if any assistance is sought. One of their kind services is during impending flood situations; members volunteer all day and night, keeping an eye on the level and velocity of rising water to execute timely actions, alert warnings, and proclaim evacuation for vulnerable community segments.

6. Role of YMA During Disaster Event

Stretching across the state, the presence of YMA in every corner results in being a first responder in an emergency. The role of NGOs during a disaster is to have a quick response and save as many lives as possible (Mondal et al., 2015). The immediate search and rescue operation heavily relies on the hands of YMA, especially in remote areas where outsourced assistants hardly set foot. Per the CYMA's advice and request, some branch YMA set up a special committee on DM and disaster response force in their respective localities. 'CYMA Disaster Response Force' is mandated to deal with disasters and perform quick responses. They were also made available in situations where a local

The significance of YMA has been experienced mainly in hard- times like the COVID pandemic. Many Mizo youths volunteer through YMA performing humanitarian actions to benefit less privileged sections of the community (Harikrishnan & Sailo, 2020). During the lockdown, the daily wagers in Mizoram were severely affected, where starvations are at an alarming rate. YMA has extended its services during the lockdown, feeding those without food and supplies for medical and personal needs to those in isolation.

Figure 8 : Provision of Food During COVID Lockdown

6.1 Resources Available for Search and Rescue operation

CYMA has various resources for prompt and effective response to a disaster. The equipment's primary sources are donations made by government agents and through several generous assistances (Fig. 9 & 10; Table 1). The property of CYMA was made available to be utilized by every branch on request. CYMA Resource Sub-Committee and CYMA Property Sub-Committee were established to manage and register the property in and out movement. However, the equipment for Search and Rescue was administered mainly by the 'CYMA Disaster Management Sub-Committee' and 'CYMA DM Response Force.'

Figure 9 : Search and Rescue Equipment of YMA

Figure 10 : Morgue Van Donated by DM&R, Govt. of Mizoram

Table-1 : List of Equipment Issued to CYMA by Department of Disaster Management & Rehabilitation, Govt. of Mizoram

Sl.No	Name of equipment/ Product	Quantity
1	Morgue Van	1
2	Bolero Camper	1
3	Harness	4
4	Screw Carabineer	10
5	Oval Lock Carabineer	5
6	Descender	3
7	Jumar Pair	4
8	Mitten Pair	10
9	Tape Sling (150 cms)	6
10	Double pulley	4
11	Rescue Pulley	4
12	Tandem pulley	4
13	Paw	3
14	Safety Helmet	20
15	Imported Rope 10mm	100mt
16	Imported Rope 8mm (for sling)	50mt
17	Indian Rope (12mm)	200mt
18	Indian Rope (10mm)	100mt
19	Four fold Stretcher	1
20	Rain coat	30
21	Pelican Search Light (Model: 94 10L)	1
22	Ground sheet	5

6.1.1 The Notable Innovation- HRUAITLUANG HLANG (STRETCHER)

The hilly terrain and steep slopes of Mizoram often retarded the execution of Disaster Response Force. It was a major continuous challenge for the 'CYMA Disaster Response Force' to save an injured person's life when rescue are operated in a steep slope (Lalhruaitluanga, personal communication, 10th October 2021).

Mr. Lalhruaitluanga, Central Executive Committee Member, in charge for ‘CYMA DM Response Force’ and former chairman of ‘CYMA DM Sub- Committee,’ painstakingly searched for a solution to numerous obstacles faced during ‘Search and Rescue’ operation. He has successfully innovated a stretcher specifically designed to meet the obstructions. The stretcher called ‘Hruaitluang Hlang’ was donated to CYMA, named after the innovator (Fig. 11).

Figure 11 : Interior and Exterior Structure of 'Hruaitluang Hlang'

Figure 12 : Delivery of Casualty Using' Hruaitlang Hlang'

It is a metal-enclosed stretcher with bedding and a tied belt. Holes were stripped at the cover to maintain ease of respiration and engaged communication between the rescuer and the rescue. A first-aid box is also installed inside the stretcher.

On 27th August 2021, in response to the call for assistance from Chawlhhmun local Branch YMA, a severe casualty from an accident on the narrow and rocky steep slope of Chawlhhmun, Aizawl was effectively delivered and rescued with 'Hruaitluang Hlang' by CYMA Disaster Response Force (Fig. 12).

7. Role of YMA In Post- Disaster

It is a traditional and cultural practice for the Mizo people to aid and console the victims of any crisis, which validly matches the essence and entity of YMA activities after a disaster. The services rendered by YMA after the event of a disaster can be broadly categorized into Relief and Reconstruction.

7.1 Relief

Immediate relief is a prime necessity for the affected community or individual in the aftermath of a disaster. It is essential to limit the relief provided according to their needs (Kumaran & Torris, 2011). It is always a desire of YMA to offer and arrange the needs of the victims. Sometimes, people entirely or partially lose their house out of fire, landslide, flood, etc. In such circumstances, YMA extended its actions by arranging temporary shelters, provisions of food and water, and supply requirements for those in need.

Relief in terms of money, mainly from society's donation, were collected by YMA. In case of a severe and comprehensive destructive disaster, the CYMA sought donations to relief funds through its branch across the state. 'Central YMA Disaster Relief Committee' was formed on 19th June 2019 to inquire about and examine the disaster's intensity. They are responsible for fixing, arranging, and division of the provision of the relief fund. Reports are submitted to CYMA if a case of bribery or corruption is felt. If CYMA, after thorough investigations found correct, the responsible group or branch will be dissolved and charged to reimburse the same amount.

7.2 Reconstruction

YMA often reconstructed damaged houses for homeless victims, preventing population displacement. These kinds of assistance and services are performed through voluntary communal labour by members of YMA.

8. Frequency of Activities Performance

The period of 2015- 2017 has been the most active year. The high frequency was because the 'Awareness Campaign for DM' was organized for Branches of 4 YMA Groups and all Branches of Aizawl City in 2015. In contrast, the COVID lockdown resulted in fewer activities during 2018-2020 (Fig. 13).

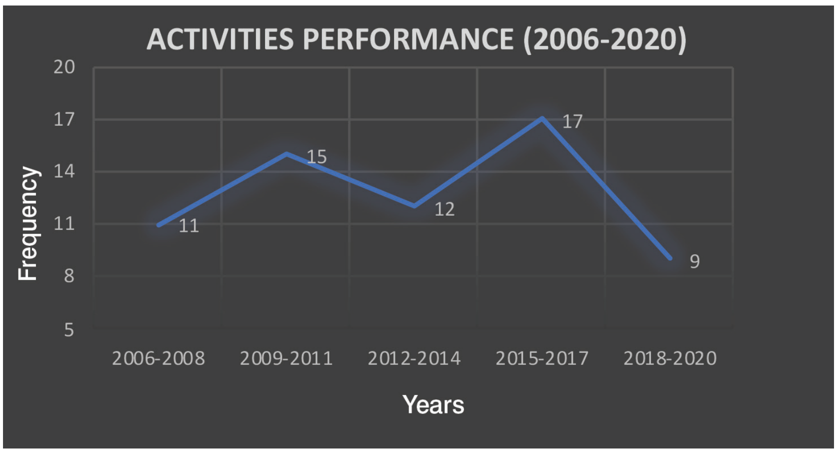

Figure 13 : Overview of DM Activities Performed by YMA

9. Conclusion

The NGO where many communities are engaged could be the best option and target to mainstream 'Community-based disaster risk reduction program' (Fitzpatrick & Molloy, 2014). This case study has highlighted the contributions and capacity of 'Young Mizo Association' toward Disaster Management.

YMA has the potential and capabilities to amplify its role in disaster management. With due respect to the so-far performance proceed, suggestions are made because of the progression and development of YMA. In today's busy world, organizing social gatherings for awareness campaigns is hardly attended by many. But, YMA is still fortunate enough to assemble its members through a regular practice of communal labour, gathering at times to console death's family, etc. Incorporating a brief disaster awareness session in between speeches in such an assembly would be effective. In addition to the current 'CYMA DM Response Force,' it would be enormously beneficial for the far-flung community if the same could be initiated at least in each sub-headquarters. Damage and impact records are crucial in vulnerability assessment; updating the data files and documents is also suggested.

However, the 'Young Mizo Association' towards Disaster Management is admirable. The members of YMA pouring the quality of altruism are found to be the driving factor of CYMA striving towards managing and reducing disaster risk in Mizoram. The multi-sectoral approach of YMA, complementing and supplementing the government policy through initiatives and implementation, is satisfying.

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