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ESTIMATION OF FLOOD VULNERABILITY BY DEA: A CASE STUDY OF NARMADA RIVER

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Abstract

The aim of this study is to analyze the situation, the background, the factors, risk circumstances, the magnitude and consequences of the flood, to record the danger and vulnerability, as well as the community's numerous implications; to analyze local awareness, traditions, and beliefs; and to develop community-based flood mitigation and disaster prevention strategies. The development of right flood control strategies necessitates a thorough understanding of the risk mechanism. Several interventions can be used at the catchments, drains, and floodplains under socioeconomic and environmental restrictions. The present study is conducted to assess the flood vulnerability of all the 22 districts in the Narmada river basin of India. This report will explore flood mitigation and prevention strategies. To proceed with a risk-based flood management strategy, its essential understand the floodplain's risk features first and afterwards identify the major element to reduce the risk.

Keywords: Vulnerability, Narmada River, DEA, Disaster, hazards.

1. Introduction

In developing countries, the negative effects of natural disasters as well as climate change are observed on the livelihoods risk of people living in such regions or countries. As the intensity increases of such

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events, it create hurdle in the strain of poverty reduction strategies. Throughout this framework, it's extremely important to keep in mind that natural disasters have the ability to derail several development programmes directed at accomplishing sustainable growth in the country, as certain areas are more prone to natural hazards than others. As in India, major section of the society is engaged in agricultural sector which mainly depends on natural rainfall. Due to high intensity of natural disasters as well as due to increase in climate change, the intensity of natural disasters has been increased such as cyclones, floods and droughts; additionally there is a shift in rainfall pattern also. In developing countries, such disasters are creating major problems such as poverty and economic inequalities.

The present study focuses on various risks faced by different households who are living in flood affected areas of rural India and it also examines the effectiveness of coping mechanisms which are adopted by the people to help themselves against the risk of such disasters. The relationship between different household specific characteristics has been made through an attempt such as age of head of the family, availability of social network, economic status as well as special coping strategy

1.1. Disaster

United Nations defined disaster as "the occurrence of sudden or major misfortune, which disrupts the basic fabric and normal functioning of the society and community" in 2012.

Indian Government defined disaster as an incident or sequence of events which can make damages, losses of life, properties, livelihood or infrastructure which is more than the normal capacity of the affected community to manage with.

Table 1: World Disaster Events

S.No.	Disaster	Year	Country	No. of People Affected
1	Floods	1931	China	35,00,000
2	Floods	1954	China	40,000
3	Cyclone	1970	Bangladesh	3,00,000
4	Cyclone	1991	Bangladesh	1,39,000
5	Earthquake	1999	Turkey	17,000
6	Tsunami	2004	Indonesia, Srilanka, India, Malaysia, Somalia, Bangladesh and Thailand	2,30,210
7	Hurricane, Katrina	2005	USA	1,836
8	Earthquake	2008	Susichuan, China	87,476
9	Cyclone, Nargis	2008	Myanmar	1,38,000
10	Earthquake	2010	Haiti	3,16,000

Source: CRED – 2013

Ecological imbalances as well as climatic changes are the reason in recent years for the frequent disastrous events such as flood at the world level. It becomes important to comprehend this disaster at every single level.

1.2. Why Flood in Narmada?

According to "State Disaster Management Authority of Madhya Pradesh, 2005", Madhya Pradesh has been divided into 10 different river basins. The names of the river basins of Madhya Pradesh are: Chambal, Sindh, Tapti, Mahi, Betwa, Son, Ken, Wainganga, Tons and Narmada. These river basins are shown in the figure given below:

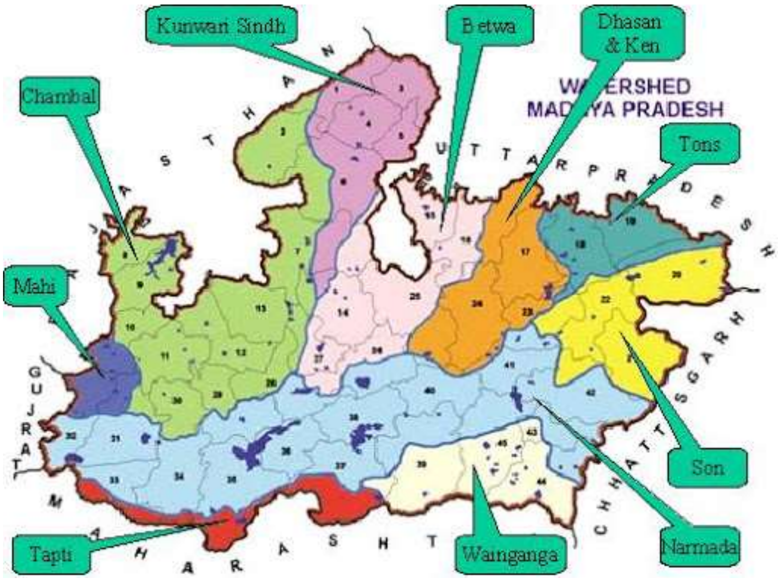

Figure 1: River basins of Madhya Pradesh (2005)
Source: - MPWRD

The challenges caused by rapidly increasing cities' susceptibility to urban flooding rise with susceptibility as the rate at which urban areas develop raises the susceptibility, resulting in a decrease in water penetration and infiltration into the earth. Due to deficiency of management and amalgamation among institutions which are answerable for managing the city, run-off water and solid waste management is aggravated because of the unplanned urbanization and solid waste management by the urban people. For urban planners, urban flooding is now becoming a challenge for making cities stronger to urban floods. Through several planning strategies for the urban development, it is important to address the emerging issues of urban flooding. It is important to understand different features and also to measure the susceptibility of urban areas because of unrealized as well as unplanned development. (Ouma & Tateishi, 2014)

1.3. Why DEA is used in this research?

DEA technique is used for making a model by taking different approaches into consideration to make the improvements upon traditional methods due to DEA approach which do not need any determining weight parameters. The performances of various entities engaged in various activities are evaluated by using DEA modelling which includes education, banks, healthcare, manufacturing and management (Anderson et. al, 2002). But it was also observed that only few studies are performed in the area of DEA field of natural disasters.

DEA model is considered as an excellent and easy used methodology according to the researchers for modelling of operational processes for the performance evaluations on the basis of concept of relative efficiency. The properties of connections inside the regional natural disaster system are considered as the disaster losses which include hazards, exposure units and disaster formative environment. The human society is threatened by hazards which are considered as the physical processes of the earth. The physical environment which reduces the effects of hazards is considered as “disaster formative environment” which includes elevation, vegetation, soil and slopes. All type of human activities is included in exposure units.

When people live along a river with a very low elevation, flood becomes a threat and more dangerous, which can be seen as the behaviour of "disaster formative climate. "Danger and disaster formative environment are the only related conditions for disaster risk since hazard is directly related to individual socioeconomic behaviour. The vulnerable locale will suffer loss only when the human activities & structures are the constitute components. In regional human activities, this variable vulnerability is a unseen distinctive which simply reflects the difference strictness of the disaster loss sustained by various areas under the same “natural hazards scenario”.

However, disaster situations are compared with the reflections of same disasters amid different 3-D and time domains. Moreover, the prejudice of comprehensive flood index is overcome by the method by utilizing the prior weighting system which happens in disaster vulnerability approximation of current disasters.

1.4. Objective

- To evaluate the flood vulnerability of the districts in the Narmada river basin
- On the basis of vulnerability index value, the priority level of the districts is determined.
- For policy makers, a scientific approach is provided with the implementation of flood anticipation and mitigation technique.
- The applications of mathematical model are also provided for disaster management issues.

2. LITERATURE REVIEW

Numbers of studies are performed to study the vulnerability of flood disaster. Vulnerability of different regions must be analyzed and different periods are also required for enabling the government to make policies for the distribution of relief funds as well as to help the regions so that they can enhance their capabilities against disasters. For the evaluation of Vulnerability, physical or economic-ecological perspective is needed on the basis of the researchers' concern as per (Li et al., 2013). However, vulnerability is considered as the base for both systems as it involves detailed description of disaster management as well as flood severities. The over-all flood system has been decomposed into several factors which are as follows: disaster environment, disaster driver, disaster bearer as well as disaster intensity. Some factors are mentioned here which are used for demonstrating the flood disaster components such as disaster drivers risk levels, disaster environment stability levels as well as disasters bearer sensitivities.

Charnes, Cooper and Rhodes were the first people who together introduced data Envelopment analysis in 1978 (Kuah et al., 2010). DEA are in wider research as they are used in various fields and domains. Some of the applications are: information technology, agricultural industry, education, power plants, supply chain, stock market, computer industries, sports, banking industry, etc. Moreover, this study also presents the current research trends. On the other hand, various research trends in the field of DEA are also mentioned by (Kamat, 2019). Some of his works are: network DEA model, applications of DEA, fuzzy DEA models and stochastic DEA models. These can be used in future research.

(Huang et.al., 2008) used images of AVHRR 1991, MODIS 2003, and 2007 were used to generate water-inundated region maps, which were then used to estimate the 20-year frequency of water logging by overlaying the maps. A pixel's weight was determined by the frequency of water logging. Every nation and city was ranked according to the weighted score of the area and frequency of water logging danger.

(Purba et.al., 2002) argued in their study that using photos from remote sensing, it is possible to determine how many regions have been damaged by flooding. Before and during the flood, they generated the data using near real-time satellite pictures. Using data from both the pre-flood and during the flood, a flood map was created.

According to the study conducted by (Shi et. al, 2003), water logging was considered as the most serious hazards. The main groups of society were greatly affected by this disaster. A method of scenario simulation had been introduced by the author who is mainly used as a base. Then on the basis of concept structure of vulnerability, for the development of an indicator system representative indicators were selected on the basis of objective weights derived from the Principle Component Analysis. Population vulnerability assessment was performed by using this method which is based on the scenario simulation of rainstorm-induced water logging for 50 years. Several degrees of population vulnerability were observed from the final results.

(Huang et al, 2013**)** as there are many methods to assess the vulnerability of flood, the three methods of assessment disaster loss, the vulnerability index system and the vulnerability curve method but he preferred the vulnerability index system-based method.

3. METHODOLOGY

The “flood vulnerability” is described through DEA model. This study is performed on the plain of Narmada River, India for the reduction of negative effects of expected vulnerability. The study is divided into five important sections as shown in the figure given below:

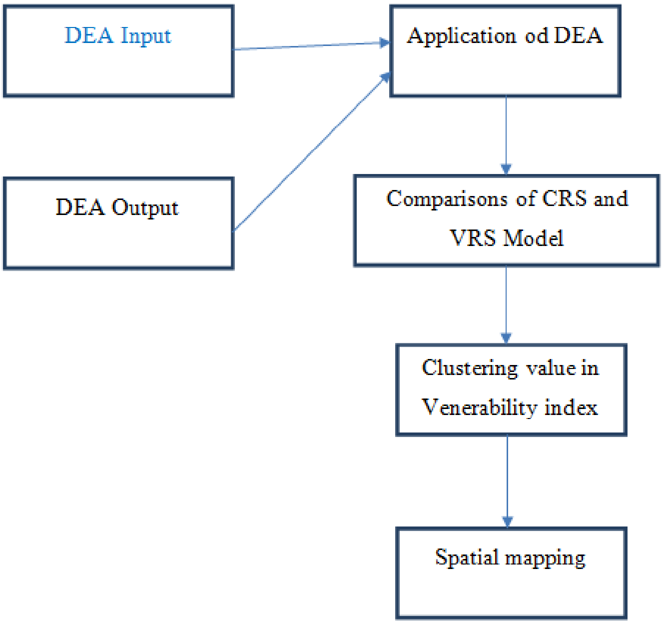

Figure 2: Layout of work

Stage 1

For DMUs, first stage is considered as the determination. Description of the problem, basic evidence about the usability, collection of data, determining tools for the present study as well as determination of the decision-making unit are observed. Evaluation is done through DMUs or decision making units. (Sherman & Zhu, 2006)

Stage 2

The input and output are selected through this second stage. It is considered as the most significant stage because if decision variables are incorrectly selected than incorrect results will be obtained. (Wei et al. 2002) introduced a theoretical framework for flood disaster system which defines flood disaster system as the consequence of comprehensive effect of hazards, vulnerability as well as exposure. Input-output system is the other name given to flood disaster process and efficiency index of the system is used for defining flood vulnerability.

The exposure parameter (Input)is

1. District wise population density per sq. km (2011)
2. District area (sq. km) and
3. The flood frequency since 2005 in that DMU.

The study employs four outputs (disaster loss)

1. No of people affected (2019)
2. Fully damaged kutcha houses (2019)
3. No of animal lost (2019)
4. Total agricultural area of crop loss (in Ha.)2019

Stage 3

This stage considers application of DEA in input-output oriented system and then the flood vulnerability was assessed by scheming efficiency index of different model of DEA. Various DEA models are observed in the literature section. “Constant returns to scale” assumptions are obtained through CCR models and “variable return to scale” assumptions are obtained through BCC models with DMUs demonstrating IRS, CRS as well as DRS.

Stage 4

DEA model construction is the fourth stage in this study. Different models and methods must be applied (CRS and VRS) for the evaluation of its efficiency; results are compared as well as expert’s knowledge must be used to figure out the problem before coming to the conclusion.

Stage 5

Grouping of “decision-making units” is the last stage of this study that is done by the Clustering of the obtained Vulnerability Index Value. DMUs are classified on the basis of model results. On the basis of preferential basis, DMUs are being considered as per the classification.

3.1. Data selection and processing

For the present study, data has been collected from 22 districts of three states from where Narmada flows. Madhya Pradesh, Gujarat and Maharashtra are the three states of India from where Narmada River flows. The table mentioned below provides the detailed information about every district. For example, it provides detail about district wise population density that collected from the data book of Census India 2011, the demographic data area of the district collected from the respective states static book, frequency of flood since 2005 to 2019 collected from the Annexure-1 which is in the data book of SDMA (State Disaster Management Authority) of respective States Head department , people affected due to flood in 2019 in each DMUs of the respective states also collected form collected from the Annexure- 6 which is in the data book of SDMA , the data of animals lost due to flood 2019 from Animal husbandry department from Annexure-4, agricultural loss data having details in the Annexure-3 of SDMA , number of people affected in the flood taken from the Annexure-6 of SDMA and data of fully damaged kutcha houses from the Annexure -5 form of SDMA data book.

Table 2: Data selection

DMUS	district wise population density per sq. km (2011)	district area (sq km)	flood frequence since 2005	no of people affected (2019)	no of animal lost (2019)	total agricultral area of crop loss (in Ha.)2019	fully damaged kutcha houses (2019)
Balaghat	184	9299	3	21798	12	1148	95
Betul	157	10043	11	0	26	185971	15
Bharuch	296	5246	11	4977	30	382800	0
Chhindwara	177	11815	10	3030	112	5217	25
Damoh	173	7306	10	0	5	77277	26
Dewas	223	7020	6	3661	11	165628	0
Dhar	268	8153	10	0	12	35106	7
Hosangbad	185	6710	2	4833	25	47862	13
Indore	841	3896	7	0	1	0	28
Jabalpur	473	5211	10	0	12	0	1
Jhabua	285	3600	4	0	8	479	62
Khandwa	178	8304	1	12787	6	130188	13
Khargone	233	8030	1	0	8	170062	9
Mandla	182	5800	11	2344	43	109	102
Narmada	215	2755	11	9300	21	159200	0
Narsinghpur	213	5133	2	0	27	50299	186
Raisen	157	8466	2	6132	32	84282	102
Sagar	232	10252	2	0	36	163880	51
Sehore	199	6578	1	0	41	135066	8
Seoni	157	8758	2	0	33	1690	115
Shahdol	172	6283	2	0	64	0	0
Vadodara	535	7794	11	5700	43	564043	0

4. RESULTS AND DISCUSSION

The presented work is done on VRS and CRS model. On the basis of input parameters and the output parameters of DEA models the efficiency of both CRS and VRS Models are calculated as mentioned below in table 5.1, and the Scale Efficiencies (SE) score obtained by dividing the efficiency of CRS and VRS (Coelli et al, 2005; Coelli, 1996).
Values of FVI range from 0 to 1. 0 indicates less vulnerability and 1 indicates high vulnerability to flood. there are 15 districts having efficiency 1 indicating the flood Vulnerability High and the district that having FVI less than 1 further classify in two category, Medium and Low Vulnerability. The DMUs having scale efficiency 1 means they working within their optimal size and the DMUs having Scale efficiency less than one or more showing that they are very low or too big from the optimal size.

Table 3: Flood vulnerability index based on efficiency of input-oriented DEA model

DMU No.	**DMU Name**	**Input-oriented**			
		VRS Efficiency	**CRS Efficiency**	**SE**	**RTS**
1	Balaghat	1	1.00000	1.00000	Constant
2	Betul	1	1.00000	1.00000	Constant
3	Bharuch	1	1.00000	1.00000	Constant
4	Chhindwara	1	1.00000	1.00000	Constant
5	Damoh	0.9766	0.48054	0.49700	Increasing
6	Dewas	0.8994	0.65938	0.73310	Increasing
7	Dhar	0.6775	0.18340	0.27070	Increasing
8	Hosangbad	0.9908	0.73922	0.74608	Increasing
9	Indore	0.8612	0.19833	0.15054	Increasing
10	Jabalpur	0.6361	0.22863	0.35942	Increasing
11	Jhabua	1	0.47528	0.47528	Increasing
12	Khandwa	1	1.00000	1.00000	Constant
13	Khargone	1	1.00000	1.00000	Constant
14	Mandla	1	1.00000	1.00000	Constant
15	Narmada	1	1.00000	1.00000	Constant
16	Narsinghpur	1	1.00000	1.00000	Constant
17	Raisen	1	1.00000	1.00000	Constant
18	Sagar	1	1.00000	1.00000	Constant
19	Sehore	1	1.00000	1.00000	Constant
20	Seoni	1	1.00000	1.00000	Constant
21	Shahdol	1	1.00000	1.00000	Constant
22	Vadodara	1	1.00000	1.00000	Constant

Table 4: Flood vulnerability index based on efficiency of output-oriented DEA model

DMU No.	DMU Name	Output-oriented			
		VRS Efficiency	CRS Efficiency	SE	RTS
1	Balaghat	1	1.00000	1.00000	Constant
2	Betul	1	1.00000	1.00000	Constant
3	Bharuch	1	1.00000	1.00000	Constant
4	Chhindwara	1	1.00000	1.00000	Constant
5	Damoh	0.5865	0.48054	0.81930	Increasing
6	Dewas	0.7146	0.65938	0.92270	Increasing
7	Dhar	0.1851	0.18340	0.99080	Decreasing
8	Hosangbad	0.8529	0.73922	0.86671	Increasing
9	Indore	0.3119	0.19833	0.63587	Increasing
10	Jabalpur	0.2375	0.22863	0.83368	Increasing
11	Jhabua	1	0.47528	0.22863	Increasing
12	Khandwa	1	1.00000	1.00000	Constant
13	Khargone	1	1.00000	1.00000	Constant
14	Mandla	1	1.00000	1.00000	Constant
15	Narmada	1	1.00000	1.00000	Constant
16	Narsinghpur	1	1.00000	1.00000	Constant
17	Raisen	1	1.00000	1.00000	Constant
18	Sagar	1	1.00000	1.00000	Constant
19	Sehore	1	1.00000	1.00000	Constant
20	Seoni	1	1.00000	1.00000	Constant
21	Shahdol	1	1.00000	1.00000	Constant
22	Vadodara	1	1.00000	1.00000	Constant

4.1. Clustering of obtained vulnerability index value

Finally, using the K-means method, cluster analysis was performed on the vulnerability indices in order to group the zones based on similarity in their degrees of vulnerability, and the spatial pattern of the various vulnerability levels was mapped. The cluster analysis is performed on the basis of three parameters such as Low, Medium and High vulnerability. And for these parameters, the results are calculated for no. of districts and cluster centres.

Table 5: Cluster Analysis

Cluster	Number of districts	Cluster Centres
High Vulnerability	15	1
Medium Vulnerability	4	0.588605
Low vulnerability	3	0.203453

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There are three clusters taken in the present study which are as follows: C1, C2 and C3. These clusters particularly define the zones of Narmada Basin. The values of clusters C1, C2 and C3 are 1, 0.588605 and 0.203453 respectively.

The cluster centre C1 is 1 in which there are 15 districts (Bharuch, Vadodara, Narmada, Khargone, Khandwa, Betul, Sehore, Raisen, Chhindwara, Sagar, Narsinghpur, Senoi, Balaghat, Mandla, Shahdol) are in the zone of High Vulnerability.

The cluster centre C2 is .588605 in which there are 4 districts (Jhabua, Dewas, Hosangabad, Damoh) are in the zone of Medium Vulnerability having efficiency scores .47528, .8994, .9908 and .9766 respectively.

The cluster Centre C3 is .203453 in which there are 3 districts (Dhar, Indore, Jabalpur) are in the zone of Low Vulnerability having efficiency scores .18340, .19833 and .22863 respectively.

Different districts of Narmada Basin are shown in the figure representing different colours. C1, C2 and C3 are the three clusters which indicates orange, green and purple colour respectively. Orange colour indicates high vulnerability, green colour indicates medium vulnerability and purple colour indicates low vulnerability to flood. 15 districts come in C1, 4 districts come in C2 and 3 districts come in C3 cluster as shown in the figure 5.3. Figure 5.4 shows the names of districts of different clusters in Narmada Basin.

Figure 3: K Means Cluster Map with names of the districts

5. CONCLUSION

Floods have a negative effect on the socio-economic status of livelihoods for people living along the Narmada River, as addressed in different sectors and across sectors. This was clear from the above discussion that floods impact households in various ways. Societies should be encouraged to construct homes made of durable materials and away from flood-prone locations as a method of coping with floods. It is imperative that communities be encouraged to expand the area planted on upland via Extension Services in order to enhance their food security position. Farmer input support programmes for farmers with limited resources but high productivity should be addressed. Clearly, greater and more effective flood-preparation measures are required. As a means of reducing flood hazards, increased attention is being paid to limiting the damage caused by floods. Risk management solutions focused on modifying land use and learning to live with floods are known as "resilience flood risk management" strategies. Even though flood maps are typically seen as static, the conditions shown on them are often dependent on assumptions and events that have already taken place. For example, if a location is experiencing moderate or large flooding in a wet or non-rainy environment, the scenario will alter. As a result, flood maps need to be revised to reflect the current state of affairs.

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