Coupling of GIS-Analytical Hierarchy Process Based Spatial Prediction of Soil Erosion Susceptibility in Keleghai River Basin, India

Project Submitted to Midnapore City College
for the Partial Fulfillment of the Degree of
Master of Arts/Science (Geography)

Submitted by

Sarmistha Maity, Sathi Ghosh, Shilpa Mallik, Shrabani Poria, Shreya Mondal, Sk Atikul Haque,Somnath Maity, Sonali Mandal, Sougata Manna, Soumik Ghosh, Soumyadip Mandal, Pintu Ghosh, Piu Bhunia, Priya Ghosh, Priyanka Jana

Guided by

Nityananda Sar

Department of Biological Sciences
MIDNAPORE CITY COLLEGE
Kuturiya, P.O. Bhadutala,
Paschim Medinipur, Pin-721129
West Bengal, India

2023

Certificate

This is to certify that the project report entitled "**Coupling of GIS-Analytical Hierarchy Process Based Spatial Prediction of Soil Erosion Susceptibility in Keleghai River Basin, India"** submitted by Sarmistha Maity, Sathi Ghosh, Shilpa Mallik, Shrabani Poria, Shreya Mondal, Sk Atikul Haque, Somnath Maity, Sonali Mandal, Sougata Manna, Soumik Ghosh, Soumyadip Mandal, Pintu Ghosh, Piu Bhunia, Priya Ghosh, Priyanka Berato the Midnapore City College, Midnapore, West Bengal, India during the year of 2023 in partial fulfillment for the award of the degree of M.A/M.Sc. in **Geography** is a bona fide record of project work carried out by him/her under my/our supervision. The contents of this report, in full or in parts, have not been submitted to any other Institution or University for the award of any degree**.**

Guide name and Designation

Principal/TIC
MIDNAPORE CITY COLLEGE

Director
MIDNAPORE CITY COLLEGE

Date:
Place: Midnapore City College, Paschim Medinipur

Declaration

I do hereby declare that the present Master thesis entitled '***Coupling of GIS-Analytical Hierarchy Process Based Spatial Prediction of Soil Erosion Susceptibility in Keleghai River Basin, India***' embodies the original research work carried out by me in the Department of Geography, Midnapore City College, Paschim Medinipur, West Bengal, India under the supervision of Nityananda Sar, Assistant Professor, Department of Geography, Midnapore City College, Kuturiya, Bhadutala, West Midnapore, West Bengal. No part thereof has been submitted for any degree or diploma in any University.

Date:

Place: Midnapore City College, Paschim Medinipur (……………………)

Approval Sheet

This project report entitled '**Coupling of GIS-Analytical Hierarchy Process Based Spatial Prediction of Soil Erosion Susceptibility in Keleghai River Basin, India**' by Sarmistha Maity, Sathi Ghosh, Shilpa Mallik, Shrabani Poria, Shreya Mondal, Sk Atikul Haque, Somnath Maity, Sonali Mandal, Sougata Manna, Soumik Ghosh, Soumyadip Mandal, Pintu Ghosh, Piu Bhunia, Priya Ghosh, Priyanka Bera is approved for the degree of M.A/M.Sc in Geography.

(Signature of Examiners)

(Name :..)

(Signature of Guide)

(Name :...)

(Signature of Teacher-In-Charge)

(Name: Dr. Kuntal Ghosh)

(Dr. Pradip Ghosh)
Director
Midnapore City College

Date: ____________
Place: ____________

Dedicated to my Parents

Acknowledgement

I would first like to acknowledge Dr. Pradip Ghosh, Hon'ble Founder Director, Midnapore City College, Paschim Medinipur for providing me the opportunity to study and complete my thesis work in this college. I am gratefully indebted to him for his very valuable comments on this thesis.

I would like to thank my thesis advisor Nityananda Sar of the Department of Geography at Midnapore City College. The door to Prof. Sar office was always open whenever I ran into a trouble spot or had a question about my research or writing. He/She consistently allowed this paper to be my own work, but steered me in the right the direction whenever he/she thought I needed it.

I would also like to thank the other Faculties Anirban Baitalik, Amartya Pani, Kartic Bera, Dipak Kumar De and other non-teaching staffs for their support to carry out this research project. Without their passionate participation and input, the validation survey could not have been successfully conducted.

Finally, I must express my very profound gratitude to my parents (or any other person) for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them. Thank you.

Author

[……………………………………]

Abstract

Soil erosion susceptibility maps can be an essential tool in erosion prone areas as they explain and display the distribution of risk and areas likely to be affected to different magnitudes. Therefore, it is very useful to planners and policy makers initiating remedial measures and for prioritizing areas. In this study, thematic data layers of sixteen soil erosion conditioning factors were integrated to prepare a soil erosion susceptibility map using a weighted linear sum model (WLSM) in GIS environment. The Analytical Hierarchy Process (AHP) was used to derive the preference scale factor rating values (R_i) and Frequency Ratio (FR) model was applied to obtain the prioritized vector weights (W_i) for all the soil erosion conditioning factors considered in the study. The integration between (R_i) and (W_i) was made in weighted linear sum model (WLSM) on a GIS platform to estimate the soil erosion susceptibility value (SESV) for each pixel and a suitable classification technique was incorporated to prepare the soil erosion susceptibility map (SESM) of the Keleghai River basin. The multicolinearity, receiver operating characteristic (ROC) curve and kappa index of agreement were used for the assessment of overall performance of the AHP. The results depicted that in general, a high to severe susceptibility condition of soil erosion was found in the study area and the proposed approach was also able to identify the areas under high and severe susceptibility that require urgent intervention on a priority basis. Based on this study, comprehensive erosion susceptibility management strategies were anticipated for the efficient management of present and future erosion disaster in the area.

Keywords: Analytical hierarchy process (AHP), Frequency ratio (FR), weighted linear combination model (WLSM), Soil erosion susceptibility map (SESM)

List of Tables

List of Figures

Table of Contents

1. 0 Introduction

Soil erosion is one of the most serious environmental problems in the world today, as it seriously threatens agriculture, natural resources and the environment. Soil erosion is a natural geomorphic process occurring persistently over the earth's surface. Some of the problems associated with soil erosion include loss of fertile topsoil for agriculture, siltation of streams and lakes, eutrophication of surface water bodies and loss of aquatic biodiversity (Onyando et al., 2005).Management practices to minimize these problems can be effectively carried out if the magnitude and spatial distribution of soil erosion are known. Soil erosion models can simulate erosion processes in the watershed and may be able to take into account many of the complex interactions that affect rates of erosion. Soil erosion prediction and assessment has been a challenge to researchers since the 1930s and several models were developed (Lal, 2001). These models are categorized as empirical, semi-empirical and physical process-based models. The most commonly adopted empirical models are the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1965) and Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1991). Other models like the Erosion Productivity Impact Calculator (EPIC) (Williams et al., 1990), European Soil Erosion Model (EUROSEM) (Morgan et al., 1992) and Water Erosion Prediction Project (WEPP) (Flanagan and Nearing, 1995) are also used to estimate the status of soil loss. These methods analyze soil erosion by attempting to estimate the volumes or masses of soil loss. However, soil erosion by water is one of the major causes of land degradation and, therefore, it is necessary to establish soil conservation measures to reduce the land degradation and ensure development of a sustainable management of soil resources. The implementation of effective soil conservation measures has to be preceded by a spatially distributed erosion hazard and risk assessment (Moussa et al., 2002; Souchère et al., 2005). A soil erosion hazard map is essential and erosion hazard mapping can be a starting point of any regional interventionpolicy for soil erosion control and conservation. In order to calculate a region's erosion hazard, its soil conditions, climate characteristics, vegetation, terrain, ground cover, etc. must be studied. Various papers involve methods of evaluating erosion hazard and risk, based on many parameters, such as morphometric variables (Jozefaciuk and Jozefaciuk, 1993), sediment yield information (Rooseboom and Annandale, 1981), and rainfall erosion indices (Hundson, 1981). A simple erosion risk scoring system was previously proposed by Stocking and MA Stocking and HA Elwell (1973) using morphometric variables and rainfall indices. Using advanced remote sensing and GIS techniques and modelling, investigators also developed methods for erosion hazard and risk evaluation, such as integrated and systematic approaches (Vezina et al., 2006; Tian et al., 2008), fuzzy and artificial neural-network evaluation methods (He, 1999), geo-statistical multivariate approaches (Conoscenti et al., 2008), sensitivity analysis approaches (Mendicino, 1999), soft computing method (Gournellos et al., 2004), analytical risk evaluation methods (Wu and Wang, 2007; Masoudi and Patwardhan, 2006). Even though most of these approaches were used for quantitative analysis, some of these were found very complex and time consuming, and the variables used in the models are not always easy to be acquired and assessed. For example, the neural-network method requires a range of historical data, which especially is a particular problem of using existing domain knowledge in the learning process. However, all this activity indicates an expanding interest in the study of erosion and related processes for evaluation and understanding of environmental changes.

Reliability of the susceptibility maps depends mostly on the amount and quality of available data, the working scale and the selection of the appropriate methodology of analysis and modeling. The process of creating the maps involves several qualitative or quantitative approaches (e.g., Mantovani, F., Soeters, R., & Van Westen, C. J. 1996; Aleotti and Chowdhury, 1999; Guzzetti*et al*., 1999). Early attempts had defined susceptibility classes by qualitative overlaying of geological and morphological slope-attributes to soil erosion inventories (Nielsen *et al*., 1979). However, more sophisticated assessments involved techniques such as AHP, bivariate, multivariate, logistic regression, fuzzy logic, or artificial neural network (ANN) have been reported in recent years. For examples; by Chacón*et al*. (2006); Lee *et al*. (2006); Akgun*et al*. (2008); Oh *et al*. (2008); Muthu*et al*. (2008); Van Westen*et al*. (2008); Vijith and Madhu (2008). Qualitative methods depend critically on expert opinions. Most common types simply examine landside inventory maps to identify sites of similar geological and geomorphological properties that are likely susceptible to failure. Some qualitative approaches, however, incorporate the idea of ranking and weighting, and may evolve to be semi-quantitative in nature. The application of the analytical hierarchy process (AHP) method, developed by Saaty (1980), for soil erosion susceptibility mapping has been found in, e.g., Barredo*et al*. (2000); and Yagi (2003), while the use of weighted linear combination (WLC) technique was reported in Ayalew*et al*. (2004). Being partly subjective, results of these approaches vary depending on knowledge of experts. Hence, qualitative or semi-quantitative methods are often useful for regional studies (Mantovani, F., Soeters, R., & Van Westen, C. J. 1996; Guzzetti*et al*., 1999). Quantitative methods are based on numerical expressions of the relationship between controlling factors and soil erosion activity. There are two types of quantitative methods: deterministic and statistical (Aleotti and Chowdhury, 1999).

Deterministic quantitative methods depend on engineering principles of slope instability expressed interms of the factor of safety. Due to the need for exhaustive data from individual slopes, these methods are often effective for mapping only small areas. Soil erosion susceptibility mapping using either multivariate or bivariate statistical approaches analyzes the historical link between soil erosion-controlling factors and the distribution of soil erosions (Guzzetti*et al*., 1999).

The spatial technologies, such as remote sensing and GIS, and numerical modelling techniques have been developed as powerful tools for ecological and environmental assessment (Krivtsov, 2004; Rahman and Saha, 2009). Combining these technologies not only supplies a platform to support multi-level and hierarchical resource and environmental analysis, but also integrates the information in a comparative theoretical framework (Li et al., 2006; Rahman et al., 2009). It should be noted that soil erosion is a complex issue with many related factors, and investigators face great challenges for quantifying the relationships between soil erosion and these factors. Thus, an integrated and systematic approach should be implemented. Therefore, in order to provide an effective result for soil erosion hazard assessment, remote sensing (RS) and geographical information system (GIS) technologies were adopted, and AHP. Particularly, this was an integrated approach to determine the spatial dynamics of soil erosion vulnerability by surface factors. The increase of computer-based tools has been found to be useful in the hazard mapping of soil erosions. One of such significant tools is geographic information systems (GIS). A GIS is commonly defined as a powerful set of tools for collecting, storing, retrieving at will, displaying, and transforming spatial data (Burrough and McDonnel, 1998). With help of GIS, it is possible to integrate spatial data of different layers to determine influence of the parameters on soil erosion occurrence. The process of

GIS-aided soil erosion susceptibility mapping at present involves several methods that can be considered as either qualitative or quantitative as stated earlier. In this context, the objective of this study was to provide a soil erosion susceptibility map by applying the proposed method, from which a comprehensive erosion hazard management strategy could be developed for the study area.

2. 0 Literature Review

1. Soil erosion (SE) is a severe environmental issue that hovers over as a grave danger to agricultural productivity and the long-term viability of natural ecosystems worldwide (Mohammed et al., 2020; Chalise et al., 2019).

2. Globally Asian sub-continent is mostly affected by soil erosion (35 million hectares of soil erosion per year), followed by Europe, America, and Africa (Arabameri et al., 2019).

3. Long-term soil erosion can cause severe damage to the soil's productive capacity by percolation and extermination of soil's organic and topsoil matters (Mosavi et al., 2020).

4. In India, 29.70 % of the total geographical area has a significant degradation of land quality due to soil erosion (Published in Desertification and Land Degradation Atlas of India, by Space Application Centre, ISRO, Ahmedabad, 2021).

5. It indicates a serious risk (Hembram and Saha, 2018), and sustaining this resource's management at the national and local levels is viewed as a critical issue that must be resolved successfully for sustainable agriculture, food security, management of water resources, and protection of the environment (Mosavi et al., 2020; Arabameri et al., 2019).

6. Therefore, identifying the potential soil erosion zone with advanced methodologies is of utmost importance for the betterment of mankind. Recently the traditional methods (e.g. Russell's universal soil loss equation and AHP methods to estimate soil erosion) used for mapping environmental phenomena are being replaced by numerous researchers and gradually introduced(Tehrany et al., 2017; Yang et al., 2021).

3. 0 Personality of the Study Area

The Keleghai river basin lies between 22º05'10"N to 22º21'05"N latitude and 87º05'09"E to 87º51'03" E longitude. The selected basin with an area of 1440 km^2 and located in the north-western part of Purba and Paschim Medinipur district. It consists of 25 villages, which are the second order administrative units within the province (Fig. 1). In the study area four type of land use and land cover unit are identified named wet/waterlogged land, vegetation/forest land, agricultural land and other land.The existing river basin in 1976 was mainly dominated by wet/waterlogged land (17.3%), vegetation/forest land (13.4%), agricultural land (60.3%) and other land (9.0%) through the entire period the valley presented a strong persistence of land uses and the main conversions detected are deforestation and agricultural intensification.

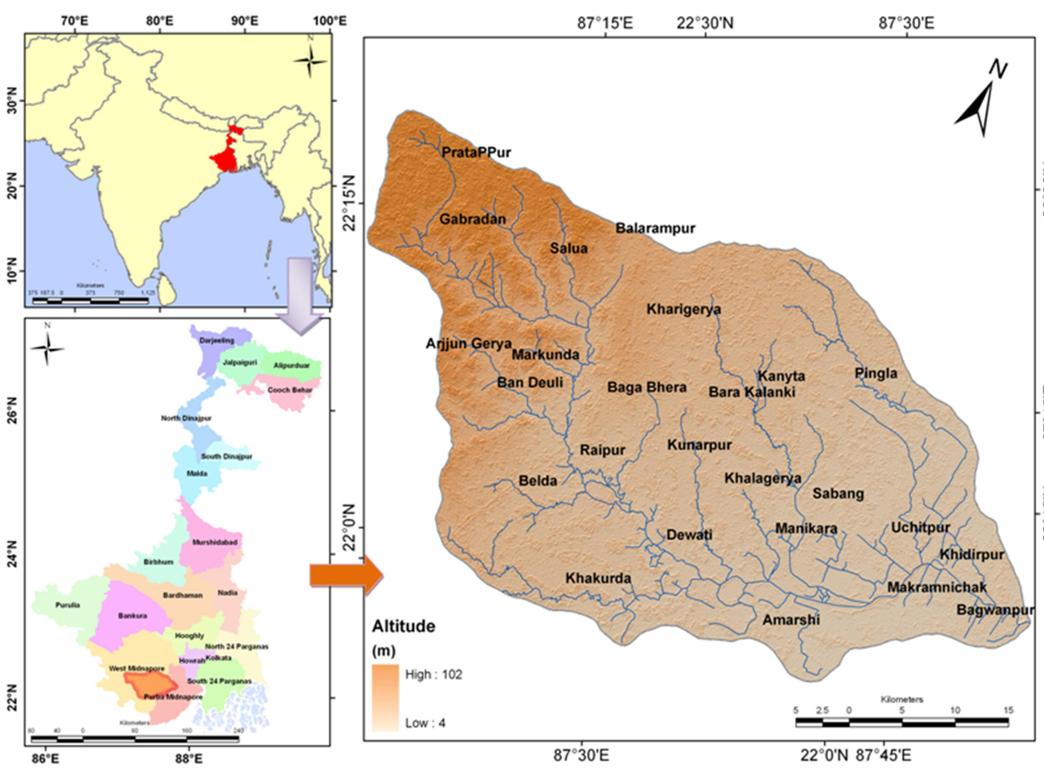

Fig 1 Location of the study area

4.0 Aims and Objective

There are two objectives being set to delineate the study as-

(i) to prepare the soil erosion susceptibility map (SESM) of the Keleghai River basin.

(ii) topropose remedial measures of soil erosion in the study area.

5.0 Materials and Methods

5.1 Materials

The soil erosion status of an area depends upon the regional conditions of the area, such as climate, soil condition, land use/land cover, topography, lithology, etc. Therefore, to assess the erosion hazard of the area a range of evaluation criteria, objectives and attributes should be identified with respect to the problem situation (Rahman and Saha, 2008).

In this study, thematic data layers of all the soil erosion conditioning factors were integrated to prepare a soil erosion susceptibility map using a Weighted Linear Sum model in GIS environment. The Analytical Hierarchy Process (AHP) was used to derive the preference scale factor rating value (R_i) and Frequency Ratio (FR) model was applied to obtain the prioritized vector (W_i) for all the soil erosion conditioning factors considered in the study. The integration between (R_i) and (W_i) was made in weighted linear sum model on a GIS platform to estimate the soil erosion susceptibility value (SESV) for each pixel and a suitable classification technique was incorporated to prepare the soil erosion susceptibility map (SESM) of the Keleghai River basin. In this study, the multicolinearity, ROC curve and Kappa index of agreement (Tien Bui et al., 2015) were used for the assessment of overall performance of the AHP. Data layers for soil erosion inducing factors were generated using GIS environment. The data used in this study are shown in **Table 1**.

Table No. 1 Details of data frame used in the study

Data	Sources (URL)	Type	Time/Period
Digital elevation model	http://gdem.ersdac.jspacesystems.or.jp/search.jsp	Satellite-borne sensor ASTER	ASTER GDEM V 2.0, 17th October, 2011
Satellite images	http://landsat.usgs.gov; earth.esa.int	IIRS P6/Sensor-LISS-III and Landsat 7 (Thematic Mapper ™)	WRS-Path = 139 WRS-Row = 045 4th April, 2011
Rainfall data	http://www.worldclim.org	Grid data	1950-2010
Soil map	http://www.nbsslup.in	Reference type	End Report: AS3 229, 2005
Geomorphology	http://www.portal.gsi.gov.in	Reference type	2010
Drainage networks	http://www.surveyofindia.gov.in http://earth.google.com	Toposheet (73N/3; 73N/4; 73N/7; 73N/8; 73N/11 and 73N/12) and Google image	1973 and 2011

5.2 Methods

5.2.1 Extraction of thematic layers

Various thematic data layers representing soil erosion conditioning factors shows in **Fig. 2** These factors fall under the category of preparatory factors, responsible for the occurrence of soil erosion in the basin for which pertinent data can be collected from available resources as well as from the field. The triggering factors such as rainfall and river bank erosion the movement by shifting the slope from a marginally stable to an actively unstable area. The attributes of the ground in terms of soil erosion susceptibility are considered. Management practices and bank erosion or shifting of channel thalweg is triggering factors and temporal phenomena. However, past data on these triggering factors in relation to soil erosion occurrence are not available, and therefore, these factors are not considered in this study.

5.2.2 Analytical hierarchy process

The analytical hierarchy process (AHP) is a semi-qualitative method, which involves a matrix-based pair-wise comparison of the contribution of different factors for soil erosion. AHP is a multi-objective, multi-criteria decision-making approach, which enables the user to arrive at a scale of preference drawn from a set of alternatives (Saaty 1980). It helps decision makers find out the best suits their goal and their understanding of the problem. This mathematical method widely used in site selection, suitability analysis, regional planning, routing modeling, and soil erosion susceptibility analysis. The process includes several steps: (1) break a complex unstructured problem down into its component factors which are the parameters chosen in this study; (2) arrange these factors in a hierarchic order; (3) assign numerical values according to their subjective relevance to determine the relative importance of each factor; and (4) synthesize the rating to determine the priorities to be assigned to these factors (Saaty and Vargas 2001). When arranging the factors in a hierarchic order, there should be relative importance of one factor over another forming a pair-wise comparison matrix. In the construction of a pairwise comparison matrix, each factor is rated against every other factor by assigning a relative dominant value between 1 and 9 to the intersecting cell.

Table 2 The priority weights of each soil erosion conditioning factors by analytical hierarchical process (AHP)

Factor	t_{wi}	$\vec{\theta}$	d_{ri}	r_{pc}	h_{eb}	g_{eo}	l_{uc}	r_{in}	s_{ty}	v_{nd}	θ_{ls}	θ	s_{pi}	s_{ti}	d_{fl}	d_{rd}	Weights (w_i)	Rank of Condition Factors
t_{wi}	1	5.0	5.0	2.0	2.0	2.0	4.0	5.0	3.0	5.0	5.0	3.0	3.0	5.0	5.0	2.0	0.055	7
$\vec{\theta}$		1	7.0	5.0	6.0	6.0	6.0	2.0	5.0	7.0	3.0	5.0	6.0	6.0	*4.0*	6.0	0.013	14
d_{ri}			1	6.0	4.0	4.0	3.0	7.0	6.0	2.0	6.0	6.0	6.0	7.0	7.0	3.0	0.189	1
r_{pc}				1	3.0	2.0	5.0	5.0	3.0	4.0	5.0	4.0	2.0	3.0	4.0	3.0	0.054	8
h_{eb}					1	2.0	3.0	6.0	3.0	3.0	5.0	3.0	4.0	4.0	6.0	2.0	0.082	5
g_{eo}						1	2.0	6.0	3.0	4.0	5.0	3.0	3.0	4.0	5.0	2.0	0.068	6
l_{uc}							1	6.0	3.0	2.0	5.0	5.0	4.0	5.0	7.0	2.0	0.119	3
r_{in}								1	6.0	7.0	5.0	5.0	7.0	6.0	2.0	6.0	0.010	16
s_{ty}									1	4.0	5.0	3.0	2.0	2.0	5.0	4.0	0.04	10
v_{nd}										1	6.0	6.0	6.0	5.0	7.0	3.0	0.150	2
θ_{ls}											1	3.0	5.0	5.0	*3.0*	5.0	0.017	13
θ												1	5.0	2.0	3.0	5.0	0.024	12

s_{pi}	1	2.0	5.0	4.0	0.041	9
s_{ti}		1	5.0	5.0	0.031	11
d_{fl}			1	4.0	0.011	15
d_{rd}				1	0.095	4

Consistency Index (CI) 0.094

Random Index (RI) 1.592

Consistency ratio (CR) 0.059

6.0 Results

In this study, both frequency ratio model and analytical hierarchy process (AHP) have been adopted for identifying the areas susceptible to soil erosions in the Keleghai river basin. A total of 340 soil erosion locations were mapped using satellite images, toposheets and field surveys. For susceptibility analysis, sixteen soil erosion conditioning factors were used such as topographic wetness index, slope aspect, plan curvature, distance from river, elevation, geomorphology, land sue/cover, rainfall, soil type, normalized difference vegetation index, slope length, slope, stream power index, sediment transport index, distance from fault, distance from road. A frequency ratio model and AHP were applied to analyze the soil erosion susceptibility using above-mentioned sixteen factors.

The SESM represents the high to severe susceptibility of a soil erosion occurrence. Therefore, the higher the index, the more susceptible the area is to soil erosion. These SESM values were then divided into five classes based on the natural breaks range, which represent five different zones in the soil erosion susceptibility map. These are severe (0.81-1.00), high (0.61-0.80), moderate (0.41-0.60), low (0.21-0.40) and very low (0.00-0.20) susceptibility zones (Fig 4). In the Keleghai river basin, Khidirpur, Pingla, Sabang, Amarshi, Uchitpur, Bhagwanpur and Baga Bhera were severe susceptible to soil erosion; Belda, Khakurda and Dewati were characterized by high soil erosion soil erosion susceptibility; Pratappur, Raipur, Kantya, Manikara; Salua, Makranichak, Bara Kalanki, Kharigerya, Markunda, Khalagrya and Arjjun Gerya, Kunarpur, Gabradan, Ban Deuli, Balarampur areas fell into moderate, low and very low respectively. The percentage covering areas of each susceptibility class are along with number of reference training and validation set. From data, it is obvious that only 29.31% of the total soil erosion susceptibility area was classified as being in the severe soil erosion susceptibility zones but they had accommodated about 25.07% of the soil erosion patches. Other areas are located in the high (30.49%), moderate (26.79%), low (9.44%) and very low (3.97%) susceptibility zones and they had accommodated about 30.31%, 22.18%, 14.58% and 7.87% respectively of the soil erosion patches.

To evaluate validity of the results may more quantitatively, the percentage frequency ratio (FR) values for each identified class are also given. These values were computed from ratio of the percentage soil erosion occurrences and the percentage area coverage (for each individual class to the whole study area). The possible values begin from 0 onwards where relatively high ones (e.g. much greater than 1) indicate high chance of having soil erosions while low values (e.g. close to 0) indicate lower chance of having soil erosion over the area. FR equals 1 means the considered area is having equal chance for soil erosion occurrence to that of the average value for the entire area. The FR values of 1.02% for the severe zone and 39.44% for the high zone indicate the notably higher chance of having soil erosion activities in these areas when compared to those of the moderate (27.92%), low (6.71%) and very low (3.09%).These results emphasize the applicability of the susceptibility map that was constructed based on the AHP method and being depicted.

Based on the results three most influencing factors to soil erosion activity (judged from their associated weights) are distance from river (0.189), normalized vegetation index (0.150), and landuse/landcover (0.119). And the three least influencing factors are slope aspect (0.013), distance from fault (0.011), and mean annual rainfall (0.010). The obtained susceptibility map and its relevant data indicate that the high and severe susceptible zones cover about 59.80% of the total area while about 40.20% were classified as being the moderate, low and very low susceptible zones. The frequency ratio plots of five soil erosion susceptibility zones for AHP models. Generally, there is a gradual increase in the frequency from the very low susceptible zone to the severe susceptible zone for the study area. The results of the prediction curve**.** It is clear that the susceptibility map using success rate curves with AUC (0.925) and SE (0.426), which corresponds to the prediction accuracy of 92.50 %, whereas Prediction rate curves with AUC (0.893) and SE (0.531), the prediction accuracy is 89.30 %. Kappa index establish the confidence level of this thematic classification lies almost perfect (0.81–1.0) i.e. 0.73%.

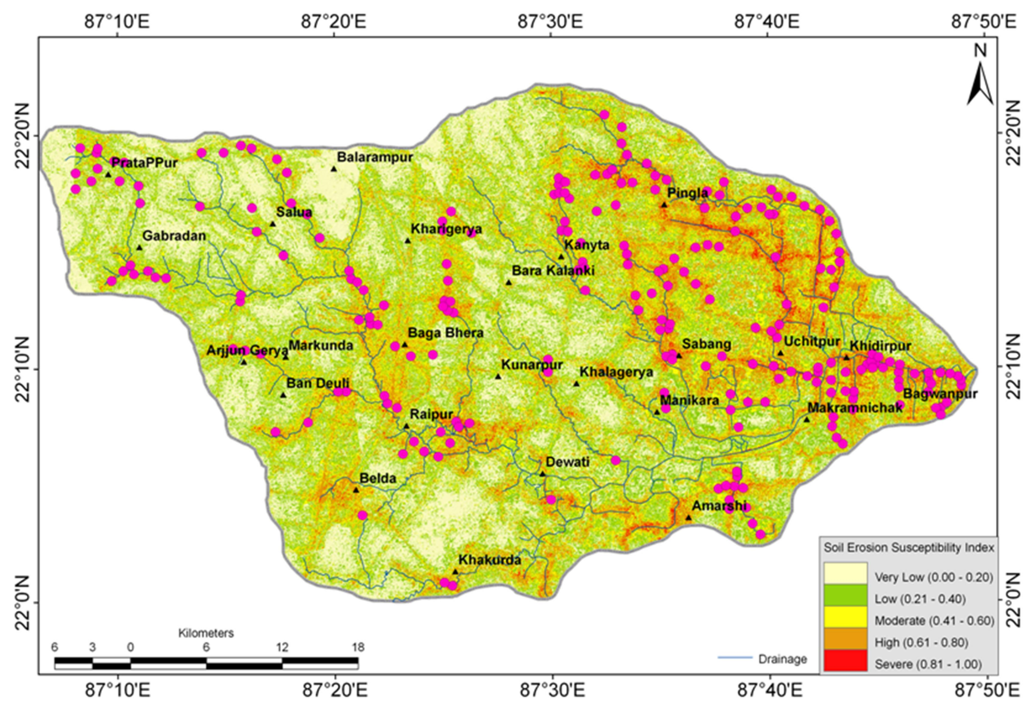

Fig 2 Soil erosion susceptibility map based on analytical hierarchy process (AHP) model

7.0 Discussion

Soil erosion susceptibility of the Keleghai river basin was affected by the interaction between soil erosion conditioning factors and existing soil erosion. Class frequency ratio indicates the relative importance of individual classes for each factor and provides important information for analyzing the role of these factors in inducing soil erosion. The class frequency ratios (weights) of the sixteen soil erosion conditioning factors are presented. In order to most important conditioning three factors are: **(a)** Distance from river of the basin varies from near 500m in the north-eastern and most northern parts to far (3001-5448m) towards the outskirts and valley areas. Most of the soil erosion occurred in areas with distance 500m from main channel, whose FR (weight) values range between 0.80 and 0.91. Distance from river was associated with high to severe soil erosion susceptibility and a large number of soil erosion occurrences (59.80%). **(b)** It is universally accepted that satellite derived NDVI is an important index to assess vegetation canopy on ground surface. The analysis of NDVI is regarded as the rough estimation of vegetation amount present and ground water prospect over the space. Based on the NDVI values study area is classified into five zones, the value 0.1-0.5 that can be treated as high soil erosion conditioning factors in the areas like in the north-eastern and south-eastern parts of the basin. FR (weight) values range between 0.56 and 1.47. **(c)** The major land-use type in the study area are river/water bodies, built up area, dense forest, vegetation cover, scrub land barren land agricultural cropland and agricultural fallow land. Around 29.98% of the total area is agricultural fallow land, which is contributing to soil erosion is about 31.30% of the total soil erosion susceptibility. The derived FR values revealed that moderate to high soil erosion susceptibility zones are associated with barren land, agriculture crop land and agriculture fallow land and dominated by high intensity of soil erosion and could be treated as maximum probable areas of soil erosion occurrences. Pratappur, Raipur, Kantya, Manikara Belda, Khakurda, and Dewati were characterized by such type of land use and highest FR values ranging from 1.11 to 3.42 in one hand. On the other hand least three conditioning factors are (**e**) Slope aspect is an important factor for the influencing of soil erosion. Higher degree of slope aspect results in rapid runoff and increased erosion rate with feeble recharge potential. The slope aspect map of the study area was prepared based on satellite data using the spatial analysis tool in ArcInfo 9.3. Slope aspect grid is identified as “the maximum rate of change in value from each cell to its neighbours” (Burrough, 1986). Based on the slope aspect, the study area can be divided into nine classes. The areas having southwest slope aspect (202.5-247.5) fall into the ‘very good’ category because of the nearly flat terrain and relatively high infiltration rate and least soil erosion. Whereas the area was having sloped west (247.5-292.5) is considered as ‘extremely poor’ and ‘unsuitable’ due to higher steep slope and does not favour to direct percolation and may be occurred soil erosion; whose FR (weight) values range between 0.91 and 1.13. (**f**) The study on distance from fault showed that most of the major soil erosion locations are very close to the faulted lineament area (Pingla and its adjacent areas). (**g**) The mean annual rainfall of the study area is around 116 mm for the long term average (1950-2010). The south-west monsoon accounts for 21%, north-east monsoon 46%, winter 6% and summer 27% of total rainfall. The study area depends mainly on north-east monsoon rains, which are brought by the troughs of low pressure establishing in south Bay of Bengal between October and December. Rainfall distribution along with the slope gradient directly affects the infiltration rate of runoff water hence increases the possibility of groundwater potential zones. But in this area slope does not confer with rainfall to occurring soil erosion. The value of FR ranges from 0.16 to

3.26.The other intermediate ten influencing factors shall remain constant to amplify soil erosion. The following areas under fell into least affected soil erosion areas like Arjjun Gerya, Kunarpur, Gabradan, Ban Deuli, Balarampur, Salua, Makranichak, Bara Kalanki, Kharigerya, Markunda and Khalagrya.

8.0 Conclusions

This paper attempts a novel methodology approach to improve theoverall performance of soil erosion susceptibility models with the use ofthe frequency ratio and AHP techniques for a case study of the Keleghai river basin. They are the two state-of-the art machines learning techniquesand according to current literature the two techniques have not beenused for soil erosion modeling. According to this case study, the AHP model has the highest prediction capability compared with the frequency ratio models. Therefore researcher concludes that the AHP is a new promisingtechnique that could be used for soil erosion susceptibility mapping.The frequency is considered to be another promising technique. In order tocheck the overall performance of the AHP and frequency ratio models and for thetwo techniques to be more generally used, more case studies shouldbe conductedThe results of this study suggest that soil erosion susceptibility mapping forthe Keleghai river basin of West Bengal is viable. The maps results may be helpful for planners, decision makers, and engineers in slope management and land use planning in the studyarea. This map is produced in a regional scale, so further study need be carried out at thesite-specific level to determine the exact extent site of the erosion unsteadiness.

9.0 Future Scope

Soil erosion estimation and hazard assessment is essential for the proper planning and management of future soil erosion disasters. Therefore, the developed soil erosion hazard map can befurther incorporated into land-use planning decisions. The results of the study can be used as basic data to assist conservation management and land-use planning, and the methods used in this study are valid for generalized planning and assessment purposes to identify areas that are vulnerable to soil loss. This may help to reduce potential erosion damage in the study area. A comprehensive plan addressing soil erosion hazard management is therefore, necessary. This plan should combine land-use strategies for each zone with careful consideration of certain structural controls. This can be achieved by minimal disruption of natural environments. The following presents an example of general management strategies based on this study, field investigations and expert opinion. These strategies could serve as basic components in a comprehensive erosion management plan for the study area.Soil erosion in the study area was a combination of natural erosion and accelerated erosion. The accelerated erosion arises from cultivation, spoiled vegetation, uncontrolled infrastructure development, overgrazing, road construction, and from other human activities. It may also arise due to the lack of proper conservation practices. Therefore, preservation of natural vegetation, proper land-use planning and appropriate conservation processes shouldbe the top priority when formulating policy for the management of soil erosion. Severe and high susceptibility areas are the most important areas to concentrate management effort due to their vulnerability.

References:

1. Annual Flood Report of Irrigation & Waterways Department, West Bengal, 2013 (http://www.wbiwd.gov.in/pdf/ANNUAL_FLOOD_REPORT_2013.pdf)

2. Ashkar, F., &Bobée, B. (1987). The generalized method of moments as applied to problems of flood frequency analysis: some practical results for the log-Pearson type 3 distribution. Journal of Hydrology, 90(3-4), 199-217.

3. Burn, D. H. (1990). Evaluation of regional flood frequency analysis with a region of influence approach. Water Resources Research, 26(10), 2257-2265.

4. Cunnane, C. (1988). Methods and merits of regional flood frequency analysis. Journal of Hydrology, 100(1-3), 269-290.

5. Dalrymple, T. (1960). Flood-frequency analyses, manual of hydrology: Part 3 (No. 1543-A). USGPO,.

6. DeGroot, M. H., &Schervish, M. J. (2012). Probability and statistics.Pearson Education.

7. Dirk, R. A. E. S. (2013). Frequency analysis of rainfall data. College on Soil Physics—30th Anniversary (1983-2013), The Abdus Salam International Centre for Theoretical Physica, 244-10.

8. Flynn, K. M., Kirby, W. H., & Hummel, P. R. (2006). User's manual for program PeakFQ, annual flood-frequency analysis using Bulletin 17B guidelines (No. 4-B4).

9. Garba, H., Ismail, A., &Tsoho, U. (2013). Fitting probability distribution functions to discharge variability of Kaduna river. International Journal of Modern Engineering Research, 3, 2848-2852.

10. Government of India Report on disaster management in India (2011) Ministry of Home Affairs Chapter 1, p 20

11. Griffis, V. W., &Stedinger, J. R. (2007). Log-Pearson Type 3 distribution and its application in flood frequency analysis. I: Distribution characteristics. Journal of Hydrologic Engineering, 12(5), 482-491.

12. Haan, C. T. (2002). Statistical methods in hydrology.The Iowa State University Press.

13. Hamed, K., & Rao, A. R. (Eds.). (1999). Flood frequency analysis.CRC press.

14. IACWD (1982) Flood Frequency Estimates and Documented and Potential Extreme Peak Discharges in Oklahoma (https://pubs.usgs.gov/wri/wri014152/pdf/wri014152.pdf)

15. Jha, V. C., & Bairagya, H. P. (2011). Flood plain evaluation in the Ganga-Brahmaputra delta: a Tectonic review. Ethiopian Journal of Environmental Studies and Management, 4(3), 12-24.

16. Kamal, V., Mukherjee, S., Singh, P., Sen, R., Vishwakarma, C. A., Sajadi, P., ...& Rena, V. (2017). Flood frequency analysis of Ganga river at Haridwar and Garhmukteshwar. Applied Water Science, 7(4), 1979-1986.

17. Koutrouvelis, I. A., &Canavos, G. C. (1999). Estimation in the Pearson type 3 distribution. Water resources research, 35(9), 2693-2704.

18. Kumar, R., Chatterjee, C., Kumar, S., Lohani, A. K., & Singh, R. D. (2003). Development of regional flood frequency relationships using L-moments for Middle Ganga Plains Subzone 1 (f) of India. Water Resources Management, 17(4), 243-257.

19. Langbein, W. B. (1949). Annual floods and the partial-duration flood series. Eos, Transactions American Geophysical Union, 30(6), 879-881.

20. Limpert, E., &Stahel, W. A. (2011). Problems with using the normal distribution–and ways to improve quality and efficiency of data analysis.PLoS One, 6(7), e21403.

21. McMahon, T. A., &Srikanthan, R. (1981). Log Pearson III distribution—is it applicable to flood frequency analysis of Australian streams?. Journal of Hydrology, 52(1-2), 139-147.

22. OSU. 2013. Analysis techniques: flood frequency analysis. Streamflow evaluations for watershed restoration planning and design.Oregon State University.Civil, Construction, and Environmental Engineering Department.(http://streamflow.engr.oregonstate.edu/analysis/floodfreq/index.htm)

23. Raes, D. (2004). Frequency analysis of rainfall data. KU Leuven Inter-University Programme in Water Resources Engineering (IUPWARE): Leuven, Belgium, 42.

24. Ray, K.B., (1954). Flood Prevention in the Rivers of Bihar, North Bengal and Assam. Economic and Political Weekly (http://www.epw.in/system/files/pdf/1954_6/41/flood_prevention_in_the_rivers_of_bihar_north_bengal_and_assam.pdf)

25. Singo, L. R., Kundu, P. M., Odiyo, J. O., Mathivha, F. I., &Nkuna, T. R. (2012, October). Flood frequency analysis of annual maximum stream flows for Luvuvhu River Catchment, Limpopo Province, South Africa. In 16th SANCIAHS National Hydrology Symposium, University of Pretoria, South Africa, Session 2c.

26. Smith, K. (2003). Environmental hazards: assessing risk and reducing disaster. Routledge.

27. Stedinger, J. R., & Cohn, T. A. (1986). Flood frequency analysis with historical and paleoflood information. Water resources research, 22(5), 785-793.

28. Stephens, M. A. (1974). EDF statistics for goodness of fit and some comparisons.Journal of the American statistical Association, 69(347), 730-737.

29. USDA (2007) Stream Restoration Design National Engineering Handbook (https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17781.wba)

30. U.S. Geological Survey (USGS), 1982. Guidelines for determining food flow frequency. Hydrology Subcommittee, US Department of the Interior, Geological Survey, Office of Water Data Coordination, Bulletin-17B, Reston, VA, pp. 14-35.

31. Wallis, J. R., & Wood, E. F. (1985). Relative accuracy of log Pearson III procedures. Journal of Hydraulic Engineering, 111(7), 1043-1056.

32. Webb, R. H., & Betancourt, J. L. (1992). Climatic variability and flood frequency of the Santa Cruz river, Pima County, Arizona (No. 2379). US Geological Survey,.

33. Weibull, W., 1939. A statistical theory of the strength of materials.IngeniorsVetenskapsAkademiensHandlingar Nr 151 (Proceedings of The Royal Swedish Institute for Engineering Research) Stockholm, Sweden, p. 45.