ISSN NO 2320-5407 International Journal of Advanced Research (2013), Volume 1, Issue 5, 366-371

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

AN INTEGRATED APPROACH FOR ENVIRONMENTAL IMPACT STUDIES ON SOIL EROSION IN VAMSADHARA RIVER BASIN, INDIA.

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Manuscript Info

Manuscript History:

Received: 13 June 2013
Final Accepted: 24 June 2013
Published Online: July 2013

Key words:
Environmental impact,
Vamsadhara river basin,
Remote sensing,
Soil erosion and vegetation/crop cover.

Abstract

The environmental impact studies on floods of Vamsadhara river basin have been attempted utilizing remote sensing, geotechnical, geomorphological, hydrometeorological and sedimentation data. Various thematic maps on vegetation/crop cover, soils, slope and rainfall are superposed to demarcate the probable areas, prone to erosion. The study reveals that the area with sparse vegetation and shifting cultivation coupled with heavy rainfall in the steep slopes has been subjected to the removal of the fine fertile top soil through runoff, resulting in sedimentation and silting up of the river course in the lower reach of the Vamsadhara river basin. The increase in the flood frequency in the recent years (1980-2010) may be due to the environmental degradation brought about to the vegetation/crop cover practices in the catchment area.

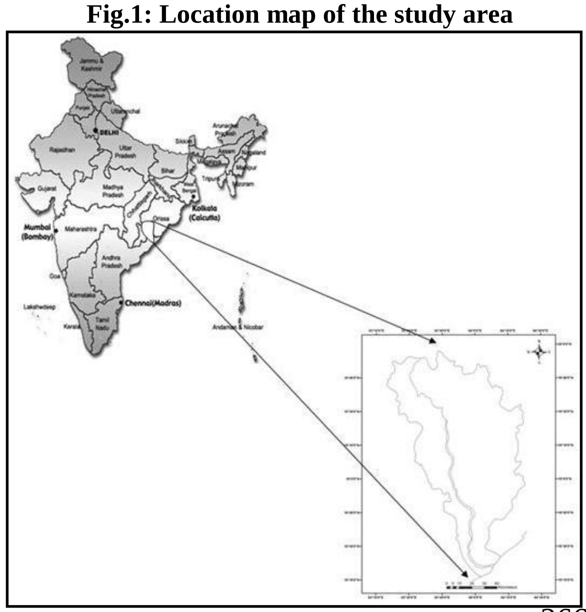
Introduction

Certain parts of Orissa, Andhra Pradesh and Tamil Nadu in the east coast of India often get flooded with the movement of pre and post monsoon cyclonic storms formed in Bay of Bengal (Chellappa and Seshadri, 1981). Different methods of flood protection have been adopted by the state and central governments. It is stated that, while complete control of flood is not possible, it is always possible to mitigate impact of floods thus reduces the suffering due to floods (Anand, 1982). Vamsadhara river basin is narrow and highly undulated (Avinash Agarwal, 2005). Keeping in view these aspects, environmental studies of Vamsadhara river floods have been taken up using multidisciplinary approach.

LOCATION

Vamsadhara river basin with an aerial extent of 10,601.5 sq.km is an interstate catchment area between Orissa and the Andhra Pradesh. It lies between 83^0 25' and 84^0 57' E longitude and 18^0 15' and 19^0 57' N latitude situated between Mahanadi and Godavari river basins in South India (fig. 1). The river originates from Kala-handi and travels through a distance of about 254 km before it joins the Bay of Bengal. Its principal tributaries are Chauldua, Phaphalia, Ganguda, Sanna Nadi, and Mahendrathanaya (Avinash agarwal, 2009).

Fig.1: Location map of the study area



PHYSIOGRAPHY

Nearly 70% of the total catchment area is occupied by the Eastern Ghats hill range and the rest is plain. Elevations within the basin range from slightly less than 10 mts above mean sea level in South (Kalingapatnam) to 1545 mts on the Northwest hills (near Bissam Cuttack). Hilly region is covered with various types of vegetation.

CLIMATE

The basin area has two types of climate. The area between the coast and the foot hills of the Eastern Ghats experiences semi-arid (D) climate and the upper reaches fall under the dry sub-humid type of climate (Subrahmanyam, 1983). Mean daily temperature varies from minimum of 20^0C in December to maximum of 35^0C in May. The total annual evaporation in the basin is about 170 cm. The average annual rainfall is 1300 mm and it increases from coast to hilly terrain. The total surface water potential is about 5600 MCM (Ammindu, 1984) in which only 30 percent is being utilized for irrigation and other purposes and the rest drains into the Bay of Bengal.

METHODOLOGY

The methodology includes in its purview, remote sensing, geotechnical, geomorphological, hydro-meteorology and sedimentation studies. Vegetation cover mapping has been prepared using remote sensing techniques and correlated with ground truth data. AWiFS satellite imagery data of 2002 was interpreted by Arc GIS 9.2 and ERDAS Imagine 9.1 soft wares.

Slope calculations are made using Wentworth method (1930). The total basin area has been divided into various slope categories as per the classification of Leamy and Panton (1966). About 70 soil samples are collected at various locations covering the entire river basin. Samples are analyzed for various physical parameters and are classified (ISI: 1948-1970). The annual rainfall data for the period 1930-2010 was analyzed.

RESULTS AND DISCUSSION

Vegetation cover classification made in the catchment is shown in figure 2. The Eastern part of the basin is mostly covered by sparse vegetation with widespread dry crops. Dense vegetation has been observed adjacent to the river courses and in the NW part of the basin. Forest cleared/ shifting lands are mostly present in the Eastern parts of the basin. Plantations like bamboo and teak are grown in the middle slopes of the south-eastern parts of the basin. The lower part of the basin is mostly occupied by culturable lands and water bodies. Gully lands are frequently found on the eastern part of the basin. The areas of various vegetation cover categories demarcated from the satellite image are listed in table-1 and shown in figure.3.

Fig.2: Vegetation/Crop coverage in the study area

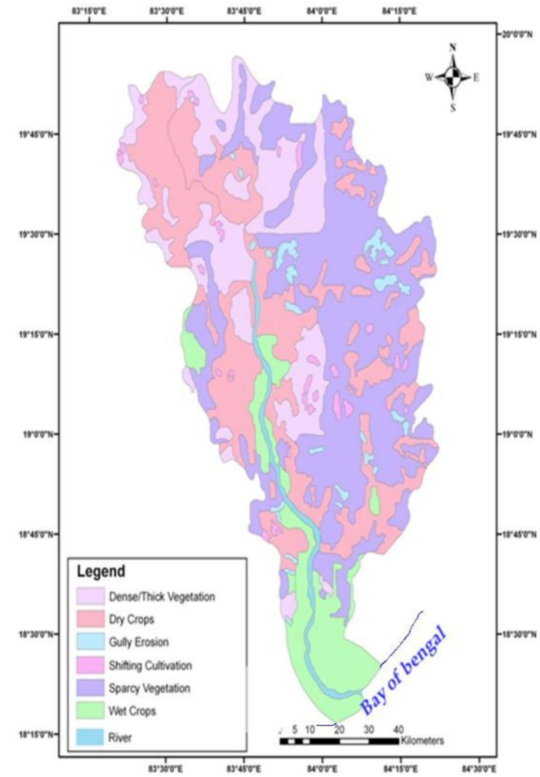
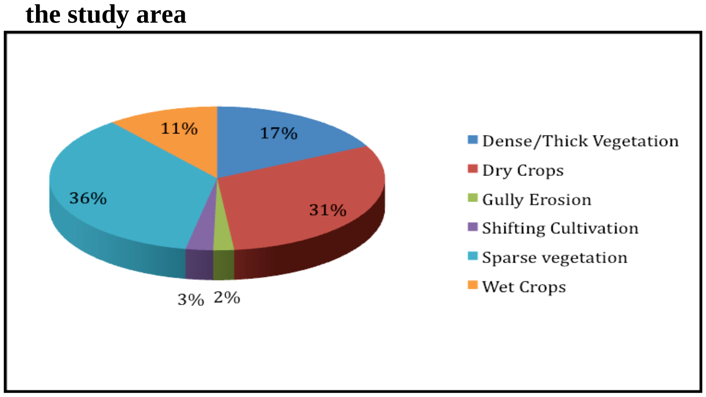


Fig.3: Pie diagram of Vegetation/Crop coverage in the study area



Broadly three categories dark, medium and light tone areas are demarcated. It shows the broad variartion in vegetation, soil and different vegetation cover features. The number of vegetation cover classifications made in this study from AWiFS 2002 is less than that identified by Amminedu (1984) from aerial photographs of 1979.

Table-1: Vegetation/crop categories in the study area

Sl.No	Category	Area in sq.km	Area in %
1	Dense/Thick Vegetation	1813.34	17%
2	Dry Crops	3175.23	31%
3	Gully Erosion	206.35	2%
4	Shifting Cultivation	272.6	3%
5	Sparse vegetation	3730.71	36%
6	Wet Crops	1114.32	11%
7	Total	10312.55	100%

A comparative study of AWiFS (2002) and aerial photographs (1979) indicates the changes in vegetative cover. It may be due to converting sparse vegetation land to dry cultivation in the foot hills of the terrain and dry cultivation to wet cultivation in the plains during recent years after development of irrigation facilities. In the hill slopes shifting cultivation is practiced by degrading the sparse vegetation.

Slope studies

The average slope map provides information on slope distribution over the entire basin (fig.4). In general the slope of the terrain increases from south to north with highest inclination (above 20^0) marked on the high altitudes of the ranges. Table-2 reveals the area-slope distribution which is proportional to the total surface area falling within each group of slope.

Fig.4: Slope Map of Vamsadhara River basin

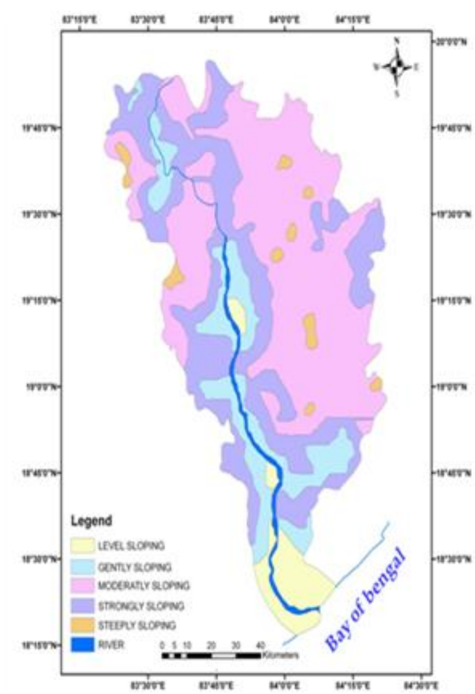


Table-2 Area-Slope distribution in Vamsadhara River Basin

Category Name	Slope Limits (degrees)	Area (Sq. Km.)	% of the Basin area
Level or nearly level	Less than 2	704.3	6.64
Gently sloping	2-6	1297.1	12.24
Strongly sloping	6-12	3222.4	30.40
Moderately steeply sloping	12-20	5251.4	49.53
Steeply sloping	20-25	126.3	1.19
Total		10601.5	100.00

The slope group of 12^0 – 20^0 and 6^0-12^0 occupies respectively the highest percentage of the total area 49.53 and 30.40 respectively (Table.2). The steep slope concentration is mainly on the NE and NW portion of the basin (fig.4). Most of the agriculture lands lie between less than 2^0 slope in the lower part of the basin. The cultivated land in the hilly terrain lies in the moderate to steep slopes.

Sedimentation studies

A stream gausing station is located across the main river course near Kashinagar. The available sediment data at Kashinagar gauging site from 1973 to 1977 show an upward trend in sedimentation, finally resulting in an enormous increase of more than 5 times within a span of five years. Yearly and monsoonal sediment, rainfall and runoff at Kashinagar gauging station are given in Table-3.

Fig.5: Soil Map of Vamsadhara River basin

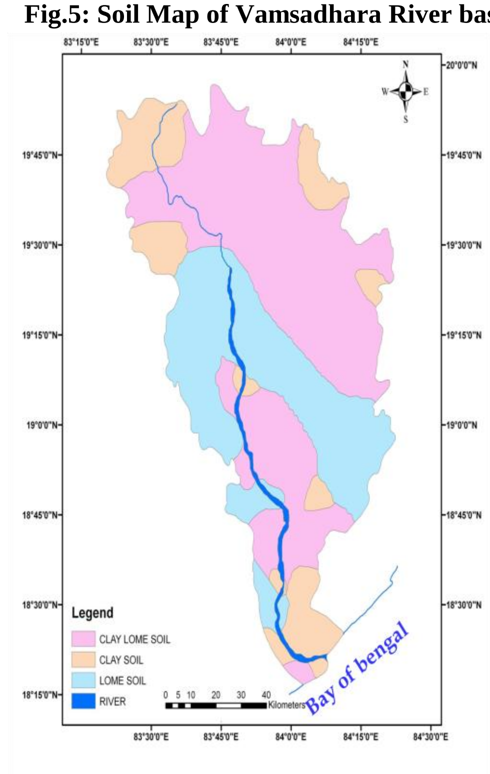


Table -3: Rainfall, Runoff and Sedimentation load data up to Kashinagar Site

Year	Monsoon			Annual		
	Rainfall (mm)	Runoff (mcm)	Sediment load(tons/sq.km.)	Rainfall (mm)	Runoff (MCM)	Sediment load(tons/sq.km.)
1973	907.5	149.2	317.3	1104.8	181.39	323.6
1974	905.9	119.5	335.5	1054.5	136.23	340.46
1975	1139.5	347.5	619.4	1273.3	386.97	625.18
1976	1078.8	320.8	643.4	1287.4	345.56	651.94
1977	1024.0	183.8	1396.7	1216.5	236.95	1631.10

Soil studies

The soil types in the river basin are shown in figure-5. Broadly the soils in the study area are identified as loamy, clayey loam and clay soils which have low, medium and high erosion properties respectively. Loamy soils are observed at few places in the limited area in the upper reaches of the catchment.

Most of the basin area is occupied by clay loam, distributed in the steep slopes and clay in the moderate slope areas. All the three types of soils are present in the plain areas and shown in fig.5. The soil erosion in the basin area is mainly due to sheet erosion; in the eastern part it is due to gully erosion, where the area is covered by clay loam soils.

Hydrological studies

The average annual rainfall data for the period 1930-2010 in the Vamsadhara river basin are analyzed.

Average annual rainfall distribution

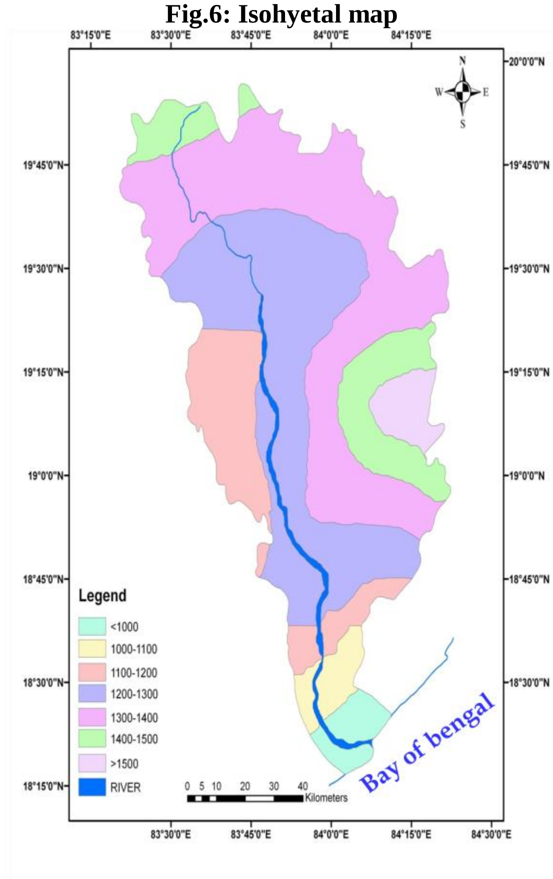
The general trend of the average annual rainfall map (fig.6) indicates an increasing trend of Isohyets from south to north, with a minimum of 1000 mm contour near coast and maximum of 1500 mm contour at the northern boundary of the hilly region. The average depth of rainfall is 1305 mm with the higher altitude recording a minimum of 1100 mm and maximum of 1500 mm the increasing trend is from east to west. Closer Isohyets are observed in the eastern part of the basin.

Environmental Impact of heavy rainfall causing Floods

The environmental impact studies of the basin constitute the integration of meteorological, geomorphology, vegetation/crop cover, soil and sedimentation studies. The areas prone to environmental degradation are demarcated by superposing all the thematic maps prepared on the same scale.

The procedure includes superposition of rainfall, slope, Vegetation/Crop covere and soil maps. Each theme has been divided into three categories such as high, medium and low erodable zones (table-4).

Fig.6: Isohyetal map



On the basis of the above classification, stepwise thematic map superposition is carried out. Rainfall and Slope (Gradient) maps are superposed on one other and the resultant map (RG) is classified in to nine groups by cross correlation. Again these are broadly regrouped into high, medium and low erosional zones. Vegetation/Crop cover map is again superposed on the resultant RG map. The resultant map thus obtained is designated RGV. The RGV map is superposed over soil map. After each superposition the areas in resultant maps are classified into high, medium and low zones of erosion. The final map obtained by these superposition's of 4 maps is grouped into 9 erosional zones depending upon the possible soil erodability. The nine erosional zones are shown as H_1, H_2, H_3, M_1,M_2,M_3 and L_1,L_2,L_3 with H_1 showing the highest erodability and L_3 the lowest erodability (fig. 7) and the aerial extent of each zone is presented in Table-5.

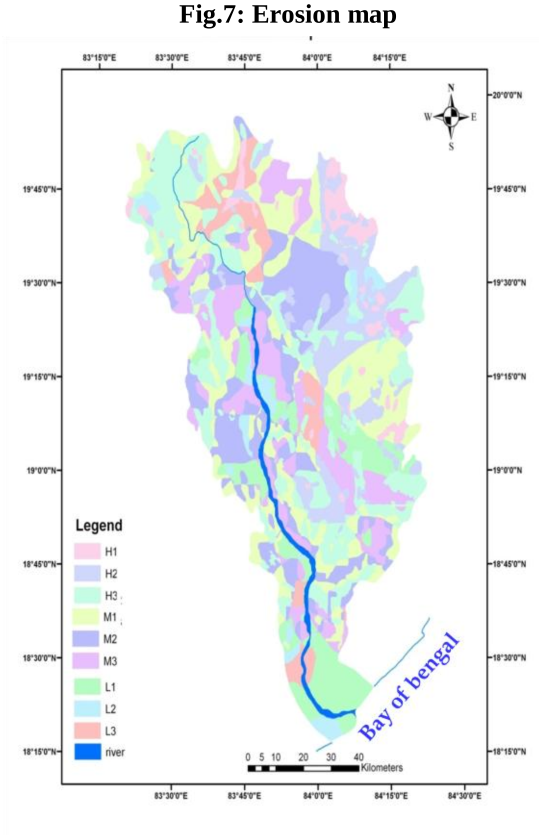
Only the quantitative gradation has been carried out on the basis of geomorphological features and rainfall. Quantification is yet to be attempted and can be carried out only by establishing sedimentation measuring units.

Table-4: Erosion categories

Theme	Low Erosion	Medium Erosion	High Erosion
Rainfall (G)	1000 - 1200 mm	1200 - 1400 mm	> 1400 mm
Slope (G)	$< 2^0$	$2^0 - 12^0$	$12^0 - 25^0$
Vegetation/Crop cover (V)	Dense Vegetation	Sparse vegetation, wet crops	Bare soils/Gullied lands/Podu cultivation/ Dry cultivation
Soils(S)	Loamy	Clay loam	Clayey

Sl.No.	Symbol	Type of erosion	Area in Sq.km	% of the total basin area
1	H_1	Very High	539.2	5.13
2	H_2	Medium High	686.9	6.53
3	H_3	High	536.9	4.26
4	M_1	High Medium	1521.3	14.47
5	M_2	Medium Medium	851.7	8.10
6	M_3	Low Medium	737.4	7.01
7	L_1	Low	1279.4	12.17
8	L_2	Medium Low	1396.0	13.28
9	L_3	Very Low	3052.7	29.05

Fig.7: Erosion map



Summary & Conclusions

The vamsadhar river basin an interstate drainage basin between Andhra Pradesh and Orissa with an aerial extent of 10,601.5 sq.km. is frequently prone to floods. The area of the basin between the coast and the foothills of Eastern Ghats falls under semi-arid climate and the upper reaches come under dry sub-humid type of climate. The methodology includes remote sensing, geotechnical, geomorphological, hydro-meteorology and sedimentation studies.

Remote sensing techniques are used for Vegetation/Crop cover mapping from the aerial photographs of 1979 and AWiFS satellite imagery data of 2002, and correlated with ground truth data. The comparative study indicates the reduction in vegetable cover due to converting sparse vegetation land to dry cultivation in the hilly terrain and dry cultivation to wet cultivation in the plains. Slope studies indicates the most of the study area is covered with moderate to steep slope. Steep slope areas are covered with sparse vegetation, where the shifting cultivation is also prevailing. Soils in the study area are identified as loamy, clayey loam and clay soils. More than half of the basin area is covered by clayey soils with high percentage of fines indicating low permeability and hence infiltration loses could be considered minimal. The trend of the average rainfall map indicates an increasing trend of isohyets from south west to north east. The concentration of rainfall is more in the eastern part of the basin. A perusal of the flood history of the basin reveals that the flood frequency has increased since 1970 may be due to the environmental degradation in the recent years in the catchment area. A few years observations of runoff and sediment load data up to kasinagar site reveals even though runoff is increasing nor decreasing, but the sediment load is always increasing trend from 1973 to 1977. The areas prone to environment degradation are demarcated by super imposing the thematic maps rainfall, slope, Land use/land cover and soil. The nine erosinal zones are shown as H_1, H_2, H_3, M_1,M_2,M_3 and L_1,L_2,L_3 with H_1 showing the highest erodability and L_3 the lowest erodability and the aerial extent of each erodible zone is presented. By analyzing the slope, Vegetation/Crop cover, soils, rain fall with support of sedimentation data reveals the area with sparse vegetation and shifting cultivation coupled with heavy rainfall and steep slopes are subjected to the removal of the fine fertile of soil through runoff, resulting in sedimentation and silting up of the river coarse in the lower reaches of the basin.

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