

Report No. _____

PREDICTING SOIL EROSION FOR ALTERNATIVE LAND USES IN BINA RIVER BASIN

**(PILOT BASIN STUDIES: IWRM IN BINA RIVER BASIN
IN BUNDELKHAND REGION OF MADHYA PRADESH)**



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PREFACE

It has been estimated that an area of over 80 million hectares or about one-fourth of the total area of India is exposed to wind and water erosion out of which 40 million hectares of land has undergone serious erosion. Ironically the extent of soil erosion is increasing in spite of our efforts to check soil erosion. Experts have estimated that about 40,000 hectares of land in India is permanently lost to cultivation and much larger area is rendered less productive every year due to wind and water erosion. About 21 million hectares are subject to severe wind erosion in Rajasthan and adjoining areas of Punjab, Haryana, and Gujarat. Madhya Pradesh has rapid soils erosion in its northern part along the Chambal and its tributaries. Large scale gully erosion can be seen in the belt around the districts of Gwalior, Morena and Bhind. Since the soils of this area are light and lack vegetation thus water takes away soils with its flow and results in erosion. Soil erosion not only disturbs the topographic and ecological balance but a large part of fertile sub surface land also goes waste through runoff.

The Universal Soil Loss Equation (USLE) developed by USDA is most widely used parametric model for quantifying the soil erosion in a watershed. The Geographical Information System (GIS) is extremely useful in storing, retrieving, and manipulating the spatial as well as non-spatial data. GIS and Remote Sensing capability to generate slope map, landuse/land cover map, soils map used for computation of input parameters to the soil erosion models make it more expedient.

In the present study an attempt has been made to predict the soil erosion for alternative land uses in Bina river watershed, a tributary of Betwa river in Bundelkhand region of Madhya Pradesh. The yearly expected soil erosion for present land use pattern in the Bina river basin have been estimated as 24.416 lakh tones. The soil loss under six different land use scenarios have also been predicted and best land use management practices have been suggested to maximize the food production and minimize soil erosion in the Bina river watershed. I hope the study will be useful to the Water Resources Department, Sagar (M.P.) especially for planning of dead storage capacity and catchment area treatment plan for the proposed 'Bina Complex: Multipurpose Project' on Bina river.

Dr. Tejram Nayak, Scientist 'E' and team of Ganga Plains South Regional Centre, Bhopal have carried out the study under the Pilot Basin Studies: IWRM in Bina river basin in Bundelkhand Region in Madhya Pradesh during the year 2014-15. The State Water Data Centre, Water Resources Department, Bhopal deserves our special thanks for supplying hydrologic data for this study.

(Raj Dev Singh)
DIRECTOR

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ABSTRACT

The basic concept of Integrated Water Resources Management (IWRM) is to integrate not only the stakeholders but also put together all aspects of natural resources for efficient use of available water in a river basin. Silting of water bodies is one of the major issues for conservation of water bodies as well as protection of fertile lands. Soil erosion and sediment yield are strongly affected by land use/land cover (LULC). Spatially distributed erosion models are of great interest to assess the expected soil erosion and sediment yield. A number of parametric models have been developed to predict soil erosion at drainage basins, yet Universal Soil Loss Equation (USLE) is most widely used empirical equation for estimating annual soil loss from agricultural basins. While conventional methods yield point-based information, Remote Sensing (RS) technique makes it possible to measure hydrologic parameters on spatial scales while Geographical Information System (GIS) integrates the spatial analytical functionality for spatially distributed data.

In the present study expected soil loss from Bina river watershed has been estimated using USLE model in GIS platform. The ancillary data on landuse/land cover was interpreted from the satellite imageries IRS LISS III digital data of the catchment area. The rainfall data collected for the rain gauge stations have been spatially distributed by moving average point interpolation technique. The rainfall erosivity factor (R) has been derived from the annual rainfall. The soil erodibility factor (K) map was derived from the soil class for which the map was obtained from the NBSS & LUP, Nagpur. The LS factor map was generated from the slope map derived from the DEM created by digitizing contour lines. The C factor values were chosen based on the land use map and P factor based on slope map. Maps covering each parameter (R, K, L, S, C and P) were integrated to generate a composite map of erosion intensity based on the advanced GIS functionality. This intensity map was classified into different priority zones.

The result shows that the estimated yearly potential soil loss in the Bina river basin is 132.776 lakh tones and the expected soil loss is 24.416 lakh tones. The impact of alternate land use planning by appropriate watershed management programme has been studied by assuming six scenarios of land use change. The study shows that the expected soil loss in the basin can be reduced by 2.3 lakh tones (9.33%) if forest planting is done in the existing open forest land and scrub land. A major water resources development project has been started in the basin, which may lead to convert the wasteland (barren land) having slope < 5% into arable land, if the canal water supply is made available. This will increase the food production as well as the soil erosion by 2.03 lakh tones (8.31%). In order to maximize the food production and minimize the soil erosion, the barren land having slope < 5% may be converted into arable land and the barren land having slope > 5% and the scrub land can be converted in forest land by plantations. This will not only increase the life of the water harvesting/storage structures but also preserve the fertile lands.

1.0 INTRODUCTION

Land degradation is a major cause of productivity losses and soil erosion is the most serious one among the various factors affecting land degradation. Therefore soil conservation is of primary importance in any land development work. There are many time-tested technologies for soil and water conservation that can be adopted for alternate land use systems whether it is crop production, horticulture, agro-horticulture systems, agro-forestry, silvi-pasture system or any other.

Soil is one of the important components of the lithosphere and biosphere system. It is a vital natural resource on which the supporting life systems and socio-economic development depends. The crisis of land degradation was mainly related to increasing population pressure. The per capita cultivable land has been declined from 0.32 ha in 1950's through 0.14 by the turn of the century to less than 0.1 ha by 2020. The soil erosion is the most serious problem faced at global level and local level too. Growing degradation and loss of soil means that the expanding population in many parts of the world is pushing this resource to its frontier. In the effects on humanity Judson (1965) was one of the first geologists to assess the world soil erosion. He estimated that the amount of river-borne soil carried into the oceans had increased from 9.9 billion tons a year before the introduction of agriculture, grazing and related activities, to the present rate of 26.5 billion tons a year. Hydrologists estimated that one-fourth of the soil lost through erosion in a watershed actually makes it to the ocean as sediment (FAO, 1978). The remaining three-fourths are deposited on foothill slopes, in reservoirs, in river plains and other low-lying areas or in the river-bed itself, which often causes channel shifts. In an overview of global erosion and sedimentation, Pimental (1995) stated that more than 50% of the world's pastureland and about 80% of agricultural land suffer from significant erosion.

The soil erosion is the process of removal of soil from the earth surface and its transport to deposit it elsewhere. The major factors responsible for erosion include rainfall, soil type and vegetation, topographic and geomorphologic characteristics of basin (Kothari and Jain, 1997) where there is lack of data on rainfall and sediment yield the relative vulnerability of watersheds can be assessed, with respect to time independent factors (soil type, topography and geomorphology). The erosion caused by agents other than the water is having localized effect and are smaller in magnitude as compared to the erosion caused by water. Annual potential yield of sediment through the water erosion is about 130 billion metric tons as discussed by Paul et al. [26].

Estimation of soil erosion are needed for studies of reservoir sedimentation, river morphology, soil and water conservation planning, water quality modeling and design of efficient erosion control structures. It is estimated that out of total geographical area of 329 Mha of India, about 167 Mha is affected by serious water and wind erosion . This includes 127 Mha affected by soil erosion and 40

Mha degraded through gully and ravines, shifting cultivation, water logging, salinity and alkalinity, shifting of rivers courses and desertification (Das, 1977). An average erosion rate of 16.35 tons/ha/yr was reported by Dhruvanarayana and RamBabu (1983) for the country.

Soil erosion risk is generally assessed on the basis of either prevailing soil erosion rate or sediment yield index (Sreenivas and Venkataratnam, 2005; Rahman et al., 2009; Bewket and Teferi, 2009). This approach, however, takes into account only the susceptibility of the soil without considering its degree of resilience or recovery at a given location. Scientific evidences based on long-term field experience imply that the soil has an inherent capacity to tolerate a maximum level of erosion depending upon its location specific attributes and still keep up its long-term productivity and sustainability (Mandal et al., 2009). The permissible soil erosion rate or the soil loss tolerance limit (SLTL), T-value, is a function of the relationship between the processes of soil formation and soil degradation. NRCS (1999) proposed a typical range of T-values in integer steps varying from 2.5 to 12.5 t/ha/year for different types of soils. Hence, permissible soil loss or T-value should also be taken into account in conjunction with the prevailing rate of erosion while planning any conservation programme based upon soil erosion risks in a given area. Such a database can be better generated and analyzed in a geographical information system (GIS) environment to delineate and prioritise the soil erosion risk areas at state or regional level.

1.1 Soil Erosion

Soil erosion is the weathering away of land surface by the action of natural agencies, viz. Water and Wind. It involves detachment, transportation and deposition of soil particles by the action of these natural forces. Natural or geological erosion is a normal feature of any landscape. Physical, chemical and biological weathering of rocks and parent material is a pre-requisite for soil formation. Geological erosion takes place steadily keeping equilibrium between the removal and formation of soil. Unless the equilibrium is disturbed by some outside agency, the mature soil preserves more or less a constant depth and character, indefinitely. Accelerated soil erosion is removal of the surface soil from any area denuded of its natural protective cover as a result of human and animal interferences. It takes place at a faster rate than at which soil is built up by the soil-forming processes. This accelerated detachment rapidly ravages the land, which is of serious concern. At normal geological place, nature requires 1,000 years to build up 2.5 cm of top soil, but wrong farming methods may take only a few years to erode it from the land of average slope. A fraction of millimeter (about 1 tonne soil/annum) is added on to 1 ha, though the loss of 100 tonnes/ha/year is not uncommon from undulating terrain. Worldwide, farmers are losing an estimated 24 billion tonnes of topsoil each year. In developing countries erosion rates per acre are twice as high as the standard, partly because population pressure forces land to be more intensively farmed. Although soil erosion is a physical process, it also affects

productivity and growth. Reductions in yield of up to 50% have been documented on severely eroded soils in Ontario. When soils are depleted the crops receive poor nourishment from the soil, the food provides poor nourishment to people.

Topsoil contains most of the soil's nutrients, organic matter, and pesticides. Soil erosion causes these substances to move also. What is left behind is soil with poorer structure, lower water-holding capacity, different pH values, and low nutrient levels. Therefore, fertilizers and organic matter must be added in an attempt to restore the soil to its original composition. The soil also has a lower resistance to drought. Much of the eroded soil is deposited both in low areas of the field or it moves off the farm and eventually enters drainage ditches, streams or rivers. Soil that enters a watercourse reduces water quality, reduces the efficiency of drainage systems and the storage capacity of lakes. Soil that settles in water systems is called sediment. Sediment fills rivers and reservoirs and reduces their capacity to hold flood waters. Sediment is considered to be a major pollutant. It can inhibit fish spawning and block the sunlight necessary to plant life. Increased runoff of chemical and nutrients from farmer's fields must be removed in order to the water be safe for drinking. So planning of measures required for conservation of soil has become prominent agenda in view of river basin managers. To develop the management plan for the soil conservation, the information of soil erosion is essential because it helps in planning and prioritizing treatments of the catchment. As the soil erosion caused by water is affected by the various parameters like slope, land use, soil characteristics, climatic parameters etc. So the efforts were put to develop some equations for estimation of water induced soil erosion by using the parameters which affect the soil erosion.

The severity of soil erosion can vary from place to place. Wind and water are the main causes of soil erosion. The velocity of water and wind, and the degree of plant cover available for protections are two main factors associated with erosion. Wind erosion is a more common problem in dry, windy regions, with a smooth, flat terrain. Water erosion is a problem in wet regions with a sloping or hilly terrain.

1.1.1 Types of Soil Erosion

The soil erosion may be classified as:

Sheet Erosion: it is the uniform removal of thin relatively uniform layer of soil particles from sloping surface of soil between rills. Although important, sheet erosion is often unnoticed because it occurs gradually.

Rill Erosion: When water takes the path of least resistance to flow over soil surface, it forms minute channels called rills. Detachability and transportability are both greater in rill erosion than sheet

erosion because of higher velocity. Rill erosion is of most serious, when storm of high intensity and top soils are loose and shallow.

Gully erosion: if the channel formed in the land are deepened and widened by erosion that their size is greater than those of common rills, the land is no longer readily usable, and the effect is then termed as gully erosion. These channels carry water and sediments during and immediately after rains. Gullies are also called ravines.

Stream channel erosion: It is a soil removal from stream banks or soil movements in the channel. Stream bank erodes either by runoff flowing over the stream bank or by scouring and undercutting below the water surface. It is often increased by the removal of vegetation, overgrazing, tolling too near banks, or straightening of the channel. Poor alignment and the presence of obstructions such as sandbars, increase meandering and are the major causes of erosion along the bank.

Mass erosion: Mass erosion is the mass movement of soil as in landslides, landslips, soil creep and mudflows. It occurs in small number every wet season and in large number about once in ten years. The quantity of sediment moved from the hill slopes in to river by mass movement is far in excess of that contributed from gullies, rills and overland flow.

Tunnel erosion: tunnel erosion occurs where there is intense penetration of the ground water. This is an underground disintegration of soils, which occurs practically in any thick layer of finally grained soils, and it sometimes referred as a special form of gully erosion. It frequently occurs in forested land causing both soil loss and water loss.

1.1.2 Problems of Soil Erosion

The following problems related to soil erosion are the major concerns at present.

- A wasteful use of our natural resources and accelerated abuse caused by increasing human and cattle population and a neglect of appropriate land use confounded the problem. The protective forest cover has been destroyed over large hilly and mountainous region due to overgrazing by cattle, sheep and goats and exploitation for other economic gains. Extensive deforestation as a result of increased demand for fuel and timber, and for bringing more land under cultivation are the other contributory causes. Shifting cultivation practiced by the tribal people over west area in Assam, Bihar, Orissa and Madhya Pradesh also causes an extensive destruction of forest and land resources. In the Khasi and Jaintia hills of Meghalaya, shifting cultivation (jhuming) is highly wasteful practice, leading to 40-80 tones/ha/year soil loss. Short jhuming cycles, a fall-out of diminishing land: main ratio, have further aggravated the problem of land degradation. Up and

down cultivation of pineapple in north eastern states and potato in Nilgiri Hills in Tamilnadu even on steep slopes cause soil erosion.

- Most glaring examples of soil erosion in India are the ravines along the Yamuna and Chambal rivers in the Uttar Pradesh, Rajasthan and Madhya Pradesh; *kotar* lands in Gujarat, *chos* (the rainy season torrents) in Hoshiarpur; and landslides in Shivaliks and Himalayas, where annual soil loss sometimes exceeds 80 tones/ha/year.
- The problems of soil and water conservation though not so serious but is equally important in the extensive cultivated fields of Punjab, Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh and Karnataka. These tracts are characterized by erosive rain fall, high wind velocity, undulating topography and shallow soils. Heavy downpours in July-August, when land has scarce vegetation cover causes heaviest erosion in these regions. The annual soil loss in these states ranges from 5 to 20 tonnes/ha/year.
- Wind erosion has been responsible for destroying the valuable top soil in western Rajasthan, Gujarat, Haryana and coastal regions of the country. An extreme example of sand movement from the coast is to be seen in the Saurashtra region of Gujarat, where the once-flourishing ports are now covered with advancing sand-dunes.
- Besides these, considerable road-side erosion also takes place owing to uncontrolled grazing of pasture, wasteland, defective highway engineering, unregulated mining and related activities. Mass wasting is phenomenal in hilly region due to landslide mining and slope failure.

1.1.3 Factors Causing Soil Erosion

The vulnerability of a field to soil erosion is dependent on a number of factors:

- The climatic conditions of the area
- The proportion of sand, silt and clay sized particles in a particular soil
- The organic matter level
- The water permeability of the soil
- The length and slope of the field
- Amount of crop rotation
- Direction of cultivation

1.1.4 Protection from Soil Erosion

It is vegetation that keeps soil from eroding. This is because soil is usually covered with shrubs and trees, by dead and decaying matter or by a thick mat of grass. The root system of plants is able to hold the soil together. Plants slow down water as it flows over the land and it allows much of the rain to soak into the ground. Plants also break the impact of a raindrop before it hits the soil. This reduces

water erosion. When this covering is stripped away through deforestation, over-grazing, ploughing and fire, soil erosion is greatly accelerated. Cultivation and compaction cause the soil to lose its structure and cohesion and it becomes more easily eroded. Soils with high clay content are more cohesive and allow soil particles to stick together. Soils with more clay are less vulnerable to erosion than soil with fine sand or silt content.

1.2 Modeling of Soil Erosion

Soil erosion from the catchment is the result of complex processes, which is controlled by climate, topography, geologic, geomorphic, and land use characteristics. Scientific planning of soil conservation requires knowledge of the relations among those factors that cause loss of soil and those that help to reduce such losses. Actual measurements of soil loss under field conditions would also be feasible for each level of these factors. Therefore, several soil erosion prediction models like WEPP (water erosion prediction and planning), WATSED (watershed model), USLE (universal soil loss equations) etc, have been developed during past 50 years.

Research that eventually led to development of the USLE started in 1940 in the Corn Belt (Zingg 1940). Research by Smith (1941), Smith and Whit (1947) and Browning et al. (1947) provided the impetus for the erosion modelling concept that resulted in the Musgrave equation (Musgrave 1947). The USLE was developed at the national run off and soil loss data centre in 1965 by Wischmier and Smith (1965). The procedure was later refined (Wischmier and Smith 1978), by incorporating more data from runoff plots, rainfall simulators and from field experience. Since 1965, research has expanded the use of the USLE by improving estimation techniques of its factors to account for additional kinds of land uses, climate conditions and management practices. The USLE has overcome many drawbacks of its predecessors and its major features include;

- More complete separation of factor effects so that results of a change in the level of one or several factors could be more accurately predicted
- An erosion index that provided a more accurate, localised estimate of erosive potential of rainfall and associated run off
- A quantitative soil erodibility factor that was evaluated directly from research data without reference to any common benchmark
- An equation and monograph capable of computing the erodibility factor for numerous soils from soil survey data
- A method of including effects of interactions between cropping and management parameter

- A method of incorporating the effects of local rainfall patterns through the year and specific cropping conditions in the cover and management factor.

1.3 GIS and Remote Sensing Techniques for Soil Erosion

The potential utility of remotely sensed data in the form of satellite sensors data has been well recognized in mapping and assessing landscape attributes controlling soil erosion, such as physiography, soils, land use/land cover, relief, soil erosion pattern (Pande et al., 1992). Remote Sensing can facilitate studying the factors enhancing the process, such as soil type, slope gradient, drainage, geology and land cover. Multi temporal satellite images provide valuable information related to seasonal land use dynamics. Satellite data can be used for studying erosional features, such as gullies, rainfall interception by vegetation and vegetation cover factor. DEM (Digital Elevation Model) one of the vital inputs required for soil erosion modeling can be created by analysis of stereoscopic optical and microwave (SAR) remote sensing data.

Geographic Information System (GIS) has emerged as a powerful tool for handling spatial and non-spatial geo-referenced data for preparation and visualization of input and output, and for interaction with models. There is considerable potential for the use of GIS technology as an aid to the soil erosion inventory with reference to soil erosion modeling and erosion risk assessment. Erosional soil loss is most frequently assessed by USLE. Spanner et al. (1982) first demonstrated the potential of GIS for erosional soil loss assessment using USLE. Several studies showed the potential utility of RS and GIS techniques for quantitatively assessing erosional soil loss (Saha et al., 1991; Saha and Pande, 1993; Mongkosawat et al., 1994). Satellite data analyzed soil and land cover maps and DEM derived and ancillary soil and agro-climatic rainfall data are the basic inputs used in USLE for computation of soil loss. Saha (1996) showed the feasibility of GIS to estimate actual and potential sediment yields following Sediment Yield Prediction Equation (SYPE) using RS derived soil and land use information, DEM derived slope and ancillary rainfall and temperature data. MMF model was used for quantification of soil loss by water erosion in Doon Valley, Dehra Dun, India, in GIS environment using various satellite remote sensing derived inputs (ASD, 2002). The availability of GIS tools and more powerful computing facilities makes it possible to overcome difficulties and limitations and to develop distributed 326 Water and Wind induced Soil Erosion Assessment and Monitoring continuous time models, based on available regional information. Recent development of deterministic models provides some spatially distributed tools, such as AGNPS (Young et al., 1989); ANSWERS (Beasley et al., 1980), and SWAT (Arnold et al., 1998). The primary layers required for soil erosion modeling are terrain slope gradient and slope length which can be generated by GIS aided processing of DEM. Flanagan et al. (2000) generated the necessary topographic inputs for soil erosion and model simulations by linking WEPP model and GIS and utilizing DEM.

1.3.1 ILWIS GIS Software

The ILWIS GIS developed at International Institute for Aerospace Survey and Earth Sciences (ITC), Enschede, The Netherlands is used for this study. The Integrated Land and Water Information System (ILWIS) provides users with the state of art of data gathering, data input, data storage, data analysis, and data output capabilities (Velenznela, 1990). It is a window based; integrated GIS and Remote sensing application consisting of display raster and multiple vector maps in map window, display of table in table window include creation of histograms, colour composites sampling and classification, filtering, and multi-band statistics. The result, interactive retrieval of attribute information, image processing facilities, manipulation of map in map calculator, and GIS analysis tools.

The ILWIS functionally for vector data include digitizing, interpolation from isolines and points calculation of segment or point density, and pattern analysis and for raster data includes creation of digital elevation model (DEM) , calculation of distance , slope/aspects, deriving attribute maps, classifying maps, and manipulation of maps, while for image processing, the ILWIS functionality includes creation of histograms, colour composites, sampling and classification, filtering, and multi-band statistics.

1.4 Watershed Management Programme in India

Drought Prone Areas Programme (DPAP) is the earliest area development programme launched by the Central Government in 1973-74 to tackle the special problems faced by those fragile areas, which are constantly affected by severe drought conditions. These areas are characterized by large human and cattle populations which are continuously putting heavy pressure on the already degraded natural resources for food, fodder and fuel. The major problems are continuous depletion of vegetative cover, increase in soil erosion and fall in ground water levels due to continuous exploitation without any effort to recharge the underground aquifers.

Though the programme had a positive impact in terms of creating durable public assets, its overall impact in effectively containing the adverse effects of drought was not found to be very encouraging. In addition, many of the States had also been demanding inclusion of additional areas under the programme. With a view to identifying the infirmities in the programme and also for considering the case for inclusion of additional areas under the programme, a High Level Technical Committee under the chairmanship of Prof. C.H. Hanumantha Rao, Ex-Member Planning Commission was constituted in April 1993 to critically review the contents, methodology and implementation processes of all area development programmes and suggest suitable measures for improvement.

Based on the recommendations of the Hanumantha Rao Committee (HRC), comprehensive guidelines for Watershed Development, commonly applicable to Drought Prone Areas Programme, Desert Development Programme and Integrated Wastelands Development Programme were issued in October 1994 and were made applicable with effect from 1.4.1995. Subsequently, based on the feedback received from States, Project Implementation Agencies and others concerned, the Guidelines were revised in September 2001. On the basis of the HRC recommendations, five different programmes were brought under the MoRD, namely, DPAP, DDP, IWDP, I-JRY and EAS. But over the next decade the multiplicity of programmes and guidelines remained. Thus, in 2005, the Department of Land Resources within the MoRD constituted a Technical Committee under the Chairmanship of Shri S. Parthasarathy to address major issues in watershed programmes and to recommend viable strategies and mechanisms for their effective implementation of these programmes.

The landmark report of the Parthasarathy Committee recommended a paradigm shift in the implementation of watershed programmes in India. Building a powerful case for a great step up in watershed investments, the report argued: “In our view, raising the productivity of rainfed areas is an imperative if we are to meet the goal of national food security in the coming years. We have estimated that, even in the most optimistic scenario of further irrigation development in India, nearly 40% of national demand for food in 2020 will have to be met through increasing the productivity of rainfed dryland agriculture . . . and this demands intensive watershed work in these regions.” It proposed a common Integrated Watershed Management Programme (IWMP) unifying IWDP, DPAP and DDP and designed a new set of guidelines for the same. This led to the setting up of the National Rainfed Area Authority in 2006. In 2009, the DPAP, DDP and IWDP programmes were merged into a single modified programme called the Integrated Watershed Management Programme (IWMP). It was also felt that the role of the NRAA vis-à-vis the Department of Land Resources needed clearer demarcation. Thus in June 2012, the Ministry of Rural Development constituted a Committee under the Chairmanship of Dr. Mihir Shah, Member, Planning Commission to revisit the Common Guidelines for Watershed Development Projects to provide necessary flexibility within the Guidelines and to ensure momentum to IWMP, even while strengthening its innovative features.

The committee suggested that the objectives of the watershed programme may be emphasized on (i) Increase in the availability of surface and ground water to meet the needs of drinking water, drought proofing and protective irrigation (ii) Regeneration of degraded natural resources, reducing soil erosion and restoration of ecological balance (iii) Improvement of land productivity in rainfed areas (iv) Promoting sustainable livelihoods and diversifying livelihood options (v) Strengthening local institutions (vi) Promoting location-specific technological solutions based on local resources and local knowledge and (vii) Mitigating the adverse impacts of climate change and promoting adaptation strategies.

In order to effective implementation of the watershed development programme, institutional mechanism is established at National level viz., Central Level Nodal Agency (CLNA) within the Department of Land Resources, Ministry of Rural Development to the field level viz., Watershed Development Team.

1.5 Objectives

The assessment of soil erosion risk or soil erosion thus essential for raising awareness among governmental and non-governmental institutions, besides the residents and other stakeholders in a given region to adopt appropriate strategies for sustainable and efficient use of natural resources for the current and future generations. Therefore, a methodology USLE was used to estimate soil erosion in Bina river basin of Madhya Pradesh State of India with the following objectives:

- To determine expected soil loss from the Bina river basin
- To delineate and prioritise the vulnerable area
- Impact assessment of the alternate land use management plan

2.0 STUDY AREA

2.1 Location and Extent

Bina river is a major tributary of River Betwa in Bundelkhand region of Madhya Pradesh, which originate from Begumganj block of Raisen district and enters Sagar district at Rahatgarh block and traverse through Khurai and Bina tehsil before confluence with river Betwa near Basoda town in Vidisha district. Presently, domestic water supplies to Rahatgarh, Khurai and Bina town; railways requirement at Bina Railway Junction and industrial supplies for Bina Refinery and JP power project are met from the Bina and Betwa rivers, beside limited irrigation from the river by direct pumping as per the availability of river water. “Bina Complex- Irrigation and Multipurpose Project” has been proposed. Under this project, four dams are proposed, the Madia dam and Chakarpur dam-cum-pickup weir on Bina river and one each on Dehra and Dhasan rivers, which are the tributaries of river Betwa. The study area is located partly in Sagar, Vidisa and Raisen districts of Madhya Pradesh. Various maps of Bina Basin are shown below. The geographical area of the Bina river basin is 2808 Km² and the geographical area upto the proposed dam site is 1139 Km². Bina river basin which traverses through the fertile plains of Madhya Pradesh, is one of the important tributary of Betwa River, which is one of the important basin of Yamuna River. Bina river basin is situated at 24° 10’ N to 24° 42’ N latitudes and 78° 09’ E to 78° 23’ E longitudes. The study area is located in Survey of India toposheet Nos. 55I/2, 3, 6, 7 and 11 on 1:50,000 scale. Soil erosion computation has been carried for the entire Bina river basin as well as the watershed upto Rahatgarh G&D site as shown in figure 2.1.

The upper part of the study area is highly undulating and covered by forests, barren lands and localized rain-fed agriculture. The drainage density is more in the upper catchment as compared to the lower part of the Bina river basin, the later is mostly gently sloping to plain topography largely covered with agricultural fields. The streams are dry after the monsoon months despite enough rainfall; the average annual rainfall in recent years over the basin is 1016.37 mm and during monsoon months, i.e. June to October the rainfall is 980.35 mm. Therefore groundwater is exploited for domestic and agricultural uses during Rabi season causing depletion of the water table in most of the area.

2.1.1 Climate

The average normal annual rainfall of the area is 1205 mm and about 90% of the annual rainfall takes place during the southwest monsoon period i.e. June to October, only 5.5% of annual rainfall takes place during winter and about 4.5% of rainfall occurs during the summer season. The maximum monthly rainfall occurs during the month of July followed by August. The climate of study area can be classified mainly into three seasons: Winter season starting from middle of November to

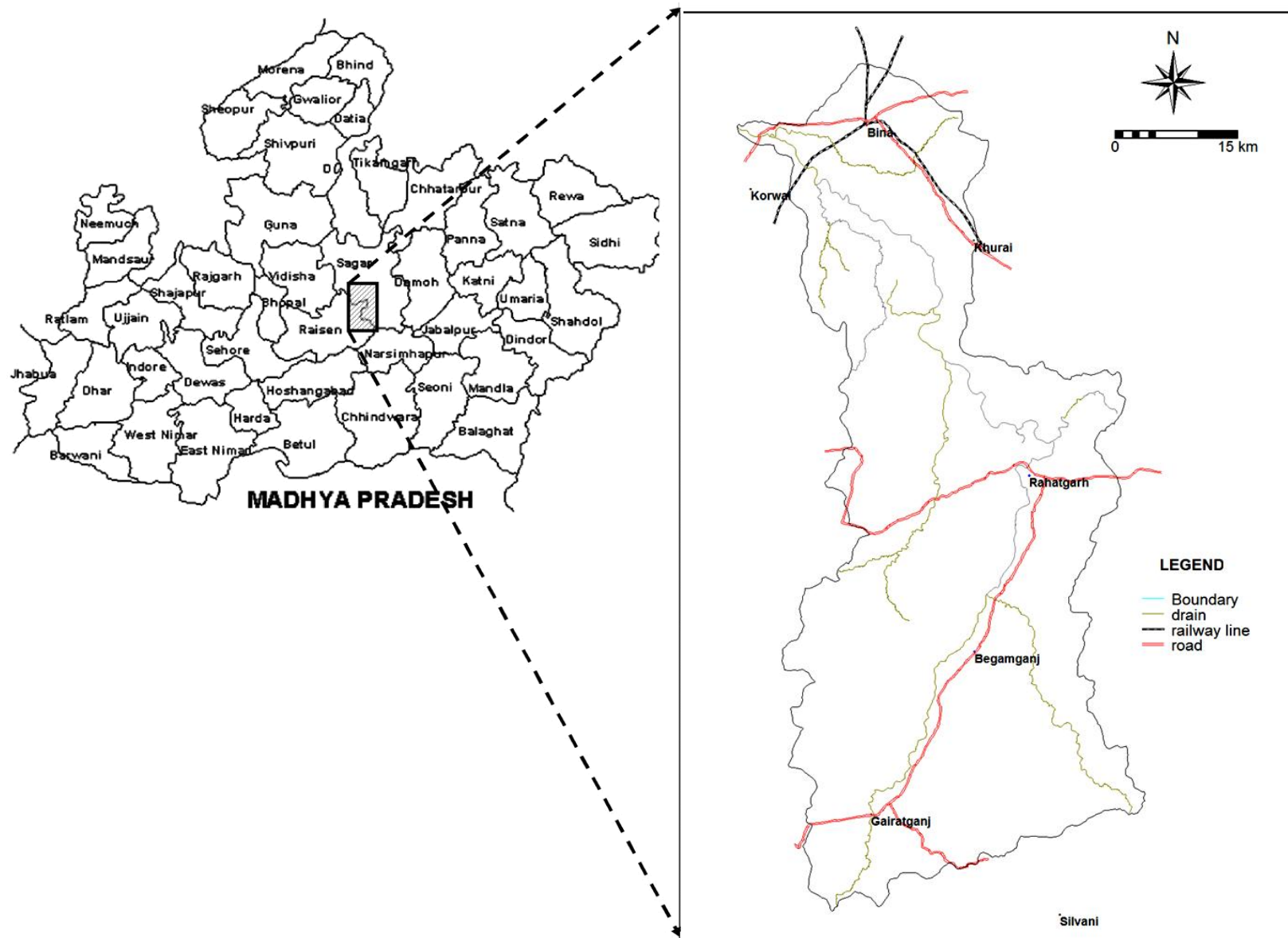


Fig. 2.1: Index map showing location of Bina river watershed

end of February; March to May constitutes the summer season whereas the monsoon season starts from second week of June to middle of October. During winter season the January is the coldest month with the average minimum temperature of 11.5°C whereas the hottest month is May with average maximum temperature up to 40.9°C.

2.1.2 Physiography and Relief

The study area falls under Bundelkhand plateau as per broad physiographical classification. The topography of the area is rolling to undulating. The land slope is characterized by flat topped hillocks. This topography is a result of the variation in hardness of different flows. Due to rolling and undulating topography, the upland areas have excessive surface drainage which has resulted in severe loss of surface soil. The soils removed from uplands get accumulated on the valley land. The valley land is moderately to poorly drain. The uplands having dendrite drainage pattern have limited natural drains and the drainage density is low. The district has fairly extensive network of rivers, mostly rainfed. There are five major rivers, which flow through the district namely Dhasan, Bebas, Bina, Bamner and Sonar. And some rain fed rivers like Kadan, Gadheri, Dehar and others also contribute in rainy season.

2.1.3 Geology

The geology of the area comprises of the lower and upper Vindhyan system and the important rock formations occurring in the area are Vindhyan sand stone, Quartzitic sand stone, lime stone and Deccan traps called basalt. Basalt rocks overlie the Vindhyan sand stone. Lower Vindhyan is represented by quartzitic sand stone and shales where as upper Vindhyan consists of sand stone and shales with subordinate limestone. Lameta lime stone is also found in lower reaches. This basic rock formation mainly governs the soil characteristics of the watershed area.

2.1.4 Soil and Crops

The area around Bina river basin is mostly fertile black cotton soil and some area under red soil. The main crops grown in Kharif season are soyabean, urad and paddy and main crops grown in Rabi season are wheat, red gram. Other staple crops like linseed, chickpeas, sorghum, oilseeds are also grown in the study area. The area around Bina river basin is mostly fertile black cotton soil and some area under red soil. As per the demographic information collected for villages in catchment area, around 40% of area in Rabi season is under wheat cultivation. The area under wheat cultivation varies from 36% in Dehra to 47% in Dhasan village. Gram is grown in around 38% of area cultivated in Rabi. The area covered under gram cultivation in the villages is in the range of 35-45%. Less than 20% area in rabi season is under lintel cultivation. Lintel is grown more in Madia village which is around 25% of the total Rabi crop. The kharif crops are mostly rainfed and there is no canal irrigation facility.

The farmers make their own arrangements to irrigate the crops by pumping groundwater or surface water bodies, in order to save the crops during the dry spell period in kharif season. Mostly wheat crops grown in the rabi season are irrigated through the groundwater pumping, as there are limited surface water storage structures, like check dams, tanks, ponds, weirs etc.

2.2 Water Resources Issues of Bina River Basin

2.2.1 Surface Water

Bina river is a major tributary of River Betwa in Bundelkhand region of Madhya Pradesh, which originate from Begumganj block of Raisen district and enters Sagar district at Rahatgarh block and traverse through Khurai and Bina tehsil before confluence with river Betwa near Basoda town in Vidisha district. The Bina river watershed experience very heavy rainfall during monsoon but due to lack of water conservation and management practices the river goes dry by the end of November or mid December, depending on the departure of monsoon in this region. Another, major issue is land use change, farmers intend to grow more water required crops, like wheat as the availability of electric supply is improved and advancement in technology for deep bore-wells. This practice has resulted into depletion of groundwater in the region. The depletion of groundwater has intensified the drinking water problem in rural areas and also led to rapid reduction in vegetation cover (forest cover). Three medium cities, namely Rahatgarh, Khurai and Bina, and about 150 villages fall in the jurisdiction of Bina river basin. The lower part of the basin has good fertile lands which produce the best quality wheat.

Recently, there is rapid growth in industrial development after commissioning of the Bharat Oman Refinery Project (Bina Refinery Project) and JP Thermal Power Project, otherwise agricultural practices are the main source of livelihood for the population in the basin. The large populations in the basin come under weaker socio-economic group, for which safe drinking water should be ensured, apart from the need for the domestic water supply in cities and towns. Presently, domestic water supplies to Rahatgarh, Khurai and Bina town; railways requirement at Bina Railway Junction and industrial supplies for Bina Refinery and proposed JP power project is met from this river beside limited irrigation from the river by direct pumping. “Bina Complex- Irrigation and Multipurpose Project” has been proposed by the Water Resources Department, Govt. of Madhya Pradesh is an ambitious project of the region for irrigation, power generation, industrial and domestic water supply etc. Under this project, four dams are proposed- two on river Bina and one each on Dehra and Dhasan rivers, which are the tributaries of river Betwa. The Madia dam and Chakarpur dam-cum-pickup weir are proposed on river Bina, Dhasan diversion on river Dhasan and Dehra dam on river Dehra, a tributary of Bina river.

2.2.2 Ground Water

The groundwater in the basin is exploited for irrigation to the largest showing area of wheat crops in Rabi season, because there is no major reservoir and canal water supply in the area. The surface water in the Bina river is generally available for the beginning of the rabi season only till the end of December and farmers are dependent on the groundwater pumping from the private dug wells or tube wells. Few number of minor irrigation tanks are available in this basin to supply irrigation water in the Rabi season. During the summer months, almost all villages depend on the groundwater for their drinking and domestic purposes, however pond water is used for live stocks. The groundwater table is about 5m to 15m below ground level and more than 50% area is under decline trend, the rainwater recharge in the basin reclaims the declining water table during the rabi season. More water conservation measures are required to maintain the sustainable groundwater in the sub-basin.

2.2.3 Drought Prone Area

Drought is an extended shortfall of precipitation that results in water supplies insufficient to meet the needs of humans and the environment (Wilhite and Buchanan-Smith, 2005) and occurs routinely as part of the natural hydrologic cycle. So the occurrence of drought event does not scale the proneness of that particular area. Probability distribution of annual rainfall helped in identifying the drought prone blocks in study area. The probability of occurrence is 80.86% at Begamganj which indicates that, it is not a drought prone area. The probability of occurrence of annual rainfall at Rahatgarh and Jaisinagar were 78.87 % and 70.04 % respectively, come under drought prone area. The probability of occurrence of seasonal rainfall at Rahatgarh, Jaisinagar and Begamganj were 78.58%, 69.73% and 76.57% respectively, fall under drought prone region.

3.0 METHODOLOGY

In the present study, the well known model, Universal Soil Loss Equation (USLE) has been used to estimate soil erosion in Bina river basin. Remote sensing and GIS techniques have been used for data generation, storage and analysis and Microsoft Excel software has been used for tabulating the results in presentable format.

3.1 The Universal Soil Loss Equation (USLE)

The Universal Soil Loss Equation (USLE) erosion model is designed to predict the long term average field soil losses under specified condition. This model enables the planners to estimate the average rate of soil erosion for a particular soil type, rainfall pattern, and topography (Wishmeier and Smith, 1965). When these predicted losses are compared with given soil loss tolerances, they provide specific guide lines for effective erosion control. The USLE can be used to estimate the annual average rate of soil loss in the field using the following equation.

$$A = R * K * L * S * C * P \quad \dots \quad (3.1)$$

Where,

A= the computed soil loss per unit area, usually in tones par acre per year

R= the rainfall and runoff factor, the number of rainfall erosion index (EI) units, plus a factor for runoff from snowmelt or applied water, where such runoff is significant

K= the soil erodibility factor, the soil loss rate per erosion index unit for a specified soil as measured on a unit plot, which is defined as a 72.6 ft length of uniform 9% slope in continuously clean-tilled fallow

L= the slop length factor, the ratio of soil loss from the field slope length to that from a 72.6 ft length under identical conditions

S= the slope steepness factor, the ratio of soil loss from the field slope gradient to that from a 9% slope under otherwise identical condition

C=the cover and management factor, the ratio of soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow

P= the support practice factor, the ratio of soil loss with a support practice like contouring, stripcropping, or terracing to that with straight row farming up and down slope.

All the factors of the USLE are geographic in nature. Therefore computation of these factors can be done easily and efficiently using GIS with various data layers representing watershed boundary, slope, rainfall distribution, land use and management practices, and soils. The combined data layers of GIS allow the calculation of soil erosion per pixel (NIH, 1999).

The USLE model groups the numerous physical and management parameters that influence erosion under six factors, which can be expressed numerically. Interrelation between the variables involved in water erosion processes are represented in the flowchart shown in figure 3.1.

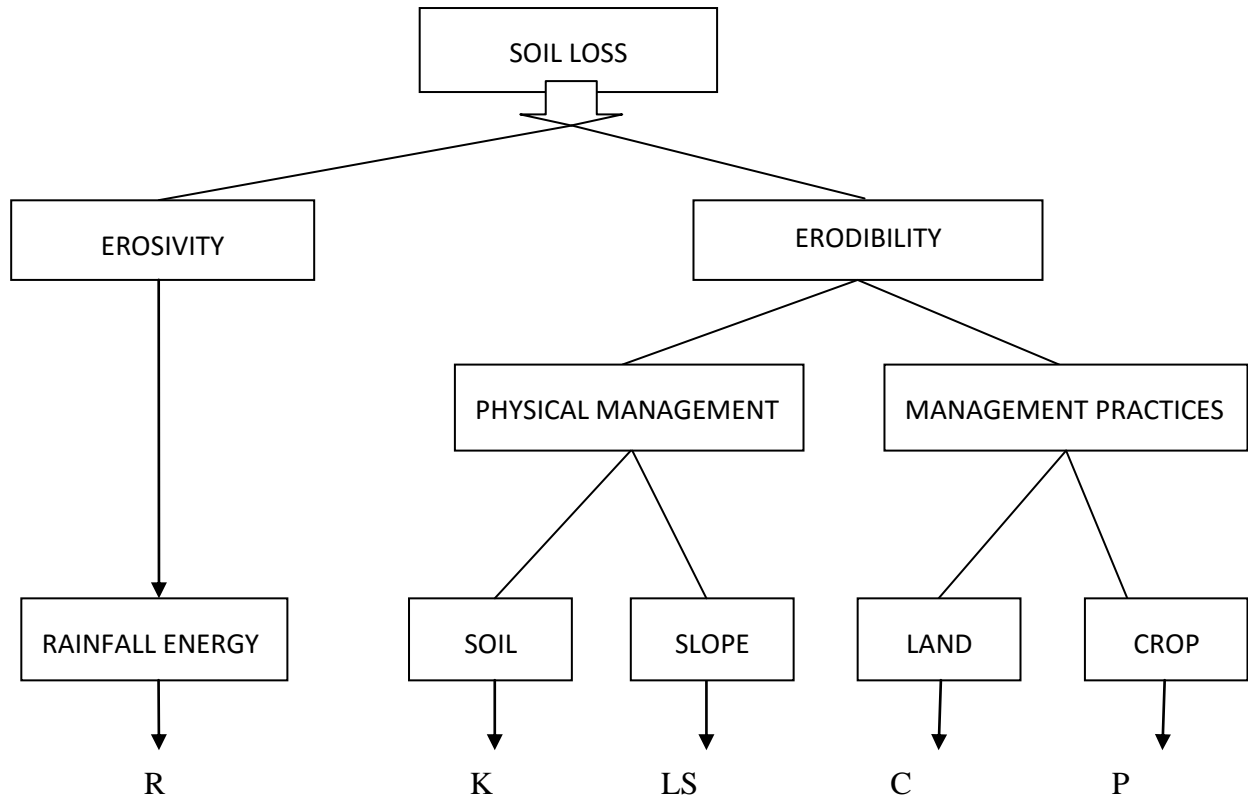


Fig. 3.1: Flow chart showing the computation of soil loss

The various factors have been computed by using the field and RS data and thematic maps have been prepared separately for each factor in GIS platform.

3.1.1 Rainfall Erosivity Factor (R)

The fundamental cause of soil erosion is that rain acts upon the soil, and the study of erosion can be divided into how it will vary for different conditions of soil. Erosivity can be defined as the potential ability of the rain to cause erosion and for given soil conditions one storm can be compared quantitatively with another and a numerical scale of values of erosivity can be created. Soil loss is closely related to rainfall partly through the detaching power of rain drops striking the soil surface and partly through the contribution of rain to surface runoff. The erosivity of a rainstorm is a function of its intensity and duration and of the mass, diameter and velocity of the raindrops.

The impact of rainfall and its related parameters is best described as erosivity, which is determined by the raindrop size, rainfall intensity, amount and frequency of the rain as well as runoff

amount and velocity. The erosivity is further influenced by the terrain (slope gradient, length, aspect, shape) and ground cover (Lal et.al, 1977). The erosivity of rainfall is scientifically best expressed with an index based on the kinetic energy of the rain. Thus the erosivity of a rainstorm is a function of its intensity and duration, and of the mass, diameter and velocity of the raindrops (Morgan 2001). Due to the difficulties to measure these highly varying characteristics an equation on the general relationship between kinetic energy and rainfall intensity was developed by Wischmeier and Smith (1958): $KE = 0.0119 + 0.0873 \log_{10} I$, where I is the rainfall intensity (mmh-1) and KE is the kinetic energy (MJ ha-1mm-1).

To better match regional rainfall characteristics several more equations emerged. In India, simple relationship between erosivity index (R) and annual or seasonal rainfall (X) has been developed by Singh et al, (1981) after analyzing the data collected from 45 stations distributed in different rainfall zones throughout the country. The coefficient of correlation was found to be 0.83 for annual and 0.88 for seasonal regression equations. The relationship can be expressed by the following equations.

$$R_a = 79 + 0.363 * X_a \quad \dots \quad (3.2)$$

$$R_s = 50 + 0.389 * X_s \quad \dots \quad (3.3)$$

Where,

R_a / R_s = annual / seasonal erosivity index, and

X_a / X_s = average annual / seasonal rainfall (mm)

3.1.2 Soil Erodibility Factor (K)

The soil erodibility factor in the USLE relates to the rate at which the different soil erodes. It is the quantitative measures of the inherent erodibility of a particular soil. Soil erodibility describes the soil's susceptibility "to detachment and transport by the agents of erosion" (Lal, 1994). The soil's resistance to erosion depends on its texture, aggregate stability, shear strength, organic matter content, clay mineralogy, infiltration capacity and chemical constituents. Some of these properties can change over the time due to the impact of land use, management practices, and farming systems. Erodibility is also influenced by the terrain. The infiltration rate of the soil and the amount of runoff that results when the infiltration capacity is exceeded are crucial for the rate of erosion. Since it depends on most of these factors the infiltration rate can be seen as a major contributor to soil erodibility.

Soil texture is a soil property of very high importance. Sandy soils have higher infiltration rates, but are easily detached whereas clay soils are less easily detached because of their cohesiveness but favour higher run-off rates and increased erosion. Silty soils and fine sands are most erodible since their resistance to both detachment and transported is relatively low. The consolidation of subsoil with higher clay contents, can lead to even greater run-off. Especially soils with a permeable surface that covers an impermeable clay layer are very highly susceptible to erosion since their surface easily become sodden and change into a semi-liquid mass. Morgan (2001) found that soils with a silt content

above 40 per cent are highly erodible, whereas Evans (1980) considers “soils with a clay content between 9 and 30 percent as the most susceptible to erosion” (Morgan, 2005). Values for K typically range from about 0.10 to 0.45 (customary English units), with high-sand and high-clay content soils having the lower values and high-silt content soils having the higher values. Because of its great range in possible values, the K factor may be of slightly greater importance, from a sensitivity point of view, than is the R factor. Users have little difficulty choosing a K-factor value because SCS has identified K values for all major soil mapping units. However, the site specific K value can be quite different from the K value given in soil survey information. The erodibility monograph is the most commonly used tool for estimating K values, but it does not apply to some soils. Under situations in which details of soil information for input is not available, the following Table 3.1 have been used. Knowing the organic matter content and textural class of the soil, the magnitude of soil erodibility can be found. The values shown in the following table are estimated averages of specific soil groups.

Table 3.1: Soil erodibility factor

Textural Class	Organic Matter Content		
	Average	Less than 2%	More than 2%
Clay	0.22	0.24	0.21
Clay Loam	0.30	0.33	0.28
Coarse Sandy Loam	0.07	-	0.07
Fine Sand	0.08	0.09	0.06
Fine Sandy Loam	0.18	0.22	0.17
Heavy Clay	0.17	0.19	0.15
Loam	0.30	0.34	0.26
Loamy Fine Sandy	0.11	0.15	0.09
Loamy Sand	0.04	0.05	0.04
Loamy Very Fine Sand	0.39	0.44	0.25
Sand	0.02	0.03	0.01
Sandy Clay Loam	0.20	-	0.20
Sandy Loam	0.13	0.14	0.12
Silt Loam	0.38	0.41	0.37
Silty Clay	0.26	0.27	0.26
Silty Clay Lome	0.32	0.35	0.30
Very Fine Sand	0.43	0.46	0.37
Very Fine Sandy Loam	0.35	0.41	0.33

(Adapted from Ontario Ministry of Agriculture, Food & Rural Affairs: May 2000)

3.1.3 Topographic Factor (LS)

The slope length and steepness is one of the major factor contributing to soil erosion are used in USLE to determine the soil loss. The velocity and volume of the surface runoff (and thus the grade of erosion) increase with the slope steepness and its slope. The soil loss is proportional to the product of the slope length and the tangent of the slope angle (Kumar et.al. 2007). Thus, both result in increased erosion potential, but in a non-linear manner. Slope Length slope factor (L) is the ratio of soil loss from field to the corresponding loss from a 22.13 m slope length which is expressed as:

$$L = \left(\frac{\lambda}{22.13} \right)^m \quad \dots \quad (3.4)$$

Where λ is length of the field in meters. Value of 'm' is variable (0.2 to 0.5) and very rarely (0.9) for different locations and other conditions, average value being 0.5. Thus,

$$L = \left(\frac{\lambda}{22.13} \right)^{0.5} \quad \dots \quad (3.5)$$

Degree of slope factor (S) is the ratio of soil loss on actual gradient to that from 9% slope under otherwise identical conditions. Different works have evaluated the exponent for variation of soil loss with percent slope, such as 1.49 (Zingg, 1940), 1.35 (Musgrave, 1947). The following equation suggested by Wischmeier and Smith (1965) may be used for evaluating the slope gradient factor:

$$S = \frac{0.43+0.30(G)+0.043(G)^2}{6.613} \quad \dots \quad (3.6)$$

Where, G is the slope gradient in percent.

For convenience L and S are frequently lumped into a single term. In the present study, two equations defining the LS factor were used, one for slope gradient less than 9 % and other for slope gradient of 9 % or more.

1. The equation for slope gradient up till 9 %, the original USLE formula for estimating the slope length and slope gradient factor, is:

$$SL = (\lambda/22.13)^{0.5} * [0.065 + 0.045(G) + 0.0065(G)^2] \quad \dots \quad (3.7)$$

2. Equation used for slope gradient of 9 % or more (Gaudasasmita, 1987) is:

$$SL = (\lambda/22.13)^{0.7} * [6.432 * \text{Sin}(\theta)^{0.79} * \text{Cos}\theta] \quad \dots \quad (3.8)$$

Where,

- SL = Slope length and slope gradient factor
- λ = Slope length (m)
- G = Slope gradient in percent
- θ = Slope gradient in radians

3.1.4 Crop cover and Management factor (C)

The presence of plant cover is the best natural protection having a big impact in the soil erosion. The land cover intercepts the rainfall, increase the infiltration and reduce the rainfall energy. Soil loss rates are generally very low under natural vegetation but with cultivation or vegetation removal the rates change dramatically. Research has shown that the percentage of soil coverage by biomass (plants or plant residues) is the most important factor influencing water infiltration, and runoff (Derpsch). The C-factor is the ratio of soil loss from land with specific vegetation to the corresponding soil loss from continuous fallow (Wischmeier and Smith, 1978).

The effectiveness of plant cover in reducing erosion depends upon the height and continuity of the canopy, the density of ground cover and the root density. Meszek et al (1975) concluded that the forest with a dense canopy, good undergrowth and undisturbed litter have the most significant effect on the surface runoff and thereby on the intensity and course of erosion. On the other hand, studies have indicated that whilst interception by the canopy reduces the volume of rain reaching the ground surface, it does not significantly alter its kinetic energy which may even be increased compared with that in the open ground (Chapman, 1948; Mosely,1982). This is because of the greater percentage of large drops in the rainfall as a result of the coalescence of the rain drop on the leaves. This condition holds true where there is no appreciable ground cover under the canopy. Jaiswal (1982) determined the cropping management factor for different land use patterns in the Gagas sub-watershed of Upper Ramganga Catchment. Gurmel Singh et al (1981) presented various experimental results conducted in India for the crop management factor, which is given in Table 3.2.

3.1.5 Conservation Practice Factor (P)

The conservation practice factor, P, in the Universal Soil Loss Equation is the ratio of soil loss with a specific support practice to the corresponding loss with up and down slope culture. Practices included in this term are contouring, strip cropping (alternate crops on a given slope established on the contour), and terracing. As a rule of thumb, contouring reduces to one-half the soil loss caused by up-and-down hill farming, strip cropping to one-half that of contouring, and terracing to one-half that of strip cropping. The value of P ranges from 1.0 for up & down cultivation to 0.25 for contour strip cropping of gentle slope. In computing the P factor, only the cultivated area of the watershed is considered. Finding the ploughing pattern for each and every cropping field is very difficult. Based on the results of intensive studies from runoff plots Wischmeier and Smith (1978) suggested the P factor values for various slopes for the agricultural fields. The P-factor is computed only the cultivated area (Agricultural area) of the watershed based on the slope percent, which is given in Table 3.3. P-factor value for non-agricultural area is assigned as 1.0.

Table 3.2: Crop management factor at various locations in India

CROPS	A	B	C	D	E	F	G
Moong	0.27						0.45
Ground nut	0.19	0.41					0.42
Cowpea	0.16	0.39		0.17			
Green gram		0.39					
Black gram		0.54					
Soyabean		0.42					
Guar		0.59	0.42				0.35
Maize		0.50		0.35	0.54		
Johar		0.62				0.64	
Johar + Arhar		0.33					0.28
Natural cover		0.14				0.12	
Fallow		1.0			1.0	1.0	1.0
Til		0.51					0.39
Bajra		0.61				0.40	
Paddy			0.28				
Pigeonpea			0.38				
Pomegranate with weed					0.08		
Pomgranate clean					0.56		

A: Vasad

C: Agra

E: Dehradun

G: Rehmankhera

B: Kota

D: Kharagpur

F: Hyderabad

Table 3.3: Conservation practice factor for different slope gradients

Sl.No.	Slope %	'P' value	Max. Slope Length
1.	1.0 - 2.0	0.6	131.2
2.	2.0 - 5.0	0.5	98.4
3.	5.0 - 8.0	0.5	65.6
4.	8.0 - 12.0	0.6	39.4
5.	12.0 - 16.0	0.7	26.2
6.	16.0 - 20.0	0.8	19.7
7.	20.0 - 25.0	0.9	16.4

3.2 Computation of Soil Loss

The USLE formula considers six variables for computation of expected soil loss from a watershed. If we do not consider the land cover factor (C) and management practices factor (P), there remains only four variable, RKLS. Together, they can be considered as the erosion susceptibility (RKLS) or potential erosion or soil loss (tons/ha/year) for the area. It can also be defined as the maximum possible soil erosion from the area without any management practices and land cover (vegetation). In natural conditions no watershed is completely barren and always some cover is there on the soil except the rocky outcrops. The land cover protects soil from detachment and moving away. Also, it reduces the impact of raindrop falling over the vegetation first and then on the soil surface. The various factors responsible for soil erosion, i.e. R, K, L, S, C and P were brought in the form of raster maps as stated earlier. Now, these factor maps were multiplied together using MapCalc operation to create expected soil loss map.

3.3 Soil Erosion Management Practices

Increase in agriculture production is the prime requirement for food security and economic development of the developing countries. In India, more thrust was given on the development of irrigation projects and increase in the agricultural area in the later half of the 20th Century. However, the watershed management aspects were neglected and soil and water conservation in the river basins were given less importance. This has resulted into more and more soil loss from the catchment area and high rate of sedimentation in the reservoirs as was assumed during the construction of dams. Implementation of Integrated Watershed Management Programme (IWMP) in the catchments of water bodies need to be intensified in order to control the soil erosion and reduce the sedimentation.

Recently, in June 2012, the Ministry of Rural Development constituted a Committee under the Chairmanship of Dr. Mihir Shah, Member, Planning Commission to revisit the Common Guidelines for Watershed Development Projects to provide necessary flexibility within the Guidelines and to ensure momentum to IWMP, even while strengthening its innovative features. The key features of these Guidelines include professionalization, capacity building, institution building, role of civil societies, focus on physical outcomes and monitorable indicators, etc. The committee strongly advocated that “A watershed programme must follow the ridge-to-valley principle since the ridge is the catchment of streams and water bodies in the lower reaches. If we do not treat these catchments, the capacities of dams in the valley are likely to be impaired.”

Many of our water bodies, including those constructed during 500-1000 years old large water tanks to the recent water bodies 25-50 years old reservoirs have been found under rapid silting rate and

more often get dry during the drought years. The Chandela and Bundela tanks in Bundelkhand region in central India are one of such examples. The major reservoirs constructed in Narmada valley, Chambal river basin and Betwa river basin are having more silting rate than those considered during the design period before construction of these reservoirs. Dredging and desilting of the reservoir cost many fold that that of creation of the same storage capacity, however the catchment area treatment for control of soil erosion of equivalent storage capacity cost less. Hence, protecting the created water storage structures from silting should be given more attention than creation of new reservoirs.

3.4 Impact Assessment

As discussed, the impact of rain drops have detachment force and soil particle size distribution and cohesive force resist the kinetic force imposed by the rain drops. The slope steepness and slope length also control the soil erosion process and sediment transport through overland flow. The combination of all these factors (RKLS) together gives the value of potential soil erosion from a watershed. The crop (land cover) factor and management practices factor (C, P) together reduce the potential soil erosion and gives the expected soil erosion from a watershed. Therefore, by alternate soil cover (land cover) and best management practices, soil erosion can be controlled effectively.

Estimation of expected soil loss using Universal Soil Loss equation in GIS platform by multiplying various thematic maps enables us to discretise the erosion process at pixel level. All the six parameters used in USLE for computation of expected soil erosion in a watershed is actually divided into small units called pixel of the raster map and soil erosion from each and every pixel is computed individually and summed up to get the total quantity of soil erosion. The rainfall, soils and slope may not be changed and thus the potential soil erosion in a watershed remains more or less same. However, the land use/cover and cropping management practices can be changed to minimize the soil erosion. Some engineering measures, viz. contour bunds, contour farming, loose boulder structures, gully plugging, vegetative barriers, plantations in the barren/shrubs land may be adopted to reduce the soil erosion. Impact of such measures can be quantified by assigning the changed land use, management practices and slope in the existing maps and then computing the expected soil loss with the revised factors. This will enable the planners to select the best management practices and alternate land cover in different slopping areas, wastelands, etc.

4.0 DATA USED AND ANALYSIS

The Universal Soil Loss Equation for estimation of soil erosion from Bina river basin requires annual/seasonal rainfall, soils, land use and cover, degree and length of slope, cropping pattern, and conservation practices adopted in the agricultural fields. These data were collected from various departments/organizations in both spatial and non-spatial format. These data were stored in ILWIS GIS and further analyzed. A brief description of various data collected from different sources and its analysis is given in the following paragraphs.

4.1 Thematic Maps

The map for all the six factors used in Universal Soil Loss Equation model have been created in Raster format and stored in GIS platform having uniform spatial resolution and coordinate system.

4.1.1 Base Map

The base map was created from 1:50,000 scale SOI topographic map No. 54 L/4 & 8, 55 I/1, 2, 3, 5, 6, 7 & 11. The base map was prepared showing watershed boundary, road, railway and drainage network and major settlements. The watershed boundary was marked on the basis of the contours and the drainage lines available on the SOI topographic map. UTM Projection coordinate system was adopted to generate a general coordinate system for the Bina river basin. In this projection system the coordinates can be assigned in metric and geographic units both. The objects were digitized and stored as thematic maps in GIS for further analysis. The geographical area of the Bina river basin was computed by creating histogram of the polygon map, which is found to be 2808.08 sq. km. The base map is given at figure 4.1.

4.1.2 Rainfall Map

Total seven raingauge stations, namely Bina, Kurwai, Khurai, Rahatgarh, Begumganj, Gairatganj and Silvani fall in and around Bina river basin. The annual rainfall observed at these stations available for last fifteen years were collected from State Water Data Centre, Water Resources Department, Bhopal (M.P.). Most of the rainfalls occur during the monsoon period, and the rainfall intensity is also very low therefore soil erosion during monsoon months is negligible. Further, the runoff during non-monsoon period in the Bina River is very low (mostly due to the base flow), hence, water erosion during this period may be considered as nil.

The seven rain gauge stations were marked on the basin map and stored as point map. The Interpolation operation on the point map was carried out by choosing the Criging interpolation method to get the distributed rainfall map in Raster format. The pixel size in the map has been kept as 24 m to

match with the landuse map derived from the IRS LISS-III images having the same pixel size. Further, using the MapCalc operation in GIS, the rainfall map was converted into the ‘R’ Factor map by applying the equation 3.3 and the output map was named as ‘rfactor’. The average annual rainfall observed at seven rain gauge stations and corresponding R-factor values are given in Table 4.1. The map showing distribution of R-factor in Bina river basin is given at figure 4.2.

Table 4.1: Rainfall distribution in Bina river basin

S. No.	Raingauge Station	Av. Annual Rainfall (mm)	R-Factor
1	Bina	1064.1	465.3
2	Korwai	1002.5	442.9
3	Khurai	1193.3	512.2
4	Rahatgarh	1166.9	502.6
5	Begamganj	1209.2	517.9
6	Gairatganj	1183.8	508.7
7	Silvani	1067.3	466.4

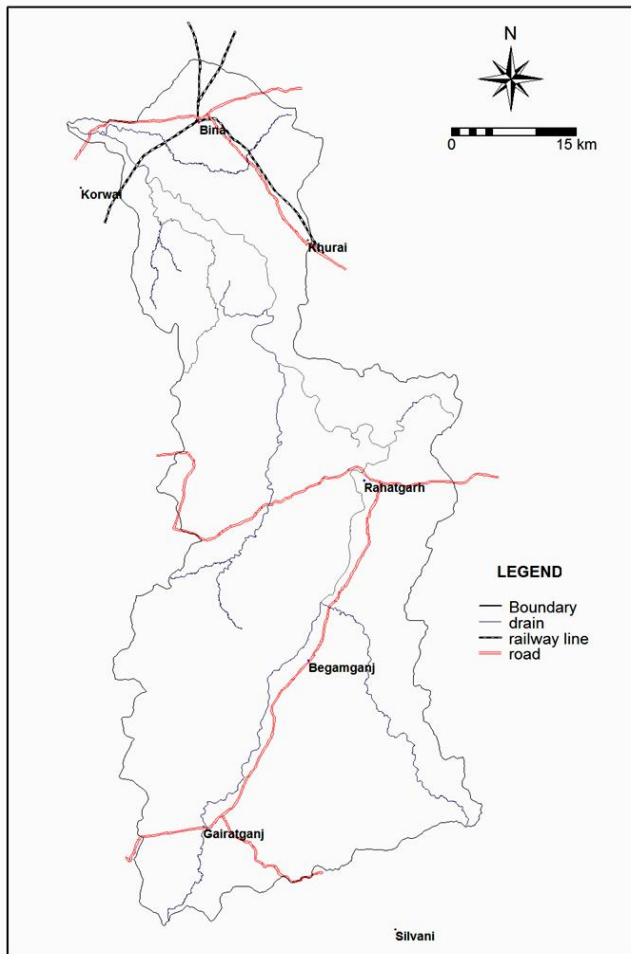


Fig.4.1: Base map showing Bina river basin

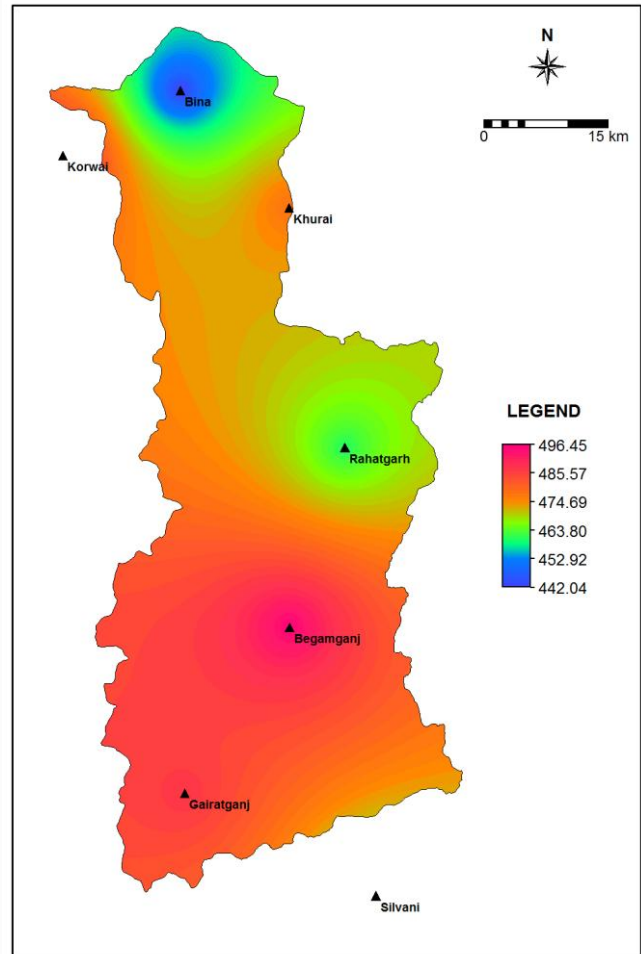


Fig.4.2: Distribution of R-factor in Bina basin

4.1.3 Soil Map

The soil maps published by the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Nagpur, Maharashtra was digitized and stored in vector format. Various categories of soils are found in the study area, namely loamy sand, sandy clay loam, coarse sandy loam, heavy clay, clay and silty clay etc. In the Indian soil classification of these soils are put under Pellusterts, Chromusterts and Ustochrepts i.e., medium and shallow black soils categories. The Organic Matter (O.M.) contents in both the soils are about 2%. The information on soils classification and O.M. contents were taken from the report ‘Soils of Madhya Pradesh for Optimising Land Use’ and ‘Soil Series of India’ published by National Bureau of Soil Survey and Land Use Planning (ICAR), Nagpur. Thus the K-factor for the different soil group on basis of O.M. content, soil texture and soil classes were obtained from available literature. Figure 4.3 shows the soil map. The geographic area under each soil class and the value of ‘K’ factor are given in Table 4.2. The soil class map was converted into value map with the corresponding ‘K’ factor values and stored as ‘kfactor’ map.

Table 4.2: Distribution of soil class and ‘K’ value

Code	Soil Class	Area	K-Factor
203	Fine sandy loam	9.36	0.35
305	Silty loam	366.02	0.38
311	Silty clay loam	162.82	0.32
314	Heavy clay	203.82	0.17
315	Silty clay	580.64	0.26
317	Clay loam	291.89	0.30
325	Sandy loam	21.85	0.13
342	Coarse sandy loam	14.49	0.07
352	Fine sandy loam	7.68	0.18
355	Sand	24.02	0.02
362	Clay	12.45	0.22
376	Silty clay loam	328.18	0.32
377	Sandy clay loam	395.43	0.20
398	Loamy fine sand	389.43	0.11

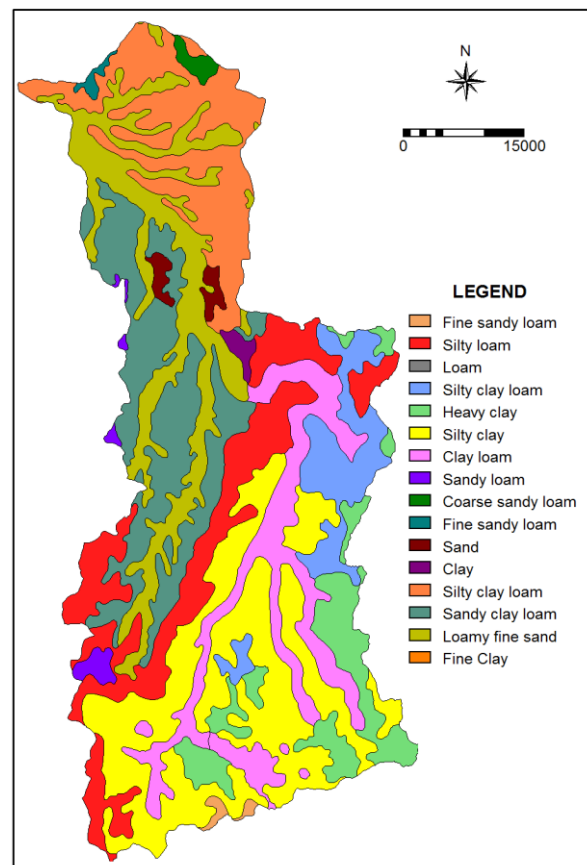


Fig.4.3: Soil map of Bina river basin

4.1.4 Topography

Contour lines given in the Survey of India topographic maps were digitized and the corresponding heights above mean sea level (Contour values) were assigned to each line. The contour

lines at 10 m intervals and the spot heights available at some places have also been digitized and stored in vector format as segment/point maps ‘isoline’. To create a Digital Elevation Model (DEM) map, interpolation of the segment map ‘isoline’ was done via the operation InterpolSeg in ILWIS GIS. The DEM map thus generated is a raster map showing the elevation or height above mean sea level at each pixels in the study area. Figure 4.4 shows the DEM map of Bina basin. In order to calculate the slope percentage of DEM map, the following steps involved in ILWIS GIS:

- (i) The digital gradient filters dfox and dfdy were applied to create two so called x-gradient and y-gradient maps.
- (ii) Next these two gradient maps are used to derive differences in elevation in all directions in the construction of a slope map. To create the slope map ‘slope’ in percent, the equation 4.1 was applied in MapCalc operation.

$$\text{Slope} = [\text{hyp}(D_x, D_y) / \text{pixel size}] * 100 \quad \dots \quad (4.1)$$

- (iii) The ‘slope’ map shows the slope in percentage and this can be converted into degree map by using ‘RADDEG’ and ‘ATAN’ functions of ILWIS and applying the following formula:

$$\text{Slope}(\text{deg}) = \text{raddeg}(\text{atan}(\text{slope}/100)) \quad \dots \quad (4.2)$$

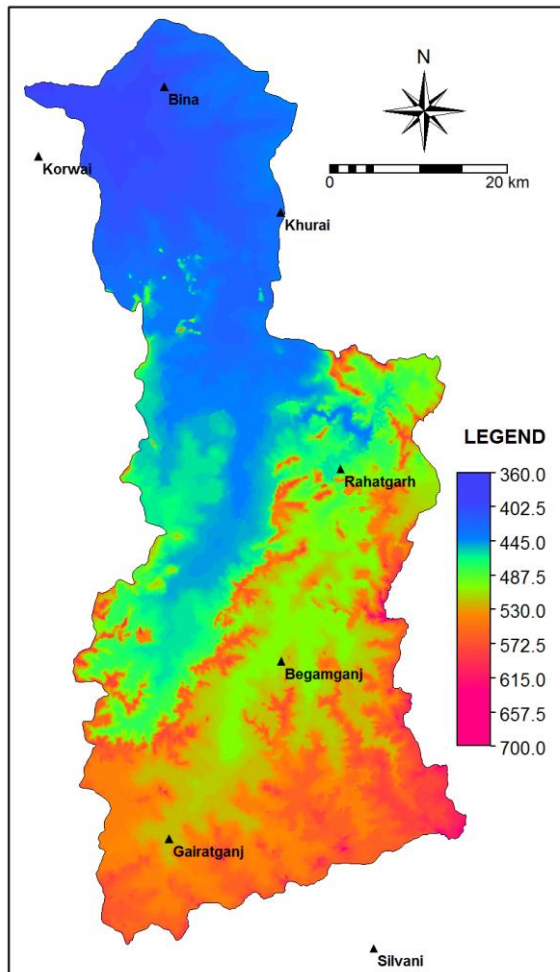


Fig.4.4: Digital Elevation Model (DEM)

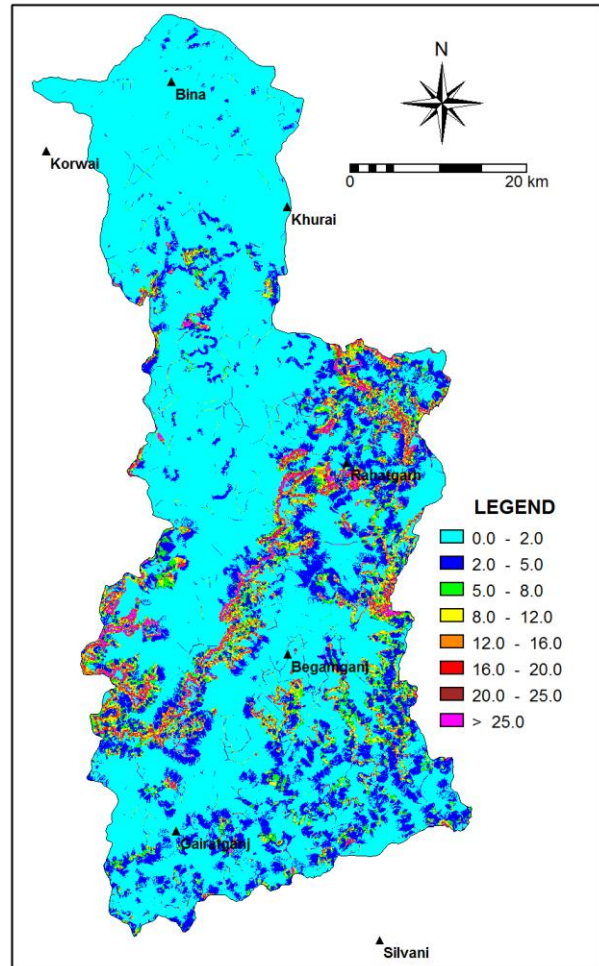


Fig.4.5: Slope map (%) of Bina river basin

To convert degrees to radians, the angular function ‘DEGRAD’ may be used. The slope map is given at figure 4.5. For the present study, the slope length was taken as the pixel size, i.e. 24 m for the calculation of ‘LS’ factor. ‘LS’ factor map was calculated for the slope upto 9 % and >9 % using the equations 3.7 and 3.8 respectively by putting the value of the slope length and the degree of slope. Then, by combining these two maps, the ‘lsfactor’ map was created showing the values of ‘LS’ factor for each pixel.

4.1.5 Land Use Map

The land use map of the Bina watershed was prepared by IRS satellite LISS-III imagery data. Digital Image Processing (DIP) technique using the Maximum Likelihood Classifier (MLC) was applied to prepare the land use map of the Bina basin using remote sensing data. Total nine land use classes could be identified in the Bina basin through DIP module available in ILWIS. Based on the ground truth survey and discussions held with the Joint Director, Department of Agriculture (Govt. of M.P.), Sagar, the cropland was classified good crop and poor crop. In the good crop, the crops are healthy and hence the tillage etc. was expected more, whereas the poor crop areas were linked with less tillage. The current fallow is the agricultural land without crops for that particular season. The forest areas were also classified into two categories, i.e. open forest and dense forest. Four other land use classes include settlements, water body and land with or without scrubs. The land use map thus classified from satellite imagery has been stored in raster format. The spatial distribution of land use in Bina basin is shown in the figure 4.6. For Indian conditions, Jaiswal (1982) and Gurnel Singh et al (1981) suggested the values of ‘C’ factor based on the field experiments conducted all over the country. Table 4.3 shows the value of ‘C’ factor assigned to different land use class with their geographical areas for the Bina river basin.

Table 4.3: Landuse map and ‘C’ factor

Landuse Class	Area in Sq.km.	% of Basin Area	‘C’ Factor
Agriculture-1	121.32	4.3	0.25
Agriculture-2	786.70	28.0	0.28
Current fallow	450.15	16.0	0.30
Dense forest	140.61	5.0	0.02
Open forest	543.76	19.4	0.05
Scrub land	490.28	17.5	0.15
Barren land	116.23	4.1	0.45
Settlement/rock outcrop	151.90	5.4	0.20
Water body	7.13	0.3	0.001

4.1.6 Conservation Practice Factor

The loss of soil and water under natural vegetation is the lowest. But lands must be cultivated and grown with crops to produce food. This can be done without much harm to the soil if proper soil and water conservation methods are followed. Such methods aim at encouraging water to infiltrate into the soil, reduce its velocity and check run off losses. The conservation practice factor (P) is

considered only for cultivatable lands; therefore the agricultural lands (good crop and poor crop area) were masked out from the land use map of Bina basin. In absence of detailed information about the soil conservation practices adopted in the agricultural fields by the farmers, the 'P' value has been decided based on slope percent. The slope map 'pslope' was classified as per the slope class given in Table 4.4 using 'Slicing' operation applied to the raster map 'slope'. Then the classified map 'pslope' was attributed to the column P-factor to create a raster map of 'P' factor value. The forest and non-agricultural lands (agriculture forest, scrub/bushes and barren/grazing land/water body) were assigned the value 1.0 for 'P' factor. The P-factor map is shown at figure 4.7.

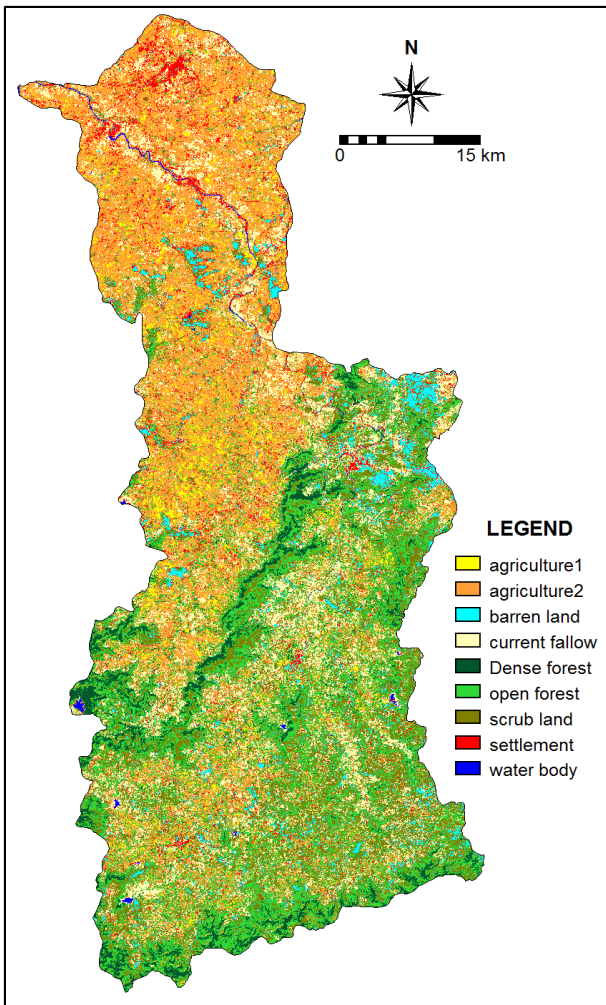


Fig.4.6: Landuse map of Bina river basin

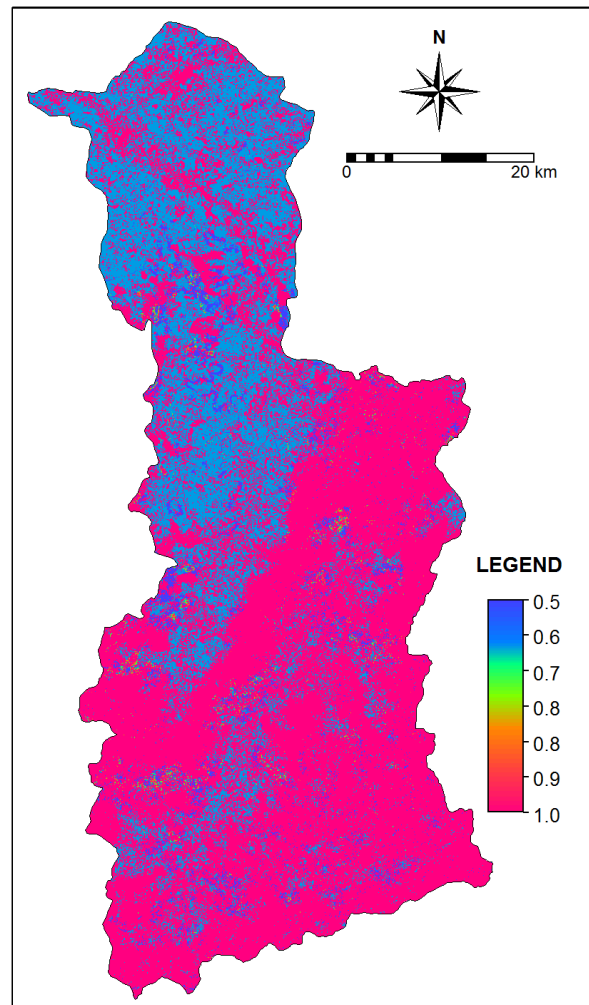


Fig.4.7: P-factor map of Bina river basin

Table 4.4: Slope distribution in Bina river basin

Sl. No.	Slope range in percent	Area under slope class	Percent of total area
1	0.0 - 2.0	1981.26	70.55
2	2.0 - 5.0	460.35	16.40
3	5.0 - 8.0	123.26	4.39
4	8.0 - 12.0	83.17	2.96
5	12.0 - 16.0	56.45	2.01
6	16.0 - 20.0	34.75	1.24
7	20.0 - 25.0	29.02	1.03
8	> 25.0	39.82	1.42
		2808.08	100.00

5.0 RESULTS AND DISCUSSION

The Universal Soil Loss Equation (USLE) has been applied to estimate the soil erosion from the Bina river basin, a major tributary of Betwa river. The study area falls in Raisen and Sagar districts of Bundelkhand region in Madhya Pradesh. Remote sensing and GIS acts as a useful media to provide a spatial dimension. At the same time, it integrates maps from various sources encompassing various vistas. An attempt has been made to create a digital database, mainly of watershed area, rainfall, soils, slope and landuse/land cover to estimate the quantum of soil erosion from Bina basin using toposheet and satellite remote sensing data in GIS environment to generate output in tabular as well as map form. The inputs to the USLE model are six factors derived from rainfall, soils, slope and landuse/land cover. The spatial distribution and total quantum of soil erosion computed in the study shall be useful for targeting the vulnerable zones, where soil conservation management practices be adopted on priority to minimize the adverse effects of soil erosion in the basin. The outcome of the study also includes the effect of landuse changes in the watershed on total soil erosion.

5.1 Soil Loss Calculation

5.1.1 Potential Soil Loss Calculation

The rainfall erosivity, soil erodibility, length of slope and degree of slope factors as elements of the USLE equation can be considered as naturally occurring factors determining the sheet and rill erosion processes without human interference (without considering management factors). Together, they can be considered as the erosion susceptibility (RKLS) or potential erosion or potential soil loss (tons/ha/year) for the area. It can also be defined as the maximum possible soil erosion from the area without any management practices and land cover (vegetation). Hence, both cropping-management factor and conservation practice factor are considered as one (1.0) for the soil and topography. Potential erosion (RKLS) zone for the study area were created by multiplying the maps showing the variation of R-factor, K-factor and LS-factor using 'MapCalc' operation in ILWIS. The potential erosion (RKLS) map was created in raster format. Histogram of the map 'RKLS' was created to get the area under different intensity of soil erosion.

5.1.2 Expected Soil Loss Calculation (A)

In natural conditions no watershed is completely barren and always some cover is there on the soil except the rock-outcrops. In this watershed, the land use/ land cover map was prepared using IRS LISS-III satellite data as described in the previous chapter. The potential soil loss map 'RKLS' was multiplied with the maps 'C-factor' and 'P-factor' using 'MapCalc' operation to create expected soil

loss map 'USLE'. Histogram of the map 'USLE' was then created to get the total expected soil loss from the Bina watershed. The 'USLE' map was sliced to get the spatial distribution of severity of erosion in the basin. The area under different category of soil erosion is given in Table 5.1.

It is very clear from the result that the vegetative cover in the watershed area and the conservation practices adopted in the agricultural fields have reduced the potential soil erosion drastically from 132.776 lakh tons/year to only 24.416 lakh tons/year. The expected soil loss is about 18.4% of the potential soil loss. The expected soil loss from the Bina watershed was further aggregated to create the classified expected soil loss map 'usleclfy'. The map given at figure 5.1 shows the spatial distribution of different intensity of erosion in Bina river basin. The average expected soil loss in the Bina river basin has been computed as 8.695 t/ha/year. By knowing the distribution of severity of soil loss in the basin and comparing potential and expected soil loss maps, the cause of increased erosion might be detected and improved management action could be proposed to prevent further degradation. The most vulnerable area generally fall in the high slope area or barren hilly ranges, which is more common in the southern parts of the basin in Raisen and Sagar districts. The plain area in the northern part of the basin in Bina and Khurai Tehsils of Sagar district fall in the less soil erosion prone area.

Table 5.1: Potential/Expected soil loss of Bina river basin

Sl. No.	Erosion Class	Erosion Value (t/ha/year)	Potential soil loss		Expected soil loss	
			Area (Sq.km.)	Percent to Total Area	Area (Sq.km.)	Percent to Total Area
1	Very Low	0 – 05	286.50	10.20	1959.90	69.80
2	Low	05 – 10	477.55	17.01	410.16	14.61
3	Moderate	10 - 20	1005.50	35.81	213.55	7.61
4	High	20 - 40	519.53	18.50	94.49	3.36
5	Very High	40 - 80	200.98	7.16	69.43	2.47
6	Severe	80 - 140	88.18	3.14	30.12	1.07
7	Very Severe	> 140	229.85	8.18	30.43	1.08
Total			2808.08	100.00	2808.08	100.00

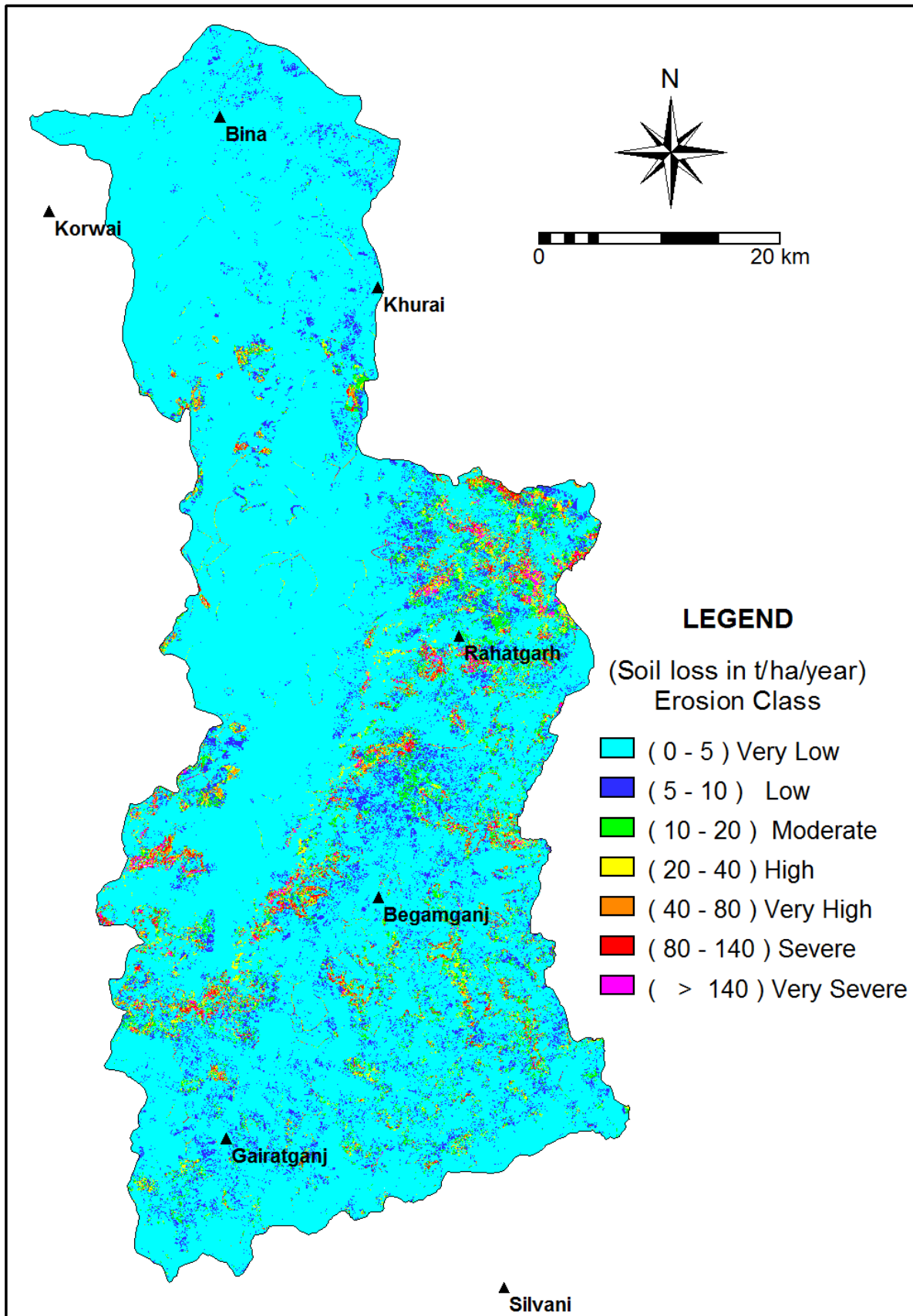


Figure 5.1: Expected soil loss in Bina river basin

5.2 Comparison of Results

Two empirical relations to estimate the quantity of sediment likely to deposit in the proposed reservoir, namely Joglekar's Curve and Khosla's Method were used to compare the results obtained from Universal Soil Loss Equation.

5.2.1 Joglekar's Curve

Joglekar analysed (Joglekar, 1965) the data from the reservoirs located in Central India, Maharashtra and Vidarbha region and he gave an equation of an enveloping curve to the observed data as

$$Q_s = \frac{0.597}{A^{0.24}} \quad \dots (5.1)$$

Where, Q_s = the annual silting rate from 100 sq. km of watershed area ($Mm^3/100$ sq. Km/yr)
 A = the catchment area (sq. km)

For Bina river watershed, $A=2808.08$ sq. km was put in the above equation, therefore

$$\begin{aligned} Q_s &= 0.08879 Mm^3/100 \text{ sq. km/year} \\ &= 8.879 m^3/ha/year \\ &= 9.767 \text{ tons/ha/year} \quad (\text{Assumed sediment density } 1.1 \text{ kg/m}^3) \end{aligned}$$

Sediment density as recommended by USDA for the reservoirs, water stored for winter and summer use and the silt deposit is exposed for some time only, is 1100 kg/m^3 .

5.2.1 Khosla's Method

Khosla analysed (Khosla, 1953) the data from various reservoirs in India and abroad and observed that the annual rate of sediment deposition decreased with the age of reservoirs. He plotted a curve between the annual sediment deposited and the catchment area and suggested the following empirical formula.

$$Q_s = \frac{0.323}{A^{0.28}} \quad \dots (5.2)$$

With the symbols as defined for Eq. (5.1). The results obtained by Khosla's equation are generally very much on the lower side. In most of the cases the actual sedimentation rate has been found more than three times the value assumed in the design on the basis of Khosla's equation.

By applying the Khosla's formula, the annual sediment deposit for Bina watershed was found to be:

$$\begin{aligned}
 Q_s &= 0.03497 \text{ Mm}^3/100 \text{ sq. km/year} \\
 &= 3.497 \text{ m}^3/\text{ha/year} \\
 &= 3.846 \text{ tons/ha/year}
 \end{aligned}$$

Thus the expected soil loss from the Bina watershed using USLE, Joglekar's Curve and Khosla's Method is as follows:

Method Used	USLE	Joglekar's Curve	Khosla's Method
Soil Loss in tons/year	8.695	9.767	3.846

5.3 Alternative Strategies to Reduce Soil Erosion

The impact of land use/land cover changes in the watershed area can be well analysed in GIS. However, the temporal changes can not directly be modeled in the GIS, but the changes in values of different parameters due to change in land use/land cover can be redefined in the GIS. Expected soil loss in a watershed may be estimated by assigning the new values for cropping management practices assuming the alternate land cover. The USLE model in raster format can be reliably used for environmental impact assessment associated with alternative land management practices and pertinent policy making. The primary purpose for conducting raster based USLE model simulations is to assist local policymakers to change the land use within the Bina river watershed. One of the major challenges is to identify strategies that reconcile the inherent conflict between food production and soil protection in the area. The proposed alternatives reflect alternative land use practices. Obviously, USLE modeling cannot answer all policy questions, but it may assist with defining: (i) the environmental effects of alternative land uses and (ii) the watershed management practices.

The six land use scenarios simulated include:

- (i) the base,
- (ii) all forest planting in open forest and scrubland,
- (iii) open forest in 50% scrubland and 50% barren land,
- (iv) all grain production in barren land upto 5% slope,
- (v) all grass growth in barren land,
- (vi) all grain production in barren land upto 5% slope, and forest plantations in > 5 % slope & in scrub land.

The base consisted of current land cover and land use conditions in the Bina river watershed, which is 48 % cropland, 24 % woodland, 18 % scrubland and 4 % barren land. For scenario (ii), the open forest and scrub land have been defined as dense forest for computation of soil erosion, i.e. assigned the C-factor value as 0.002. The scenario (iii) consisting on a hypothetical LULC condition in the future, provided that land use will be managed and half of the scrub land and barren land would be converted to forest land. This scenario has been created by assigning the crop management practice factor appropriately, i.e. average of open forest and current land use. The scenario (iv) has been hypothesized in view of the construction of proposed irrigation canal, most of the plains and mild slopping area may be converted into agricultural fields once the canal irrigation facility is made available to the farmers. Even the barren land under government control may be given to the sufferer of the project under Rehabilitation and Resettlement programme and shall be used for food production. In this scenario, all the barren land having < 5 % slope has been classified in agriculture category. The scenario (v) has been conceptualized if the barren land is converted into grassland by panchayats for fodder requirements of the live stocks. Generally the grain producing field results in more loose soil and causes more soil loss. If increase in agricultural area is counter balance by forest plantations in the high slope area would be effective in reducing the total soil loss from a watershed. With this concept, scenario (vi) has been assumed as all grain production in barren land upto 5% slope and forest planting in the barren land having more than 5% slope and in scrub land.

5.4 Discussion of Results

The USLE model has been run for all the six scenarios and gross annual soil loss in the Bina watershed has been computed for different scenarios. The quantity of annual total soil loss in case of different scenarios has been worked out as shown in Table 5.2.

Table 5.2: Expected soil loss in different scenarios assumed for Bina watershed

Sl. No.	Assumptions on land use changes	Scenario	Soil loss (t/year)	% change from base
1	The base	S-I	24.416	Base
2	All forest planting in open forest and scrubland	S-II	22.137	-9.33
3	Open forest in 50% scrubland and 50% barren land	S-III	23.289	-4.62
4	All grain production in barren land upto 5% slope	S-IV	26.444	8.31
5	All grass growth in barren land	S-V	25.148	3.00
6	Scenario-IV with forest plantations in barren land with more than 5% slope and in scrub land	S-VI	21.712	-11.07

Such land use changes can have local, regional or global effects on hydrological processes including the alteration of the soil erosion of a given region. The land use change scenarios have been applied in the USLE model to highlight the effects of land use changes on soil erosion in Bina watershed. The graphical representation of soil loss for different land use conditions (scenarios) is given at figure 5.2.

It is seen from the results that the forest plantations in half of the scrub land and barren land is found to be very effective measure for controlling soil erosion. The total expected soil erosion reduced by plantation (S-II) from the present value of 24.416 t/yr to 22.137 t/yr, i.e. by 9.33%. Whereas, the grain production in barren land upto 5 % (S-IV) increases the total expected soil erosion by 8.31%. But, the crop land is necessary to produce food grains for the livelihood of the local population, which increase the soil erosion. In order to keep the total soil loss at minimum, the increase in soil loss due to increase in cropland by converting (barren land into arable land must be counter balance by planting in the high slope barren land (with > 5% slope) and scrub land in the Bina watershed (S-VI), in this scenario, the total soil erosion would be reduced by 11.1%.

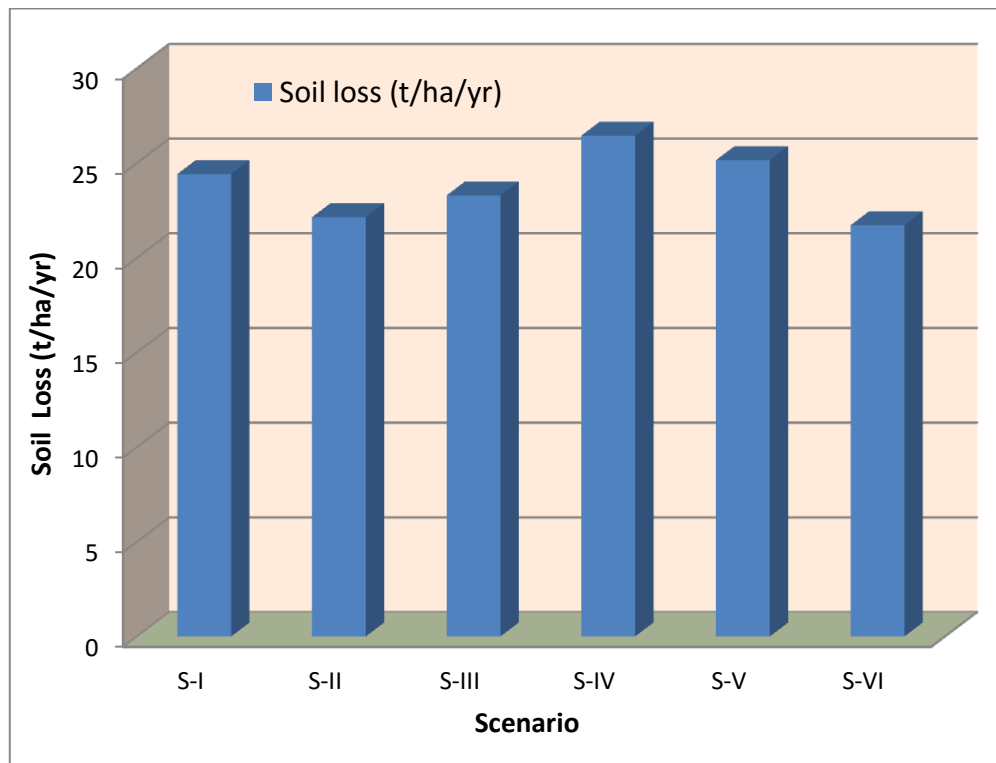


Figure 5.2: Expected Soil loss for different scenarios

6.0 CONCLUSIONS

The soil erosion can be controlled effectively if it is predicted accurately under alternate management strategies and practices. The Universal Soil Loss Equation model has been accepted and used most widely all over the world to predict the soil erosion from a watershed. In India also many researchers have applied the model and different model parameters (factors) have been estimated for Indian conditions. The expected soil erosion from Bina river watershed estimated using USLE is compared with two empirical formulae, namely Joglekar's Curve and Khosla's Method. The expected soil loss has also been quantified for six different scenarios under changed land use conditions. The increase or reduce of the total annual soil loss has been compared with the base year, i.e. present year and alternate management practice (land use) has been suggested.

In the Bina river watershed, the total area under scrub land and barren land is 17.5 sq. km and 4.1 sq.km respectively. The alternate land use to minimize the soil erosion could be the forest plantations in these areas. But, that will limit the development of agricultural lands for increased food production to cater the increasing population. If the barren land is converted into agricultural land, that will increase the soil erosion. Hence scenario S-VI has been developed to control the soil erosion as well as increase the food production. From the present study, following conclusions may be drawn.

1. GIS is a powerful tool to analyse the spatial as well as non-spatial data.
2. Maps interpreted from the remote sensing data can directly be stored and manipulated in GIS.
3. Various factors used in USLE model can be efficiently and accurately calculated using raster and vector operations in GIS.
4. The annual expected soil loss from the Bina catchment was estimated to be 24.416 lakh tones, i.e. 2.2196 lakh m³ in the present land use and topographic conditions.
5. The estimated expected soil loss computed by USLE model and Joglekar's curve are comparable, however the soil loss computed by Khosla's equation is under estimated.
6. The estimated expected soil loss reduces by 9.33%, if plantation is done in the present scrub land and open forest in the Bina river catchment and this will increase the life of the water bodies.
7. One major project, Madia dam is under construction to irrigate about 20,000 ha. In the Bina river basin, which may lead to converting the barren land having <5% slope into arable land. The soil loss in Bina watershed will increase by 8.31% in this scenario.

8. In order to optimize the food production and soil loss together, The barren land having $<5\%$ slope may be converted into arable land and forest planting may be taken in the barren land with $>5\%$ slope and scrub land.
9. The model can be applied for more alternate management practices, such as effect of soil stabilization, contour bunding, terrace farming etc.
10. Quantification of soil loss under different scenarios can help for better planning of watershed management in any river basin.
11. Knowing the benefits of increased food and fodder production and loss of fertile soil and nutrients due to soil erosion, an economic planning can be prepared using USLE model.

REFERENCES

1. Arnold JG, Srinivasan R, Muttiah RS, Williams JR (1998). Large area hydrologic modeling and assessment. Part I. Model development. *J. Am. Water Resour. Assoc.* 34:73–89.
2. ASD (2002). Agriculture & Soils Division, IIRS P.G. Diploma Course pilot project report on Soil Erosion Inventory using IRS-WiFS data and GIS - a case study of Dehradun district (Uttaranchal).
3. Beasley DB, Huggins LF, dan Monke EJ, (1980). ANSWERS: A model for watershed planning. *Transaction of the American Society of Agricultural Engineers*, 23, 938-944.
4. Bewket W, Teferi E (2009). Assessment of soil erosion hazard and prioritization for treatment at watershed level: Case study in the Chemong Watershed, Blue Nile basin, Ethiopia. *Land Degradation & Development* 20: 609–622.
5. Browning GM, CL Parish and Glass J (1947). A method for determining the use and limitations of rotation and conservation practices in the control of soil erosion in Iowa. *J. Am. Soc. Agron.*, 39 (1): 65–73.
6. Choudhary MK and Nayak TR (2003). Estimation of soil erosion in Sagar lake catchment of central India, *Proc. Int. Conference on Water and Environment: WE-2003*, Bhopal.
7. Das DC (1977). *Soil Conservation Practices and Erosion Control in India – A Case Study*. FAO Soils Bulletin 33 11–50.
8. Dhruva Narayana, VV and Ram Babu (1983). Estimation of soil erosion in India, *J. Irrig. and Drainage Eng.*, ASCE 109(4): 419-433.
9. Evans R, (1980). Mechanics of water erosion and their spatial and temporal controls: an empirical viewpoint. In: Kirkby, M.J. and Morgan, R.P.C. (ed.). *Soil Erosion*. p. 109-128. John Wiley & Sons. New York.
10. FAO (1978). *Soil erosion by water*. Agricultural Development Paper No. 81. 2nd printing. Rome. 284 p.
11. Flanagan DC, Renschler CS and Cochrane TA (2000). Application of the WEPP model with digital geographic information. 4th Int. Conf. on Integration of GIS and Environmental Modeling: Problems, Prospects and Research needs.
12. Gaudasmita K (1987). Contribution to Geo-Information system operation for prediction of erosion, M. Sc. Thesis, ITC, The Netherlands.
13. Government of India (1972). *Hydrology and Sedimentation*, Central Unit for Soil Conservation, Ministry of Agriculture (GOI), New Delhi.
14. Gurmel Singh G, Ram Babu and Subhash Chandra (1981). Soil loss prediction research in India, Bull. No. T-12/D-9, Central Soil and Water Cons. Res. Training Inst., Dehradun, India. 70 pp.
15. Indian Council of Agricultural Research (1987). *Handbook of Agriculture*, ICAR, New Delhi.
16. Jaiswal SK (1982). Runoff and sediment yield from Gages watershed of Ramganga catchment, Thesis, M.Tech. in Agriculture Engg., G. B. Pant University of Agriculture and Technology, Pantnagar.
17. Joglekar, DV (1965). *Irrigation research in India*, Central Board of Irrigation and Power, Publ. No. 78.

18. Judson S (1965). *Physical Geology*, Prentice Hall, NJ, USA, 3rd edn, pp. 143–144.
19. Khosla AN (1953). *Silting of Reservoirs*, CBI&P, New Delhi.
20. Kothiyari UC, Jain SK (1997). Sediment yield estimation using GIS. *Hydrol Sci J* 42(6):833–843.
21. Kumar S, Kumar A, Saha SK and Kumar A (2007). Stereo Cartosat-1 Satellite Remote Sensing Data in Assessing Topographic Potential of Soil Erosion. *Journal of Indian Remote Sens.* 36:159-165
22. Lal VB, Banerji S and Narayanan J (1977). Sediment yield in relation to drainage basin characteristics in some Indian river valley projects. *Proc. Paris Symp., IAHS-AISH, Publ. No. 122.*
23. Lal R (1994). Global overview of soil erosion. *Soil and Water Science: Key to Understanding Our Global Environment.* ‘Soil Sci. Soc. Amer. Special Publication No. 41, pp. 39-51.
24. Mandal D, Sharda VN and Kumar A (2009). Soil loss tolerance limits for conservation planning in different states of India. *Technical Bulletin No. T-56/D-35, Central Soil and Water Conservation Research and Training Institute, Dehradun, pp.102.*
25. Mongkolsawat C, Thurangoon P and Sriwongsa (1994). Soil erosion mapping with USLE and GIS. *Proc. Asian Conf. Rem. Sens., C-1-1 to C-1-6.*
26. Morgan RPC (2001). A simple approach to soil loss prediction: a revised Morgan–Morgan–Finney model. *Catena* 44: 305–22.
27. Morgan RPC, (2005). *Soil erosion and conservation.* Third edition, Blackwell publishing, Oxford, UK. 303 p.
28. Musgrave GW, (1947). The quantitative evaluation of factors in water erosion: A first approximation, Jr. *Soil and Water Conserv.*, 2(3): 133-138.
29. Natural Resources Conservation Service (NRCS). (1999). *National Soil Survey Handbook- Title 430-VI*, <http://www.statlab.iastate.edu/soils/nssh/>.
30. Nayak TR (2001). GIS for Soil Erosion Modelling: A Case Study of Bebas Watershed. ICORG, *Spatial Information Technology: Remote Sensing and Geographical Information Systems*; Edited by Prof. I.V. Muralikrishna; BS Publications, Hyderabad (A.P.), India; Vol. 1, pp. 191-196.
31. Nayak TR, Jaiswal RK and Singh Surjeet (2003). Estimation of reservoir sedimentation using remote sensing and GIS techniques, *Int. Conference on Advanced Modeling Techniques for Sustainable Management of Water Resources*, NIT, Warangal, January 28-30, 2004.
32. Pande LM, Prasad J, Saha SK and Subramanyam C (1992). Review of Remote Sensing applications to soils and agriculture. *Proc. Silver Jubilee Seminar, IIRS, Dehra Dun.*
33. Paul R, H Eswaran, and F Beinroth, Global dimensions of vulnerability to wind and water erosion, in 1999 *Proc. Sustaining Global Farm, 10th International Soil Conservation Organization Meeting*, Purdue University, USA, pp. 838-846.
34. Pimentel D, Harvey C, Resosudarmo P, Sinclair K, Kurz D, McNair M, Crist S, Shpritz L, Fitton L, Saffouri R and Blair R (1995). Environmental and economic cost of soil erosion and conservation benefits, *Science*, 267: 1117-1123.

35. Rahman MR, Shi ZH, Chongfa C (2009). Soil erosion hazard evaluation— an integrated use of remote sensing GIS and statistical approaches with biophysical parameters towards management strategies. *Ecological Modelling* 220: 1724–1734.
36. Ram Babu, Tejwani K G, Agarwal M C and Bhushan L S (1978), ‘Distribution of erosion index and Iso-rodent map of India’, *Indian Jour. Soil Conservation*, 6 (1): 01-11.
37. Rao, S V N, Rao M V and Gupta V (1996). ‘A study of sediment yield from Chenab river system in western Himalayas’, *National Institute of Hydrology, Roorkee, CS(AR)- 197*.
38. Saha SK, Kudrat M and Bhan SK (1991). Erosional soil loss prediction using digital satellite data and USLE, pages 369-372. *In Applications of Remote Sensing in Asia and Oceania – environmental change monitoring* (Shunji Murai ed.). Asian Association of Remote Sensing.
39. Saha SK and Pande LM, (1993). Integrated approach towards soil erosion inventory for environmental conservation using satellite and agro-meteorological data. *Asia-Pacific Rem.Sens. J*, 5(2) : 21-28.
40. Saha SK (1996). - Integrated use of Remote Sensing and GIS for soil erosion hazard modelling - a case study. *Proc. 17th Asian Conference on Remote Sensing, Sri Lanka*.
41. Singh G, Ram Babu and Chandra Subhas (1981). Soil loss prediction research in India, *Central Soil and Water Conservation Research and Training Institute, Dehradun, Bull No. T-12/D-9*.
42. Sreenivas K, Venkataratnam L (2005). A spatially distributed event based Model to predict sediment yield. *Journal of Spatial Hydrology* 5:1–19.
43. Smith DD (1941). Interpretation of soil conservation data for field use. *Agricultural Engineering*, 22 (5): 173–175.
44. Smith DD and Whitt DM (1948). Estimating Soil Losses from Field Areas. *Ag. Eng.*, 29, 394-396.
45. Spanner MA, Strahler AH and Estes JE (1982). *Proc. Int. Symp. Rem. Sens. Environ., Michigan, USA*.
46. Venzela CR (1990). *Introduction to Geographical Information System. ITC Publication No 22, International Institute for Aerospace Survey and Earth Sciences Enschede, The Netherlands*.
47. Wischmeier WH and Smith DD (1978). *Predicting Rainfall Erosion Losses- A Guide to Conservation Planning, Agriculture Handbook No.537, U.S. Dept. of Agri., Washington, D.C.*
48. Wischmeier WH and Smith DD (1958). Rainfall energy and its relationship to soil loss, *Trans. Am. Geophys. Union*, 39: 285-291.
49. Wischmeier WH and Smith DD (1965). *Predicting rainfall erosion losses from cropland east of Rocky Mountains, Agriculture Handbook No.282, U.S. Dept. of Agri., Washington, D.C.*
50. Young RA, Onstad CA, Bosch DD and Anderson WP (1989). *AGNPS – Agriculture-Non-Point Source Pollution Model: A watershed analysis tool. Conservation Res. Report 35, USDA, ARS, Morris, MN, USA*.
51. Zingg AW (1940). Degree and length of land slope as it affects soil loss in runoff. *Agricultural Engineering*, 21(2): 59-64.