Modelling of Soil Erosion by Non Conventional Methods

Ganesh D. Kale and Sheela N. Vadsola

Abstract—Soil erosion is the most serious problem faced at global and local level. So planning of soil conservation measures has become prominent agenda in the view of water basin managers. To plan for the soil conservation measures, the information on soil erosion is essential. Universal Soil Loss Equation (USLE), Revised Universal Soil Loss Equation 1 (RUSLE1or RUSLE) and Modified Universal Soil Loss Equation (MUSLE), RUSLE 1.06, RUSLE1.06c, RUSLE2 are most widely used conventional erosion estimation methods. The essential drawbacks of USLE, RUSLE1 equations are that they are based on average annual values of its parameters and so their applicability to small temporal scale is questionable. Also these equations do not estimate runoff generated soil erosion. So applicability of these equations to estimate runoff generated soil erosion is questionable. Data used in formation of USLE, RUSLE1 equations was plot data so its applicability at greater spatial scale needs some scale correction factors to be induced. On the other hand MUSLE is unsuitable for predicting sediment yield of small and large events. Although the new revised forms of USLE like RUSLE 1.06, RUSLE1.06c and RUSLE2 were land use independent and they have almost cleared all the drawbacks in earlier versions like USLE and RUSLE1, they are based on the regional data of specific area and their applicability to other areas having different climate, soil, land use is questionable. These conventional equations are applicable for sheet and rill erosion and unable to predict gully erosion and spatial pattern of rills. So the research was focused on development of non-conventional (other than conventional) methods of soil erosion estimation. When these non-conventional methods are combined with GIS and RS, gives spatial distribution of soil erosion. In the present paper the review of literature on non- conventional methods of soil erosion estimation supported by GIS and RS is presented.

Keywords—Conventional methods, GIS, non-conventional methods, remote sensing, soil erosion modeling

I. INTRODUCTION

THE soil erosion is the most serious problem faced at global level and local level too. The soil erosion is the process of removal of soil from the earth surface and its transport to deposit it elsewhere. Erosion is caused by the various agents like flowing water, ice, wind and thermal change effects (http://en.wikipedia.org/wiki/Erosion). Annual potential yield of sediment through the water erosion is about 130 billion metric tons as discussed by Paul et al. [26]. 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. Erosion due to water can be classified as splash erosion, sheet erosion, rill erosion, gully erosion, bank erosion. Splash

Ganesh D. Kale is Assistant Professor in Civil Engineering Department, S. V. National Institute of Technology, Surat, Surat-395007, Gujarat, India (phone: 02612201836; e-mail: gdk@ced.svnit.ac.in, kale.gd@gmail.com)
Sheela N. Vadsola, M. Tech (WRE) II Year Student, Civil Engineering Department, S. V. National Institute of Technology, Surat, Surat-395007, Gujarat, India (e-mail: sheela.vadsola@gmail.com).

erosion is detachment and air born movement of soil particles due to impact of raindrops while sheet erosion is detachment of soil particles by raindrop impact and their removal down slope by flowing water as overland flow as sheet instead of channel. Rill erosion refers to formation of small ephemeral flow paths which act as sediment source and sediment delivery system both.

Gully erosion occurs when water flows in narrow channels during or immediately after the heavy rains or melting ice while bank erosion occurs along the bank of the river due to flowing water (http://en.wikipedia.org/wiki/Erosion). Soil erosion causes the loss of most fertile upper layer of soil, sedimentation of reservoirs. Loss of most fertile upper layer causes reduction in crop production and on the other hand sedimentation of reservoirs causes loss in reservoir capacity and so loss of effective storage available for the various uses like drinking, irrigation, industrial purpose etc. So planning of measures required for conservation of soil has become prominent agenda in view of water basin managers. To plan for the measures of soil conservation the information of soil erosion is essential. Because information of soil erosion 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 up to develop some equations for estimation of water induced soil erosion by using the parameters which affect the soil erosion. The development of Universal Soil Loss Equation (USLE) in 1978 by Wischmeier and Smith was an initiation of such process as discussed by Paul et al. [26]. USLE, RUSLE1, MUSLE, RUSLE 1.06, RUSLE1.06c, RUSLE2 are most widely used conventional erosion estimation equations. The USLE was developed by the Agricultural Research Services, USA in collaboration with Purdue University. Federal state co-operative research projects at 49 locations contributed near about 10,000 plot year basic runoff and soil erosion data along with field plot data of 16 states in USA were used for the summarizing and overall statistical analysis as discussed elsewhere [36]. MUSLE was developed by the Williams in 1975. Toy and Foster in 1998 developed RUSLE 1.06 as discussed elsewhere [31] and US Department of agriculture, Agricultural Research Service and National Sediment Laboratory in 2003 developed RUSLE1.06c and RUSLE2. RUSLE1.06c and RUSLE2 were discussed elsewhere [32]. The essential drawbacks of USLE, RUSLE1 equations are that they based on average annual values of its parameters so their applicability to small temporal scale is questionable as discussed by Foster et al. [10]. Also these equations not involve direct runoff estimation (these equations estimate rainfall and runoff factor on the basis of erosion index) which is required to estimate runoff generated soil erosion. So applicability of these equations to estimate runoff generated

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soil erosion is questionable. Data used in formation of USLE, RUSLE1 equations was plot data so its applicability at greater spatial scale needs some scale correction factors to be induced. On the other hand MUSLE is unsuitable for predicting sediment yield of small and large events as discussed by Pandey et al. [25], in spite of its individual storm erosion estimation capacity and applicability to large spatial scales. Although the new revised forms of USLE like RUSLE1.06c and RUSLE2 were land use independent and they have almost cleared all the drawbacks in earlier versions like USLE and RUSLE1 as discussed by Foster et al. [10], they are based on the regional data of specific area and their applicability to other areas having different climate, soil, land use is questionable. These conventional equations are applicable for sheet and rill erosion and unable to predict gully erosion and spatial pattern of rills. So the research was focused then on development of non- conventional methods of soil erosion estimation. When these non-conventional methods combined with GIS and RS gives spatial distribution of soil erosion. In the present paper the review of literature on non-conventional methods of soil erosion estimation supported by GIS and RS is presented.

II. LITERATURE REVIEW

USLE, RUSLE1, MUSLE, RUSLE 1.06, RUSLE1.06c, RUSLE2 are most widely used conventional erosion estimation equations. USLE and RUSLE1 equations do not involve direct runoff estimation (these equations estimate rainfall and runoff factor on the basis of erosion index) which is required to estimate runoff generated soil erosion. So soil erosion estimation methods which include estimation of runoff were developed and used.

Tabassum [30] studied soil erosion which was needed immediate prediction from sub-watersheds in Dikrong river basin in Arunachal Pradesh of India, for soil conservation. Area covered by these eleven watersheds was 313.40 km². In this study the SCS curve number method was used for the estimation of runoff and then morphological parameters along with new introduced land use factor (F) approach was used for prioritization, 11 sub-watersheds were prioritized namely DN14, DS5, DS6, DS7, DS8, DN12, DN10, DS4, DN9, DN2, DN11 and were found to be under Very High Priority (VHP), which need immediate attention for soil conservation works.

Jasrotia et al. [13] performed soil erosion modeling by using Morgan and Finney model supported by RS and GIS in Tons Watershed of Dehradun district of Uttaranchal state of India. The model was having two phase i.e. water phase and sediment phase. Water phase was dealing with the detachment of soil particles while the sediment phase was dealing with the transportation of sediment by runoff. The runoff in the second phase was estimated by the SCS curve number method. Higher soil erosion was observed in the northern part of the Tons watershed. The average soil loss for all four sub watershed was calculated and it was found that maximum average soil loss of 24.1 t/ha in the sub watershed I.

Behera et al. [4] studied modeling of soil erosion using Morgan-Morgan-Finney (MMF) model by incorporating layers derived from RS and GIS. The study area was located in Song

watershed of Lower Himalayan belt of India. IRS 1C, LISS III satellite data was used for the preparation of land use map which was used to derive RD map, BD map, K map. Digital elevation model provided slope map to generate G map and soil map provided MS map, BD map and K map. After study it was found that, high value of 4572.333 kg/m² was observed for G map which depicted transport capacity of overland flow, comparatively low values 13.15 and 7.98 kg/m² were observed for F map which depicted erosion due to rainfall impact. Subtracted image of the aforesaid layers produced the real image with highest value 3.770 kg/m² which was found in the midland region of the site.

Kim et al. [15] studied prediction of soil erosion in Fraser's Hill, Pahang in Malaysia which was 1.5 km² in size and lies between 1060 and 1350 m above sea level. GIS software, ARC/INFO version 3.4 was used to develop the database. Results obtained shown that about 48% of the Sg. Hijau catchment falls under the slope gradient of 12°- 25° while 26% of the area under the slope of more than 25°. Four empirical methods based on the applications of erosivity were used for soil erosion computation. They were from USLE, Roose (1975), Balamurugan (1990), Morgan (1974) and rainfall of more than 25 mm/hr adopted in this study. By comparison, Roose generated the highest erosion rate with 1.757 t/ha/yr followed by Balamurugan with 0.685 t/ha/yr, 25 mm/hr with 0.567 t/ha/yr and lastly, Morgan with 0.532 t/ha/yr. Erosion rates of less than 1 t/ha/yr were computed for most of the area in the study watershed: soil erosion rates ranged from 0.363 to 0.642 t/ha/yr. This study shown that the erosion estimation can be performed using USLE in GIS environment. The results obtained were comparable with the measured soil loss from unit plots under similar conditions. Most of the studies carried out in given study area shown that the erosion seldom exceeds 1 t/ha/yr.

Kokh-Shrestha [17] performed soil erosion modeling using Morgan model and RS and GIS at Jhikhu Khola Watershed, Nepal. Annual soil loss estimation was calculated by comparing two maps of soil detachment rate and transport capacity and minimum value from them was used. The result of study by running a soil erosion model shown that, rain fed agriculture was contributing maximum soil losses, 32.5 t/ha/yr. The lower soil losses were recorded under forest cover (0.01-0.4 t/ha/yr) and irrigated agricultural land (0.9 t/ha/yr). Average estimated annual soil loss of the study area was 12.6 t/ha.

Phai et al. [27] carried out prediction of the soil losses using simple distributed and GIS assisted model in small agricultural watershed within sloping lands in the northern Vietnam. Predict and Localise Erosion and Runoff (PLER) model was used to identify the hot spots of the soil erosion. PLER was conceptual model on physical base. The model imitates the soil erosion process as dynamic process consisting of detachment, transportation and deposition of sediment. PLER was used for two complete years 2003 and 2004. The disparity for soil erosion quantity between the experiment and the run model was 5.1% in 2003 while that of in 2004 was 4.9%. These two study years were having different annual amount of rain. It was found from the study that PLER model took into

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account this discrepancy in the rainfall characteristics between year 2003 and 2004. PLER model maps underlined the fact that erosion process occurs mainly at the top of the landscape and highlighted a different behavior for detachability and soil erosion between the western and the eastern parts of the study watershed.

As the conventional empirical methods based on the plot data having specific conditions (such as percent slope and slope length and soil, climate, vegetation of particular area) their applicability to areas having different specific conditions than plot data is questionable so some regional soil erosion models were developed to suit the regional conditions.

Wang et al. [33] used RS and GIS to analyze the spatial distribution of soil erosion in Hubei Province, China. Mathematical methodology for study of soil erosion was explored and developed. In this methodology first of all the soil erosion is graded in different grades from weak erosion to most intensity erosion. The soil erosion of different elevation area, different slopes, different aspect, different land use, various degree of land use is analyzed and soil erosion index were calculated for different unit. The method was used for the estimation of the soil erosion.

Anrong et al. [3] studied prediction of soil erosion using ANN analysis supported by GIS and RS in Miyun County of China. The first step in this methodology was to collect data on land use, terrain slope and vegetative cover which affect erosion. Second step was to classify the soil erosion classes depending upon the data according to national standards. In the second step the watershed boundary and administrative boundary have been used as a reference for the calculation and statistics. This approach of soil erosion modeling was found to have less data requirement, less calculations and economically cheap as compared to conventional methods. After study it was found that the existing situation of soil erosion in Miyun County was well due to planting, monitoring and managing by both central and local government.

Huang et al. [12] carried out quantitative assessment of regional soil erosion in Chengdu plain in Sichuan province of China on the basis of vegetative cover and slope steepness and normalized difference vegetation index (NDVI) derived from Landsat-7 ETM+ image acquired at 2000-11-02. Process of soil erosion monitoring was performed through geographical information system and information from remote-sensing data and DEM data. In this way the status of soil erosion in Chengdu plain was assessed.

Milevski [21] estimated soil erosion risk in the upper part of Bregalnica watershed-republic of Macedonia (225 km long, 4307 km^2 catchment area) by using empirical equation developed by Prof. S. Gavrilovic using DEM and satellite imagery. The equation was in form: G=T*H*3.14*sqrtZ3*f, where: G is average annual soil erosion in m^3, T is temperature coefficient ((t+0.1)/10), H is annual precipitation in mm, Z is erosion factor and f is watershed area in km^2. Among these factors, Z (with values of 0 to 1.5) has special importance combining: soil erodibility (Y), vegetation (X), anti-erosive measures (a) and slope angle (J). Because of proven accuracy, several recent GIS adaptations of this equation were available. Identification and quantification of soil erosion risk was

performed through the detailed analyses of raster grids of topography acquired from 3"SRTM DEM and raster grids for vegetation cover acquired from Landsat ETM+ satellite imagery. In that way influence of most relevant topographic indices and vegetation index was estimated. Then, with clustered module incorporated in SAGA GIS software and superimposing of several layers sites with excessive erosion processes were identified and showed as high erosion risk areas. Average soil erosion potential of the area was estimated from the combination of DEM with satellite image derived raster grids in related equations. These computations were resulted in the formation of the digital map of the soil erosion which when compared with real indicators of soil erosion shown satisfactory fitting.

ANH [2] studied soil erosion estimation in the centre of Himalayan ranges using regional scale erosion model of Thornes. The soil erosion model parameters were generated from temporal MODIS NDVI, daily precipitation data and soil map of Uttarakhand state at a scale of 1:500,000. The results obtained from study shown that, slope and vegetation cover were the most sensitive parameters and soil erodibility was the least sensitive parameter. Soil erosion rate per rain day of 35 days in monsoon season (15 days of July, 10 days of August and 10 days of September 2006, respectively) was computed. Also it was concluded that the average soil erosion rate per rain day equals 1.26 t/ha in the rain period of 35 days. The maximum, minimum and mean of soil erosion rate in 35 rain days was 2379 t/ha, 0.004 t/ha and 44 t/ha respectively.

Nabi [24] studied grid based regional scale sediment yield model (RSSYM) which was set up for different catchments of Indus basin. Equations of fractal constant and fractal dimension were developed using DEM of 1 km^2. A comparison was made between fractal constant equation and fractal dimension equation, in which fractal dimension equation gave better results as compared to fractal constant equation. Applicability of temperature index approach for Indus basin was tested by application of snowmelt runoff model (SRM) to Astor catchment. The output of the model was discharge hydrograph. The coefficient of efficiency was found to be 0.91which shown good correlation between the observed and simulated values. The statistical test showed that the model performance was good. A snowmelt runoff model was developed using temperature index approach. The model was coupled with RSSYM. The coupled model was named as modified regional scale sediment yield model (MRSSYM). MRSSYM model was applied to Astor and Gilgit catchments. For the Astor catchment total observed sediment load was 3.98 million tons whereas the simulated sediment load was 4.34 million tons. The coefficient of the model was 0.89 whereas the coefficient of determination was 0.83. Similarly for Gilgit catchment the measured and simulated sediment loads were 4.50 and 4.48 million tons respectively. The coefficient of model and coefficient of determination were 0.95 and 0.88 respectively. It was concluded that MRSSYM can be applied with confidence to various catchments of Indus basin where runoff was due to snowfall and snow melting.

Evangelou [6] studied the prediction of soil erosion risks in Europe by USLE & PESERA models using GIS. PESERA is

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Pan Europian Soil Erosion and Risk Assessment; it combines the effect of topography, soil and climate in to single integrated forecast of runoff and soil erosion. GIS technology was found to be a powerful tool for identifying areas on a large scale having high potential for erosion. GIS technology was used with either expert-based or model-based approaches to determine erosion risks. GIS offered a practical tool for development of more effective national and international policies concerned with sustainable land use practices.

Although model based on continuity equation was also developed because of its non-empirical nature. Sharma [29] derived a distributed spatial sediment delivery model for the arid regions of Argentina and India. Model was based on basic-principles like continuity equation and was linked with a personal computer-based low cost GIS to facilitate preparation, examination and analysis of spatially distributed input parameters as well as to link the sediment delivery from a micro-scale to the macro basin scale. The heterogeneous and complex land surface was divided in to the sub areas. Data on vegetation cover was found from the digital analysis of satellite images. From the study it was found that prediction of sediment yield quantity from bare land was high as compared to land surfaces covered by vegetation though the flow shear stress values were same for the two land cover types. So results showed model accuracy in the prediction of soil erosion from the different land uses. The study demarcated the hot spots of the soil erosion in the study area to decide and carry out suitable soil conservation measures.

Another important drawback of conventional empirical methods of soil erosion is that they are unable to predict spatial pattern of rill and gully erosion so efforts were put up to develop the models which can predict spatial patterns of rills and gully erosion. Lloyd and Favis-Mortlock [19] carried out modeling of rill erosion using RillGrow2 model on conditionally simulated DEMs of bare soil surfaces. The Rillgrow2 model was developed by the Favis and Mortlock in 1998. The modeling approach considers movement of runoff is controlled by the micro topography which was modified by passage of erosive flows. This iterative procedure leads to the development of complex system i.e. rills and micro-rills. The conditionally simulated DEMs of bare soil surfaces were given as input to the model. So with given input of soil micro topography the model was able to predict the pattern of erosion along the small hill slope. This research explored the relationship between changes in short range variation of inputs to RillGrow2 model outputs. In this way, the sensitivity of RillGrow2 to variations in inputs was assessed.

Dondofema et al. [9] identified gullies and determined their relationship with environmental factors using GIS in the Zhulube meso-catchment of Zimbabwe. The data collection involved analysis of core samples of soil and measurement of gully characteristics. GIS and RS were used to determine the sedimentation and stream power indices in the study area. The statistical analysis was focused on the correlation between gully, soil and vegetation characteristics as a means of identifying areas susceptible to gully erosion. The results from this study shown that 36% of major gullies were discernible using Landsat TM imagery, 56% using spot panchromatic

imagery and 77% using orthophotos. A significant relationship between gully depth and bulk density was evident with $r^2=0.87$ (p<0.05). So it was showing reduction in soil erosion with an increase in clay proportions. Other significant relationships were evident between gully depths, stream erosive power and slope gradient at $r^2= 0.62$ (p<0.05), while streams sediment loadings showed a non-significant effect on the gully depth with at $r^2= 0.02$ (p<0.05). It was concluded from the study that GIS and remote sensing techniques were applicable in gully identification, with variable accuracy levels depending on the spatial, spectral and temporal resolution of the imagery.

As the conventional empirical models like USLE and its revisions (except MUSLE) are based on the plot data their applicability at greater spatial scale is questionable so attempts were put up to develop soil erosion models at watershed scale. Lanuza and Paningbatan [18] carried out validation and sensitivity analysis of Catchment Runoff and Erosion Simulation Technology (CREST), a GIS assisted soil erosion model at watershed level. A GIS-assisted methodology for modeling soil erosion was developed using PC Raster to predict the rate of soil erosion at watershed level. The GIS-assisted hydrology and erosion models were validated at Tanghaga watershed of Philippines using the observed values from previous experiment. The predicted peak rates, Qp shown a highly significant relationship with the observed Qp, with an r^2 value of 0.75. For soil loss prediction, a significant relationship was also noted with an r^2 value of 0.74. The model response was most sensitive to Manning's roughness coefficient (n) for Qp. An increase in n value from 0.02 to 0.13 resulted in a decrease of 546% in the predicted Qp. On the other hand, the predicted soil loss was found to be most sensitive to the vegetative cover. Increasing the value of vegetative cover form 0.20 to 0.95 was resulted in decrease of soil erosion about 1567%. Also from the study, locations of erosion hotspots were predicted within and along the tributary channels as well as in areas with low vegetative cover and steeper slope gradient.

Jain and Geol [14] studied prediction of soil erosion from the Ukai reservoir located on the river Tapi in Gujarat state, India using Watershed Erosion Response Model (WERM) supported by GIS and RS. The area was divided into 16 watersheds and different soil, vegetation, topography and morphology-related parameters were estimated separately for each watershed. From the study carried out it was found that two watersheds were identified as being most susceptible to soil erosion.

Some researchers compared the methodology of preparation of erosion feature maps and given the methodology which best suits with the observed data. Mohammadi and Nikkami [22] compared methodologies of preparation of erosion features map using GIS and RS. For this study 314 control points across the north-east Tehran, Iran were selected. Comparison was made between seven methodologies for preparation of erosion feature maps, each one consisting of combination of three data sets (out of all) required for estimation of soil erosion. Out of these seven methods, erosion features map prepared by using combination of land use, rocks sensitivity to

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erosion and units was found to be close to actual erosion rate at all the control points.

Mohammadi and Haghighat [23] compared methodologies of preparation of erosion feature maps of surface, rill and gully. For this study Varamin sub-basin, north-east Tehran in Iran was selected. Comparison was made between photomorphic (working) unit maps and four other maps prepared by the integration of different data layers including slope, plant cover, geology, land use, rocks erodibility and land units. Comparison of ground truth maps of erosion types and working unit maps indicated that the integration of land use, land units and rocks erodibility layers with satellite image photomorphic unit map provided the best erosion types maps.

Mohammadi and Shadparvar [20] investigated the possibility of preparation of supervised classification map for gully erosion in two mountainous and plain land types. These land types were the parts of the Varamin plane, Tehran province and Rood bar sub basin, Guilan province, as plain and mountainous land types. In plain and mountainous land types, position of 652 and 124 ground control points were recorded by GPS. Regarding ground control points and other secondary points, training points of gully erosion and other surface features were introduced in ILWIS software. Using maximum likelihood method the supervised classification map of gully erosion was prepared and overall accuracy of gully erosion map was also calculated. The study concluded that the preparation of supervised classification map of gully erosion was not possible in the study area. Although more studies were needed for the generalization of results at other mountainous parts.

Estimation of soil erosion along with the prioritization is essential for prioritization of treatments at the critical areas. Though the soil erosion magnitude can be estimated by the conventional soil erosion modeling methods they do not prioritize the area under study.

So researchers used different approaches like Intelligent Remote Sensing Interpretation, Naïve Bayes Probability, farmer's perception, qualitative approach and some new models for the estimation of soil erosion and rating of areas for prioritization of treatments. Yang and Zhu [37] used Intelligent Remote Sensing Interpretation to monitor soil erosion in Guiyang, China. Study was included the components like preparation of knowledge data base of soil erosion, digitizing influent factors of soil erosion, interpreting the soil erosion information, interpreting message from the soil erosion deteriorated, evaluating the hazards of the soil erosion. In this study soil erosion and soil erosion deteriorated in the study area for period 1994-1998 was found out along with finding influential factors of soil erosion, interpretation of message from soil erosion and erosion deteriorated and finally hazards of soil erosion were evaluated for the study area. This Intelligent Remote Sensing Interpretation approach was found useful to monitor soil erosion in large catchments.

Kothyari and Jain [16] developed a method for determination of the sediment yield from a catchment using GIS at Karso watershed in Bihar state of India. The method involved spatial disaggregation of the catchment into cells having uniform soil erosion characteristics. The surface erosion from each of the discretized cells was routed to the outlet of catchment using sediment delivery ratio concept. The study revealed the areas contributing to sediment yield at the outlet.

Weihua et al. [35] studied assessment of soil erosion based on Naive Bayes in E'Dong Mountain of Hubei province of China. Four factor indexes affecting erosion intensity were chosen and Naive Bayes probability of each index of soil erosion based on the observed plot sample data was calculated. Secondly, the model abstracts affected factor parameters of soil erosion by RS (Remote Sensing) and GIS (Geography Information System) in study region. Finally, the erosion intensity of region was classified into six classes in terms of the Naive Bayes probability: extreme, very high, high, moderate, low, very low.

Wan and Sangchyoswat [34] explored the effect of the major socioeconomic parameters on the erosion processes and conservation measures in dry zone farming context for producing the erosion risk map of the area. In order to gain over view of status of erosion of study area and for identifying potential areas where effective erosion protection may be useful, erosion risk assessment was carried out by RS, GIS and by farmer's perception. Multiple logit model was used for the study for the identification of the major socio-economic parameters influencing the soil erosion in the context of individual farmer's specific data on multiple choices. Yield variation, change in soil color and appearance and occurrence of stony and pebbles followed by rill, gully and sheet formation were used by the farmers to identify soil erosion and land degradation. DEM, digital geologic map and Landsat data were used in ICONA model to estimate the spatially explicit soil erosion in the study area. Finally results of the study shown that the 76.5% of the study area was having low erosion risk, 21.8% area was having medium erosion risk and 1.7% of the area was at high erosion risk status. Study had shown the applicability of the ICONA model for estimation of spatial soil erosion along with farmer's perception about soil erosion and land degradation. Farmer's perception was found useful in improving the accuracy of the model. Amiri and Tabatabaie [1] studied EPM approach for erosion modeling by using RS and GIS from Ghareh Aghach watershed in central part of Iran by integration of geological, geomorphology faciess, slope maps from the satellite images, aerial photos of 1:40000 scale and data obtained from the field visits. It was found that results of EPM model for homogenous and uniform sampling units indicated that 0.19% (16.69 ha) of the total watershed area was classified as class I of erosion category with very low sedimentation and 15.1% (1352.64 ha) was classified as class II of erosion category with low sedimentation and 41.3% (3698.8 ha) was classified as class III of erosion category with medium sedimentation and 13.2% (1175.3 ha) was classified as class IV of erosion category with high sedimentation and finally 30.2% (2711.41 ha) was classified as class V of erosion category with very high sedimentation. After study it was found that the erosion and sediment values estimated by EPM model and the same values measured at site not differ significantly ($P<0.05$).

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Curzio and Magliulo [7] studied soil erosion assessment using geomorphological remote sensing techniques at an area 228.6 km^2 wide in Southern Italy. Study area was first characterized from a lithological, pedological, land-use and morpho-topographic point of view and thematic maps were created. Then, the geo-referenced Landsat ETM 7+ satellite imagery was processed using RSI ENVI 4.0 software. Particular attention was given to the NeFELs (Newly Formed Erosional Landsurfaces), which were located using a global positioning system (GPS). The results of the classification process were checked in the field. Finally, a spatial analysis was performed by converting the detected land surfaces into vectorial format and importing them into the ESRI ArcView GIS 9.0 software.

Dengiz et al. [8] used qualitative approach of modeling of soil erosion using GIS in Ankara-Guvenc basin which located about 44 km north of Ankara and covering the area of 17.5 km^2. The qualitative approach based on the knowledge of surveyor to detect and recognize the reasons behind the soil erosion dynamics. Four main types of parameters used for this approach were soil/geology, slope/gradient, land use and land cover along with erosion and mass movement. The selected theme layers of the model include topographic factor, soil factors (depth, texture, impermeable horizon) and land use. According to land use classification, the most common land use type and land cover was rangeland (50.5%) then rain fed (36.4%), week forest land (3.2%), irrigated land (0.7%) and other various lands (rock out crop and lake) (9.2%). Each land characteristic was also considered as a thematic layer in geographical information systems (GIS) process. After combination of layers, map of soil erosion risk was prepared. The results showed that 44.4% of the study area was at high soil erosion risk, whereas 42% of the study area was insignificantly and slightly susceptible to erosion risk. Also it was found that only 12.6% of the total area was moderately susceptible to erosion risk.

Hassen [11] identified the intensity and patterns of erosion hazard levels for the past seventeen years (1990-2007) by Erosion Hazard Model (EHM) using GIS and RS at Bale Mountains National Park (BMNP) in Ethiopia. Five factors were selected for identification of erosion intensity and patterns of erosion hazard levels. These five factors were slope, drainage density, soil erodibility, rainfall amount and land use land cover (LULC). From the study of LULC it was found that forest, shrub and water bodies were having negative increment in area by 11.9 % (12173 ha), 14.8 % (12596 ha) and 18 ha (19.8%) respectively. On the other hand grass, bare and arable lands shown increase in area by 23652 ha (80.4%), 659 ha (42%) and 476 ha (150.2%) respectively between 1990 and 2007. This study shown the deterioration of forest and shrub land covers of the park since 1990. The results of the study were verified against the field collected erosion indicators through model calibration and validation, which improved model output accuracy from 80.9% to 89.4%. The erosion hazard map categorized erosion hazards into five level as Unnoticeable, Low, Moderate, High and Very high erosion hazard levels. The overall result of the study shown that unnoticeable and low erosion hazard levels decreased by 2056 ha (4.6%) and 10555 ha (23.2%). On the other hand moderate, high and very high hazard levels were increased by 10227 ha (14.4%), 2310 ha (97.2%) and 92 ha (484.2%) respectively between 1990 and 2007. The erosion hazard pattern of change shown that 12887 ha (5.9 %) of the total area had shown improvement, 29660 ha (13.6%) had shown aggravation and 176186 ha (80.5%) had remained unchanged in their hazard level between 1990 and 2007.

Belaid and Karteris [5] studied potential soil erosion in a typical Mediterranean watershed in Tunisia, Greece, Italy and Spain using GIS. GIS (GRASS) was used to establish an information database to characterize a watershed in northern Greece and located potential erosion areas using proximity analysis and modeling involving six layers. Results were obtained using a complex model based on weight assignment and using geology, soil, rainfall, slope, first order stream buffer zones and land cover/use. The model located potential erosion areas which need control and preventive measures according to the degree of erosion.

III. CONCLUSION

The variety of empirical, conceptual and physically based soil erosion models other than the conventional soil erosion models (USLE, its revisions and modifications) are available. The researchers should try to use these models in their research works wherever these models are giving satisfactory results compared to the observations.

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