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Soil Erosion Risk Assessment Using Corine Model - A Case Study from Harve 1 Micro Watershed, Central Karnataka Plateau, India

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Abstract

The soil erosion risk in Harve 1 microwatershed of Chamarajnagar district, Karnataka, India was studied using CORINE model (Coordination of Information on the Environment). The input data for CORINE model was determined from soil survey data (soil erodibility, Topography and vegetation cover) and monthly meteorological data (erosivity) respectively. The soil map consists 15 series of Alfisols and Inceptisols with 37 phases. . Sixty eight per cent of area in watershed had loamy sand (39.39%) and sandy loam (29.46%) textures with moderate soil erodibility. The erosivity was calculated from the ratings of Modified Fournier index (MFI) and Bagnouls - Gaussen aridity index from climatic data over a period of 55 years. The study area has mean MFI of 141 and mean BGI of 169 to define as very dry. Both were rated as high to yield erosivity of more than 12. The study area had nearly level to very gently sloping granitic lands to generate potential soil erosion risk map. The results showed that the Harve 1 microwatershed has 52.06% of area at high erosion risk (267.35ha), 26.69% of area under moderate risk (138.09 ha) and low risk at10.52%. The land cover map showed that 55.45 per cent of area is fully protected area (forest, dense shrub etc) with high actual soil erosion risk in 33.05% of total area.

Keywords: Soil erodibility; Corine model; Modified fournier index; Aridity index; Soil erosion risk; Hot moist semiarid ecosystem.

Introduction

Soil in drylands are highly vulnerable to degradation in the globe (Lal, 2001) with the largest share of water induced soil erosion (Rodrigo et al., 2015) . It was reported that 264.5 million hectares (Mha) is being used for agriculture, forestry, pasture and other biomass production wherein 146.8 Mha is degraded (NBSSLUP, 2004) with an average soil erosion rate of 16.4 t/ha^{-1} year^{-1} resulting in total soil loss of 5.3 billion tons throughtout country (Dhruvanarayana, 1983) and loss of production of US$162 billion (Sharda et al., 2010).The soil erosion studies in Karnataka reported that 49% of total geographical area is subjected to water erosion (>10 t/ha/year) and placed 5th in position among Indian states (ICAR-NASS, 2010). The district wise soil erosion risk maps were generated using weighted erosion index values (Biswas et al., 2019) and reported that more than 70 per cent of areas in five districts viz., Bagalkot, Chamrajnagar, Dharwad, Koppal and Uttar Kannada have erosional rates more than 10t/ha/year.

In recent times , many soil erosion studies using remote sensing and geographic information systems (GIS) technologies have been used to generate soil erosion risk maps with reasonable costs and accuracy (Pandey et al., 2007, Biswas, 2012). Many studies used Universal Soil Loss Equation (USLE) for the estimation of surface erosion (Chatterjee

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et al., 2014; Kourgialas et al., 2016) and also used, RUSLE to estimate soil loss (Kumar et al., 2014; Ganasri and Ramesh, 2015; Rawat et al., 2016, Kalambukattu and Kumar, 2017). Similar kind of studies on soil loss using Revised Universal Soil Loss Equation (RUSLE) has been reported in T.G. Halli Watershed (Narayana Swamy et al., 2017) and in sub-watersheds of Kali River basin in Karnataka (Markose and Jayappa, 2016). In many soil erosion studies, CORINE model was used successfully at different scales and areas. For example , CORINE model using Remote Sensing (RS) and Geographic Information System (GIS)was employed to determine soil erosion risk in Dalaman Basin of west Mediterranean region (Doran et al., 2000); Golbasi environmental protection area of Turkey on 1:25000 scale using geographic information system (GIS) technique (Deniz and Akgul, 2005), Goz Watershed of Menzelet Dam in the eastern Mediterranean city of Kahramanmaras in Turkey. (Reis et al., 2016) and the Kartalkaya Dam Watershed in Turkey (Yuksel et al., 2008). An attempt was made to generate soil erosion risk maps using CORINE model in Ramgad watershed of Nainital region (Gupta and Uniyal, 2012) but few studies were come across in Karnataka state per se. During an initial implementation workshop of sujala project in Karanataka, the problem of soil erosion was very well addressed and proposed to generate soil erosion risk maps for implementation of soil water conservation programmes near foot hills of Nilgiri mountains of chamrajnagar district. The objective of present study was to determine the heterogeneity soil erosion risk and to assess potential erosion risk areas along with actual erosion risk areas in the form of spatially distributed maps of Harve 1 microwatershed of Central Karnataka plateau, India using CORINE methodology.

Methods and Materials

Description of study area

Harve 1, microwatershed (11°55′33″-11°57′45″ N to 76°48′29″-78°41′12″E) in Chamrajnagar district of Karnataka was selected for the soil erosion risk assessment and mapping (Fig. 1). The study site has an elevation of 800-900m. This hilly agricultural micro watershed cover 459.49 hectare but severely subjected to water erosion. The climate was characterized as hot moist semiarid ecosubregion of Central Karnataka plateau (AESR 8.2) with length of growing period of 120 to 150 days (Mandal et al., 1999). The average annual rainfall is 586 mm. The south west monsoon contributes about 75 % of total rainfall in the region. The major crops grown are rice (Oryza sativa), ragi (Eleusine coracana) and sugar cane (Saccharum officinarum). Geologically, the study site has Ramanagaram granitic hills of oldest formations (>3000 million years) of the earth's crust. The important formations of this group were Peninsular Gneiss, Dharwar schists, and Charnockites with dendritic drainage pattern. The different landforms discernable on the imagery have been broadly classified into Pediments, pediplains, valley fills, residual and inselburgs (Nagaraju et al., 2017). The occurrence of dark reddish brown (5YR4/4) to dark red (2.5YR4/4) soils of subgroups of Alfisols such as Typic Rhodustalfs with CEC to clay ratio of o.4 to 0.6 and Typic Haplustalfs were associated with the subgroups of Inceptisols viz., Typic Haplustepts in the region (Pinki seth et al., 2017). The existence of forests provides raw materials for industries like paper, rayon, saw mills, safety matches and sandal wood (Basavarajappa et al., 2015). The natural vegetation mainly consists of trees and shrubs namely Acacia (Acacia auruculiformis), Neem (Azadirachta indica) and Eucalyptus (Eucalyptus sideroxylon and Eucalyptus regnana).

Soil resource data base

The soil resource data base was generated (on 1:10000 scale) under Sujala – III project of Karnataka and carried out detailed soil survey using cadastral map in conjunction with Indian remote sensing (IRS)-P6 merged with Cartosat-1 imagery for ground truth verification of land forms and land use/land cover. The field traverse was made to verify land units and to check boundaries. Sixty five soil profiles were dug and recorded latitude, longitude and elevation with hand held Global Positioning System (GPS). After correlation, 15 soil series were identified and described for morphological features as per the standard guidelines of Schoeneberger et al., (2012). These soils were classified upto series and its phases as mapping units (Soil Survey Staff, 2014). The soil map was generated with 37 phases under GIS with ARCinfo version10.3. In profile description proforma, the details of slope and surface cover was recorded and used for further defining the land units. The land use / land cover map was generated using land use statistics at village level. The fifty five years (1960-2014) of rainfall and temperature data collected from KSNDMC (Karnataka State Natural Disaster Management Centre) for calculating modified fournier index (MFI) and Bagnouls and Gaussen index (BGI).

CORINE Model

Using CORINE model (1992), the stepwise integration of land resource data sets with their corresponding indices and then grouping to derive potential and actual erosion risk were made as per scheme presented in Fig.2. This model consists of six steps such as (i)development of soil eodibility map using soil texture, soil depth and stoniness, (ii) computation of modified Fournier index and Bagnouls-Gaussen index to derive erosivity layer , (iii) the slope layer from field observation and the recording of site elevations from GPS , (iv) integration of the layers of soil erodibility, erosivity and slope layers to generated potential soil erosion risk maps and (v) LULC layer (Land use / Land cover layer) form IRS-LISS-IV merged Cartosat -1 imagery was prepared with sufficient ground truth and final sixth step was to combine LULC map with PSER maps to derive actual soil erosion risk map. A detailed description of data sets required for actual soil erosion risk map was discussed as under:

Soil Erodibility

The soil erodibility was calculated considering the 3 scale ratings of soil texture, depth class and stoniness. The soil texture was grouped into three classes such as: (1) slightly erodible (clay (C), sandy clay (SC) and silty clay (SiC)), (2) moderately erodible (sandy clay loam (SCL), silty clay loam (SiCL), clay loam (CL), loamy sand (LS)), and (3) highly erodible (loam (L), silt loam (SiL) and sandy loam (SL)). There are three depth classes such as: 1) slightly erodible (> 75cm), (2) moderately erodible (25- 75cm), and (3) highly erodible (< 25cm) and only two classess of stoniness (2surface cover of stones) such as: (1) >10% and (2) soils having <10%. The soil erodibility index was calculated with the multiplication of textural class X depth class X stoniness class (eq. 1). The soil erodibility was further classified as (1) low (0-3), (2) moderate (3-6), and (3) high erosion (>6). The soil erodibility index was computed as per eq.1. as under:

Soil erodibility index = textural class x depth class x stoniness class - (eq.1)

Erosivity

The erosivity (R) was calculated simply with the multiplication of coded value of MFI (modified Fournier index, Arnoldus, 1980) and BGI (Bagnouls and Gaussen, 1952). The monthly rainfall and mean air temperature data of 55 years collected from KSNDMC (Karnataka State Natural Disaster Management Centre) was used to calculate MFI and Bagnouls - Gaussen index. The MFI was calculated from monthly precipitation (Pi) to total mean precipitation (Pa) as per eq.2.

1. Modified Fournier index (MFI) = $\sum_{i=1}^{12} \frac{P_i^2}{P_a}$ (eq. 2)

Where Pi is total precipitation in a month, P_a is mean annual precipitation

As per CORINE model, the MFI was classified into five categories such as : 1.very low (<60), 2.low (60-90), 3.moderate (90-120), 4.high (120-160) and 5.very high (>160).

2. The BGI as second climate index was computed as the ratio of the temperature and precipitation and its calculation was done as per eq.3.

   Bagnouls-Gaussen index (BGI) = $\sum_{i=1}^{12}(2T_i-P_i)k_i$ (eq.3)

Where, T_i is temperature in a month

P_i is total precipitation in a month

k_i is proportion of the month during which $(2T_i-P_i) > 0$. 4 classes were made based on the BGI index as :1. humid (0), 2. moist (0-50), 3.dry (50-10) and 4.very dry (>130)

The erosivity was determined with the multiplication of coded values of these two climatic indices as follows: rating of MFI X rating of BGI. The erosivity was further reclassified into 3 classes such as :low (<4), moderate(4-8) and high(>8).

Potential soil erosion risk (PSER)

The slope map was generated using IRS-LISS-IV data merged cartostat data at the scale 1:10000 and classified the slopes into 4 groups very gentle to flat (<5%), gentle (5-15%), steep (15-30%) and very steep (>30%). Then the potential soil erosion risk (PSER) map was determined as:

PSER class = Soil erodability class X erosivity class X slope class (Eq. 4) and generated map under GIS. The potential erosion risk zones were delineated and grouped as none (0), low (0-5), moderate (5-11) and high (>11).

Actual soil erosion risk (ASER)

The land use / cover estimations from satellite data as well as the present land cover at the time of field survey and land records was used. The vegetation cover was classified broadly into two classes such as : fully protected (>50%) and not fully protected (<50%). Finally actual soil erosion risk map (ASER) was generated with the combination of potential soil erosion risk layer and vegetation cover layer at the study site. ASER was further reclassified into three groups : low, moderate and high.

Results and Discussion

3.1.Soil map

The micro watershed area has granite and granite gneiss and schist landscape. The soil map (Fig. 3) of study area has fifteen soil series , of which 12 soil series are identified in granite and granite gneiss landscape and 3 series on schist landscape. The 12 soil series of granite gneiss landscape include viz., Lakkur (LKR) series - 68 ha (13%) > Harve (HRV) - 66 ha (13%) > Kengaki (KGK) - 51 ha (10%) > Kutegoudanahundi (KGH)- 49 ha (9%) >, Kaggalipura (KGP) - 43 ha (8%) > Gollarahatti (GHT)- 39 ha (8%) > Hooradhahalli (HDH)- 32 ha (6%) > Kethanapura (KTP)- 19 ha (4%) > Honnenahalli (HNH)- 18 ha (3%) > Thammadahalli (TDH)- 7 ha (1%) > Balapur (BPR)- 2 ha (<1%) and Mukhadahalli (MKH) -2 ha (<1%).

Soils on granite – gneiss landscape

These soils are well drained, moderately shallow (moderately alkaline Lakkur series - LKR, moderately acid Harve series - HRV) to moderately deep (moderately acid to neutral Gollarahatti series - GHT). These soils have mostly reddish brown to dark red, gravelly sandy clay to sandy clay loam textured argillic horizons. These three series are classified under the subgroup of Typic Rhodustalfs (Soil Survey Staff, 2014) having particle size class of clayey for Lakkur and Kaggalipura series, loamy skeletal for Harve and fine loamy for Gollarahatti series. The Balapanur series are moderately alkaline with reddish brown to dark red gravelly sandy clay to clay textured nitric horizons (exchangeable

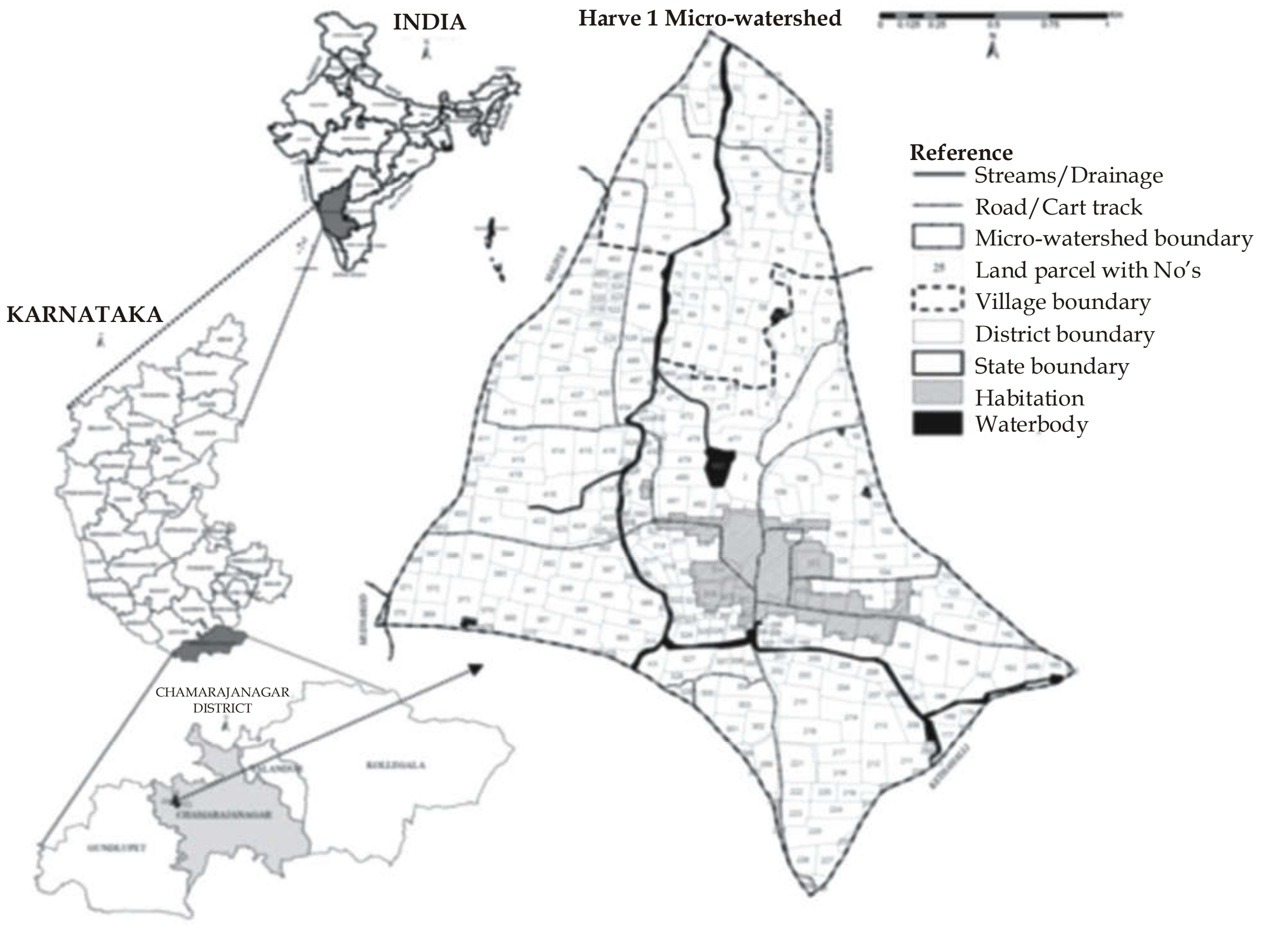

Fig. 1: Location map of Harve-1 microwatershed

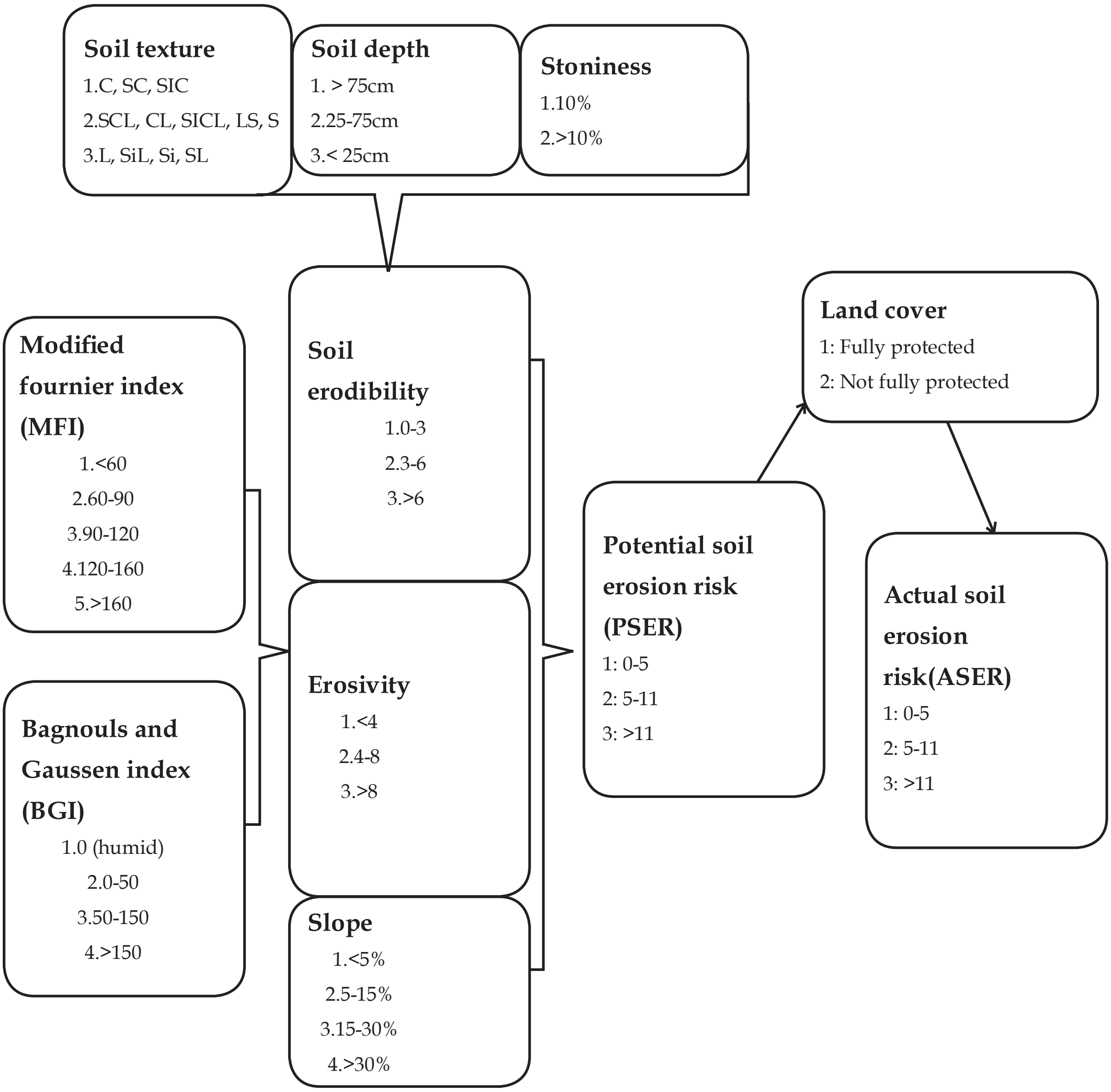

Fig. 2: CORINE methodology for soil erosion risk assessment.

sodium >15 per cent). This series is classified under the subgroup of Typic Natrustalfs. The moderately to slightly acid Hooradhahalli series, Thammadahalli soils and Kethanapura series is classified under the subgroup of Rhodic Paleustalfs where as moderately shallow, well drained and neutral to moderately alkaline Kutegoudanahundi soils and Mukhadahalli soils are classified under the subgroup of Typic Haplustalfs. The Honnenahalli (HNH) and Kengaki (KGK) series are moderately deep, well drained and slightly to moderately alkaline. This soil has brown to dark brown, sandy clay textured. These soils are classified as fine-loamy, mixed, isohyperthermic family of Typic Haplustepts.

Soils on schist landscape

The soils of schist landscape have 3 soil series viz., Sagade (SGD)-30 ha (6%) > Bettadapura (BTP)- 28 ha (6%) and Mudanakodu (MUK)- 5 ha (1%). The brief description of each soil series along with classification (Soil Survey Staff, 2014) is given as under:

Mudanakodu soils are shallow (25-50 cm) and well drained. This soils is moderately alkaline and have dark brown to brown, sandy clay to clay cambic horizons. This soils is classified as fine, mixed, isohyperthermic family of Typic Haplustepts where as moderately deep and strongly alkaline Sagade soils with shiny pressure faces on ped surfaces and faint slickensided zone with shrink-swell properties

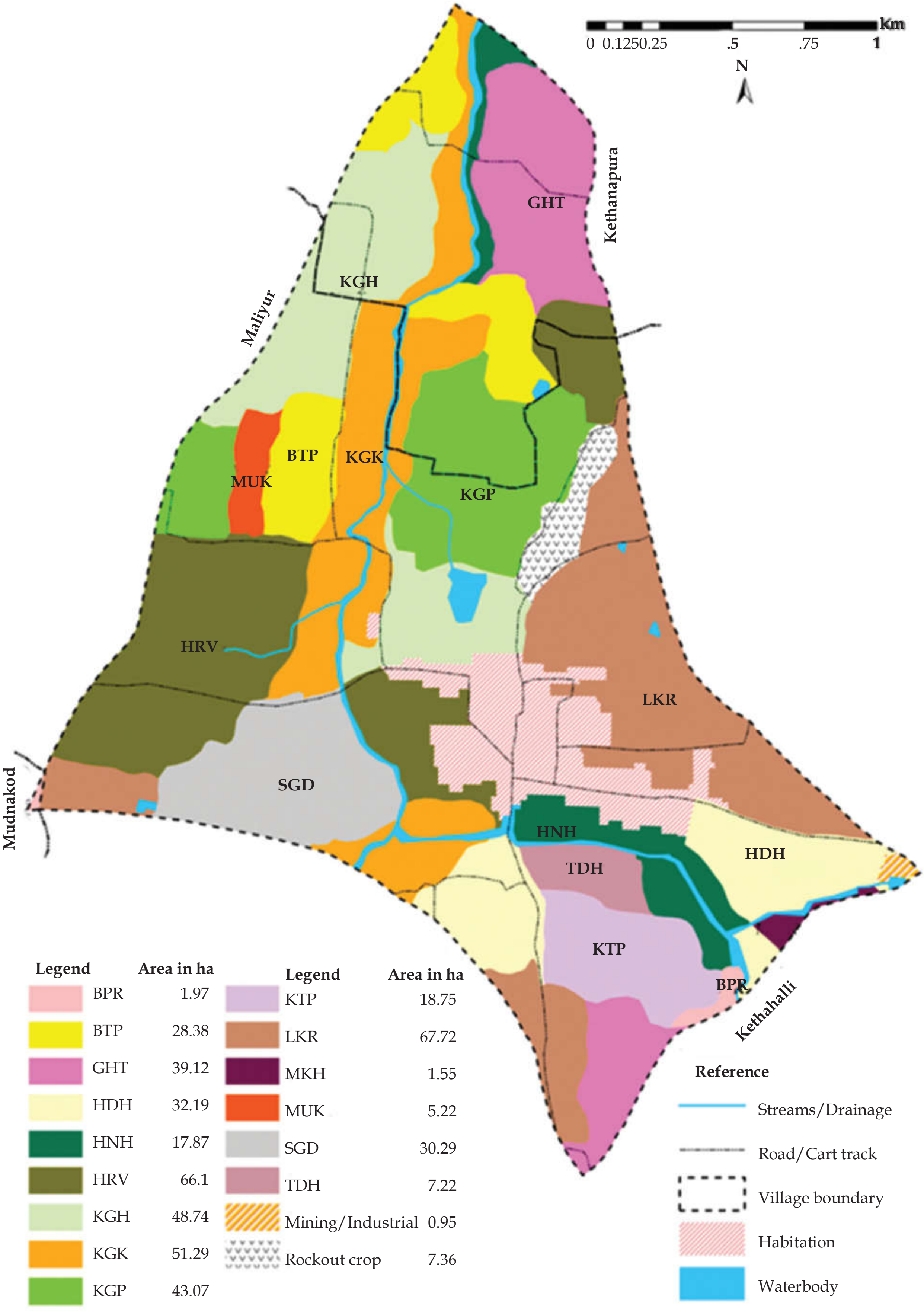

Fig. 3: Soil map of Harve-1 microwatershed.

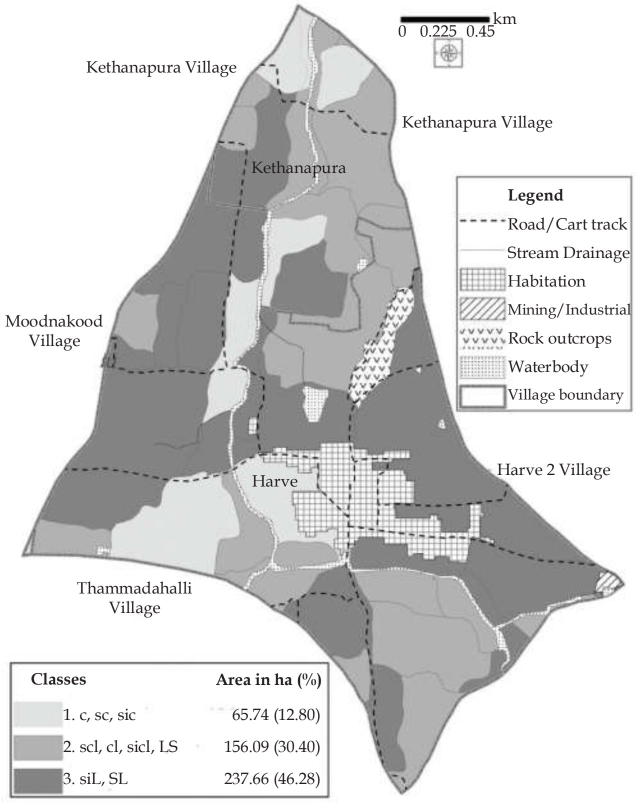

Fig. 4.(a): Soil texture.

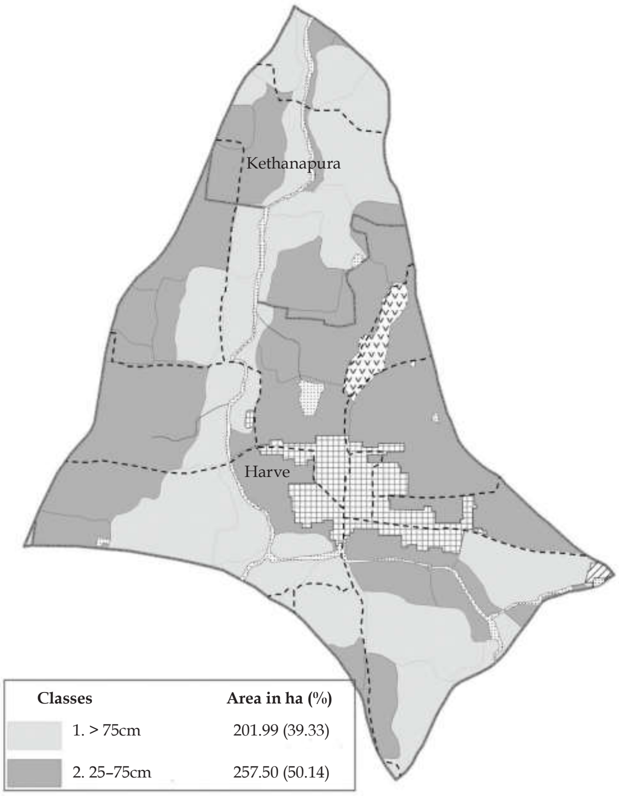

Fig. 4.(b): Soil depth.

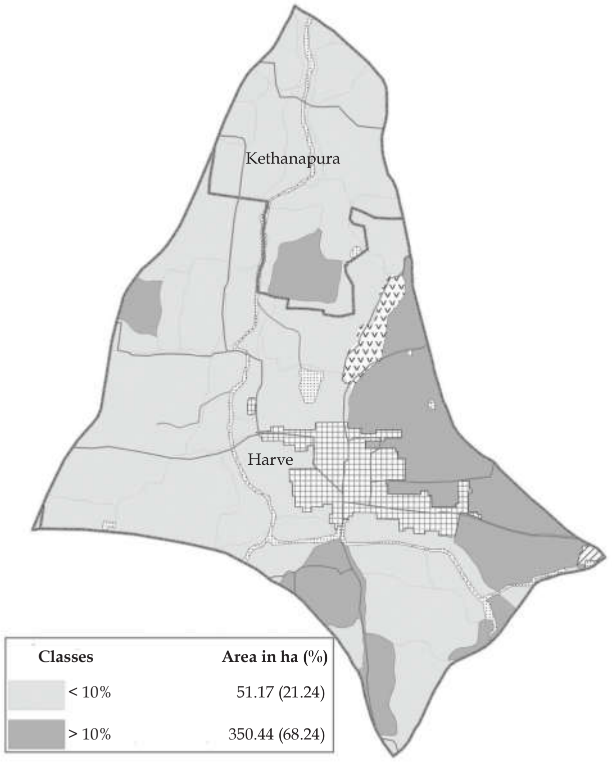

Fig. 4.(c): Stoniness.

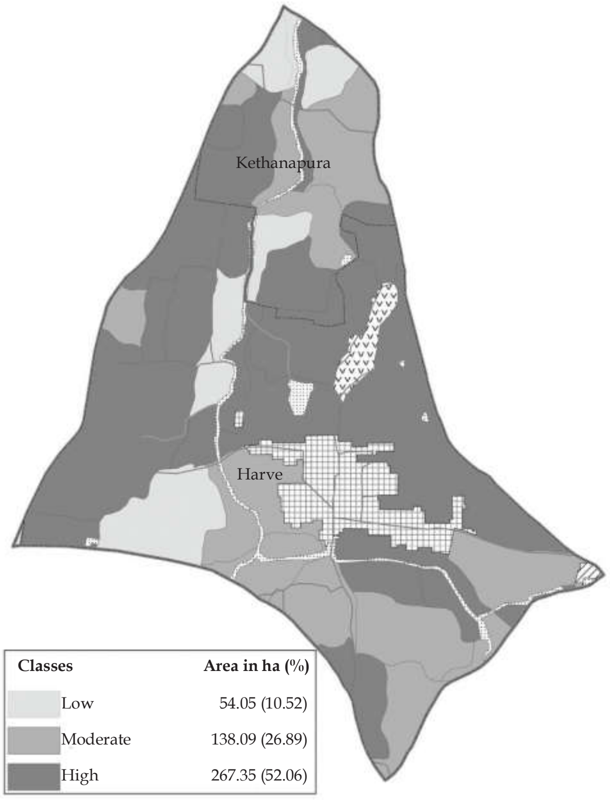

Fig. 4.(d): Soil erodability.

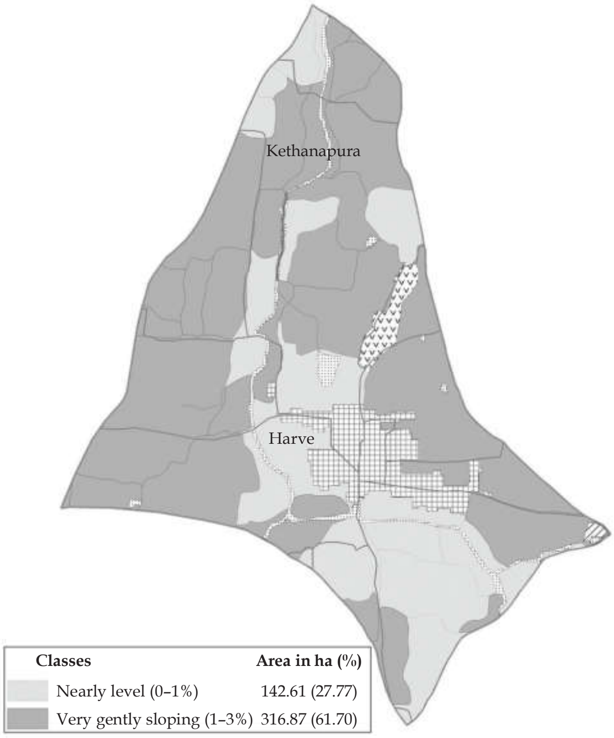

Fig. 4.(e): Slope.

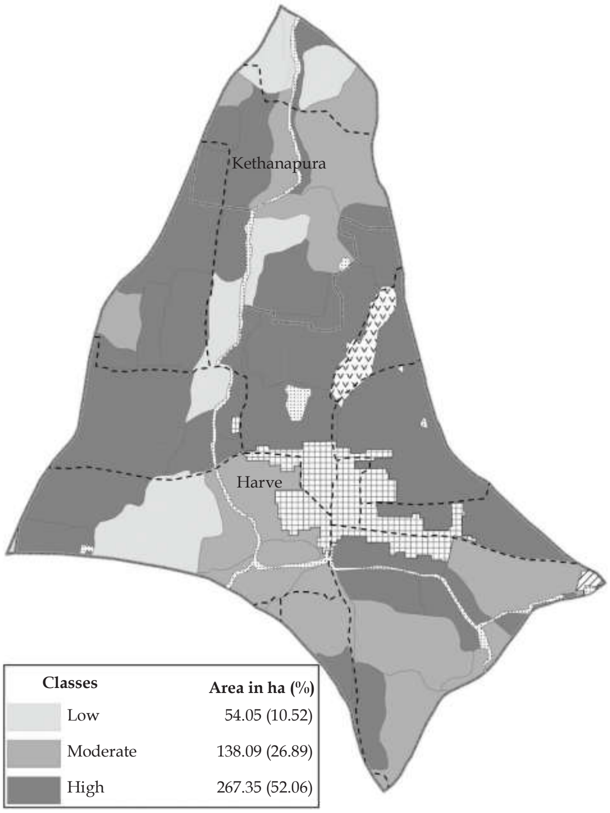

Fig. 4.(f): PSER

Fig. 4.(g): Vegetation.

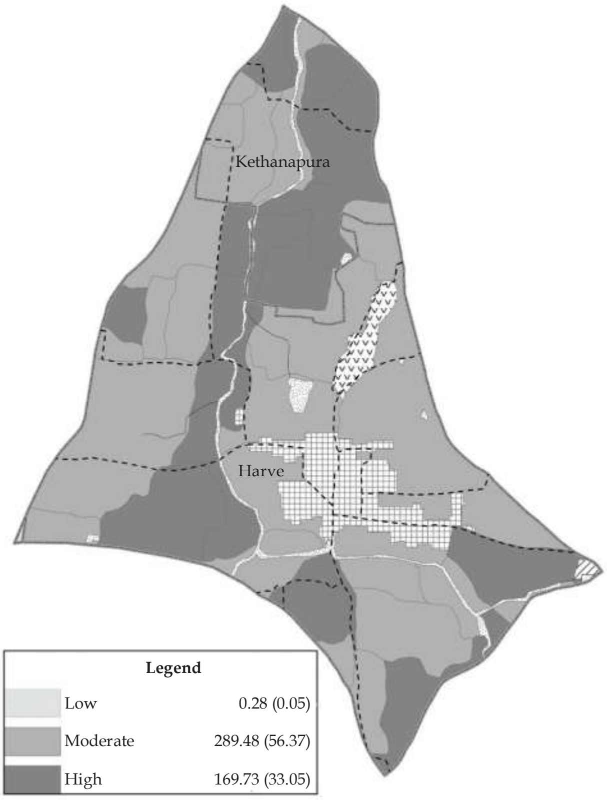

Fig. 4.(h): ASER

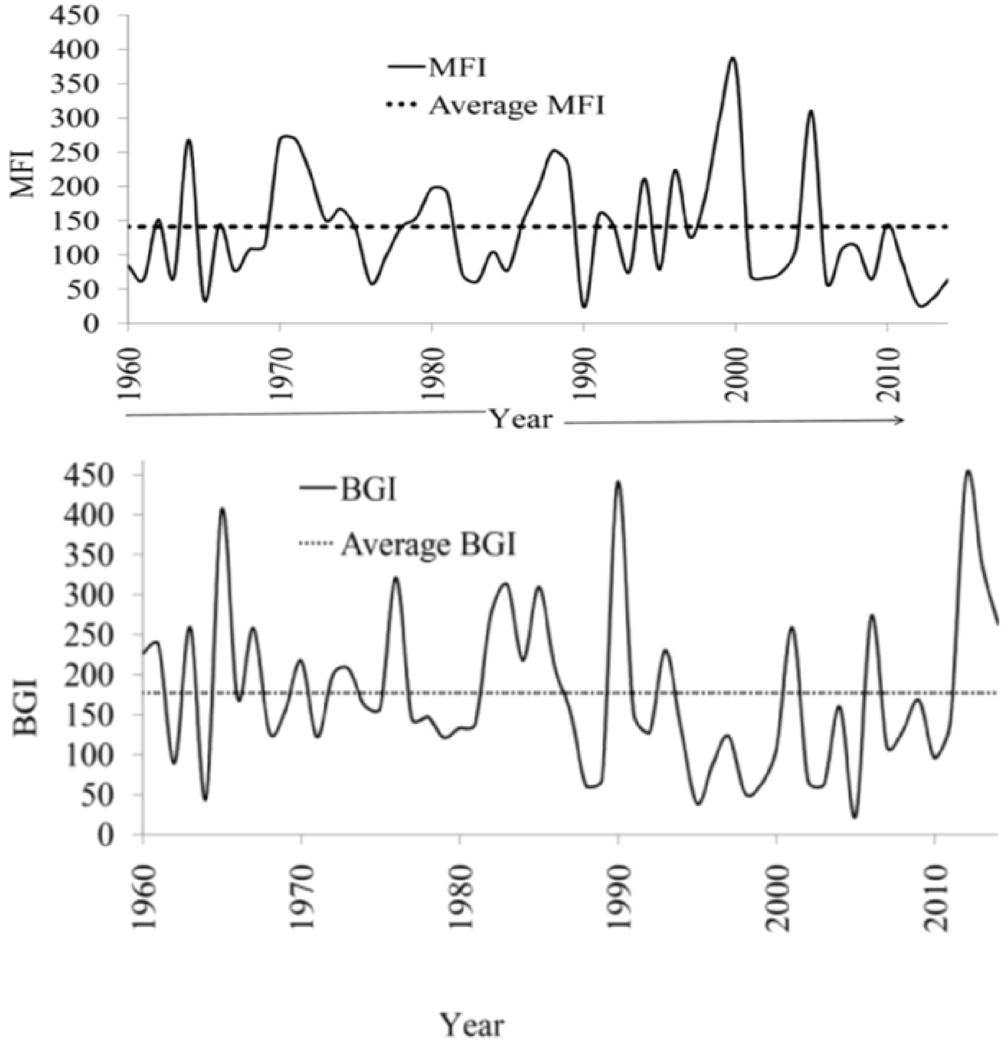

Fig. 5: Yearly modified Fournier index(MFI) and Bognols-Gaussen index for Harve-1 microwatershed.

is classified as a fine, smectitic, isohyperthermic family of Vertic Haplustepts and the deep black to dark grey cracking clay Bettadapura soils are classified as very fine, smectitic, isohyperthermic family of Typic Haplusterts.

Soil erodibility

Soil erodibilty is very important parameter in soil loss estimations and mostly depends on the soil structural stability towards rainfall/runoff. Soil erodibility factor is estimated from soil attributes measured in the field during soil survey such as: soil texture, soil depth and stoniness as considered in CORINE model. The soils of microwatershed have five textural classes such as loamy sand (LS), sand loam (SL), sandy clay loam (SCL), sand clay(SC) and clay(C). Sixty eight per cent of area have loamy sand (39.39%) and sandy loam (29.46%) textured soils. The thematic map of texture (Fig.4a) shows that the sandy loam textured soils are mostly concentrated in western and eastern parts whereas clay to sandy clay texture all along stream lines flowing from north to south direction and of loamy sand in northern tip of watershed. The watershed has only two depth class such as soil more than 75 cm covering 39.33 per cent of total area of microwatershed (201.99 ha). These soils are mostly concentrated all along the streams (Fig.4b). The shallow to moderately deep soils cover 50.14 per cent of area (257.50 ha) and localised in western and eastern parts of study area. The stoniness as derived from the soil map shows that 68.24 per cent of microwatershed area has more than 10 per cent and the rest has less than 10% stoniness (21.24% of total area, Fig. 4C). The ratings are assigned to each property under study and then the multiplied each rating to derive combined scores of soil erodibilty. The soil erodibility was further divided into three classes viz., low, moderate and high. The soil erodibility map was derived using GIS (Fig.4D). This map shows that sandy soils are rated as highly erodible in western and eastern parts of microwatershed (52.06%, 267.35ha), loamy sand to sandy clay loam soils in south eastern to northern parts (26.89%) as moderately erodible, and clay/ sandy clay textured soils near stream floors as low erodible (10.52%).

Erosivity

Meteorological data of microwatershed is used to prepare the erosivity layer over the period 1960 to 2014. The two climatic indices modified Fournier index (MFI) and Bangouls-Gaussen aridity index (BGI) were calculated and then coded as per the CORINE model. The modified Fournier index (MFI) was calculated from monthly rainfall amounts. Fig. 5 depicts the annual variation of modified Fournier index. BGI was calculated using monthly temperature and monthly rainfall. The mean ± SD MFI was 141 ± 101.09 with coefficient of variation of 71.7 per cent and rated as 4. The BGI index has a mean ± SD of 169 ±148.3 with coefficient of 56.36 and assigned a rating of 3 (High class). The combined effect of MFI and BGI has yielded a value of 12 to rate it as high.

Potential soil erosion risk (PSER)

Slope is the main controlling factor for overland flow depth, the flow velocity, and shear stress of soils during extreme rainfall events (Liu et al., 2001) and also assumed as a measure of the sediment transport capacity that affect runoff, and erosion (Moore and Burch, 1986). Major area of about 317 (62%) have very gently sloping (1-3% slope) class and is distributed in the major part of the microwatershed. An area of about 143 ha (28%) in the microwatershed is under nearly level (0-1%) lands and distributed in the central, northern and southern part of the micro watershed At such slopes, the agricultural fields near foot hills are subjected to sever erosion under high intensive rainfall events during south west monsoon (Fig. 5). By integration of soil erodibility, erosivity and slope layers, the potential erosion risk map was generated (Fig. 6a). This map shows that high erosion risk is estimated in 52.06% of the study area (267.35ha), moderate risk at 26.69% (138.09ha) and low risk at10.52% of total area.

Actual soil erosion risk (ASER)

Finally actual soil erosion risk was generated simply combining potential soil erosion risk map with vegetation cover over lay. The cadastral level (field survey number wise) vegetative cover and land use conventions of the study site have been recorded and generated maps under GIS environment. Indeed, the results show that 55.45 per cent of the study areas is fully protected (forest, dense shrub), while 34.02 per cent of the area is not fully protected (agricultural lands and open areas). The north to southern parts of the study areas have intensive stream lines but devoid of the vegetation and rated 33.05 per cent of area as high actual soil erosion risk zone (Fig.6b). The remaining 56.37 per cent of protected area in eastern to western parts of watershed has moderate actual soil erosion risk. The difference between the areas of potential and actual erosion risk reflects the protective influence of present land cover in the microwatershed. By combining PSER map with vegetation cover layer, the area is decreased to 33.05% under actual soil erosion risk map.

Conclusions

The land resource inventory of Harve 1 micro watershed was carried out on 1:10000 scale with collection of collateral information on agriculture at farm level. The CORINE model was applied to delineate soil erosion risk assessment with the integration of soil – site datasets viz., soil erodibility (texture class X depth class X stoniness class), erosivity (MFI code X BGI code) and slope code to generate potential soil erosion risk zone (PSER). The data shows that 52.06% of the study area (267.35ha) is categorized as high erosion risk whereas 26.69% (138.09ha) as medium and low risk at10.52%.With overlay of land /cover, the actual soil erosion risk is estimated as the difference in area under high the potential soil erosion risk map decreased 52.06 % to 33.05% in the actual soil erosion risk. In future studies, there is a scope for refining ASER with soil erosion classes of conventional soil survey of study area with the due consideration of the incidence of extreme storms within the year and between the year variations of rainfall data.

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