# Rapid Reconnaissance Survey

Soil is one of the most important natural resources vital for the sustenance of mankind. The growing demand for food, fuel and fiber for huge population of the country without providing adequate protection to soil, has led to the degradation of land by way of soil erosion by wind and water, salanization and/or alkalization, waterlogging etc.

Out of 329 million ha geographical area of India about 175 million ha land are subjected to some kind of land degradation. The area affected by different types of erosion is estimated around 150 million ha, out of which 69 million ha is in the critical stage of deterioration. Encroachment of forest and pasture lands and faulty management of cultivable lands aggravates the problems of soil erosion further resulting in rapid sedimentation of costly multipurpose dam reservoirs and frequent flood in the command area.

Realizing the seriousness of the problem the Ministry of Agriculture, Govt. of India launched centrally sponsored schemes for soil conservation and integrated watershed management in the catchment areas of major river valley projects (RVP's) in 1969 which has been subsequently extended to the catchments of Flood Prone Rivers (FPR's). Under these centrally sponsored schemes the Soil and Land Use Survey of IndiaOrganisation, Dept. of Agriculture has been assigned the task of conducting rapid reconnaissance survey for providing relevant data on soil and terrain characteristics, for planning and implementation of conservation and watershed management programmes. The mandate of the organisation in respect of rapid reconnaissance survey has now been extended to include areas outside the centrally sponsored RVP/FPR Catchments, as well. It has now been contemplated to carry out RRS work for the entire country.

In the face of enormity of degradational problems and constraint of financial resources coupled with limitation of expertise, a scientific approach to land resource management calls for an evolution of suitable methodology for clear identification of critical areas for treatment. Prioritization of areas into very high, high, medium, low and very low vulnerability helps in addressing the conservation and management efforts to secure maximum benefit.

Watershed prioritization is a prerequisite to operationalise any major scheme as it allows the planners and policy makers to adopt a selective approach considering the vastness of the catchment area, severity of the problems, constraints of funds and man power demands of the local and political system. The prioritization of watersheds varies with the objectives of different schemes but the basic framework of watershed remains the same.

## Different Models :-

Several empirical equations such as USLE (Wischmeier and smith 1978), silt yield prediction equation for computation of silt yield and run-off equation have been used by several workers. These equations are, however, based on several dynamic factors and their applicability for different areas is controlled by the physical characteristics of the area itself and correct evaluation of several component parameters.

The Soil and Land Use Survey of India has developed **Sediment Yield Index (SYI)** and **Runoff Potential Index (RPI)** models and has been carrying out priority delineation survey in the RVP & FPR Catchments. The priority approach followed for the catchments of River Valley Project is based on Sediment Yield Index (SYI) where as Runoff Potential Index (RPI) is applied for prioritization of watersheds in the catchments of Flood Prone River. All the RVP and FPR catchments areas could be prioritized based on the objectives of others schemes, viz., National Watershed Development Project for Rainfed Areas (NWDPRA) and watershed based developmental project on Wasteland of Department of Land Resources, Ministry of Rural Development. In all these endeavors, the basic framework of watershed will remain the same but priority will vary and it will be in accordance with the objective of the various schemes.

## 1. Sediment Yield Index (SYI) Model

As stated prioritization leads to adopt a selective approach and helps to phase out the planning in a systematic manner. The identification and demarcation of watersheds in the catchment that are prone to yielding higher sediment yield is the primary task envisaged by the Natural Resource Management Division, Department of Agriculture and Cooperation, Ministry of Agriculture towards phasing the action plan for catchment area treatment.

Commensurate with the needs of database, All India Soil and Land Use Survey (AISLUS), Department of Agriculture and Cooperation, Ministry of Agriculture developed Sediment Yield Index (SYI) model for watershed prioritization in the catchments of River Valley Project (Anon, 1990). It’s a predictive model based on the soil and land characteristics of reconnaissance level that are acquired through rapid reconnaissance.

**Concept:** The sediment yield index (SYI) is defined as the sediment yield per unit area and SYI value is obtained by taking the weighted arithmetic mean of the products of the erosion intensity weightage value and delivery ratio over the entire area of the hydrologic unit by using suitable empirical equation. The foundation of the sediment yield model lies with the basic concept of sediment yield, which is described as:

**Sediment Yield** = Erosivity × Erodibility

The erosivity is an expression of rainfall (velocity, angle, frequency and duration) where erodibility indicate the soil detachment and transportation potential of the detached material. The erodibility factor is governed by the empirical equation as described below.

$$\mathbf{R} = P - F$$

Where, R stands for run-off, P is the precipitation and F is the infiltration capacity. Thus run-off is the resultant impact of rainfall induced by the infiltration capacity of the soil and land attributes.

**Parameter of Sediment Yield:** Sediment yield from an area at a point of measurement is a resultant of detachment of soil material and its transportation. Detachment is a resultant of an impact of rainfall and running water on earth's surface and the strain of this impact on the underlying strata. The natural factors responsible for sediment production from an area include:

- Climate (Total precipitation and its frequency and intensity)
- Geomorphology (Land form, Physiography, Slope and Drainage Characteristics)
- Soil characteristics (Texture, structure, organic matter, swell-shrink potential, porosity, hydraulic conductivity, mineralogy, thickness of the solum, etc.)
- Land Use/ Land cover (Density of forest or grassland, plant residue, rock out crops etc.)
- Soil management

The relationship of these factors with soil detachment is quite complex. In practice, various set of these attributes are identified in the field and erosion intensity mapping units are framed accordingly.

For assessing relative values of soil detachment, weightage values are assigned to the erosion intensity mapping units by adjudging the factor individually and grading them as per their influence on soil detachment and sediment transport. Obviously, the factors will assume positive or negative grading as per their accelerating or retarding effect on soil detachment and subsequent transport.

**Sediment Transport and Delivery Ratio:** Delivery ratio refers to the percent of soil material detached from the hydrologic unit, reaching the reservoir site through surface flow or traveling through drainage courses. The factors governing the transport of detached materials are:

- Soil texture, reaction, ESP, clay mineralogy etc.
- Physiography and relief
- Land Use/Land Cover
- Size and slope of the watershed
- Watershed gradient
- Drainage density and drainage pattern
- Stream gradient
- Proximity of the eroded area to the active stream or reservoir
- Presence or absence of silt traps/ponds etc.

The calculation of Sediment Yield Index (SYI) is subsequently done by computing the area of different mapping unit and using the empirical formula.

$$\textbf{Sediment Yield Index (SYI)} = \frac{\sum (Ai \times Wi \times Di)}{Aw} \times 100$$

Where,

i = 1 to n

Ai = Area of $i^{th}$ mapping unit
Wi = Weightage assigned to $i^{th}$ unit
Di = Delivery ratio assigned to $i^{th}$ unit
Aw = Total area of the watershed

The model consists of two aspects, viz., delineation and codification of the catchment area into micro watershed level based on drainage map generated from 1:50000 scale Survey of India topographic map and generation of Erosion Intensity Map based on rapid traversing of the catchment.

**Methodology:** Study of the Survey of India topographical map on 1:50000 scale to have an idea of the catchment area and identification of the major landscape and land use. The methodology of Priority Delineation Survey comprises the following steps.

- Preparation of framework of micro-watershed through systematic delineation
- Codification of different stages of delineation by using Alpha-numeric symbolic code
- Rapid Reconnaissance Survey on 1:50,000 scale base (SOI Toposheets, aerial photographs and other base material) leading to the generation of a map indicating Erosion Intensity Mapping Units (EIMU).
- Assignment of weightage values to various Erosion Intensity Mapping Units based on their relative sediment yield/run-off potential.
- Assignment of delivery ratio to various Erosion Intensity Mapping Units
- Computation of Silt Yield Index/Run-off Potential Index for individual micro-watersheds
- Grading of micro-watersheds into very high, high, medium, low and very low priority categories

Formulation of Erosion Intensity Mapping Unit (EIMU) Legend comprises soil and land characteristics for mapping. The mapping legend is updated based on field information and a progressive legend is developed and finalized.

EIMU is an assemblage of land and soil characteristics, viz., physiography, slope, land use and land cover with density, surface condition, soil depth, texture and structure of surface and sub-soils, colour, drainage condition, salinity and alkalinity, stoniness and rockiness, erosion condition and existing management practices.

Though the sediment yield does not have any relevance with the actual sediment yield gauged at the sediment gauging station but it serves the purpose of identifying and demarcation of watersheds that are severely affected by water induced soil erosion with greater accuracy. Based on the findings, watershed management planning at macro level is sanctioned by the Ministry of Agriculture, Government of India. Subsequently, watershed management project is formulated by the State Government based on detailed information on soil and land characteristics generated through detailed soil survey.

## 2. Runoff Potential Index Model

The Runoff Potential Index (RPI) model is nothing but a modified model of SYI where delivery component has been excluded and weightage value to each mapping unit is assigned based on runoff generation potential of each and every mapping unit. This model is used for prioritization of watersheds in the flood prone catchment. The delineation and codification as well as the mapping procedures including watershed categorization are alike to that of SYI model.

The Run-off Potential index (RPI) is defined as the total quantum of run-off generated per unit area. The RPI model is a modification and expansion of the SYI model where erosion intensity weight age values are replaced by run-off potential weight age values. Here the delivery ratio factor is not taken into account.

**Runoff Potential Index (RPI)** = $\dfrac{\sum (Ai \times Wi \times Di)}{Aw} \times 100$

Where,

i = 1 to n

Ai = Area of $i^{th}$ mapping unit

Wi = Weightage assigned to $i^{th}$ unit

Di = Delivery ratio assigned to $i^{th}$ unit

Aw = Total area of the watershed

## 3. Land Productivity Index Model

During 8th five year plan, Department of Agriculture and Cooperation, Ministry of Agriculture has launched one major scheme on watershed (National Watershed Development Project for Rainfed Areas) towards development of rainfed area. The objective of the scheme is to develop the rainfed agriculture where watersheds having more than 50% agriculture and less than 30% irrigation are selected for treatment purposes. The prioritization of watersheds is based on the Productivity Potential of the watersheds. Higher values of productivity index indicate lesser priority for development purposes.

According to the objectives of the NWDPRA scheme, the watersheds of the country can easily be prioritized and a selective approach of development of rainfed area can be followed. All India Soil and Land Use Survey proposed a model in this regard which has been conceptualized on Land Productivity Indices (Olson, 1981). Land Productivity Index (LPI) is a multiplicative function of the soil profile characteristics, surface texture, land gradient, land surface characters and quantum of rainfall which is expressed as

LPI = A. B. C. X. Y

Where,

A = percent rating for the general character of soil profile

B = percent rating for surface texture

C = percent rating for slope gradient

X = percent rating for site conditions other than those covered under factors A, B and C (e.g., soil salinity, stoniness, rockiness, soil erosion, etc.).

Y = percent rating for rainfall

## Assignment of Weightage Values

The assignment of erosion intensity weightage to the mapping units for prioritization in RVP catchment is based on the relative proportion of the sediments detached from the area enclosed by the unit. A factor K, rated as an inertia factor, signifying equilibrium between erosion and sedimentation, is assigned weightage value of 10 and is considered as a standard reference. Any addition this value in discrete number is indicative of erosion roughly in proportion to the added factors whereas the subtraction is suggestive of the deposition possibilities.

The assignment of run-off potential weightage to the mapping units is based on the proportionate assessed run-off generation from the area enclosed by the units. The inertia factor K in this case, taken as 0.50, signifies the equilibrium between run-off and run-on and suitable additions or subtractions, assigned generally as multiples of 0.05 value, are indicative of the assessed proportionate run-off or run-on conditions. The weightage values are assessed as the resultant of combined and reciprocal influence of a set of factors:

- Physiographic slope
- Land Use/Land Cover
- Soil depth
- Soil texture
- Surface conditions
- Erosion
- Soil conservation measures
- Climate

## Assignment of Delivery Ratios

The delivery ratio of an erosion intensity mapping unit indicates the transportability of the soil material detached from the area enclosed by the unit to the site of the dam/reservoir. The maximum values of delivery ratio adjudged for individual EIM unit are based on factors influencing the suspension and mobility of suspended material like texture, mineralogy and pH of the soil, land use/land cover conditions terrain slope, surface stoniness/ rockiness and soil conservation measure adopted. The adjustment delivery ratios are also depend on the watershed attributes

- Drainage Pattern / Drainage Density
- Watershed gradient
- Proximity to active stream resources

The maximum delivery ratio value, assigned to various EIMU ranges from 0.40 to 0.95. The lowest values have been assigned to the sandy soils of the aeolian plain with very gently slopes or well bunded paddy fields whereas highest values to the dissected stream banks with complex steep slopes having montmorillonitic clay mineralogy.

In order to remove the subjectivity and personal biasness in assigning the weightage value and delivery ratio an attempt has presently been made to grade the individual factors as per their influence on soil erosion and sediment transport. For each factor a limit is framed starting from a base value (an integer) dependent upon the characteristic influence of that factor on detachment and transport of soil material. To achieve the uniform system of rating of mapping units an accurate measurement of individual parameter, as much as possible, should be made in the field during survey. This measurement should accurately be translated in the description of the unit. The values assigned to various parameters are fixed logically centering around the equilibrium values. The resultant value of weightage and delivery ratio assigned to the mapping units could be obtained by summing up the numerical values of all attributes as follows:

Wi = Wi (base) + Wi (Slope) + Wi (land use/land cover) + Wi (soil depth) + Wi (Texture) + Wi (management) + Wi (erosion) + Wi (surface condition)

Di = Di (base) + Di (Slope) + Di (land use/land cover) + Wi (soil depth) + Di (Texture) + Di (management) + Di (erosion) + Di (surface condition)

## Grading of Microwatershed for Priority Fixation

The gradation and assignment of priority category to the micro-watersheds are based on the descending values of SYI/RPI values for deciding upon the boundaries of various priority categories namely, very high, high, medium, low and very low category, the following values of SYI / RPI have been used as boundaries for various categories (Fig. 9).

**Based on SYI/ RPI**

| S. No. | Priority Category | SYI Values | RPI Value |
|---|---|---|---|
| 1. | Very high | 1300 and above | 80 and above |
| 2. | High | 1200 – 1299 | 70.00 – 79.99 |
| 3. | Medium | 1100 – 1199 | 60.00 – 69.99 |
| 4. | Low | 1000 – 1099 | 50.00 – 59.99 |
| 5. | Very low | Below 1000 | Below 50 |

## Validity of the Models:-

Although the models discussed above do not provide the absolute values of total silt yield/quantum of run-off generation and lot of subjectivity is involved in the application of the model, nevertheless it does meet the requirement of fixing relative priorities within short span of time to cope up with the urgent need for controlling the sedimentation process, the model has also been tested in respect of the accuracy and the results have indicted that the model meets the requirement of desired accuracy level.

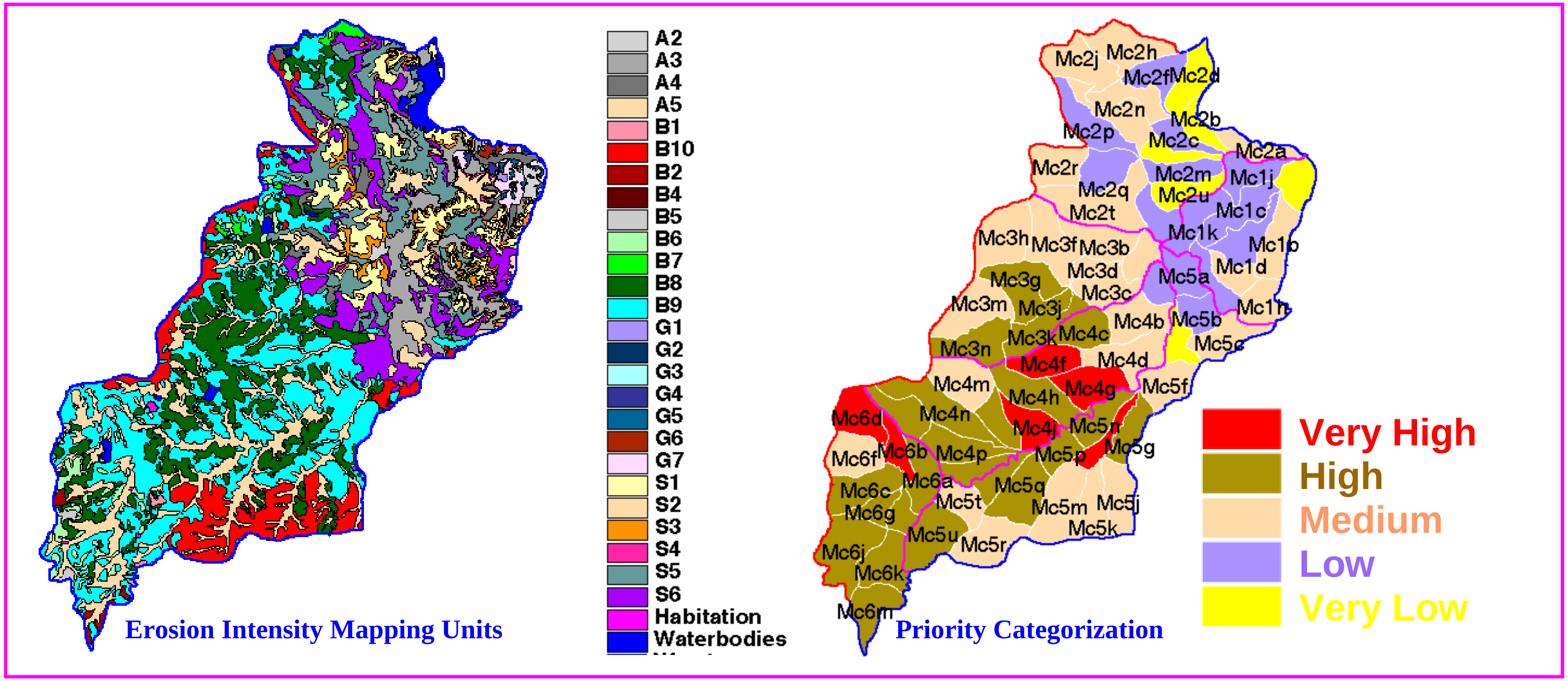


**Fig. :** Rapid Reconnaissance Survey for Priority Categorization of Watersheds

## Integrated Model for Prioritization of Watershed

An integrated model can be developed considering the objectives of various schemes dealing with watershed management in the country. It will be an ideal tool for management of land resources and development strategy under different schemes can be planned and monitored. The basic framework of watershed up-to micro-watershed level will be the same for all the schemes, which can easily be recognized as per national code. Thus all the micro-watersheds of the country could be prioritized based on the objectives and developmental programme under the various schemes could plan in a phased manner. The task could be attended using Geographic Information System (GIS) and Relational Database Management System (RDBMS). Once the framework of watersheds of the country is stored in the computerized environment, it will be a unique database in the country to render services to the nation in a systematic manner for centuries.