

ABSTRACT

Flash-flood-induced soil abrasion is the chief cause of loss of soil in the river basin of Alaknanda, Uttarakhand. Extreme rainfall in the form of cloudburst, undulating topography, and inadequate soil and water conservation practices further exacerbates this problem. In the last 30 years, the region has experienced numerous incidents of flash floods; as a result, a large portion of the soil's top layer gets lost and further leads to flooding, water siltation, and pollution. Hence, this study has attempted to estimate and establish a sub-watershed priority list, based on average soil erosion rate and vulnerability over 30 years (1991-2020). The soil loss rate was calculated for the watershed using the revised universal soil-loss equation (RUSLE) in the GIS framework. The RUSLE parameters include R-Rainfall Erosivity, Crop Management-C, Topographic-LS, Conservation Practice-P, Soil Erodibility-K, and are estimated for each of the 12 sub-watersheds and were categorised into five classes of erosion. The result showed that the maximum erosion rate is 27.8 t/ha/yr and the minimum erosion rate is 6.0 t/ha/yr, with an average value of 13.4 t/ha/yr. Various sub-watershed in the descending order of erosion rate are WS7, WS5, WS11, WS12, WS6, WS4, WS3, WS9, WS10, WS8, WS1, and WS2. Consequently, for the entire Alaknanda watershed, the average R, K, LS, C & P factors and their erosion class (in brackets) are estimated to be 437 (M) MJ mm /ha /yr., 0.07 (M) t ha h /MJ /ha /mm, 1.4 (M), 0.7 (M), and 0.62 (H), respectively. Overall, remote sensing and GIS combined with RUSLE proved vital, less expensive, and effective for estimating soil erosion and prioritising susceptible sub-watersheds.

STUDY AREA

- The study area, Alaknanda River basin, is located between 78° 45' E to 80° 15' E longitudes and 30° 10' N to 31° 5' N, in Uttarakhand.
- The basin area is about 10278 sq. km., having outlet near Rudraprayag.
- The northern part of study region experiences severe cold climate.
- The elevation ranges from 609m to 7804 m. and the average annual rainfall lies around 1600 mm.
- The region is highly prone to various natural disasters such as earthquakes, landslides, flash floods, cloudbursts, etc., resulting in huge erosion.

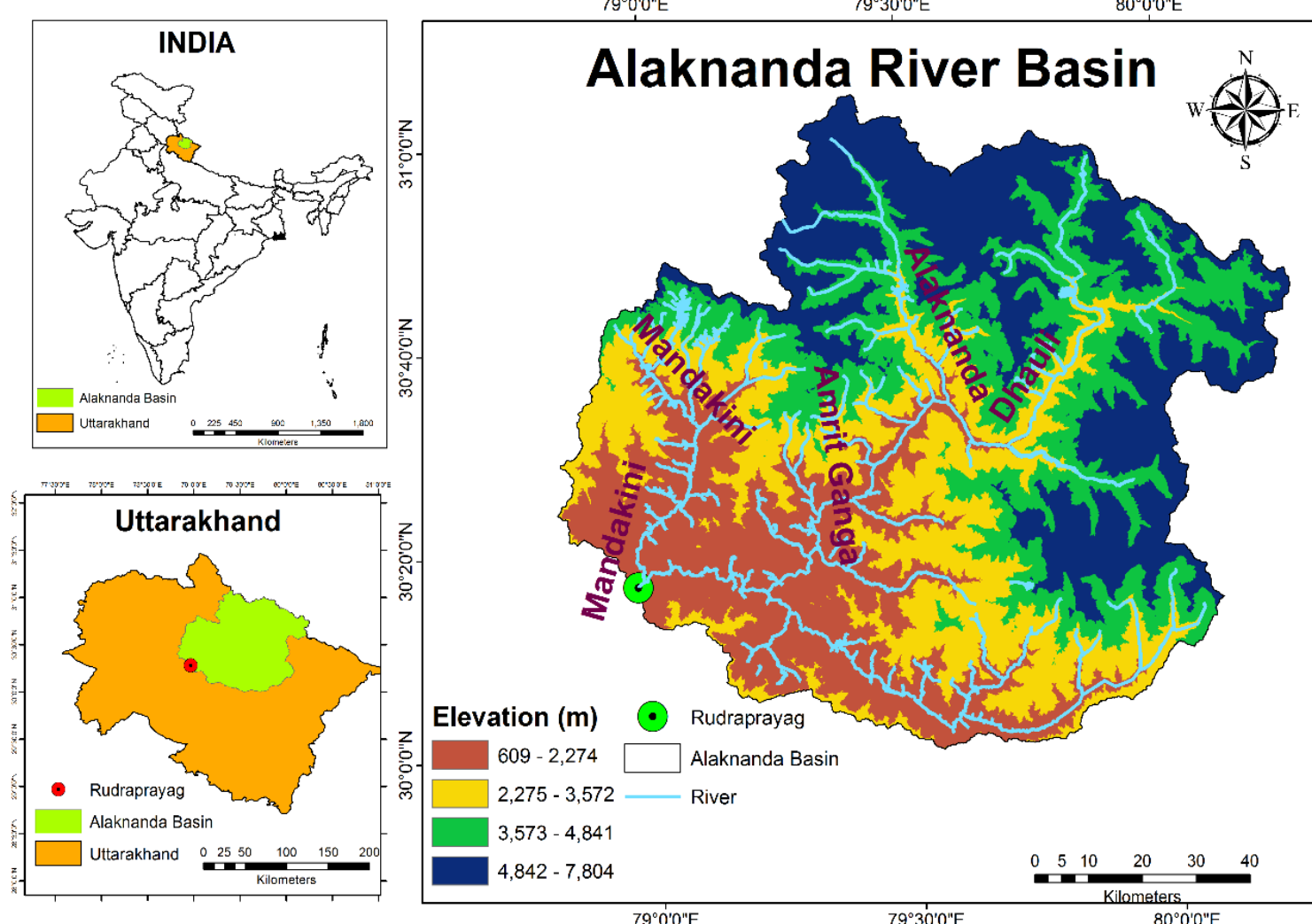


Fig. 1: Study area : Alaknanda River basin

DATASETS AND TOOLS USED

Table 1: Datasets used for the study

| Types | Data Description | Resolution/Scale |
|---------------------|-------------------------------|------------------|
| Topographical data | Digital Elevation Model (DEM) | 30 m |
| Land use land Cover | ISRO GBP | 1 : 250000 |
| Slope | Slope Map | 30 m |
| Soil data | NBSS & LUP | 1: 50000 |
| Rainfall | Rainfall map- CHIRPS | 5000 m |

METHODOLOGY

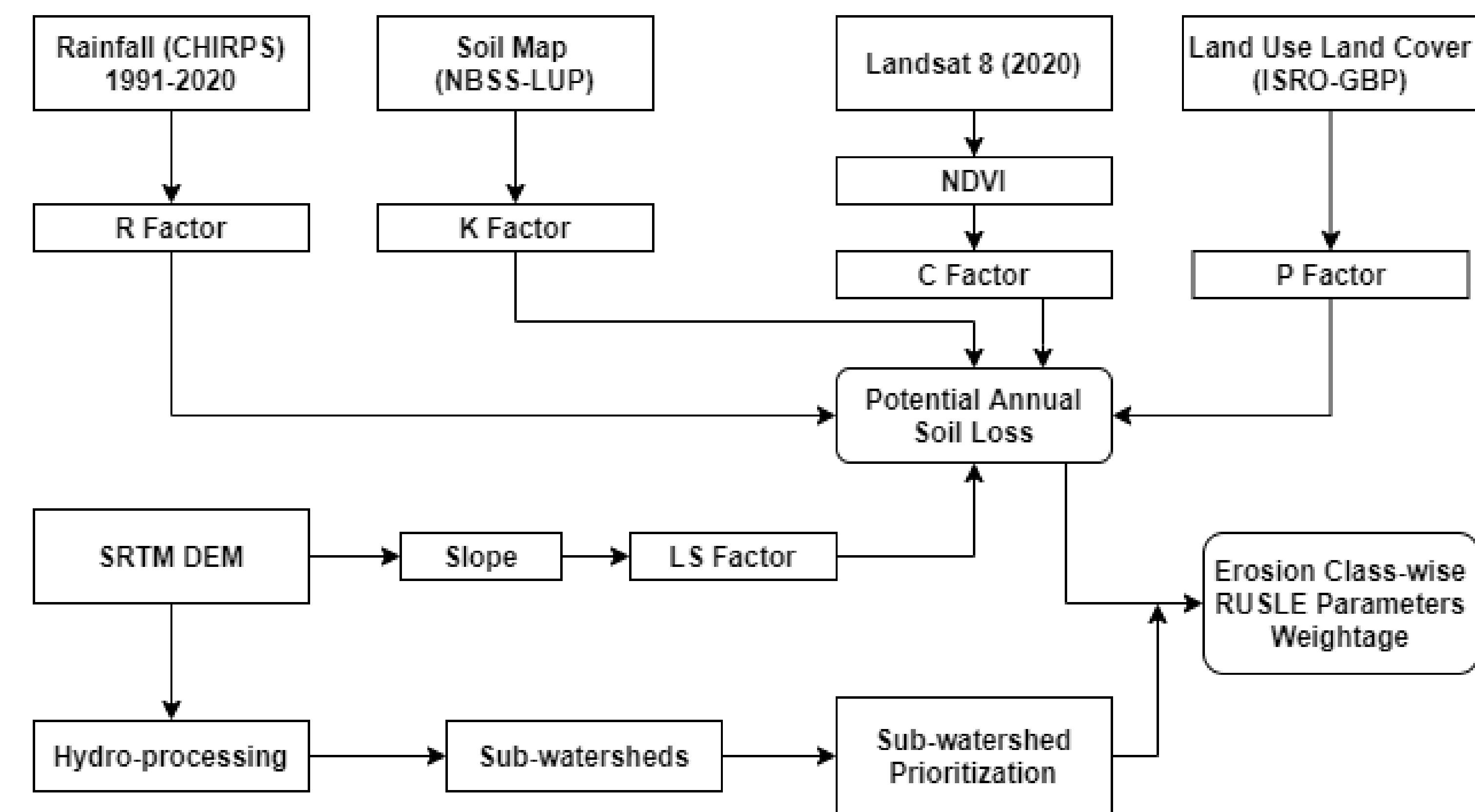


Fig. 2: Methodology adopted for sub-watershed prioritization

$$R = 79 + 0.363 * AAP$$

$$C = \exp\left[-\alpha \frac{NDVI}{\beta - NDVI}\right]$$

$$K = \frac{2.1 \times 10^{-4} (12 - OM)M^{1.4} + 3.25(s - 2) + 2.5(p - 3)}{759.4}$$

$$LS = \left(Flow\ accumulation \times \frac{Cell\ Size}{22.13}\right)^{0.4} \times \left(\sin \frac{Slope}{0.0896}\right)^{1.3}$$

$$A = R \times K \times LS \times C \times P$$

All Equation utilized for derivation of RUSLE parameter (Wischemier & Smith, 1978; Moore & Burch, 1986)

R= rainfall-runoff erosivity factor (MJ mm ha⁻¹ h⁻¹ year⁻¹); AAP= Annual average precipitation;
 K=soil erodibility (tons ha h / MJ/ha/mm); p=soil permeability code; s= soil structure code;
 OM=%organic matter; M=primary soil particle size fraction ; P= supporting practices factor;
 LS= topographic/ steepness factor/ slope length, Sin slope = slope degree value in Sin; cell size = grid cell size or DEM resolution;
 C= cover and cropping management factor and A= average annual soil loss (ton ha⁻¹ year⁻¹); α, β: parameters determining the NDVI-C curve shape and, α=2 and β=1

RESULTS

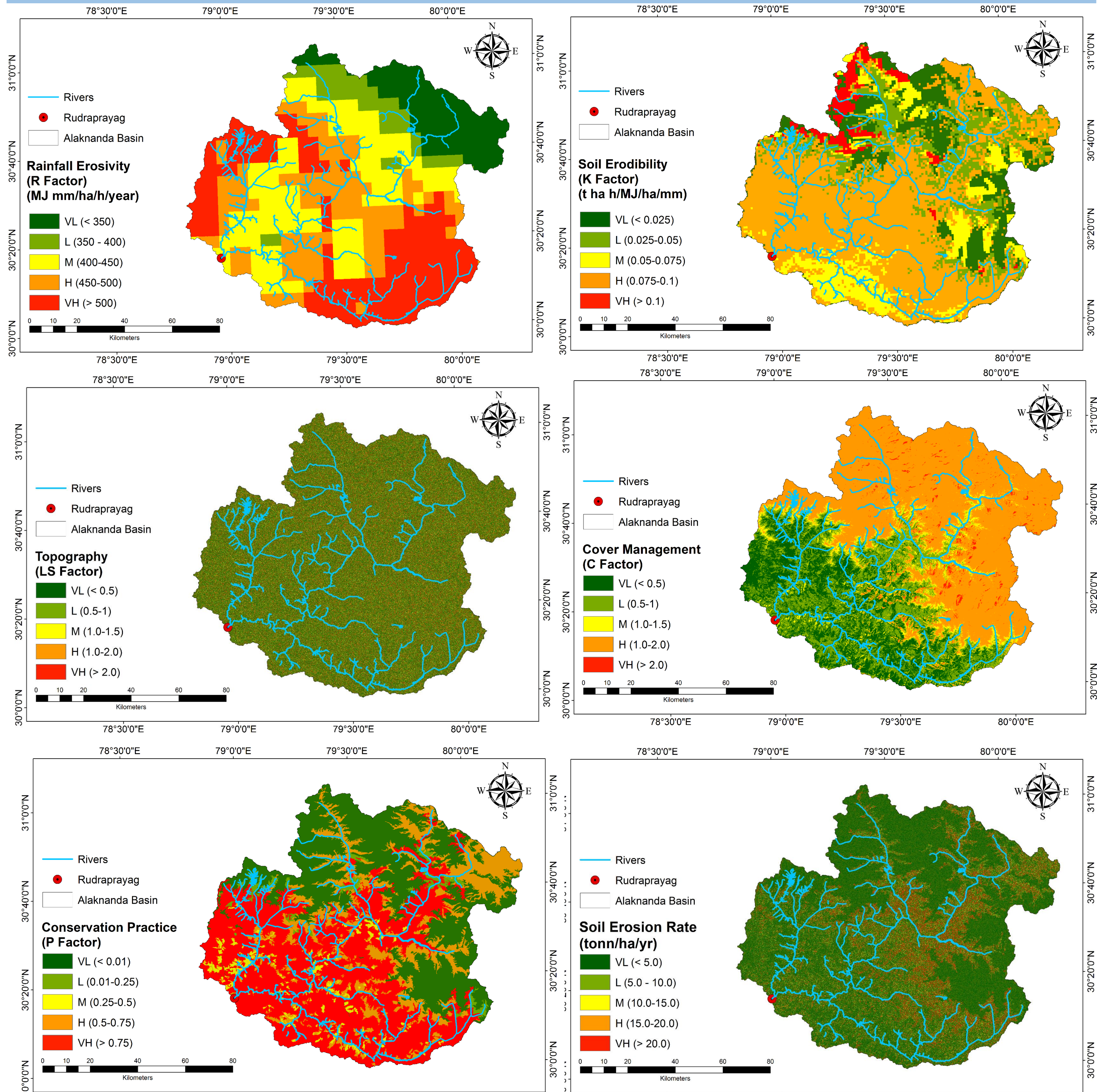


Fig 3: The river basin map depicting all RUSLE parameters

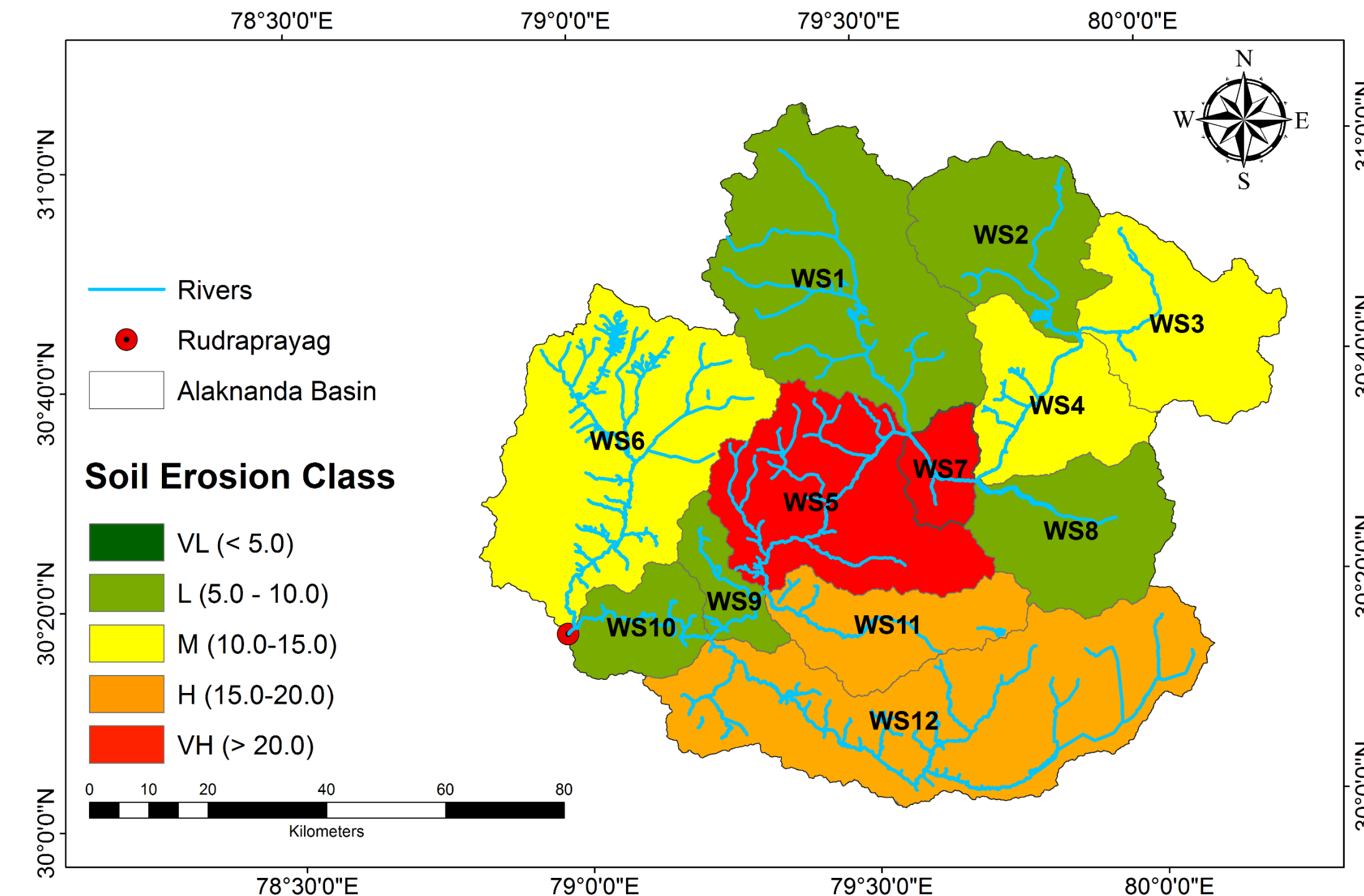


Fig 4: The erosion priority map based on soil loss rate of 12 sub-watersheds (WS1-WS12) of Alaknanda

Table 4: RUSLE parameter, Soil erosion rate and total erosion

| Sub-Watershed | Rainfall Erosivity (R Factor) | | Soil Erodibility (K Factor) | | Topography (LS Factor) | | Cover Management (C Factor) | | Conservation Practices (P Factor) | | Soil Erosion Rate (t/ha/year) | Qualitative | Area (ha) | Total Erosion (million ton/yr) |
|---------------|-------------------------------|-------|-----------------------------|-------|------------------------|-------|-----------------------------|-------|-----------------------------------|-------|-------------------------------|-------------|-----------|--------------------------------|
| | Value | Class | Value | Class | Value | Class | Value | Class | Value | Class | | | | |
| WS7 | 448 | M | 0.077 | H | 1.48 | M | 0.7 | M | 0.78 | VH | 27.8 | | 20812 | 0.579 |
| WS5 | 471 | H | 0.083 | H | 1.39 | M | 0.5 | M | 0.81 | VH | 22 | VH | 107578 | 2.367 |
| WS11 | 475 | H | 0.083 | H | 1.37 | M | 0.4 | L | 0.8 | VH | 17.3 | | 54617 | 0.944 |
| WS12 | 526 | VH | 0.073 | M | 1.36 | M | 0.4 | L | 0.78 | VH | 16.2 | H | 189261 | 3.066 |
| WS6 | 479 | H | 0.08 | H | 1.35 | M | 0.4 | L | 0.71 | H | 14.8 | | 164141 | 2.429 |
| WS4 | 411 | M | 0.045 | L | 1.5 | H | 1 | H | 0.53 | H | 14.7 | M | 62247 | 0.915 |
| WS3 | 294 | VL | 0.058 | M | 1.42 | M | 1.1 | H | 0.38 | M | 10.1 | | 77742 | 0.785 |
| WS9 | 442 | M | 0.088 | H | 1.27 | M | 0.2 | L | 0.94 | VH | 9.3 | | 22343 | 0.208 |
| WS10 | 436 | M | 0.085 | H | 1.29 | M | 0.2 | L | 0.95 | VH | 9.1 | | 33918 | 0.309 |
| WS8 | 508 | VH | 0.042 | L | 1.51 | H | 1.1 | H | 0.25 | M | 8.8 | L | 68681 | 0.604 |
| WS1 | 429 | M | 0.052 | M | 1.46 | M | 1 | H | 0.22 | L | 7.1 | | 153451 | 1.089 |
| WS2 | 328 | VL | 0.044 | L | 1.41 | M | 1.1 | H | 0.27 | M | 6 | | 72420 | 0.434 |
| Average | 437 | M | 0.07 | M | 1.4 | M | 0.7 | M | 0.62 | H | 13.4 | Total | 1027211 | 13.729 |

CONCLUSION

The study intended to prioritise the utmost erosional sub-watersheds of the Alaknanda river basin using an empirical erosional assessment model RUSLE in a GIS environment for proper watershed planning and management. It was found from the study that the sub-watersheds lying in the central and south-western region were experiencing very high erosion, which is basically due to high slopes. The possible moderate to very high soil erosion in the sub-watershed zone necessitates adequate practices for sustainable growth. This information might be useful for implementing most appropriate soil conservation techniques to help improve sustainability and socio-economic upliftment in agricultural and rural areas.

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