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Analysis of Performance of Pearl Millet Crop in Different Hydrological Soil Groups of a Watershed in Arid Ecosystem Using Remote Sensing and GIS

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ABSTRACT

Availability of water in soil profile primarily determines the crop growth in arid-ecosystem. Based on properties which control the entry of rainfall and its redistribution in soil profile, soils can be grouped into four hydrological soil groups.

Pearl millet (*Pennisetum typhoides*) is grown widely as rainfed crop in arid tract of western Rajasthan. Performance of this crop mainly depends on availability of soil moisture provided soil fertility condition is optimum. Leaf Area Index (LAI) and Normalized Difference Vegetation Index (NDVI) can be used as good indicators for evaluation of performance of any crop. But over a large region, the only practical means of estimating such parameters is by remote sensing technique. various spatial analysis among different mapped variables are possible through a Geographical Information System (GIS). The present work shows an attempt to evaluate performance of pearl millet crop grown in different hydrological soil groups of a watershed in arid-ecosystem using remote sensing and GIS techniques.

Variation in mean and median NDVI and LAI of pearl millet were computed from IRS 1C LISS III imagery for different hydrological soil group areas. Performance of pearl millet grown in hydrological soil groups A and C was better because of conducive soil environment to retain more moisture. Pearl millet growing areas was minimum (4.02 ha) in hydrological soil groups B and its poor growth condition may be attributed to low application of nitrogenous fertilizer.

Introduction

Crop growth in arid ecosystem is primarily depend on availability of water in soil profile. Ability of soil to retain rainwater and its redistribution assumes crucial for sustaining large plant population. Hydrological soil groups are grouping of soils based on properties like soil depth, clay content, infiltration and hydraulic conductivity which control the entry of rainwater into the soil surface, its movement and storage. Therefore, hydrological soil groups hold prime importance for optimum growth of rainfed crops in arid-ecosystem.

Pearl millet (*Pennisetum typhoides*), commonly known as bajra is grown extensively as rainfed crop in arid tract of western Rajasthan. Performance of this crop depends both on availability of soil moisture and soil fertility condition. Foliage density (expressed as Leaf Area Index, LAI) and Normalized Difference Vegetation Index (NDVI) can be used as good indicators for quantifying spatial variability in crop performance. Mapping these parameters over a large area through traditional ground based measurements is difficult. The only practical means of estimating such parameters is by remote sensing technique. Geographical Information System (GIS) has the capability to integrate different mapped variables for further spatial analysis.

Therefore, the present investigation was undertaken to analyse the spatial variability in crop performance in different hydrological soil groups of a watershed in arid-ecosystem using remote sensing and GIS techniques.

Study area

The study area (Siyara watershed) lies between

26°20′ to 26°40′ N latitude and 73°4°' to 74° E longitude. It covers an area of 258 sq. km and located 90 km northeast of Jodhpur city, Rajasthan. Climate of this area is predominantly arid with an annual average rainfall of 425 mm. 90% of rainfall is received during June to September; and July and August are the rainiest months. The area experiences average minimum temperature of 18°C and average maximum of 33°C. The annual evaporation is 3102 mm which exceeds far beyond annual precipitation.

Data used and methodology

Satellite data from IRS 1C LISS III sensor acquired on September 24, 1997 (good rainfall year) was used. As digital numbers do not quantitatively correspond to physical units such as radiance or reflectance (Robinove, 1982), so it has been converted to target reflectance using calibration coefficients and other header information. (Pandya *et al.*, 2002). Areas under pearl millet were identified through supervised classification with limited field check. The most widely used NDVI [=(IR-R)/(IR+R)] was computed because it has a linear relationship with fraction of absorbed photosynthetically active radiation (fAPAR). NDVI was transformed into fAPAR using the following relationship (Lind and Fensholt, 1999) : fAPAR = 1.42 * NDVI - 0.39

The LAI was computed from fAPAR using the equation (Sellers *et al.*, 1996) : $LAI = LAI_{max} * [\log (1-fAPAR) / \log (1-fAPAR_{max})]$

Where

LAI_{max} - the maximum possible LAI (it is 0.95 for pearl millet as obtained from field observation)
$fAPAR_{max}$ - the corresponding fAPAR for the LAI_{max}

Soil resources inventory for the watershed was prepared based on semi detailed survey. Soils were grouped according to specific physico-chemical properties to prepare a thematic map on hydrological soil group using ARC/INFO GIS (version 8.0). NDVI and LAI variations in terms of mean, median and standard deviation for pearl millet growing areas within each hydrological soil groups were computed through various programmes in GIS.

Results and Discussions

Land utilization pattern in the watershed (Table 1) showed that only 1672.50 ha area was under pearl millet whereas soils of 4698.34 ha area has soil degradation problem.

Table 1. Area under different landuse categories for Siyara watershed

Landuse category	Area (ha)
Pearl millet	1672.50
Other crops / foddern / plantation	13900.72
Curent fallow	5555.27
Degraded land	4698.34
Total	25826.83

Majority of farmers sown hybrid varieties of pearl millet but its performance was not uniform as evident from variation of NDVI values (Table 2) as well as LAI values (Figure 1).

Table 2. Variation of NDVI values in pearl millet growing areas

NDVI	Area (ha)
0.30 - 0.45	205.38
0.46 - 0.60	1268.09
0.61 - 0.75	199.03
Total	1672.50

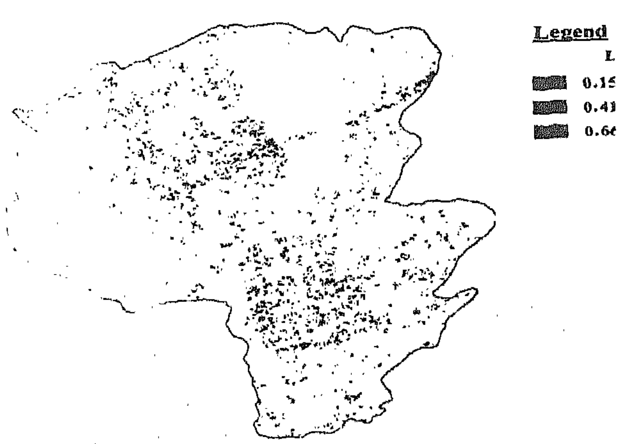

Fig. 1. Variation of LAI in pearl millet growing areas of Siyara watershed

Variations of soils in the watershed can be grouped into four hydrological soil groups (Fig. 2). By superimposing landuse over hydrological soil groups, the runoff curve number which indicate runoff potential (Durbude and Chandramohan, 2000) was generated. Considerable variations in soil properties were observed among different hydrological soil groups (Table 3). Hydrological soil group 'C' occupies maximum areas of 9555.42 ha followed by areas covered by 'A', 'B' and 'D' groups, respectively.

Pearl millet was grown in maximum area (640.50 ha) within hydrological soil group 'C' followed by 575.98 ha, 441.83 ha and 4.02 ha within hydrological soil groups 'A', 'D' and 'B', respectively (Table-4).

Amount of rainwater entry into the soil surface and its subsequent storage were more in soils of hydrological soil group A and C and hence, performance of pearl millet was relatively better as evident from higher mean and median values of NDVI and LAI. However, higher NDVI and LAI values in pearl millet were also observed in few patches of group 'D' soils because of adoption of few soil and water conservation measures that checked the runoff. In addition, variability in crop

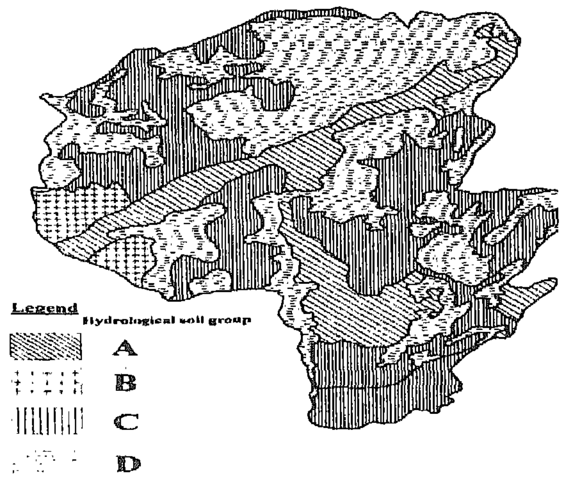

Fig. 2. Spatial distribution of hydrological soil groups in Siyara watershed

Table 3. Variation of landform, soil texture, infiltration rate, curve number and runoff potential in different hydrological soil groups of Siyara watershed

Hydrological soil group	Landform	Soil texture	Infiltration rate	Curve no. (CN)	Runoff potential	Area cov -ered (ha)
A	River bed	Coarse sand	High	25	Low	4119.72
B	Younger alluvial plain	Loamy sand, Sandy loam & Loam	Moderate	76	Moderate	1077.52
C	Buried pediment	Loamy sand Sandy loam	Slow	84	Medium	9555.42
D	Rocky and gravely	-	Very slow	89	High	1074.17

Table 4. Growth performance of pearl millet in different hydrological soil groups of Siyara watershed

Hydrological soil group	Area under pearl millet within soil group (ha)	NDVI		LAI	
		Mean ± σ	Median	Mean ± σ	Median
A	575.98	0.539 ± 0.059	0.53	0.448 ± 0.129	0.43
B	4.02	0.484 ± 0.044	0.47	0.334 ± 0.085	0.30
C	640.50	0.527 ± 0.060	0.52	0.423 ± 0.128	0.40
D	441.83	0.527 ± 0.061	0.51	0.423 ± 0.131	0.39

management practices, particularly application of nitrogenous fertilizer was another improtant factor influenced the performance of pearl millet across all hydrological soil groups. Ground observation revealed that areas showing good growth had relatively more moisture as well as higher soil fertility level.

Conclusions

Quantifying spatial variability in crop performance in terms of NDVI and LAI as assessed from satellite imagery over a large region is a recent practical approach. Further, GIS provides the facility to evaluate performance of any crop in relation to the variation of hydrological soil group in an area. Therefore, crop response can be analysed to identify the soil properties causing the variability and it will lead to delineation of areas where crop response is similar. Thus, stratifying crop variability into homogeneous units will help in demarcating crop management zones as required for precision farming.

References

Durbude, D.G. and Chandramohan, T. 2000. Application of remote sensing technique for estimation of surface runoff from an ungauged watershed using SCS curve number method. *Applied Hydrology* **XII** (1&2) : 1-9.

Lind, M. and Fensholt, R. 1999. The spatio-temporal relationship between rainfall and vegetation development in Burkina Faso. *Danish Journal of Geography* **2** : 43-56.

Pandya, M.R., Singh, R.P., Murali, K.R., Babu, P.N., Kirankumar, A.S. and Dadhwal, V.K. 2002. *IEEE Transactions on Geoscience and Remote Sensing* 40(3) : 714-718.

Robinove, C.J. 1982. Computation with physical values from Landsat digital data. *Photogramm. Eng. Remote Sens.* **48** : 781-784.

Sellers, P.J., Los, S.O., Tucker, C.J., Justice, C.O., Dazlich, D.A., Collats, G.J. and Randall, D.A. 1996. A revised land surface parameterisation (SiB2) for atmospheric GCMs. Part II : the generation of global fields of terrestrial biophysical parameters from satellite data. *Journal of Climate* **9** : 706-737.