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A Comprehensive Watershed Management Plan for a Degraded Watershed in Bundelkhand Region of M.P., India

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ABSTRACT: A comprehensive watershed management plan for the degraded Tumri watershed in Sagar district of Madhya Pradesh covering an area of 2391 hectare has been developed by rigorous hydrological analyses. The watershed is a part of the Bundelkhand region, known as a water scarce and drought prone area. Analysis revealed that estimated surface water potential of 7.80 MCM could be tapped for creation of storages within the watershed instead of let it remained unutilized because of poor management practices. The average annual rainfall and the corresponding water availability of the area have not proven condition prone to hydrological drought rather outlined lack of appropriate management practices on watershed basis. The SCS-CN model has been employed for simulating rainfall-runoff events. The surface water storage sites and areas for artificial groundwater recharge have been identified based on the analysis of topography, soil textures, water availability and geologic formations. The average soil loss from the watershed has been estimated to be 14.6 ton/hectare/year, and 23% of the watershed has been found prone to very high erosion rates exceeding 20 ton/hectare/year. Four sub-watersheds covering area of 453 hectares have been delineated for treatment on priority basis. The gross irrigation requirement estimated to be 0.974 and 5.60 MCM respectively, for kharif and rabi season has been found meet up satisfactorily from the harnessed surface water within the watershed. The SCS-CN model could simulate the daily runoff with an efficiency of 96% and 80% against the data of years 2006–07 and 2007–08, respectively. Seven sites for creation of surface storages and 32.08 ha as most-favorable area for artificial groundwater recharge have been identified.

Keywords: Degraded Watershed, Management Plan, Hydrologic Analysis, Bundelkhand.

INTRODUCTION

Watershed is recognized as the basic hydrologic unit for an integrated water resources management and land use planning. The various components of hydrological cycle are foreseeable within a watershed. Numerous investigators (Chinnamani *et al.*, 1982; Mishra *et al.*, 1991; Bundela *et al.*, 1995; Khan *et al.*, 2001; Gosain and Sandhya, 2004) considering watershed as basic unit estimated successfully different hydrologic components employing well-recognized hydrologic equations. A watershed management plan describes how a watershed can be taken from its present condition to a desirable future condition, and is (i) resource-oriented as it focuses only on watersheds rather than political boundaries, (ii) objective-oriented as it seeks to develop specific watershed policies rather than vague or undefined ends, and (iii) change oriented as it seeks to modify in a proactive manner rather than a reactive manner. A comprehensive watershed plan should therefore be comprised of integrated management of natural resources including land use planning within the watershed. A watershed based management approach for sustainable development normally changes the entire landscapes that help make land fertile if soil and available water resources are managed judiciously. However, the main issues which need to be addressed for such judicious planning and management are: (i) How are the priorities of management events to be fixed? (ii) What are the constraints on a watershed in terms of hydrology and hydrogeology, and also in land-use planning? (iii) What are the environmental and socio-economic dependability on a watershed?, etc. If these issues are not properly analyzed and integrated with the watershed development programs, the sustainability of a watershed management program in a region, which faces extremity of hydrological event like drought, can't be achieved.

The Bundelkhand region in the Country is known to be a water deficit area, and has been scaled downed to a drought prone area. It is in those considerations, a degraded watershed in the Bundelkhand region in the State of Madhya Pradesh, which is primarily considered to be a rain-fed area, has been considered for a comprehensive and in depth study. Planning and development of this rain-fed area on the basis of watershed approach calls for rigorous understanding of the hydrology including the occurrence and movement of water in the surface and sub-surface systems. Thus, the study is aimed to develop a watershed management plan based on prioritizing of events through systematic analyses of hydrologic and hydrogeologic, land-use and soil properties data, and socio-economic aspects.

STUDY AREA

The Tumri watershed is located in the Kesli block of Sagar district in Madhya Pradesh and covers a catchment area of 2391 ha. The watershed is located between latitudes 23° 23′ 25″ and 23° 27′ 05″ N and longitude 78° 42′ 30″ and 78° 46′ 39″ E and lies in Sonar basin of the Ken river system. The index map of the study area is given in Figure 1. River Chamak Dhol, which traverses 11.50 km within the watershed, is one of the main tributaries of river Sonar joins near Berar Veeran. Flash floods are frequently encountered and the stream flow ceases soon after the withdrawal of monsoon. The climate is semi-arid and the average annual rainfall is about 1182 mm; 90% of which occurs during the monsoon period (June through October). The watershed is rain-fed. The topography of the Tumri watershed is highly undulating comprising of steep hills with dense forests on ridges and few barren flat top hillocks. The geology comprises of basaltic formations and boulder-strewn plains are commonly seen in the watershed. Red soils mostly on the hills and black soils in the agricultural fields, mostly located near foothills, valley and riverbanks form the general soil textures of the watershed. Soyabean and jowar are the principal kharif crops, and wheat and gram are the predominant rabi crops.

Three small storage tanks constructed for supply of drinking water are located in the watershed. Those tanks normally get dried up by the onset of summer season. Very few tube wells are found in the watershed. The main source of drinking water besides those storage tanks is few large-diameter dug wells, which too get dried up during summer season. Drinking water scarcity is thus inevitable. The major occupation of the people is agriculture and cattle rearing. The present land use pattern is comprised of forests on the hills, agriculture on the plains and shrubs, and barren lands along the flat-topped hillocks. Abundant wasteland is available for development of grassland for the livestock.

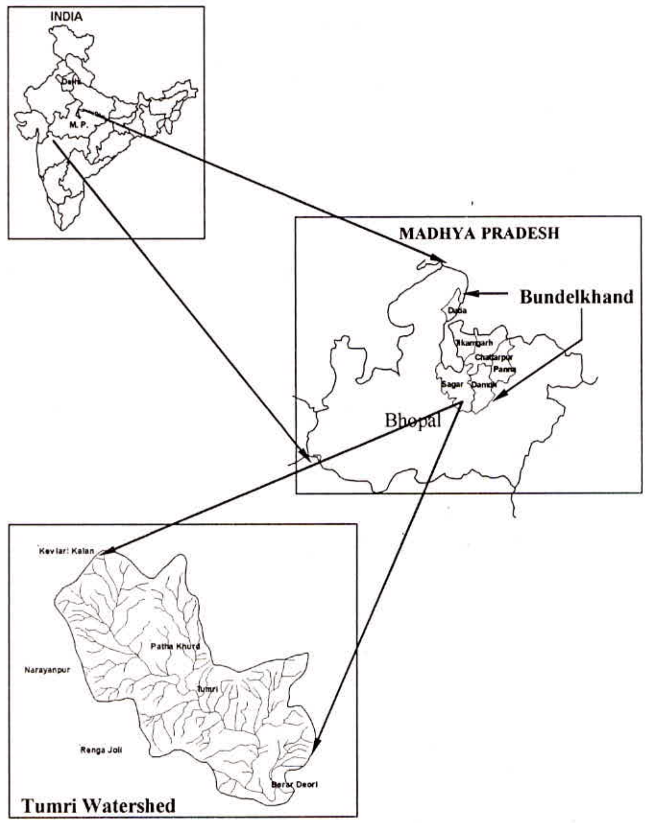

Fig. 1: Index map of the Tumri watershed

DATA USED

The daily rainfall data monitored at Kesli, and other hydro-meteorological data such as, daily maximum and minimum temperature, wind speed, sunshine hours, relative humidity and rainfall observed at Sagar by the IMD (India Meteorology Department) were utilized for analysis. The demographic and the agricultural data were used from the available records. For stream flow data a gauge-discharge measurement site was established on the Tumri stream, which is a tributary of main river Chamak Dhol. A self-recording rain gauge station and an ordinary rain gauge station were established at the Tumri watershed. Ground water levels data were monitored on monthly basis from twelve observation wells located in and around the study area. Soil infiltration rate, hydraulic conductivity, soil-type and soil-depth were determined through field tests at fourteen test sites. The land use information was extracted from the IRS-1C LISS III merged with IRS-1D Pan geo-referenced satellite data.

METHODOLOGY

The generated database and its use as inputs in different computation tools, hydrologic models and in GIS environment, helped develop required data inventories, thematic maps, and various parameters for estimation of water balance components. The various work elements and hydrological components investigated include:

1. Inventory on hydrology, meteorology, demography, land use, cropping pattern, soil information, soil and water conservation practices.
2. Soil characteristics profiling and soil textures determination.
3. Thematic maps on drainage, soil type, land use, topography, road network and geology in GIS environment.
4. Rainfall-runoff modeling using SCS-CN approach.
5. Estimation of soil loss using Universal Soil Loss Equation.
6. Water budgeting to evaluate inflows, outflows and storage components of the hydrological cycle.
7. Identification of vulnerable areas and prioritization of sub-watersheds to address problematic sub-watersheds on priority basis.
8. Land capability classification for identifying proposed land use and land treatment measures.
9. Identification of potential water storage sites using remote sensing, GIS and field information.
10. Identification of areas suitable for artificial recharge within the watershed.

RESULTS AND DISCUSSION

The analysis of rainfall data of 15 years (1993–2008) indicated that the average annual rainfall is 1182 mm, signifying not large deficit rainfall. The seasonal departure analysis was carried out for determining the dry years. Five dry years, 1995–96, 1996–97, 2000–01, 2002–03 and 2007–08 with more than 25% deficiency are found. The frequency of drought years in the watershed was evaluated based on the probability distribution of the annual rainfall. The rainfall corresponding to the 75% dependability is found to be 808 mm and the exceedance frequency corresponding to the 75% of the normal annual rainfall is 69.4%. As the probability of occurrence of 75% of the normal annual rainfall is less than 80%, the watershed can be considered to be meteorologically drought prone. The average annual Potential Evapotranspiration (PET) estimated by Thornthwaite (1948) method, which estimates PET as a function of climatic average monthly temperature and day length, is found to be 173.4 cm with variation between 155.28 cm to 187.95 cm.

The drainage network map was prepared using the Survey of India toposheets 55-I/11 and 55-I/15. Other maps namely contour, soil type, soil depth, geology and geomorphology; and digital elevation model, slope class and drainage density generated in GIS environment using ILWIS 3.0 formed the inputs for further investigations and modeling studies. The land use in the watershed has been determined from IRS-1C LISS-III merged with IRS-1D Pan geo-referenced satellite data. The land uses represent agriculture (540.14 ha), dense forests (587.97 ha), wasteland (706.13 ha), open forests (521.89 ha), water bodies (0.30 ha) and built up areas (1.17 ha). The land use map of the Tumri watershed is given as Figure 2.

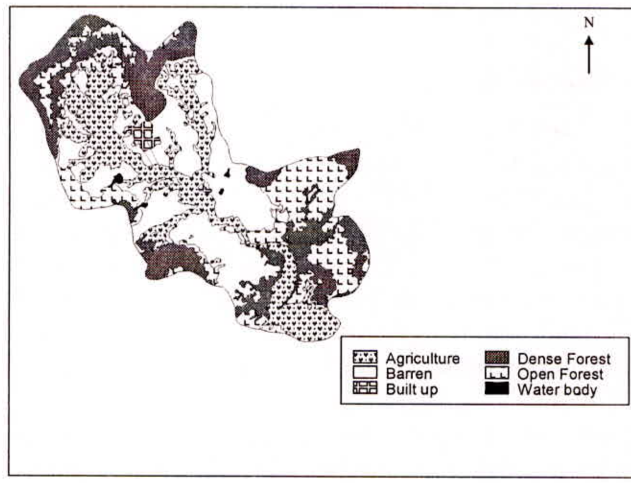

Fig. 2: Land use map of Tumri watershed

The management policy for any watershed is largely governed by the flow characteristics (viz., rate and quantity of runoff) in its catchment, which in turn depend on the infiltration rate and hydraulic conductivity of the soils. Tests were therefore conducted for determination of infiltration rates and saturated hydraulic conductivity, using double ring infiltrometer and Guelph permeameter at fourteen sites representing various soil type, land use and topography. The infiltration rates were found to vary between 0.14 and 7 cm/hr, and the saturated hydraulic conductivities between 0.59 and 8.03 cm/hr. The Horton's (1933 and 1942), and the Kostiakov's (1932) equation given in Eqn. (1) and Eqn. (2) respectively, have been applied to develop appropriate models for varying land use and soil type combinations,

$$f_t = f_c + (f_0 - f_c) e^{-kt} \quad \dots (1)$$

$$F_p = K_k t^{\alpha} \quad \dots (2)$$

where, f_t = infiltration rate at time t; f_c = constant rate of infiltration at the end of storm; f_0 = maximum rate of infiltration at the start of storm; k = a parameter which controls the decrease of infiltration capacity; F_p = cumulative depth of infiltrated water; K_k and a = parameters, which depend on soil and initial conditions.

The geomorphologic characteristics, which are useful in rationalization of the models of rainfall-runoff process for predicting model parameters of ungauged watersheds, have been determined. The Tumri watershed is of 4th order basin with basin relief of 160.2 m and drainage density of 3.84 km/sq km. Water budgeting, an important analysis in a hydrologic system that helps decide strategies for development and management of water resources in a watershed, was carried out on monthly basis water balance equation of the following form,

$$P - Q_{dsro} - Q_b - E_t - ET_f - ET_c - D_{dom} - D_{liv} = \Delta S_s + \Delta S_g + U_w \quad \ldots (3)$$

where, P = rainfall; Q_{dsro} = direct surface runoff; Q_b= base flow; E_t = evaporation from tanks; ET_f = evapotranspiration from forest; ET_c = evapotranspiration from cropped areas; D_d = domestic usage; D_l = livestock needs; ΔS_s = change in surface water storages; ΔS_g = change in ground water storage; U_w = Unaccounted water.

The evapotranspiration for forested areas and cropped areas, and the reference crop evapotranspiration have been estimated using the Penman-Monteith equation (Allen *et al.*, 1998). The crop evapotranspiration has been estimated on a ten-daily basis for various crop growth stages. Water requirements for domestic and livestock have been estimated considering per capita demand prescribed for rural India. The composite Curve Number (CN) for the watershed is estimated 83 using hydrologic soil group and land use for AMC-II condition. The surface runoff was the major outflow component estimated using the SCS-CN model given in Eqns. (4) and (5),

$$Q = \frac{(P - I_a)^2}{(P - I_a + S)} \text{ for } P > I_a \text{ ; and } Q = 0 \text{ for } P \le I_a \quad \ldots (4)$$

$$S = \frac{25400}{CN} - 254 \quad \ldots (5)$$

where, Q = direct surface runoff (mm); S = potential retention (mm); CN = curve number; I_a= initial abstraction = 0.2 S for general soils; = 0.3 S for AMC-I and black soils ; and = 0.1 S for AMC-III and black soils.

The total surface runoff including the base flow corresponding to the rainfall events is estimated to be 8.05 MCM which flows out from the watershed unutilized. To tap this unutilized water, it is required to find the feasible locations of storage structures in the watershed. The change in surface as well as ground water storage has been assessed from the actual monitoring of the water levels in the tanks and ground water levels from few observation wells in the study area. The residual term in the water balance equation which is considered to be the unaccounted water, is quantified as 1.105 MCM in monsoon season and 4.602 MCM in the non-monsoon season as given in Table 1. The unaccounted water indicates the accuracy in estimation of the water balance components, and seems to be on the higher side which may be due to the outflow into the confined aquifer, not being quantified. This component is significant, because due to the highly weathered geology of the region, the aquifer starts losing water drastically soon after the withdrawal of the monsoon.

Table 1: Water Balance of Tumri Watershed
(All values are in MCM (million cubic meter), DSRO: direct surface runoff estimated by SCS-CN model)

Components		Year (2006–07) Monsoon	Non-Monsoon
Inputs	Rainfall	24.690	0.529
Outputs	Surface runoff (dsro and base flow)	8.050	0.000
	Domestic and livestock	0.033	0.046
	Evaporation (tanks)	0.012	0.092
	Evapotranspiration (forests and crops)	2.488	4.427
	Groundwater outflow	2.241	3.586
Change in Storage (SW)		0.031	–0.019
Change in Storage (GW)		10.730	–12.205
Unaccounted water		1.105	4.602

The land capability classification useful in land use and treatment planning was carried out based on the infiltration rate, slope class, erosion class, soil type and soil depth. Six land capability classes from Class II to VII were identified. The area covered under each class along with the proposed land use and desired conservation measures have been evaluated. The land capability classification map of the watershed is given in Figure 3. The proposed land use and the conservation measures to be adopted are presented in Table 2.

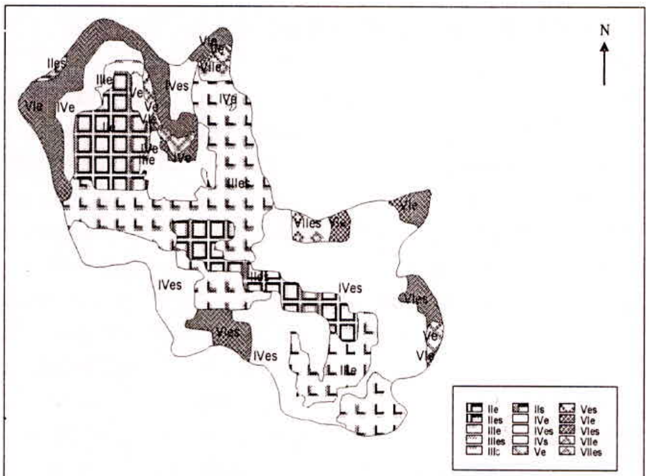

Fig. 3: Land capability classification map

Fig. 3: Land capability classification map

Universal Soil Loss equation (Eqn. 6) developed by Wischmeier and Smith (1978) has been employed to determine the soil erosion from the watershed. The maps of *R, K, L, S, C,* and *P*-factor have been generated in GIS environment and integrated to develop the soil erosion map,

$$A = RKLSCP \quad \ldots (6)$$

where, A = soil ioss in tones/hectare; R = rainfall erosivity factor; K = soil erodibility factor; L = slope length factor; S = slope steepness factor; C = cropping-management factor; P = conservation practice factor.

The erosion from the watershed has been classified into four classes namely low, moderate, high and very high erosion (Table 3). About 55% of the area is within low to moderate erosion class, and 23% of the watershed is prone to very high erosion rates exceeding 20 t/ha/yr. The average rate of soil loss is estimated to be 14.6 t/ha/yr, and the quantity of total soil erosion from the watershed is 34912.7 t/yr. Erosion from different land use classes has also been determined; the maximum erosion of 34.56 t/ha/yr is found for the barren exposed lands. Impact assessment analysis carried out to assess the impact of treatment measures on barren lands and the results indicate that conversion of the barren lands to forest plantations will reduce the soil erosion from the current rate to 9.53 t/ha/yr. The soil erosion map of the watershed is given in Figure 4.

Table 2: Land Capability Classification and Proposed Conservation Measures

Sl.No.	*Land Capabilit y Class*	*Area (hectare)*	*Proposed Land Use*	*Proposed Conservation Measures*
1.	IIe	178.93	Agriculture (Irrigated)	• Agronomic Measures: Contour farming, Strip cropping, Mixed Cropping, Conservation Tillage, Crop rotation etc. • Mechanical Measures: Contour Bunding, Grassed waterways etc.
2.	IIes	153.50		
3.	IIIe	218.96		
4.	IIIes	452.87		
5.	IVe	187.73	Agriculture (Irrigated)	• Agronomic Measures: Contour farming, Strip cropping, Mixed Cropping, Conservation Tillage, Crop rotation etc. • Mechanical Measures: Broad based Terracing, Diversion drain, Drop outlet, Grassed waterways etc.
6.	IVes	762.21	Agriculture, Pasture and Agro forestry	• Agronomic Measures: Contour farming, Strip cropping, Mixed Cropping, Conservation Tillage, Crop rotation etc. • Mechanical Measures: Broad based Terracing, Diversion drain, Drop outlet, Grassed waterways etc.
7.	Ve	45.39	Pasture and Agro forestry	• Mechanical Measures: Diversion drain, Grassed waterways. • Biological Measures: Raising of additional shrubs and grasses.
8.	VIe	271.00	Pasture and Agro forestry	• Mechanical Measures: Diversion drain, Grassed waterways, Dugout farm ponds, Temporary check dams for gully control. • Biological Measures: Raising of commercial grasses, Grassland management, Controlled and deferred rotational grazing, Agro forestry etc.
9.	VIes	77.52	Forest	• Mechanical Measures: Diversion drain, Grassed waterways, Temporary check dams for gully control • Biological Measures: Raising of additional shrubs and grasses, Agro forestry etc.
10	VIIe	16.82		
11	VIIes	26.07		

Table 3: Estimated (classified) Soil Loss from Tumri Watershed

Sl. No.	Erosion Rate tons/ha/year	Erosion Class	Area (Hectare)	Percent of total Area
1.	< 2.5	Low	892.71	37.33
2.	2.5–10.0	Moderate	432.73	18.10
3.	10.0–20.0	High	514.96	21.53
4.	>20.0	Very high	550.88	23.04
Total			2391.28	100.00

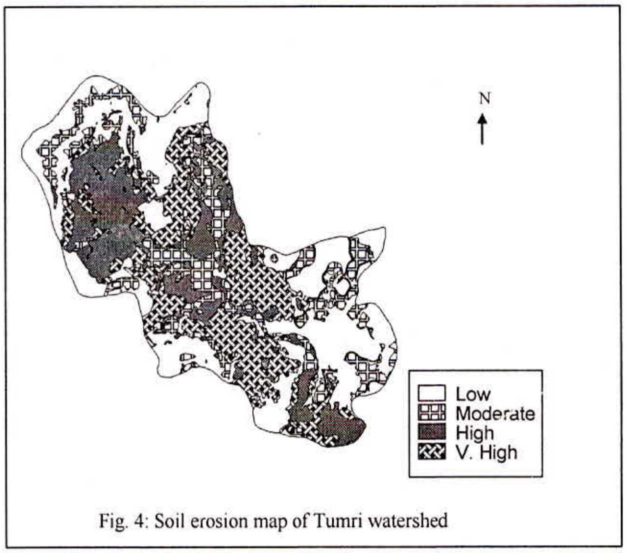

Fig. 4: Soil erosion map of Tumri watershed

Prioritization of watersheds helps economize the management strategy. The watershed has been divided into 19 sub-watersheds. The average soil loss, drainage density, average slope and sediment yield are considered as the indices of prioritization, the priority index of each sub-watershed is worked out using Eqns. (7) and (8) (Kumar, 1985; Rao and Mahawaleswara, 1990). It is done by grouping the area into four priority classes namely; low, moderate, high and very high priority. The sub-watersheds 7, 8 15 and 16 covering an area of 453 hectares has been delineated as very high priority class suggesting treatment on priority basis followed by sub-watersheds of other priority classes. Figure 5 presents the delineated priority map of the watershed, and Table 4 gives the numeric details of each sub-watershed,

$$V_s = 1.067 * 10^{0.006} P^{1.384} A^{1.292} D_d^{0.392} S^{0.129} F^{2.51} \quad \ldots (7)$$

$$F = \frac{0.21F_1 + 0.20F_2 + 0.60F_3 + 0.8F_4 + F_5}{\sum_1^5 F_i} \quad \ldots (8)$$

where, V_s = sediment yield (MM^3/yr); P = annual precipitation (cm); A = watershed area (sq. km); D_d = drainage density (km/sq. km); S = slope; F_1 = protected forest; F_2 = unclassified forest; F_3 = cultivated area; F_4 = grass or pasture land; F_5 = waste land

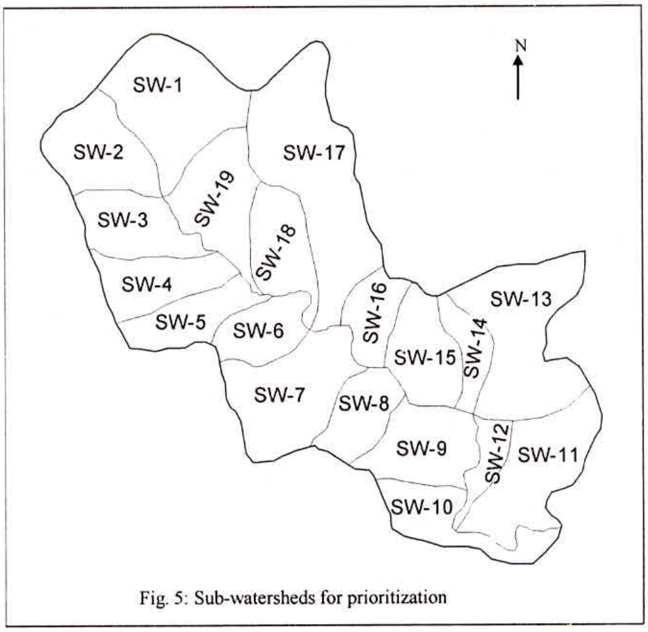

Fig. 5: Sub-watersheds for prioritization

Table 4: Priority Classes of Each Sub-Watershed

Class No.	Priority Class	Sub-Watershed No.	Area under Each Unit (ha)	Total Area (hectare)
1.	Very high	7	200.7	453.20
		8	70.5	
		15	117.4	
		16	64.6	
2.	High	9	124.79	819.01
		11	169.0	
		17	286.49	
		18	96.95	
		19	141.78	
3.	Moderate	2	126.96	446.07
		3	113.06	
		6	83.58	
		10	82.61	
		12	39.86	
4.	Low	1	214.07	672.85
		4	92.95	
		5	84.0	
		13	229.15	
		14	52.68	

Estimation of runoff is essentially required for assessing the potential of streams so as to determine capacity of small water resource structures to be constructed. The SCS-CN model, which is a single parameter model, (CN), has been used for modeling the runoff process. The Composite Curve Number (CCN) for the ungauged Chamakdhol watershed is estimated to be 83, and that for the gauged Tumri nala sub-watershed is 83.76 for AMC-II conditions. Simulation runs were performed on the gauged watershed and the model could simulate the daily runoff with efficiencies of about 96% and 80% for the rainfall events of the years 2006–07 and 2007–08, respectively. As the performance of the model was appropriate for the gauged watershed, the model was used to estimate the direct surface runoff using the same rainfall events for the ungauged Chamakdhol watershed. The comparison of the observed and simulated runoffs for the gauged Tumri watershed in the year 2007–08 is shown in Figure 6.

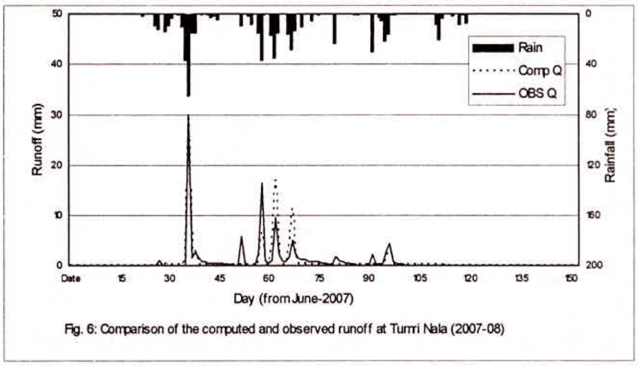

Fig. 6: Comparison of the computed and observed runoff at Tumri Nala (2007–08)

The seasonal crop water requirement for various crops has been determined on a ten-daily basis. The Penman-Monteith method (Allen *et al.*, 1998) has been used for computation of the reference crop evapotranspiration. The effective rainfall has been determined using the USDA-SCS method (1970). The gross irrigation requirement for kharif and rabi season is estimated to be 0.974 MCM and 5.600 MCM, respectively. The net and gross irrigation water requirement during both the seasons is given in Table 5. The irrigation water requirement during both the seasons can be met by tapping the surface water and ground water sources within the watershed. Creation of surface water storages will reduce the stress on the very few ground water yielding wells located in the watershed, which starts drying up soon after the withdrawal of the monsoon.

Table 5: Seasonal Gross and Net Irrigation Water Requirement

Sl. No.	*Season*	*Crop Period*	*Irrigation Water Requirement, MCM*	
			Net Irrigation Requirement	*Gross Irrigation Requirement*
1.	Kharrif	15^{th} June to 31^{st} Oct.	0.545	0.974
2.	Rabi	1^{st} Nov to 20^{th} Mar.	3.100	5.600

The Tumri watershed is located in the upstream reaches of the river Sonar; it has many limitations those include; rugged topography with flat-topped hills featuring unfavorable conditions for big projects. Small storage structures on second and third order streams are found to be best suited for such conditions. The sites for creating small storage structures have been identified on the basis of the decision rules which include; minimum submergence of dense forests and agricultural lands, availability of agricultural land downstream for irrigation purposes, catchment area large enough to create required storage capacity, minimum length of the structure and minimum of submergence, adequate depth of storage and well distribution of sites in the watershed. Based on those considerations, seven storage sites have been identified, and the locations of the proposed storage sites including their catchment extent are shown in Figure 7. The elevation-area-capacity for each of the storage structures has been worked out, and the priority of creating those storage structures determined on the basis of ratio of submergence area to catchment area, ratio of storage capacity to catchment area and pondage depth has been assigned. Site-6 is found to have the first priority site followed by Site-3 and Site-5. The salient features indicating catchment area, height of bund, maximum water level, area of submergence and storage capacity of each site are given in Table 6.

Dry-out of open wells in the watershed during November through March revealed poor scenario of groundwater availability. The average depletion of groundwater level has been reported to be more than 6.0 m. Villagers face severe hardship to meet drinking water requirement during summer season. Thus, groundwater recharge for its augmentation is necessary. The areas favorable for groundwater recharge have been delineated on the basis of land use, slope class, soil type, soil depth, groundwater fluctuation, drainage density, geo-morphology and drainage density. The criteria considered include: drainage density not more

Table 6: Salient Features of the Proposed Storage Structures

Site No.	*Catchment Area (hectare)*	*Height of Bund (m)*	*Maximum Water Level (m)*	*Area of Submer-gence (hectare)*	*Storage Capacity (MCM)*	*Runoff from Catchment (MCM)*	*Average Pondage Depth (m)*
S-1	77.95	4.5	531.0	11.18	0.22	0.27	1.96
S-2	30.56	3.0	539.5	6.50	0.08	0.11	1.27
S-3	37.19	4.0	542.5	4.46	0.13	0.13	2.81
S-4	70.79	6.0	545.5	3.50	0.10	0.25	2.91
S-5	34.19	5.5	505.0	3.60	0.10	0.12	2.91
S-6	154.97	6.5	514.5	8.73	0.45	0.54	5.12
S-7	53.79	7.0	513.0	4.08	0.14	0.19	3.47

than 5 km/sq. km, slopes less than 5%, buried pediments and alluvial plains and infiltration rate more than 2 cm/hr. The most suitable and moderately suitable areas comprising of 32.08 ha and 288.64 ha, respectively identified for artificial groundwater recharge are shown in Figure 8.

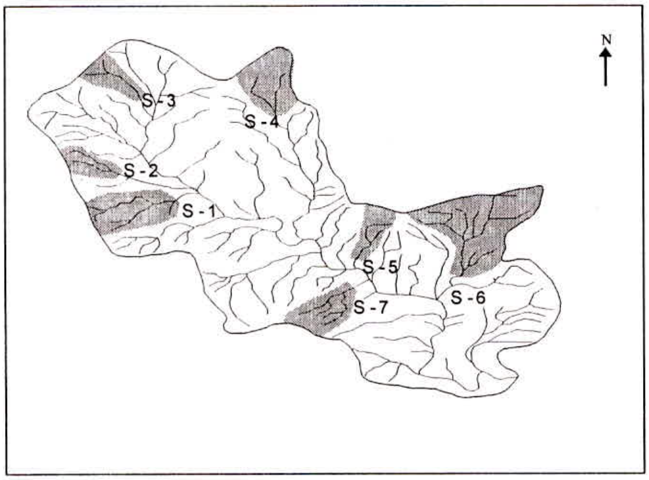

Fig. 7: Location of catchments of selected storage sites

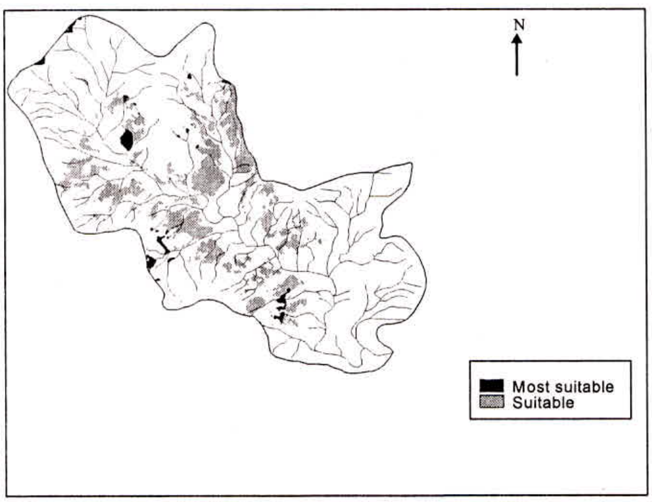

Fig. 8: Location of sites suitable for artificial recharge

CONCLUSIONS

The Tumri watershed in the Bundelkhand region of Madhya Pradesh—a highly degraded and known to be drought prone with 4th order stream networks having drainage density of 3.84 km/sq. km and basin relief of 160.2 m—has been studied exhaustively to examine hydrologic fate of the watershed and scope to develop its water resources prospect. Employing integrated analyses of various hydrologic components, a management strategy of the watershed has been proposed. It is further observed that the problem of water scarcity, inadequate soil moisture and environmental degradation commonly underlined with the region is because of lack of conservation and fragmented management practices, which can be substantiated by holistic scientific approach on watershed basis. The average annual rainfall and the estimated surface water runoffs failed to unearth conditions fitting to hydrological drought, rather call for a comprehensive and scientific planning on watershed basis to debug the region from the agricultural drought to bring into an agriculturally prosperous region. The holistic approach helps develop synergy between science and society in the watershed management programs.

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