ICIWRM – 2000, Proceedings of International Conference on Integrated Water Resources Management for Sustainable Development, 19 – 21 December, 2000, New Delhi, India

Restoring hydrologic regime of overgrazed pastures and forest land

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Abstract
The grasslands, rangelands and natural forest lands happens to be not only the major grazing support for more than 420 million live stock of the country but also the major source of fuel, wood, fodder, timber and natural habitat for wild life. Because of their common environmental inputs and land uses, these lands tend towards a series of common hydrological characteristics. Bundelkhand region of central India represents traditional rangelands of the country, which has now converted into degraded wastelands because of excessive grazing pressure and other adverse climatic & geological constraints. Two representative watersheds of this region were adopted for applying various soil and water conservation engineering (SWCE) measures like contour furrowing, shallow depth discontinuous staggered pits, contour stone dykes, micro ponds, loose boulder check dams and contour trenches to restore hydrologic regime of 1381 ha area in Jhansi district of U.P. and 500 ha area in Datia district of M.P. in India. This paper describes the impacts of watershed treatments giving encouraging results showing greater moisture conservation, reduced runoff & soil losses, increased infiltration and thus better vegetation growth and regeneration of forest.

INTRODUCTION

India with total geographical area of 329 M ha possesses only 264 M ha land having any biotic potential, out of which at least 175 M ha is degraded in one or another form. The major factor responsible for these degradations are poor land management practices, irrational land uses, excessive grazing pressure and over exploitation of land resources beyond their capabilities. The grasslands, rangelands and natural forest lands happens to be the major constituents of these degraded lands, which are not only the grazing support for more than 420 million live stock of country but also the major source of fuel, wood, fodder, timber and natural habitat for wild life. Because of their common environmental inputs Indian rangelands in general receives low precipitation, maintain sparse vegetal cover and some times saline with excessive grazing pressure on it.

To overcome this problem our prime natural resources (i.e. soil & water) needs to be conserved judiciously for sustainable production of bio-mass and thus halting the process of degradation which has now reached to a threatening dimension. Various estimates put erosion figures at 45% of total geographical area effected by water and wind erosion (Das, 1985), 6000 million tonnes top soil erosion (Dhruvanarayana , 1990); 16.35 t/ha of

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annual soil loss due to agriculture and associated activities alone (Dhruvanarayana and Ram Babu, 1983). To check the pressure on pasture land which is presently much more than the carrying capacity (Singh, and Roy, 1991) and to meet the huge gap in fodder demand and supply of 459 MT dry and 850 MT green fodder (Lal, 1990), various SWCE measures are the only option left. With these measures the wastelands could be effectively utilized and restored back to arable pastures. As per an estimate, out of 7.04 M ha about 5.019 M ha or nearly 70% area of Bundelkhand region suffers from varying degree of degradation (Nitant, and Tiwari, 1991).

The pastures and forests are mostly visible in pockets at different locations of the country. Among these, the Bundelkhand region of central India is one. In past this region was a biggest traditional pastoral belt which is now severely degraded to its worst stage, leaving lands thirsty for water and hungry for nutrients. This all together brought down the hydrologic status of the region resulting into poor soil vegetation cover complexes. The reasons being the poor land & water management practices together with excessive overgrazing with open animals in the fields. Considering this an integrated wasteland development project for the region was initiated by the IGFRI , Jhansi with the financial assistance from NAEB, Ministry of Environment and Forests, Govt. of India. Under this project a cumulative area of 1881 ha was selected covering the Jhansi and Datia Districts of Bundelkhand region having 18.6 and 30.6 % area as wastelands (Wasteland Atlas, 1993). Present paper describes the bench mark status of the study sites together with package of soil and water conservation measures adopted. Attempts have been made to quantify the effectiveness of the soil and water conservation measures for improving the hydrologic regime and overall productivity of the degraded pastures and forests in the region.

MATERIAL AND METHOD

Site description

(i) Geographical Parameters: Out of 1881 ha area , 1381 ha is in Ambabai village of Jhansi district of U.P. (Between latitude 25° 32' to 25° 34' North and longitude 78° 29' to 78° 30' east in the south-west). The remaining 500 ha is situated about 20 km away from Ambabai at Chopra village in Datia district of M.P. The general topography of the area is undulating and rolling with vertical gully-heads at places along with main drainage channels. The drainage is of dendratic pattern in upper reaches of the area with low drainage density.

Soils mainly belongs to red soils of Bundelkhand series which had developed from garanites and gneissus type of parent material from Vindhyan range. Geomorphologically the area is mainly composed of granites whose texture varies from coarse to fine and colour varies from pink to gray having quartz reefs and delerite dykes at certain locations. Dominating soil types are r*akar* and *parwa* out of which *rakar* is mostly visible which is typically and characteristically red, course, eroded, gravelly (Murram) in texture, Shallow in depth, occurring on slopes and hilly terrain, highly deficient in moisture retention capacity & organic matter / nutrients and thus having low productivity.

(ii) Hydrological Parameters: The climate of the region can be described as semi arid with lang's rainfactor 41.9 mm per degree centigrade (Nitant and Tiwari, 1991). The average annual rainfall (1981-92) in the region is about 920 mm distributed in 40-50 rainy days out of which 80 to 90 % occurs during monsoon period i.e. June to Sept. Overall rainfall pattern is very erratic and uncertain in nature giving many short duration high intensity storms. As per climatic water balance (based upon 3 years average rainfall) total surplus water of 493 mm is available during monsoon, while the total annual deficit is up to the tune of 1753 mm. As shown in Fig 1, the water surplus in the monsoon period (mid July - Mid September) indicates a possibility of water harvesting/in-situ conservation which can help to overcome the deficit in the area till February without considering the losses (Singh and Kanodia, 1992).

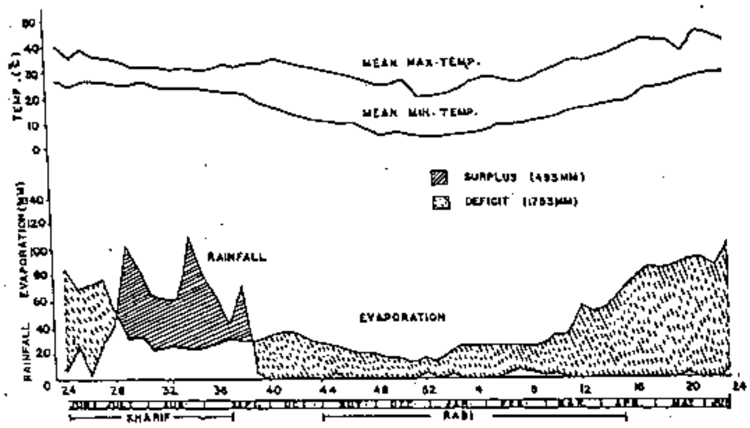

Figure 1. Climatic water balance at study site.

The infiltration characteristics of the area is highly variable (Gaur and Singh,1994) with variations in porosity & permeability (both laterally & horizontally), even at very short distances. The ground water table depth varies from 1 to 20 m below ground level. Shallow open dug cum-blast wells having low storage capacities (unit draft ranging from 0.2 to 0.5 ha-m) are more common in the area (Singh et.al., 1992).

Soil and Water Conservation Measures Adopted

Execution of conservation measures were performed with the aim to conserve the in-situ soil moisture, disposing excess runoff with safer velocities to avoid erosion damages together with surface water harvesting and water spreading at identified locations. After careful planning and precise field alignments, following engineering measures were adopted.

(i) Contour furrows: About 20 km long contour furrows (0.8 sqm. cross section) were created on uniform sloppy surfaces (2-4% slope) in the watershed area. The furrows were aligned and constructed along contours at 20 cm vertical spacing at various locations. About 1000-1500 running meter furrows were formed per hectares.

(ii) Shallow depth staggered pits: The inter spaces between the contour furrows were treated by constructing shallow depth discontinuous staggered pits of 4-5 liters capacities using the pitter discer (Singh, 1985). About 17000 pits of varying dimensions were created per ha area, which formed small mini reservoirs all over the sloppy soil surface. Grass seed pallets were successfully retained in these micro depressions in order to provide favorable germination opportunities.

(iii) Contour stone dykes: On steep sloppy and rocky hillocks, stone ridges of low depth were laid on contours with a view to detain runoff, reducing flow velocity and to arrest the silt carried with runoff. About 7 km long dykes of 0.30 m height were constructed at two specific catchments in the area, with a constant vertical interval of 1.0 m meter in between two consecutive dykes. Individual dyke length varies between 93-612 meters.

(iv) Loose boulder check dams: The drainage lines in the forest watershed at Chopra were having typical meandering characteristics and steep gradients leaving parent rocks at bottom. About 75 check dams of varying lengths (0.8-17.6 m) were constructed utilizing the locally available boulders, for treating the four drainage lines of about 5 km long.

(v) Micro ponds: At upper reaches of certain drainage lines where a considerable soil still exists, 13 small water pools were created by constructing micro-ponds of varying capacity ranging from 5 to 40 cum. At certain locations these ponds were dug adjacent to loose boulder check dam, where the excavated soil mass was placed at down stream side in compacted layers.

(vi) Contour trenches: On the large steep sloppy barren surfaces where a considerable sub-soil exists, contour trenches of 0.24 Sqm. cross section were constructed. These trenches were formed by making depressions (0.40 m deep & 0.60 m wide) of different lengths on contours. The excavated soil was placed at down side in the shape of low height bund. Both staggered and continuous types of contour trenches were constructed. The staggered trenches were of 3 and 4 meter length and aligned on contours at vertical intervals of 0.5 - 1.0 meter while the continuous trenches were of varying length as per prevailing site conditions and aligned on contours at vertical spacing of 1.5 - 2.5 m to facilitate better water spreading and in-situ conservation of runoff. In all about 10000 staggered trenches (720-960 liters storage capacity) and 17 km long continuous contour trenches were constructed covering an area of 250 ha spread over different locations in the watersheds.

Monitoring Hydrological Parameters

(i) Runoff and soil loss: To assess the degree and extent of runoff and soil loss, a runoff plot experiment was laid at Chopra watershed under which nine runoff plots (7 having 3% and 2 having 4% slope) of standard size (22 x 1.8 m) were constructed. Low boundary walls made of 3" thick brick masonry being 9" above ground level separated all the plots. Nine slot multi slot divisors having 4" x 1/2" slot dimensions were used for gauging runoff and soil loss. Before installation of divisors, all the plots were provided with runoff collectors converging towards the stilling tanks. Prefabricated cement tanks were used as stilling tank having a baffle wall in it for stilling the turbulence of in-coming runoff water so that a smooth sheet of water with uniform velocity entered into the divisor box. Entire gauging unit for each plot was calibrated for its accuracy and reliability. Various treatments (contour furrows, shallow depth staggered pits, contour stone dykes, vegetative hedges etc) were imposed in the plots with the aim to evaluate various SWCE measures.

(ii) Infiltration: Infiltration tests were conducted at several locations in the watershed using double ring infiltrometer method in which a constant water head of 10 cm was maintained throughout the test duration (min. 6 hrs) in both the rings. The infiltration rates and cumulative infiltration volumes were recorded in the pre-monsoon period at specified locations in the watershed. These major locations comprised a 10 ha micro catchment (marginal soil depth, uniform rolling topography,2-4% slope, treated with contour furrowing & shallow depth staggered pitting) , animal tacks/foot paths in forest land, intermittent alkaline patches, black soil deposits at depressions, gully beds and denuded hillocks.

RESULTS AND DISCUSSIONS

Seasonal Rainfall Pattern at Study Watersheds

There were considerable spatial and temporal variations in seasonal rainfall within the study watershed. For example during 1993 monsoon, total rainfall observed at Ambabai and Chopra was 552.5 and 607.5 mm respectively. The rain charts showed that there were 33 and 27 major rainy days at Ambabai and Chopra (about 1/3rd were in the range of 2.5 - 12.5 mm). Also no storm of more than 100 mm was observed at Ambabai while at Chopra a single heavy storm of 157.5 mm was observed (10-9-93) when land surface was barren, giving heavy runoff potential.

Infiltration Trends

Results of infiltration tests conducted at 76 locations showed a vast variation in infiltration rates and cumulative water intake per elapsed time. Highest cumulative water intake (41 cm in 6 Hrs.) was observed in a micro-catchment which was treated with contour furrowing and shallow depth staggered pitting. The initial and final infiltration rates were highest (14.62 cm/hr and 5.87 cm/hr) at locations having developed land floors, while the initial rates were lowest (3.2 cm/hr) at locations having animal tracks/foot paths in the degraded forestlands. Moreover, the final infiltration rates (after 6 hr) were minimum (0.2 cm/hr) at locations having alkaline patches, followed by intermittent black soil deposits (0.47 cm/hr). Fig. 2 depicts the fitted Horton's infiltration capacity curves for certain locations in the study area. Field observations showed that steady state infiltration rate reached after prolonged duration of six hours or more. Initial water intake rates were high in general.

These observed infiltration parameters may be of great importance in determining the amount of runoff for an effective management of the degraded lands on watershed concepts. The results advocates that infiltration capacities of forest soils may be greatly influenced by changing forest land floor conditions. It is also evident that animal tracks/ foot paths, which occupy a considerable area in degraded forest lands, have minimum infiltration and thus generating highest runoff. These areas need special attention to prevent erosion as they may initiate gully formations.

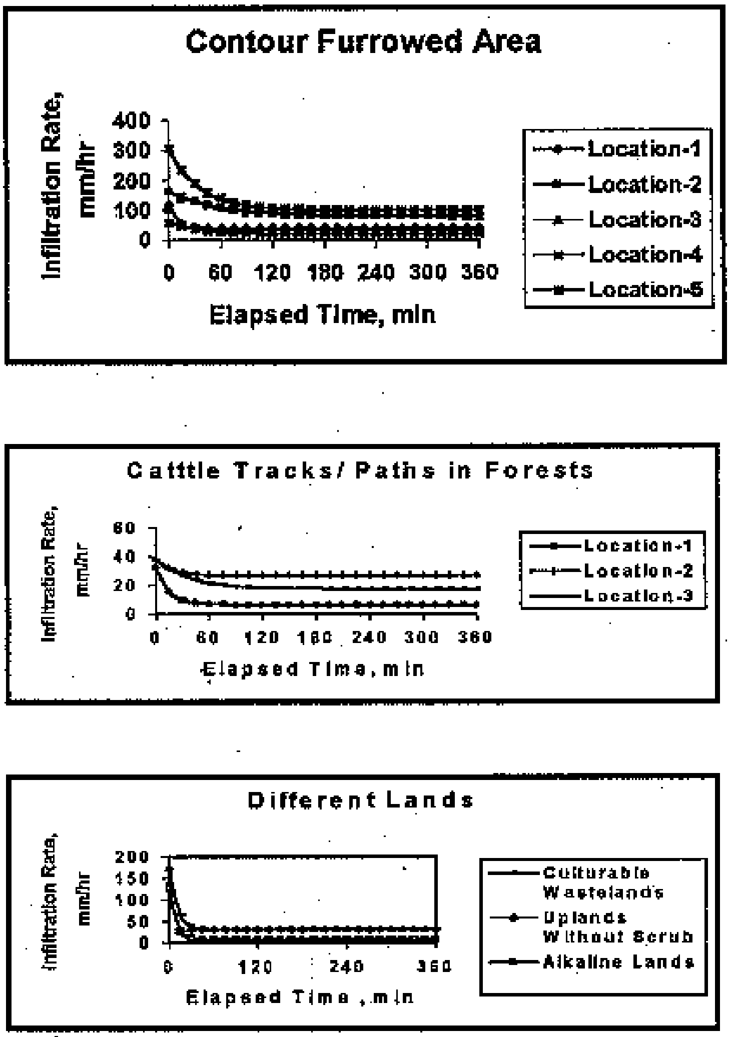

Figure 2. Infiltration trends in terms of fitted Horton's curves at different locations in study watersheds.

Runoff and Soil Loss

During initial monsoon year (1993) about 18 runoff-producing storms were observed with a cumulative rainfall of 609 mm. The results of runoff gauged through plots, showed that the runoff (on barren wasteland floors of 3% uniform slope) was varying between 47.7 to 66.5% of rainfall depending upon storms characteristics. Similarly the soil loss values for the same period and location were varying between 11.3 to 12.0 t/ha/year with a maximum one day soil loss of 0.9 t/ha (10th Sept., 1993). The runoff and soil losses were respectively 8-10% and 7-8% higher on barren land floors of 4% uniform slopes in comparison to 3% slope.

Periodic observations showed that suspended silt concentrations in out-flowing runoff from different micro watersheds were varying between 1.1 to 7.2 gm/lit. A highly sloppy and rocky catchment (15 ha) treated with loose boulder check dams and contour trenching, produced base flow up to 29 days after withdrawal of monsoon (i.e. last rain). Prior to treatment these base flows were not visible.

Surface Water Harvesting

Additional surface water storage space of about 20000 cum. was created through different SWCE measures resulting into in-situ water harvesting capacity of approx. 200 ha-cm of runoff at a time. Contour trenches offered maximum surface water harvesting space of about 140 ha-cm. Similarly through contour furrowing about 1600 cum storage space was created initially which gets reduced almost by 50% within two years as a result of siltation. Small ponds arrested 200-250 cum runoff at a time during intense storms.

Sub-Surface Moisture Conservation

Soil moisture values were maximum in vicinity of SWCE measures particularly at down stream locations. In case of contour furrows field moisture attained peak values by the end of July-August and then depleted at varying rate till the end of October when it was mostly used for plant growth.

Erosion Checking

Creating interceptions like check dams, furrows, dykes and trenches on contours reduced soil erosion. The loose boulder check dams and stone dykes were initially porous and then slowly transformed into low height bunds because of siltation and entrapment of organic matters.

Enhanced Bio-mass

Due to adoption of various SWCE measures the bio-mass yields were increased significantly along with better regeneration of natural grasses and forests. At Ambabai an 18.4 ha catchment treated with contour trenching and furrowing, conserved almost all the runoff during season except for one or two severe storms. The bio-mass yield in vicinity of trenches was manifold higher (6 t/ha dry mass) as against 1/2 t/ha at controlled locations in the same area.

The results of the present study amply proves that the highly degraded land as in the present study can be converted into arable pastures /grasslands by adopting suitable soil and water conservation engineering measures and set in motion the ecological built up of the area.

Acknowledgement

Author is grateful to Ditector IGFRI for support provided to conduct the studies as well NAEB for providing budget & facilities.

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