P-3:WATERSHED HYDROLOGY FOR CONSERVATION PLANNING

3.1 Hydrological behaviour of landuses and management practices

Hydrological evaluation of recommended forest grasses in Himalayan foothills (O.P. Chaturvedi, (till Oct. 2015) Ambrish Kumar, J. Jayaprakash, Charan Singh, B.N. Ghosh - Dehradun

The project started in 2004 with the aims to identify suitable grass species for soil and water conservation following the criteria based on hydrological responses, soil binding properties and biomass production. Five grass species, *viz*; *Pennisetum purpureum* (Hybrid Napier), *Panicum maximum* (Guini grass), *Chrysopogon fulvus* (gorda grass), *Cymbopogon flexuosus* (lemon grass), *Vetiveria zizanoides* (khus grass) were planted at spacing of 1.0 x 0.5 m^2 in runoff plots (50 m x 10 m). Soil moisture, root dynamics, runoff and soil loss had been collected and the results revealed that survival percent ranges from 76 to 96 among the grasses. Maximum soil moisture 14.9% was recorded in *Vetiveria zizanoides* (khus grass) and minimum 8.25% in control plot (Table 3.1). Maximum soil loss (4.51 t ha^{-1}) was recorded in control plot while minimum (0.83 t ha^{-1}) in *Vetiveria zizanoides* (Table 3.1). Maximum herbage yield 160.0 q ha^{-1} was harvested in *Cymbopogon flexuosus*, while minimum 51.84 q ha^{-1} was harvested from *Chrysopogon fulvus.* Root dynamics of grass species revealed that *Panicum maximum* having maximum 88.3 cm root length and *Chrysopogon fulvus* have minimum 33.85 cm length, in case of root spread *Cymbopogon flexuosus* scored high values 77.44 cm (Table 3.1).

Evaluation of hydrological behaviour and production potential of recommended land use system/ practices under different agro-ecological regions of India

A. Dehradun (J.M.S. Tomar, Uday Mandal, A.C. Rathore, Ramanjeet Singh, B.N. Ghosh and M. Muruganandam)

Study was initiated during 2012-13 on evaluation of hydrological behaviour and production potential of recommended land use systems at Pasauli village, Dehradun. After three years of plantation, fruit species (mango, lemon and guava) and one forestry species (bhimal) survived 100%. Among fruit species maximum plant height was attained by mango (1.15 cm) followed by guava (1.10 m) and lemon (0.75 m); whereas in case of bhimal it was 1.05 m. Average yield and yield attributes of paddy during rainy season (*kharif*) and mustard crop in *rabi* is presented in Table 3.2 & 3.3. Pond water irrigation provided relatively higher crop growth in terms of number of tillers and productivity of paddy. Water harvested from different land uses and an adjacent natural spring in pond located at lower reach of the project area was used for composite fish farming (Photo 3.1) using grown-up fish fingerlings (30-60 gm), following standard practices of fish feeding and water quality management. Water quality parameters were under permissible limit except water temperature during winter that falls below 12 ºC.

Total rainfall recorded from 3rd July to 3rd Sept. 2015 was 1345 mm out of which 1036 mm was received as runoff producing events. For the runoff and soil erosion, total 22 events were recorded (Fig. 3.1). Plots with lemon contributed more runoff compared to others plots. Event-wise soil erosion from different fields is also shown in Fig. 3.1 and it was observed that barring 2-3 initial events, where the soil erosion was more, all later events have no significant differences in soil erosion and the quantum have been attempted due to canopy growth and uncontrolled grass growth inside the experimental plot. Average runoff, soil loss details are given Table 3.4.

Table 3.1: ***Moisture (%) under grass cover and hydrological response of different grasses alongwith root dynamics***
तालिका 3.1: नमी (%) के अंतर्गत घास आवरण और विभिन्न घासों की जलविज्ञान प्रतिक्रिया के साथ साथ जड़ गतिशीलता

Treatments	Mean moisture (%)		Runoff (mm)	% of rainfall	Soil loss (t ha^{-1})	Crown spread (cm)	Root length (cm)	Root spread (cm)	Root volume	Yield (q ha^{-1})
	0-15 cm depth	15-30 cm depth								
Control	6.70	8.25	186.13	23.85	4.51					
Cymbopogon flexuosus	9.95	10.51	125.42	16.07	1.07	89.16	43.06	77.44	117	160.00
Pennisetum purpureum	9.42	11.61	113.72	14.57	1.20	70.50	37.09	74.95	189	145.00
Panicum maximum	8.87	10.70	106.24	13.62	1.45	73.66	88.30	45.72	40	94.84
Chrysopogon fulvus	11.72	12.95	104.86	13.44	1.80	52.83	33.85	67.11	34	51.84
Vetiveria zizanoides	13.90	14.90	94.26	12.08	0.83	80.66	36.84	64.80	81	63.72

Rainfall: 780.42 mm.

Table 3.2: ***Yield attributes and productivity of paddy during kharif season in agricultural land use***
तालिका 3.2: खरीफ मौसम के अंतर्गत कृषि भूमि उपयोग में उपज विशेषताऐं एवं धान उत्पादकता

Particulars	Plant height at harvest (cm)	Effective tillers per m^2	Ineffective tillers per m^2	Panicles per m^2	Panicle Length (cm)	Yield (kg ha^{-1})		Harvest index (%)
						Grain	Straw	
Farmer's field	77	217	49	217	17.5	2421	2938	45
Experimental field	83.2	423	86	423	20.1	4513	5362	45

Table 3.3: ***Yield attributes and mustard productivity in agricultural land use during rabi (2014-15)***
तालिका 3.3: रबी मौसम 2014–15 के अंतर्गत कृषि भूमि उपयोग में उपज विशेषताऐं एवं सरसों की उत्पादकता

Particulars	Plant height at harvest (cm)	Branches $plant^{-1}$		Pod per plant	Pod length (cm)	Grain per pod	Yield (kg ha^{-1})		Harvest index (%)
		Primary	Secondary				Grain	Straw	
Farmer's field	-- No crop only fallow land --								
Experimental field	90	4	5	42	6	15	400	1200	33

Photo 3.1: Paddy and mustard crops with fish fingerlings at project site
फोटो 3.1: परियोजना स्थल पर मछली अंगुलिकाओं के साथ धान और सरसों की फसलें

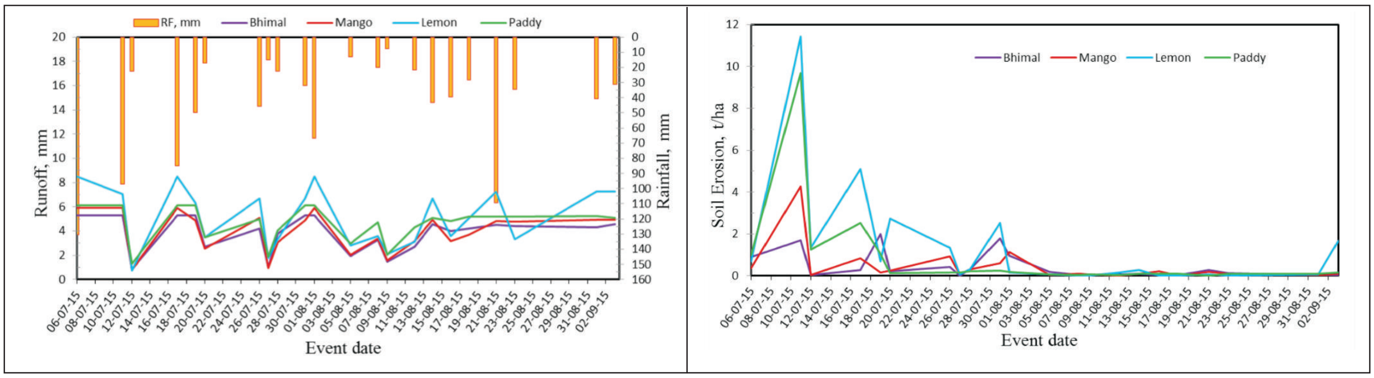

Fig. 3.1: Rainfall, runoff and soil erosion loss under different land use system of the project site
चित्र 3.1: परियोजना स्थल के विभिन्न भूमि उपयोग प्रणाली के अंतर्गत वर्षा, अपवाह और मृदाक्षरण ह्रास

Table 3.4: Average runoff, soil loss from different landuses for the year 2015
तालिका 3.4: वर्ष 2015 के लिए औसत अपवाह, विभिन्न भूमि उपयोग से मृदाक्षरण ह्रास

Particulars	Bhimal	Mango	Lemon	Paddy
Runoff (mm)	3.82	3.97	5.16	4.65
Soil loss (t ha^{-1})	0.44	0.45	1.37	0.79
Runoff % of rainfall	11.13	11.30	14.43	14.20

B. Chandigarh (V.K. Bhatt, Pankaj Panwar, Ram Prasad and Sharmistha Pal)

Project area is located in village Janouli, Distt Panchkula (Haryana). Area has been divided in three different land uses. Upper one is selected for Agri.-silvi. system, middle one for Agri.-horti. system and lower one for Agricultural use only. Entire area is rainfed and land is degraded consisting of small pebbles and gravels.

During the monsoon season of 2012, 55 plants of different multipurpose forest species (*Eucalyptus hybrid*, *Bauhinia variegata* and *Terminalia arjuna*) were planted during monsoon season. Similarly, in the middle portion 47 horticulture plants of guava, mango and *aonla* were planted. Survival and growth parameters showed that mango plants did not perform well. Guava gave highest survival and plant performance followed by *aonla*. Growth of plants is being monitored once in a year. Being rainfed area, agriculture crop is taken once in a year. During monsoon season hybrid maize was planted in 0.3 ha area and *kulthi* (legume) in between horticulture and forest plants in 0.4 ha area. Yield of maize was obtained as 21.0 q ha^{-1} and yield of *kulthi,* was 4.12 q ha^{-1}.

Each identified land use is being gauged separately through Ramser's samplers (9) in three replications each for monitoring runoff and soil loss. Photo 3.2 shows Ramser's sampler in agricultural field. Runoff and soil loss analysis indicated that agriculture land use produced maximum runoff (9.5%) and soil loss (141.1 kg ha^{-1}) followed by Agri.-silvi. and Agri.-horti. system (Table 3.5). The average height of Eucalyptus was 379.46 cm and collar girth 17.69 cm. Bauhinia recorded 163.7 cm height and 8.32 cm collar girth, whereas, terminalia recorded lowest height (97.15 cm) and collar girth of 8.2 cm (Photo 3.3).

Table 3.5: ***Runoff and soil loss from different land uses during 2015***

तालिका 3.5: वर्ष 2015 में विभिन्न भूमि उपयोग से अपवाह एवं मृदा ह्रास

Landuse	Rainfall (mm)	Runoff, mm &(%)	Soil loss (kg ha^{-1})
Agriculture	269.9	25.5 (9.5)	141.1
Agri. + Horti.	269.9	13.13 (4.9)	78.4
Agri. + Forest	269.9	24.80 (9.2)	143.1

Photo 3.2: Runoff measuring device in *kulthi* crop
फोटो 3.2: कुलथी फसल में अपवाह मापक यंत्र

Photo 3.3: Bauhinia and Eucalyptus plantation
फोटो 3.3: कचनार और नीलगिरी वृक्षारोपण

C. Udhgamandalam (K. Kannan)

The study was initiated at a farmer's field in Iduhatti watershed to quantify the impact on the hydrology and production potential of resource base, when the recommended land use systems and practices for a topo-sequence (forest and plantation crops (tea) in the upper slopes, vegetable cultivation on in the mid slopes, vegetable cultivation on bench terraces in the lower slopes and irrigated vegetable cultivation in the valley portions) are followed in the Nilgiris.

A sloping plane was selected and divided into four reaches in order to establish the recommended land use systems for these reaches along with proper land management practices. In the upper most reach silver oak saplings was planted with contour staggered trenches to establish forest plantation followed by planting of tea clones with contour staggered trenches in the upper mid slope. The reach lower to tea plantation has been converted to ten inward sloping bench terraces. A farm pond was constructed at the valley portion to give supplementary irrigation to vegetables through micro- irrigation system.

Risers of the last three terraces in the lower reach; hybrid Napier grass has been planted for fodder production and to protect bench terrace risers. Vegetable cultivation with integrated nutrient management practices has been carried out on these bench terraces during the year 2015-16. During *kharif* (June to October), broccoli, red cabbage, garlic and Chinese cabbage potato cultivation was taken up in 0.6 ha of land with south west monsoon and supplementary irrigation from the ponds. Potato cultivation taken up during *rabi* and yet to be harvested.

Yield obtained from the terrace cultivation were 6.9, 32.0, 8.6 and 29.2 t ha^{-1} respectively for garlic, Chinese cabbage, broccoli and red cabbage. Water use efficiency and water productivity were 15.3, 83.7, 20.4, 55.3 kg ha^{-1} mm and 228, 64, 72, 66 ₹ m^{-3}, respectively for garlic, Chinese cabbage, broccoli and red cabbage (Table 3.6). In addition to the main crop yields, 8 t ha^{-1} of fodder grass was harvested from CO_4 Napier grass planted on the riser. Average plant height for tea planted as block plantation and silver oak are 57 cm and 90 cm, respectively. Highest soil loss from all the land use was 4. 24 t ha^{-1} and runoff % was 7.54 (Table 3.7).

D. Agra (K.K. Sharma, S.K. Dubey and Dileep Kumar)

Data on rainfall, runoff and soil loss were collected from four land use systems (Agri.-Horti., Horti., Agri.-Forestry and Agri.-Agri.). A rainfall of 272.5 mm was received during the monsoon season (June - 84.3 mm; July – 65.2; August – 93.5 mm; September – 14.2 mm and October – 15.3 mm with 4, 9, 5, 2 and 2 rainfall events, respectively) with annual rainfall of 458.8 mm in 36 rainy days. Maximum event of 70 mm rainfall received early in last week of June, which did not produce any runoff. No runoff received from four land use systems; as a result, there was no soil loss. Year 2015 was a completely drought year in this region.

Table 3.7: Runoff and soil loss for different land uses
तालिका 3.7: विभिन्न भूमि उपयोग के लिए अपवाह और मृदा ह्रास

Plantation crops/ Land use	Area (ha)	Runoff (mm)	Runoff (% of rainfall)	Soil loss (t ha^{-1})
Silver oak tree	0.1	21.4	2.47	0.13
Tea	0.2	21.2	2.45	0.38
Vegetable crops	0.6	65.35	7.54	4.24

Seventy two seedlings of *Tectona grandis* were planted in the experimental site for developing agri.-silviculture system. Planting of one year old seedlings was carried out during July 2015 in Garhi Udairaj village. Proper inter-culture was assured till date. Twenty seedlings of *Aegle marmelos* cv. NB17 were planted for developing agri.-horticulture system (Table 3.8).

Table 3.8: *Growth characteristics of seedlings planted in Garhi Udairaj village*
तालिका 3.8: गढ़ी उदयराज गांव में रोपी गई पौध बढ़वार विशेषताएं

Name of species	Seedlings planted	Survival till Dec.2015	Initial average height (cm)	Initial average C.D. (cm)
Tectona grandis	72	63	95	1.45
Aegle marmelos	20	17	32	0.79

Pearlmillet and sesamum was sown as per plan. Initial germination and crop growth (upto 30-40 DAS) was very well. Due to late onset of monsoon and prolonged dry spell the crop dried. Sesamum crop survived upto flowering stage while pearlmillet crop failed at 30-35 DAS. Teak and *bael* was planted in July and *kharif* crop sesame was sown using standard package and practices in agroforestry system. Failure of crops is due to non- availability of life saving irrigation and very less or negligible rainfall during *kharif* season (Photo 3.4).

Soil sample were collected at different depths from 0-60 cm from all four land uses. Moisture percentage reduced from April to June in all the land uses and at all four depths (Fig. 3.2). However, it increased due to rain during the period. Similarly, moisture distribution was found to be more as depth increased in all the cases.

Table 3.6: *Crop yield, water use and water use efficiency of different crops grown*
तालिका 3.6: विभिन्न उगाई गई फसलों की फसल उपज, जल उपयोग और जल उपयोग दक्षता

Crop	Area (ha)	Irrigation from harvested water (mm)	Effective rainfall (mm)	Total water use (mm)	Yield (t ha^{-1})	WUE (kg ha^{-1} mm^{-1})	WP (₹ m^3)
Garlic	0.2	252	197	449	6.9	15.3	228
Chinese cabbage	0.1	216	167	383	32.0	83.7	64
Broccoli	0.2	252	167	419	8.6	20.4	72
Red cabbage	0.1	360	167	527	29.2	55.3	66

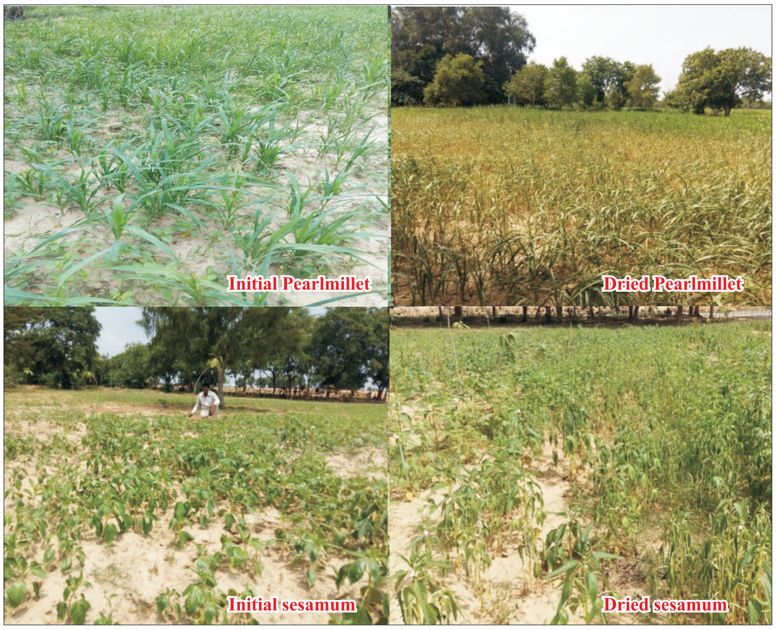

Photo 3.4: Pearlmillet and sesamum crops during initial and at 30-40 DAS during *kharif*
फोटो 3.4: खरीफ मौसम में प्रारंभिक और बुवाई के 30–40 दिन पश्चात् बाजरा और तिल की फसलें

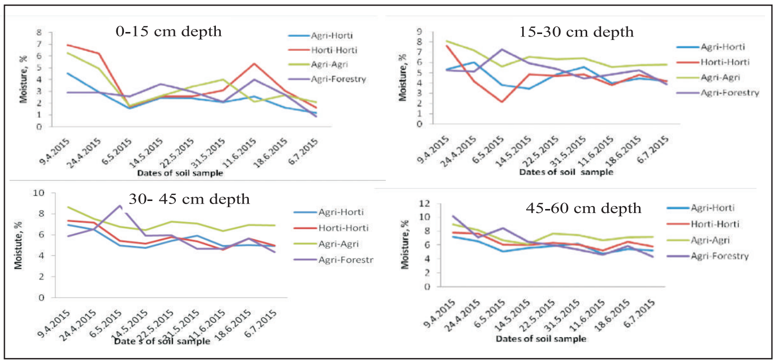

Fig. 3.2: Soil moisture distribution during April to July 2015 at different depth
चित्र 3.2: अप्रैल से जुलाई 2015 के दौरान विभिन्न गहराइयों पर मृदा नमी वितरण

E. Kota (Shakir Ali, S. Kala, B.L. Mina and H.R. Meena)

Semi-arid rainfed region of south-eastern Rajasthan experiences highly erratic rainfall coupled with extremes of temperature, limited availability of surface runoff, soil moisture. Uncertainty in rainfed crop production associated with these constraints restricts input levels and resource constrained farmers are compelled to practice subsistence farming as degrading cropping fields with multi directional slope. In order to develop a sustainable and efficient land system, there is a need to systematically investigate management induced changes in land quality and its hydrological behaviour. Keeping this in view, a project has been initiated during 2011-12 to collate information on hydrological behaviour and production potential of agricultural crop (rainfed soybean), agri-horti. (soybean + Bael) and silvi-pastoral (*Neem* + *Cenchrus ciliaris)* in semi-arid region of south-eastern Rajasthan. The experimental setup was established in Dhoti watershed. During 2012-13, three land use systems namely; T_1: Rainfed soybean (Agriculture), T_2: Soybean + Bael (*Aegle marmelos*) (Agri.-horticulture): and T_3: *Neem (Azadirachta indica)* + *Cenchrus ciliaris* (Silvi-pasture) *were* imposed over the field size plots (each 0.10 ha) in a topo-sequence. The silvi-pastoral was in upper plot, agri.-horticulture in middle plot and agricultural crop in the lower plot. Slope of the plots ranged from 1.0 to 1.5%. During the 2015, area received 774.1 mm rainfall through 38 events. A total 15-runoff producing events were recorded with 486.7 mm rainfall. The runoff generating potentials of the land use systems in order of the rainfall % were T_1 (10.1%) < T_3 (11.3%) < T_2 (12.4%) and the sediment yields were of 4.981, 6.245 and 7.435 t ha^{-1}-yr, respectively. Yield of rainfed soybean in T_1 and T_2 treatments were recorded 1.368 and 1.010 t ha^{-1}, respectively.

F. Vasad (B.K. Rao, Gopal Kumar (till Aug. 2015) and Raj Kumar)

An experiment was conducted at Vejalpura-Rampura watershed of Kapadwanj taluka, Kheda district to evaluate hydrological behaviour, and production potential of recommended land use systems in semi-arid region of central Gujarat. Recommended and prominent land uses of forestry-Wood apple with grasses, Agri.-horticultural - castor / Cotton + citrus (Acid lime), Agriculture - Castor / Cotton systems of the semi-arid part of central Gujarat were evaluated in farmers' fields (Photo 3.5). Growth/biomass parameters, yield of trees, grass and crops, fish were measured and analysed. Fish fingerlings were also introduced in farm pond and growth parameters were recorded.

Wood apple plants were grown along with the staggered contour trenches in the forestry system. The natural grasses *(Cenchrus Cilliaris* and *Dichanthium annulatum)* were come up in between the wood apple plants. The yields of *Cenchrus Cilliaris* and *Dichantium* *annulatum* were obtained as 3.1, 4.6 kg m^{-2}. Height of the citrus plants was 2.1 m in agri.-horti. system (Photo 3.6) and wood apple plants in forestry system were 1.5 m, respectively. Rainfall during monsoon season was 526 mm in 14 numbers of rainy days having 5 runoff producing events. Farm pond was filled twice. Lower runoff and soil loss was occurred in forestry system (Fig. 3.3), which is due to higher *in situ* conservation of rainwater due to staggered trenches and grass cover.

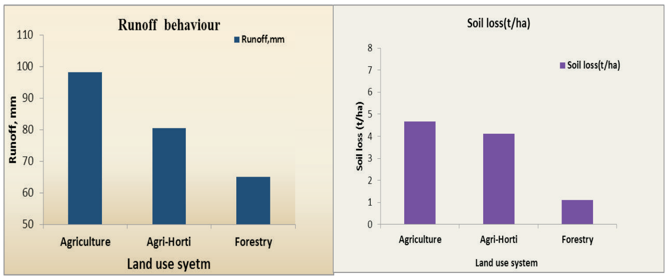

Fig. 3.3: Runoff and soil loss behaviour of various sysetms
चित्र 3.3: विभिन्न प्रणालियों के अंतर्गत अपवाह और मृदा ह्रास व्यवहार

Photo 3.5: Water stored in crop fields due to bunding (left), dugout farm pond (middle), and staggered trenches in forestry system (right)
फोटो 3.5: मेढ़बंदी के कारण फसल खेतों में जमा पानी (बाएं), खोदे गए खेत तालाब (मध्य), और वानिकी प्रणाली में कंपित खाइयां (दाएं)

Photo 3.6: Citrus plant in Agri.-horti. system
फोटो 3.6: कृषि बागवानी प्रणाली में नींबू के पौधे

Modelling the nutrient movement in agricultural watersheds and their impact on surface water resource of Niligiris (V. Kasthuri Thilagam, S. Manivannan, K. Rajan and O.P.S. Khola) – Udhagamandalam

During the reporting period, a study on watershed namely Sillahalla watershed having the area of 6501 ha with a mean elevation of 2125 m amsl and normal annual rainfall of 1340 mm was undertaken. Input data for application of AGNPS model namely land use, soil parameters, slope, runoff, sediment yield and nutrient loss were collected from primary and secondary sources. Land use data was collected and found that the Sillahalla is predominantly an agricultural watershed with main land uses of seasonal agricultural crops and tea plantation (86.0%) followed by forest (11.1%) and non- agriculture (2.9%). Slope map was generated using digital elevation model (DEM) and the general slope of the watershed is from 2% to 16% in the valleys and foot hills to about 50% on the hill sides. Information on soil characters were collected and soil map was generated. Soils are of fine textured ranging from clay loam to silt clay loam and clayey. Soils of concretion layer in Ootacamund series I are mostly sandy loam textured. The coarse sand fraction is very high in the soils of the concretion layer. Soil erodibility indicated that the dispersion ratio were in the range of 1.1 to 9.8, which indicates that out of 100 gm of silt and clay in the soil, 10 gm can be easily suspended by water. The soils have high amount of water stable aggregates ranging from 34.2% to 93% except concretion layers which had low amounts ranging from 5.2 to 23.8% due to the presence of large amounts of primary particles. Data required for generating SCS curve number was collected. Runoff and sediment yield were collected based on point sampling method and found that 37,937 tonnes of soil has been washed away every year.

The pH of the water sample is 6.79, 6.99 and 7.00 in upper, middle and lower reaches, respectively which are in neutral range. Total dissolved solid is 627, 793 and 844 mg $litre^{-1}$ and they are within the limits of Bureau of Indian Standards (1500 mg $litre^{-1}$). Sulphate and chloride content are also within in the maximum permissible limits (250 mg $litre^{-1}$) of BIS. Nitrate content in the water samples is 23.5, 34.5 and 55.5 mg $litre^{-1}$. In lower reaches the nitrate content is above permissible limit (45 mg litre^{-1}) for domestic and agriculture use. Soluble salts like calcium, magnesium and sodium also present in the permissible limits (Table 3.9). Hence, irrigation with this water will not cause any salinity and sodium hazard in the soils and crops. However, Biological Oxygen Demand (BOD) is in the higher than prescribed standards (30 mg litre^{-1}) as most of the organic wastes like agricultural waste and domestic waste are dumped in to the water bodies. All input maps for calibrating AGNPS model have been generated and calibration is in progress.

Table 3.9: ***Water quality parameters of Sillahalla watershed in different reaches***

तालिका 3.9: सिलाहल्ला जलागम के विभिन्न इलाकों में जल गुणवत्ता मापदंड

Parameters	Upper	Middle	Lower
pH	6.79	6.99	7.00
EC (dS m^{-1})	0.15	0.15	0.15
Dissolved oxygen (mg litre^{-1})	4.80	4.35	4.96
BOD (mg litre^{-1})	49	56	67
COD (mg litre^{-1})	74	92	62
TDS (mg litre^{-1})	627	793	844
TSS (mg litre^{-1})	5	6	9
Sulphate (mg litre^{-1})	12	18	13.5
Chloride (mg litre^{-1})	112	185	246
Calcium (mg litre^{-1})	56	48	50
Magnesium (mg litre^{-1})	12	14	23
Sodium (mg litre^{-1})	9.5	11.3	8.5
Nitrate Nitrogen (mg litre^{-1})	23.5	34.5	55.5
Phosphate (mg litre^{-1})	0.2	0.3	0.3

Hydrological implication of sequential alteration of land use covers in a ravine catchment *(R.S. Kurothe (till Nov. 2015), V.C. Pande and Gopal Kumar (till Aug. 2015)) - Vasad*

Two paired watersheds, called sub-catchment II and sub-catchment III, in the research farm lying geographically between 22° 27′ 3″ N latitude and 77° 7′ 0″ E longitude at a height of 34.18 m above sea level have been chosen to study the hydrological implications of sequential alteration of forest land use covers.

In year 2011 and 2012, vegetation clearance in the riparian zone was imposed in sub-catchment III keeping sub-catchment II as control. This was done by removing vegetations (shrubs/ grasses etc.) from the riparian zones (1 m height from the stream bed or the rim of the gully whichever is less). In addition to this, treatment of clearance of understory was also imposed for these years. 33% of mature trees were removed from sub-catchment III in the years 2013 and 2014 in addition to above treatments. Data on rainfall and runoff were recorded under same treatment in the year 2015. A rainfall of 493.0 mm was recorded at Vasad during 2015 in 31 rainy days. The maximum rainfall depth was recorded as 170.6 mm. Distribution of rainfall is depicted in (Fig. 3.4).

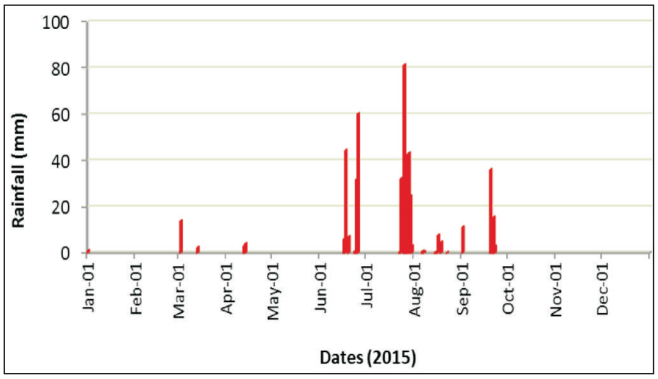

Fig. 3.4: Rainfall distribution pattern during year 2015 at Vasad

चित्र 3.4: वर्ष 2015 के अंतर्गत वासद में वर्षा वितरण पैटर्न

Rainfall and runoff relationship**:** Linear relationship between runoff from control and treated catchments for calibration, riparian vegetation removal, riparian vegetation removal + understory removal and riparian vegetation removal + understory removal + 33% tree removal was depicted in Fig. 3.5. It was expected that vegetation removal may increase the runoff (50%).

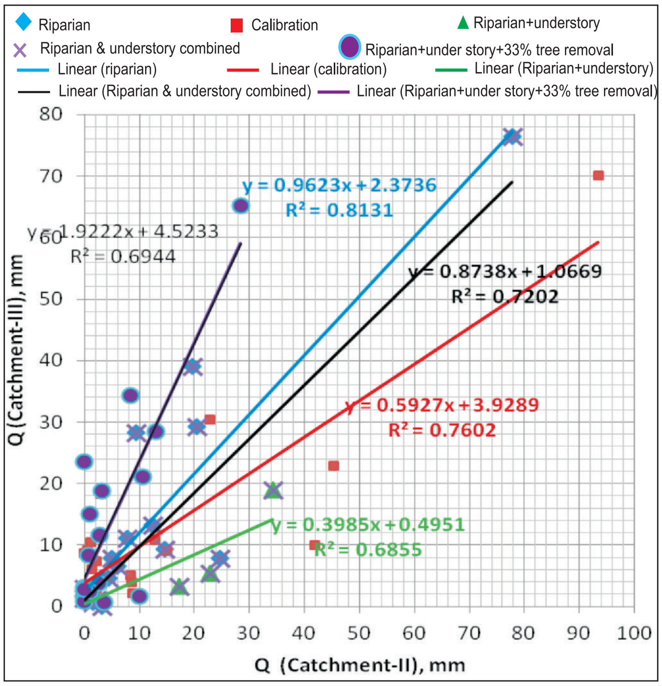

Fig. 3.5: Runoff relationship between control (C-II) and treated (C-III) catchment under various vegetation removal treatments

चित्र 3.5: विभिन्न वनस्पति को हटाने के उपचार के अंतर्गत नियंत्रण (सी–II) और उपचारित (सी– III) जलग्रहण के बीच अपवाह संबंध

***Vegetation Composition*:** This year, vegetation under the top story was removed. Species-wise composition of the removed species showed that *Lentana camera* had the highest biomass (1.1 t ha^{-1}) followed by *Holoptelia integrifolia* (0.61 t ha^{-1}), and *Grewia pilosa* (0.40 t ha^{-1}) (Fig. 3.6).

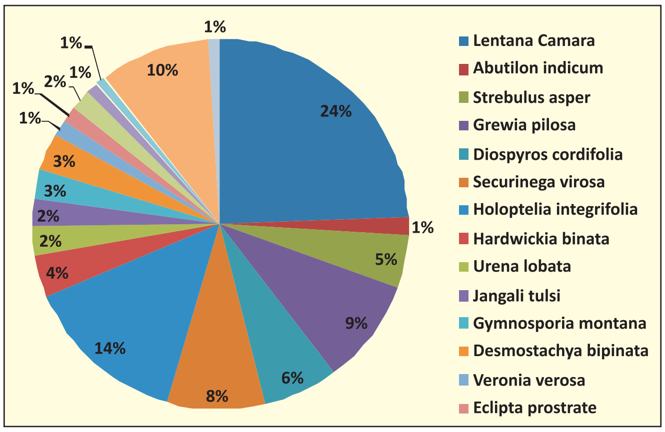

Fig. 3.6: Total biomass removed across species
चित्र 3.6: हटाई गई प्रजातियों का कुल जैवभार

Hydrologic systems analysis across multiple spatial scales and its implications on hydrologic processes in sub-humid catchment of Eastern Ghat High Land Region of Odisha (Ch. J.P. Dash, P.P. Adhikary, *D.C. Sahoo* and N.M. Alam) – Koraput

Soil erosion is a serious problem in Eastern Ghat High Land Region (EGHLR) of Odisha that originates from a combination of deforestation, mining activities, shifting cultivation, agricultural intensification, soil degradation, and intense rainfall. Runoff and subsequent soil erosion spans a wide range of spatial scales, and because of the importance of scale effects on runoff and soil erosion, the definition of scale relationships, as well as the knowledge of dominant processes and factors governing surface runoff and soil loss at each scale, is fundamental for resource management. In this project, initiated in 2015, emphasis is given to identify the pattern and relationship between runoff and soil loss process over a range of spatial scale in EGHLR of Odisha. Sakirput watershed, Semiliguda block, Koraput district is the study area, which is 125 ha, and consists of three types of land use (Agriculture, Forest, and Scrub).

In the watershed (Photo 3.7), agriculture is the dominant land use (94.2 ha), followed by forest (18.3 ha) and scrub (13.1 ha). Selected watershed is a 3[rd] order watershed, having slope range 0-61% (Fig. 3.7). The construction of gauging station in the watershed is in progress. Morphomentric study of the selected watershed was carried out and presented in Table 3.10.

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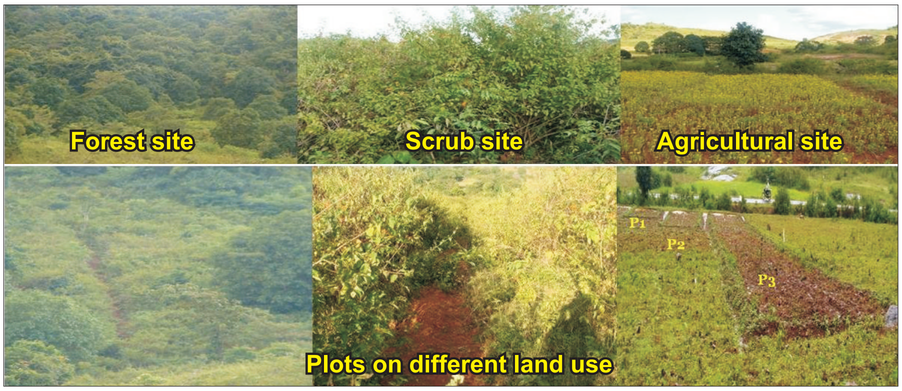


Photo 3.7: Gauging sites under different land uses in the Sakirput watershed
फोटो 3.7: सकिरपुट जलागम में विभिन्न भूमि उपयोग के तहत गेजिंग स्थल

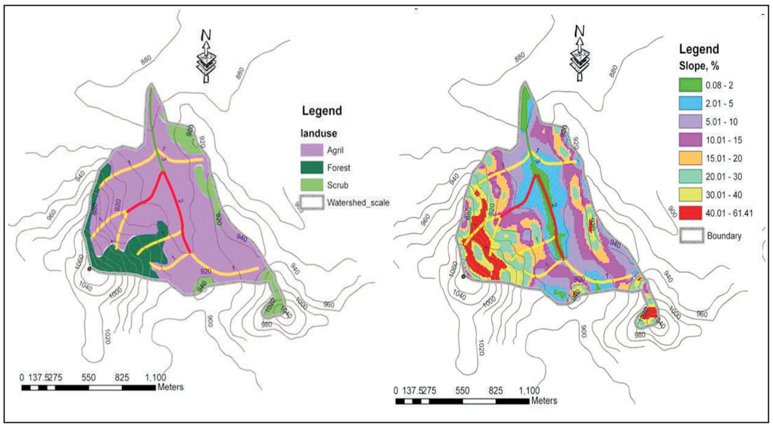


Fig. 3.7: Landuse and slope map of Sakirput watershed
चित्र 3.7: सकिरपुट जलागम के भूमि उपयोग और ढलान नक्शे

Table 3.10: ***Morphometric characteristics of Sakirput watershed***
तालिका 3.10: सकिरपुट जलागम आकारमिति विशेषताएं

Morphometric parameters	Results
Area (Sq. km)	1.25
Perimeter (km)	5.79
Watershed order	3.00
Watershed length (km)	2.30
Watershed relief (km)	0.17
Ruggedness No.	0.64
Drainage density (km^{-1})	3.75
Stream frequency (km^{-2})	7.94
Texture ratio	1.21
Form factor	0.24
Circulatory ratio	0.47
Elongation ratio	0.31
Mean bifurcation ratio	3.13
Length of overland flow (km)	0.13
Constant channel maintenance (km)	0.27
Lemniscate's value	1.05
Drainage texture (km^{-1})	1.73
Drainage intensity (km)	2.11
Infiltration No.	29.80

catchment areas of the springs/ streams have been delineated from Survey of India Toposheet and using ILWIS software drainage, slope and landuse maps of the area were prepared. Drainage map indicated four orders (1st, 2nd, 3rd and 4th) of streams and 17 nos. (SWS1-SWS17) of sub-watersheds (Fig.3.8). Study indicated that 1st order streams are dominantly ephemeral whereas 2nd order are intermittent while 3rd and 4th order streams are perennial. Slope map of the watershed was categorized in 10 classes from A-J with minimum of 0-1% and maximum of 100-300%, while land use map indicates majority of the area falls under scrub land (Fig. 3.9).

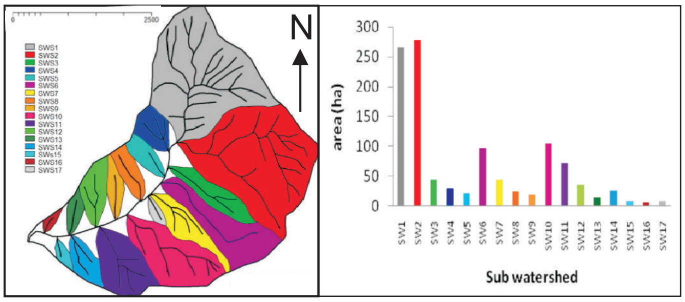


Fig.3.8: Delineation and histogram of the sub watershed with area
चित्र 3.8: क्षेत्र के साथ उप–जलागम चित्रण और हिस्टोग्राम

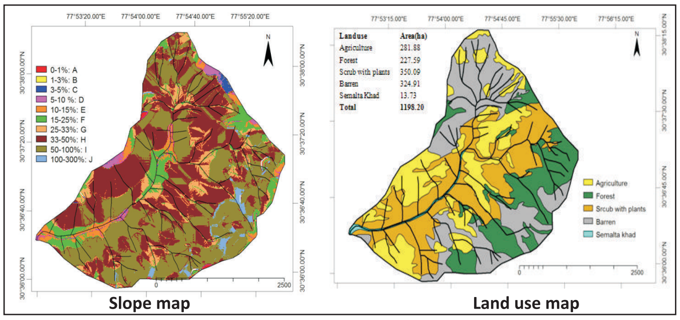


Fig.3.9: Slope and landuse map of watershed
चित्र 3.9: जलागम के ढलान और भू–उपयोग मानचित्र

3.2 Water harvesting, groundwater recharge and management

Development and rejuvenation of natural springs through soil and water conservation measures (U.K. Maurya and Ambrish Kumar from IISWC and collaborative partner Santosh Kumar Rai and S.K. Bartarya from Wadia Institute of Himalayan Geology) – Dehradun

Field studies were conducted during 2015-16 to study the hydrological behaviour of natural springs in Semalta watershed, Chakrata Tehsil, Dehradun. Surface

Four sites having different altitude, land use and geological settings (1- Degraded; 2- Scrub land; 3- One side degraded & other side forested; 4- Forested) were selected and masonry V- notch were constructed for discharge measurement on daily basis. Five non-recordable rain gauge stations were installed at an altitude of 1250-2250 m amsl for rainfall data as well as aerosol measurements. 15 natural springs and 15 streams sites were also monitored for their discharge on monthly basis (Photo 3.8).

Photo 3.8 : Discharge monitoring in different springs and streams sites
फोटो 3.8: विभिन्न झरनों और धारा स्थलों से स्राव निरीक्षण

Trend of discharge at different gauging sites from August 2015 to January 2016 are shown in Fig. 3.10 Preliminary data indicated that the flow rate of stream in Baigad Khad was nearly zero during January.

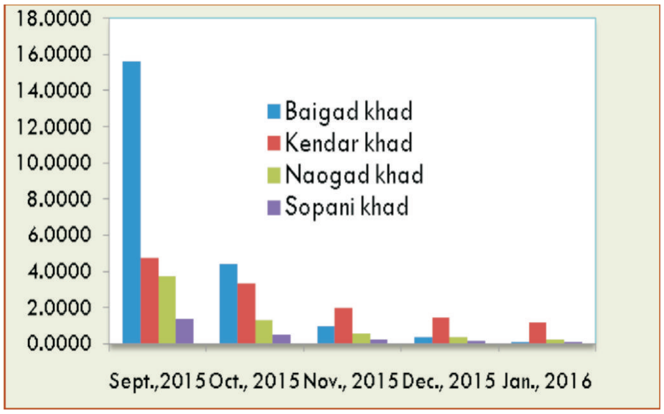


Fig. 3.10 : Discharge measurement (litre/sec)
चित्र 3.10 : स्राव माप (लीटर/सेकंड)

Geohydrological and geomorphological study indicates that most of the springs/stream flow are controlled by fracture/joints or lineaments with slate/phyllite/limestone with inclusions of quartzite as country rock. Measurements of dip and strike of fracture and joints present in different geological units have given an important clue in ascertaining the direction of groundwater flow. Based on these observations, tentative recharge/catchment areas of different springs have been identified.

The pH, EC and temperature of stream water were measured in the field using potable pH meter. The pH of most of the stream was mildly alkaline. Major ions of water samples were analyzed using Ion Chromatograph for characterizing water. Results indicated that higher percentage NH_4^+ together with NO_3^- is possibly because of anthropogenic addition, higher percentage of SO_4^- and F^- is due to lithological pyrite whereas higher percentage of HCO_3^- is due to pyrite weathering in slate (Fig.10 A&B).

Eleven samples were analyzed for $\delta^{18}O$ using Isotope Ratio Mass Spectrometer (IRMS) to know the altitude effects. Isotopic variation ($\delta^{18}O$ ‰) shows that sample collected with a total height difference of 700 m with variation of -1.8/700 i.e. -0.25 per mil for 100 m (Fig. 3.11). This provides a hope to use this proxy to ascertain altitude of recharge of springs and may form the basis for taking appropriate measure for spring rejuvenation.

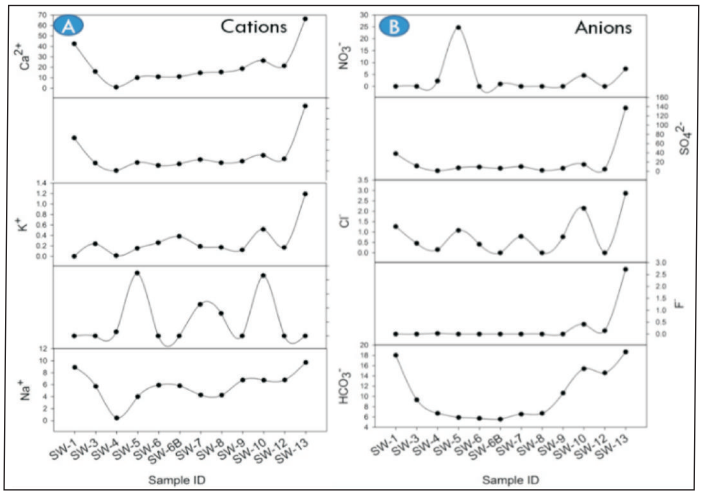


Fig. 3.10(A&B): Hydrochemical graphs of March 2015 (mg/litre)
चित्र 3.10(अ एवं ब): मार्च 2015 का हाइड्रो-रासायनिक रेखांकन (एमजी/लीटर)

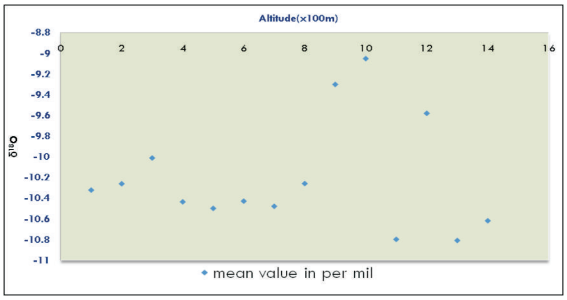


Fig. 3.11: $\delta^{18}O$ *vs* Altitude
चित्र 3.11: $\delta^{18}O$ बनाम उन्नतांश

Agri-CRP on Water: Development and management of integrated water resources in different agro-ecological regions of India (P.R. Ojasvi, P.K. Mishra, S. Patra, S.S. Shrimali, K.K. Sharma, R.B. Meena, A.K. Singh, B.S. Naik, R. Biswas, A. Raizada, V.K. Bhatt, A.K. Tiwari, S. Pal, Pankaj Panwar, S. Manivanam, D. Dinesh, O.P.S. Khola, Monalisha Pramanik, Manish Kumar, Rajeev Ranjan, G.L. Meena, R.K. Singh, P.R. Bhatnagar and B.K. Rao) - Dehradun & research Centres

This project is being implemented by a consortium of seven Institutions covering a country wide study on different aspects of RWH. In one of the objective of developing RWH, GIS database, assimilation of national data base on design rainfall, DEM, LULC has been initiated. High resolution LULC data of A.P., Telangana and Karnataka (Fig. 3.12) has been prepared and cross validation process is in progress.

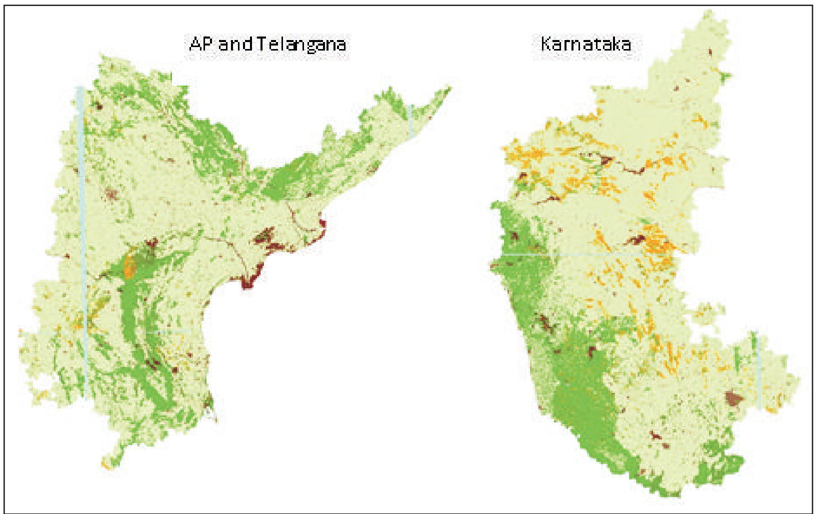


Fig. 3.12: Database of LULC of AP, Telangana and Karnataka states
चित्र 3.12: आंध्र प्रदेश, तेलंगाना और कर्नाटक राज्यों के LULC के आंकड़ाकोश

Conservation Bench Terrace (CBT) based Integrated Farming System in Himalayan Foothills (Ambrish Kumar, N.K. Sharma, B.L. Dhyani, M. Muruganandan and N.M. Alam) – Dehradun

In 2011-12, project was started with the objective to evaluate the efficacy of conservation bench terrace (CBT) of impoundment depth 10 cm in conjunction with Zero Till (ZT), Minimum-Till (MT) and Vegetative Filter (VF) treatments; and explore economical feasibility of the CBT in integration with pisciculture in harvested runoff water from the CBT. During the year 2015 fourteen runoff causing storm events amounting to a total of 915.3 mm rainfall were recorded, with the maximum daily rainfall (157.4 mm) on July 11, 2015. Runoff was estimated as 50.9, 24.1 and 17.6% in ZT, MT and VF treatments, respectively, which shows the similar pattern as with four years average of all three treatments (Table 3.11). Soil loss was found 1.67, 1.48 and 0.43 t ha^{-1} in zero tillage, minimum tillage and vegetative filter treatments, respectively, showing the similar trend as of four years average values with minor variations. Out of fourteen storms, maximum number of storms (6) occurred in range of intensity 80-120 mm hr^{-1} and four each under intensity less than 40 mm hr^{-1} and 40-80 mm hr^{-1}. Rain events analysis further indicates that number of events under the rainfall classes, *viz*; 0-50, 50-100, 100-150 and > 150 mm was 8, 2, 3 and 1, respectively. Runoff percent recorded in 2015 is relatively high over the average values (Table 3.11); possibly due to high number of rain events > 50 mm as compared to previous years. Soil nutrient loss in terms of N, K, P was recorded maximum from ZT plot, i.e. 30.9, 0.1 and 14.8 kg ha^{-1}, respectively, followed by MT and VF (Table 3.12). Maximum (18.03 kg ha^{-1}-mm) water use efficiency was estimated in ZT treatment under wheat but minimum (2.60) was found in okra crop under VF treatment (Table 3.12). Energy use efficiency under ZT, MT and VF for wheat was found 5.92:1, 5.31:1 and 4.67:1 and for okra it was 12.45:1, 11.83:1 and 9.56:1, respectively (Table 3.12). Trend of soil moisture at different depths indicates that moisture retention in recipient areas of CBT is higher than that of donor areas in the month of November i.e favourable for wheat sowing (Fig.3.13).

Table 3.11: ***Runoff and soil loss recorded from different treatments***
तालिका 3.11: अलग उपचारों के अंतर्गत दर्ज अपवाह और मृदा हानि

Treatment	Runoff (mm)	Runoff as % rainfall		Soil loss (t ha^{-1})	
	2015	2015	4 yrs average	2015	4 years average
Zero-till (14 events)	466.7	50.9	38.65	1.67	1.35
Minimum-till (11 events)	220.9	24.1	19.80	1.48	0.88
Vegetative Filter (7 events)	161.2	17.6	8.93	0.43	0.35

Total Rainfall: 915.3 mm.

Table 3.12: ***Nutrient loss through runoff, water use efficiency, energy use efficiency (MJ ha^{-1}) and energy return of different crops under different treatments***

तालिका 3.12: अपवाह के माध्यम से पोषक तत्व हानि, जल उपयोग दक्षता, ऊर्जा उपयोग दक्षता (एम.जे. प्रति हैक्टे) और विभिन्न उपचारों के तहत विभिन्न फसलों की ऊर्जा प्रतिफल

Treatment	Nutrient loss through runoff (kg ha^{-1})						Crop WUE (kg ha^{-1}-mm)		Total Input energy		Total output energy		Energy return	
	N		P		K				Okra (2015)	Wheat + mustard (2014-15)	Okra (2015)	Wheat + mustard (2014-15)	Okra	Wheat
	Avg. (4 yrs)	2015	Avg. (4 yrs)	2015	Avg. (4 yrs)	2015	Okra	Wheat						
Zero tillage	27.97	30.9	0.6	0.1	13.17	14.8	5.77	18.03	7048	10429	87809	61755	12.45 : 1	5.92 :1
Minimum tillage	13.2	16.1	0.37	0.3	5.85	6.7	2.90	15.12	7923	10429	93763	55390	11.83 : 1	5.31 :1
Vegetative filter	4.25	5.8	0.175	0.3	1.85	1.9	2.60	13.96	9035	10429	86397	48716	9.56 : 1	4.67 : 1

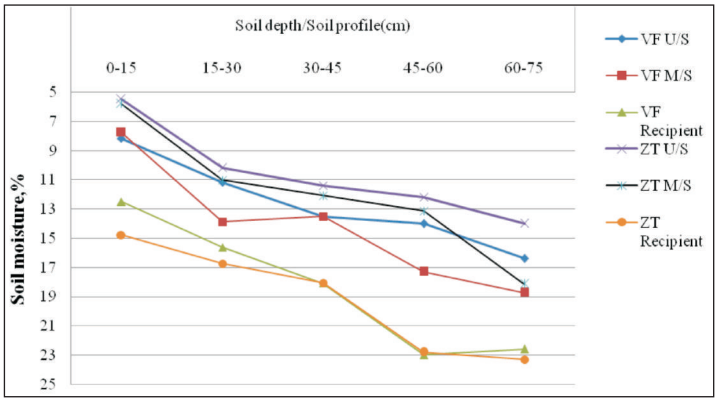


Fig. 3.13: Trend of soil moisture at different depths on 30 Nov. 2015

चित्र 3.13: 30 नवम्बर 2015 को विभिन्न गहराई में मृदा नमी की प्रवृति

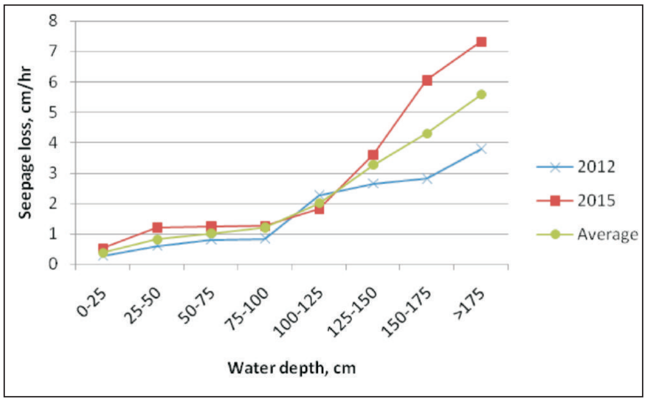


Fig. 3.14: Seepage loss from CBT masonry tank

चित्र 3.14: संरक्षण सीढीनुमा चिनाईयुक्त टैंक से रिसाव ह्रास

In the pisciculture component, nine hundred fish fingerlings (50-70 gm) produced from spawn (<5 gm, small size seedlings) in 3 months following standard practices of fish feeding and water quality management (Photo 3.9). Produced fish fingerlings stocked in culture ponds for table-size fish production further. Water quality parameters were under permissible limit except higher turbidity and transparency level (<5 cm) during intensive rainfall days. Seepage loss from CBT tank ranged between 0.53 and 7.32 cm day^{-1}. High average value of seepage loss was found when water level in the tank is above 100cm (Fig. 3.14).

Photo 3.9: Mid-stage good growth of wheat + mustard in CBT (left), and netting fingerlings from CBT tank (right)

फोटो 3.9: सीबीटी में गेहूं + सरसों की मध्य चरण में अच्छी बढ़वार (बाएं), और सीबीटी टैंक में मछली अंगुलिकाएं पकडते हुए (दाएं)

Wheat equivalent yield (2014-15) was estimated maximum (3.1 t ha^{-1}) in ZT and minimum (2.4 t ha^{-1}) in VF and okra yield varied from 5.89 to 2.71 t ha^{-1} (Table 3.13).

Table 3.13: ***Crop productivity during rabi and kharif season under different treatments***

तालिका 3.13: विभिन्न उपचारों के अंतर्गत रबी और खरीफ मौसम में फसलों की उत्पादकता

Treatment	*Crop productivity (t ha^{-1}) - Rabi* (2014-15)					*Kharif* (2015)
	Donor area		Recipient area		Wheat Equivalent yield	Donor
	Wheat	Mustard	Wheat	Mustard		Okra
Zero tillage (ZT)	2.6	0.19	2.9	0.24	3.1	5.89
Minimum tillage (MT)	2.0	0.18	2.8	0.22	2.6	2.94
Vegetative filter (VF)	1.95	0.15	2.5	0.19	2.4	2.71

Wheat : Mustard – 8 : 1.

Efficient groundwater management for enhancing adaptive capacity to climate change in sugarcane based farming system in Muzaffarnagar district (Ambrish Kumar, U.K. Maurya, Uday Mandal and A.K. gupta) – Dehradun

The study was started during 2015 at village Rasulpur Jaton, district Muzaffarnagar. As per technical programme, one water harvesting masonry structure (WHS-I) having span 8.86 m and height 2.16 m was constructed on Harsauli drain, located at 29^{o} 21′ 22″ latitude, 77^{o} 33′ 22″ longitude and 241 m amsl near Shahpur Police Station in vicinity of the selected village. Another similar type of structure (WHS-II) in upper reach of the same drain is being constructed near village Harsauli at 7.36 km apart from WHS-I (Photo 3.10). Average bed slope and width of the drain is about 0.03% and 7 m, respectively. Capacity of water storage of WHS-I and WHS-II is 35021.88 and 11812.5 cum, respectively and surface area of water spread is 32427.6 and 15750 m^2, respectively. It is expected that back water could extend upto 3.66 km and 1.5 km behind the WHS-I and WHS-II. Villagers staying along the Harsauli drain shared their experiences about less possibility of water flow in the drain even in rainy season. On this account, project team discussed the issue with District Irrigation Department, Muzaffarnagar and Chief Development Officer for releasing the water into the Harsauli drain from Baghra Minor (as its trail is connected to Harsauli drain) to impound water in the drain for recharging groundwater when there is surplus water in the canal.

In total 45 water samples from different sampling sites of Hindon and Kali rivers flowing in the boundary of the Muzaffarnagr district were collected in post monsoon (2015-16) considering waste water inflow from adjoining cities/towns and effluents of different factories fall into the rivers (Photo 3.10). Preliminary analysis indicates that most of the sites are highly polluted and they are even not suitable for irrigation. Pollution level at some sites is much more than permissible limits recommended by WHO. This is basically due to the effluent discharged by star paper mill, Titavi Sugar Mill, Saharanpur nala (Vishwakarma Chowk), Kinauni Sugar Mill, Rohana Sugar Mill, Mansurpur Sugar Mill, Niyajpura Municipal drain, Beghrajpur Industrial drain and Muzaffarnagar Dhobi Ghat.

Developing SALT for resource conservation and economic upliftment in Shiwaliks (Pankaj Panwar, Ram Prasad, V.K. Bhatt and Sharmistha Pal) - Chandigarh

The study was initiated to utilize the undulating non-arable lands for providing multiple outputs while conserving both soil and water under rainfed conditions. The experiment is located at Research Farm, Mansadevi of ICAR-IISWC, Research centre, Chandigarh.

In three hectare land three plots (micro-watersheds) of approximately 1 ha each had been demarked and three treatments have been imposed. The details of treatments are T_1: SALT model with water harvesting structure at the foot hill; T_2: SALT model with *in-situ* moisture conservation practices and T_3: Traditional practices for managing the sloping lands (control). Treatment 1 and 2 were divided into three equal parts. All the three treatments are being gauged by sharp crested weirs. Runoff is being measured by water level recorders. Data on runoff and soil loss is given in Table 3.14.

Fodder and fuel wood were harvested from *Leucaena leucocephala* hedges, in the month of June and October, 2015. Yield obtained is given in Table 3.15. Hedge row of *Leucaena leucocephala* developed is shown in Photo 3.11.

Dr. A.K. Sikka visiting WHS near Shahpur | Dr. P.K. Mishra visiting Harsauli drain | Water sample collection near Kutba village

Photo 3.10: DDG(NRM) visiting WHS constructed near Shahpur; Director discussing the feasibility of water flow at Baghra Minor tail end; and water sample collection from Hindon river near Kutba village (Muzaffarnagar)

फोटो 3.10: उप–महानिदेशक (प्राकृतिक संसाधन प्रबंधन) द्वारा शाहपुर के निकट निर्मित जल संचयन संरचना का दौरा; निदेशक पानी के प्रवाह की व्यवहार्यता पर बाघरा माइनर सिरे पर चर्चा; और कुतबा गांव के पास हिंडन नदी (मुजफ्फरनगर) से नदी जल नमूना संग्रह

Table 3.14: ***Runoff and soil loss measurement from the experiment in 2015***

तालिका 3.13: 2015 में प्रयोग से प्राप्त अपवाह और मृदा ह्रास माप

Months	Rainfall (mm)	SALT 1			SALT 2			SALT 3		
		Runoff		Soil loss	Runoff		Soil loss	Runoff		Soil loss
		(mm)	(%)	(kg ha^{-1})	(mm)	(%)	(kg ha^{-1})	(mm)	(%)	(kg ha^{-1})
July	245.6	29.4	12.0	30.7	37.5	15.3	126	29.1	11.9	114
August	235.5	64.6	27.4	143.6	74	31.4	29.6	58.9	25.0	462
September	41.2	0.0	0.0	0	0.7	1.73	0	1.27	3.08	1.1
Total	**522.3**	**94**	**17.99**	**174.3**	**112.2**	**21.48**	**156**	**89.27**	**17.09**	**577.6**

Table 3.15: ***Average Fodder and fuel wood yield obtained from each plant***

तालिका 3.15: प्रत्येक वृक्ष से प्राप्त औसत चारा और ईंधन लकड़ी पैदावार

Date	Height of pruning of hedges (cm)	Yield (kg $plant^{-1}$)	
		Fuel wood	Fodder
June, 2015	100 cm cutting	3.0	1.8
	75 cm cutting	2.5	1.0
	50 cm cutting	1.0	0.5
Oct., 2015	100 cm cutting	4.5	2.1
	75 cm cutting	3.2	1.2
	50 cm cutting	1.5	1.1

Photo 3.11: Developed hedge row intercropping system

फोटो 3.11: विकसित बाड़ापंक्ति अंतःफसली प्रणाली

Grasses maintained on the bunds of the terraces, on an average yielded 10.22 kg per one metre running length in first cut in August and about 4.25 kg per one metre running length in second cut during January (Table 3.16).

Table 3.16: ***Grass yield on the bunds of the terraces***

तालिका 3.16: छतों की सीमा पर घास पैदावार

Date	Fresh weight of grass (kg) from sample plot of 1 m running length
August, 2015	10.5
	8.4
	9.5
	12.5
Average	**10.22**
January, 2016	4.3
	4.4
	3.8
	4.5
Average	4.25

Soil Organic carbon ranged from 0.39 to 0.69% and available nitrogen varied from 185 to 213 kg ha^{-1}.

Enhancement in land productivity and livelihood security of small farmers of Nilgiris through multiple use of harvested water (S. Manivannan, O.P.S. Khola and K. Rajan) – Udhagamandalam

During the reporting period, french beans, peas and double beans was grown as first crop followed by carrot as second crop. Potato was grown as third crops and tea was cultivated throughout the year in upper reach of the experimental field. Out of three crops during the year 2015-16, yields of two crop seasons were recorded and reported. French beans, peas and double bean crops yielded as 7.5, 2.2 and 6.5 t ha^{-1} respectively, during first season. Carrot crop recorded the average yield of 37.5 t ha^{-1} and as second crop. Tea leaves of 2.9 t ha^{-1} in upper reaches in the system is harvested and generated the net return of ₹ 2,32,900. Live stocks, *viz*; Geese and rabbits added the net return of ₹ 37,117 and the total net income per ha is worked out to be ₹ 1,08,006 from the two crop seasons of multiple water use system scenario (Table 3.17). Yield of third crop is not included as the crop is yet to be harvested.

Table 3.17: ***Yield of different crops under multiple water use scenario during 2015-16***

तालिका 3.17: वर्ष 2015–16 के दौरान एकाधिक जल उपयोग परिदृश्य के तहत विभिन्न फसलों की उपज

Cropping Season	Crops	Yield (t ha^{-1})	Return (₹)	
			Gross	Net
Agricultural/horticultural crops				
First Crops	French bean	7.5	150000	
	Peas	2.2	30800	
	Double beans	6.5	28600	
Second Crop	Carrot	37.5	143000	
Annual Crop	Tea	2.9	34500	2,32,900
Livestock components		**Total weight gained (kg)**		
Geese		47.0	12925	
Rabbits		89.3	13392	
Fish		180.0	10800	37,117
			Total Revenue for farmer	**₹ 2,70,017**
			Income per ha	**₹ 1,08,006**

Water budgeting of a ravenous watershed pond for optimum crop planning under semi-arid region (K.K. Sharma, S.K. Dubey and Dileep Kumar) - Agra

A dugout farm pond of about 800 cu-m capacity was constructed at selected site for rain water harvesting from 3.5 ha ravine watershed (Photo 3.12). Depth of pond was kept at 2.5 m and bottom dimensions 10.5 x 15 m with 1:2 side slope in the all the directions. Pond bottom as well as sides was lined with Silpaulin liner material of 250 GSM thicknesses to prevent seepage loss from the pond. Area received only 272.5 mm rainfall during monsoon season in 22 rainfall events. No runoff was received from the catchment area in to the pond for harvesting and recycling.

Photo 3.12: No runoff collection in the pond during the year
फोटो 3.12: वर्ष के दौरान तालाब में भून्य अपवाह संग्रह

During *kharif*, according to contingency crop planning, mungbean and sesamum crop was sown. Initially germination was good and well established. In later stage of crop growth at 35-40 DAS after sowing and at phonological stage (15-20 cm plant height in mungbean) crop start drying due to very less and scanty rainfall and prolonged dry spell. Both crop reached upto flowering and pod formation stage it dried completely.

Study on pollution status of Yamuna river and its impact on soil and crop health in Western U.P. (Rama Pal, S.K. Dubey, R.K. Dubey and A.K. Singh) - Agra

Few studies have only been conducted on Yamuna river pollution but the comprehensive temporal and spatial information is widely lacking. This project was initiated during 2015 to assess pollution level of river Yamuna across different points and season in eutrophicated zone of Western U.P.; to evaluate impact of irrigation with Yamuna river water, and to evaluate impact of irrigation with Yamuna River on heavy metals accumulation, soil quality and crop health.

After survey by multidisciplinary team of the project, a total of 12 sampling locations for water sample collection from Yamuna River in various districts (Gautambudh Nagar, Mathura, Agra and Etawah) were identified and fixed. Geographical coordinates of the sampling locations are given in Table 3.18.

Water samples of Yamuna River were collected in Jan. 2015 (Photo 3.13) at prefixed 12 sampling locations, and data on temperature, dissolved oxygen (DO) and biochemical oxygen demand (BOD) are given in Table 3.19.

Table 3.18: ***Geographical Coordinates and location of the sampling sites at Yamuna river***
तालिका 3.18: यमुना नदी में भौगोलिक निर्देशांक और नमूना साइटों के स्थल

Sampling location/ Sample No.	Geographical coordinates of Sampling location	Name of village
I^{o}	28.41205 N, 77.49230 E	Tilwara (Gautambudh Nagar, U.P.)
I^{oo}	28.40801 N, 77.49699 E	Tilwara (Gautambudh Nagar, U.P.)
I^{ooo}	28.41305 N, 77.49461 E	Tilwara (Gautambudh Nagar, U.P.)
S1		Shergarh (Mathura, U.P.)
S2	27.34137 N, 77.78136 E	Ferah (Mathura, U.P.)
S3	27.28671 N, 77.90741 E	Akbara (Agra, U.P.)
S4	27.20313 N, 78.08656 E	Chhalesar (Agra, U.P.)
S5	26.75527 N, 78.94125 E	Bahuri (Etawah, U.P.)
S6	26.6884 N, 79.01358 E	Rampura (Etawah, U.P.)
F^{o}	26.49354 N, 79.24741 E	Bhareh (Etawah, U.P.)
F^{oo}	26.491369 N, 79.255051 E	Bhareh (Etawah, U.P.)
F^{ooo}	26.49036 N, 79.24846 E	Bhareh (Etawah, U.P.)

Photo 3.13: On site fixation of dissolved oxygen (Top) and identification of geographical coordinates of location with GPS (Bottom)

फोटो 3.13: घुलित ऑक्सीजन का साइट निर्धारण (ऊपर) और साथ जीपीएस से स्थान की भौगोलिक निर्देशांक की पहचान (नीचे)

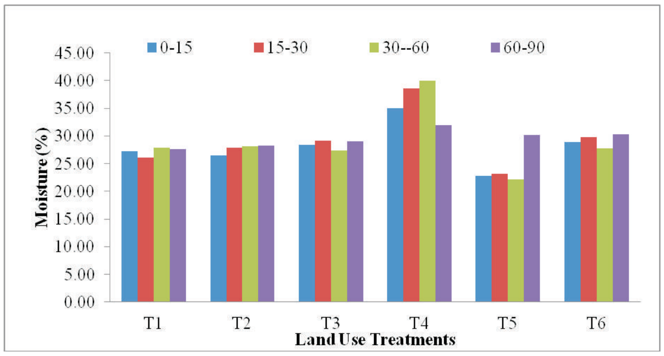
Table 3.19: *Physico-chemical characterstics of water samples taken at different locations from Yamuna river*

तालिका 3.19: विभिन्न स्थानों से यमुना नदी के पानी के नमूने की भौतिक विशेषताएं

Sample No.	Temperature (°C)	DO and BOD (mg litre^{-1})	
		Dissolved Oxygen	Biochemical oxygen demand
I^{o}	13	0.00	82.0
I^{oo}	12	1.93	44.0
I^{ooo}	12	0.00	58.0
S1	14	5.2	36.8
S2	15	3.88	35.5
S3	12	4.27	35.5
S4	16	1.55	10.9
S5	15	6.8	84.0
S6	16	7.7	81.0
F^{o}	22	9.3	52.8
F^{oo}	17	10.4	35.2
F^{ooo}	22	12.7	5.2

Estimation of water budget components for predominant land uses of south-eastern Rajasthan for conservation planning (G.L. Meena, R.K. Singh and H.R. Meena) - Kota

The project was initiated during April 2010 for estimation of water budget components for predominant land uses of south eastern Rajasthan. Two years were kept for preparation of experimental plot and calibration of plots. During 2012-13 six land use systems i.e. T_1 - **Agriculture:** Rainfed soybean, T_2 - Agri-horticulture: Soybean + Sapota (*Manilkara achras*), T_3 - Horti-pastoral: *Emblica officinalis* + *Cenchrus ciliaris,* T_4 - Pasture: *Cenchrus ciliaris*, T_5 - Silviculture: *Acacia nilotica* plantation, and T_6 - Silvi-pasture: *Acacia nilotica* + *Cenchrus ciliaris were* laid in 0.81 ha area comprising of eighteen numbers of plots each having 15 m x 30 m size. During 2015, the area received an annual rainfall of 803.7 mm in 38 events having monsoon rainfall of 644.2 mm in 30 events. Total 8 runoff producing events were recorded with 378.4 mm rainfall (Table 3.20). The runoff % generated from the land use systems were in order of T_3 (13.03%) < T_6 (14.21%) < T_4 (15.77%) < T_2 (16.87%) < T_1 (17.34%) < T_5 (18.81%) and sediment yield followed the trend as T_3 (5.97 t ha^{-1}) < T_6 (6.30 ton/ha) < T_4 (7.07 t ha^{-1}) < T_1 (7.46 t ha^{-1}) < T_2 (7.76 t ha^{-1}) < T_5 (8.16 t ha^{-1}) which similar to the trend of the previous year. Moisture Characteristics behaviour of different land uses at 1/3 bar and 15 bar is shown in Fig. 3.15.



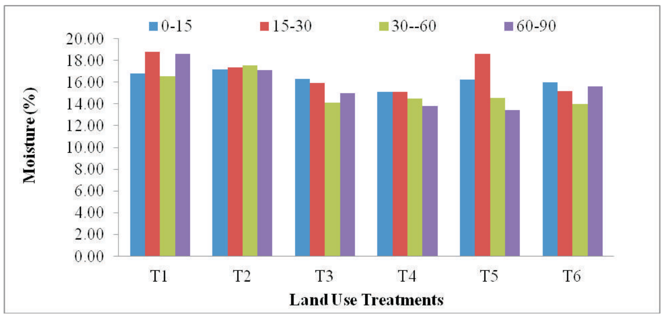


Fig. 3.15: Moisture Characteristics behaviour of different land uses

चित्र 3.15: विभिन्न भूमि उपयोग नमी लक्षण का व्यवहार

Table 3.20: ***Rainfall-runoff behaviour and sediment yield of different predominant land uses in south-eastern Rajasthan***

तालिका 3.20: दक्षिण–पूर्वी राजस्थान में वर्षा–अपवाह व्यवहार और विभिन्न प्रमुख भू–उपयोग की तलछट उपज

Date	Rainfall (mm)	Runoff (%)						Sediment yield (t ha^{-1})					
		T_1	T_2	T_3	T_4	T_5	T_6	T_1	T_2	T_3	T_4	T_5	T_6
22/7/2015	72.4	15.54	13.67	11.90	13.45	12.12	10.80	1.606	1.391	1.024	1.791	0.931	0.875
24/7/2015	15.2	33.08	22.05	7.88	22.05	19.95	18.90	0.650	0.458	0.460	0.220	0.429	0.468
25/7/2015	5.4	18.62	76.84	119.70	21.58	218.71	41.38	0.042	0.519	0.158	1.056	1.590	0.247
26/7/2015	92.6	11.12	12.24	10.08	13.10	13.79	9.82	2.167	2.360	1.759	1.037	1.983	0.727
27/7/2015	64.4	18.22	15.86	13.01	18.34	20.07	20.07	1.710	1.625	1.501	1.433	1.099	1.863
10/8/2015	23	11.45	15.96	9.37	6.25	6.94	9.71	0.146	0.321	0.128	0.279	0.129	0.167
17/8/2015	44.8	21.91	22.80	16.03	21.87	28.50	16.74	0.427	0.572	0.477	0.690	1.004	0.900
18/8/2015	60.6	22.91	18.17	9.88	25.20	12.38	15.01	0.715	0.522	0.470	0.569	1.001	1.055
Total	378.4	17.35	16.87	13.03	15.77	18.81	14.21	7.462	7.770	5.976	7.076	8.168	6.303
Annual	803.7	6.33	6.16	4.76	4.85	6.86	5.19						
Seasonal	644.2	6.65	6.46	4.99	5.09	7.21	5.44						

Annual events = 38, Monsoon event = 30, runoff producing events = 08.

Development of efficient & innovative blue and green water harvesting techniques for enhancing the land and water productivity of semi-arid districts of Gujarat (B.K. Rao, R.S. Kurothe (till Nov.2015) and P.R. Bhatnagar) - Vasad

A study has been conducted to develop and evaluate 'Blue' and 'Green' water harvesting techniques for enhancing the land and water productivity of semi-arid districts of Gujarat under Department of Science and Technology (GoI) funded project. Under this project various experiments were conducted.

***Green water harvesting techniques for rainfed crops*:** An experiment was conducted for evaluating the cost effective and adoptable green water use options for prominent cropping systems (*maize + pigeonpea, maize and cotton*). For these crops the green water use techniques such as paired row and furrow, conservation furrow and stubble mulch farming (Photo 3.14) were evaluated in farmers' fields of Panchmahal district for their modification, evaluation, demonstration and popularization for wider adoptability. Runoff and soil losses and crop yields were measured for each treatment and green water use was worked out. Rainfall during crop growth period was 512 mm. Runoff and soil losses from various treatments are shown in Fig. 3.16. From the figure it is observed that conservation furrow was producing minimum runoff, soil loss and higher green water harvesting (upto 80%). It also increases the crop yields of maize (by 31%), cotton (by 30%), and pigeonpea (by 35%). It was also observed that conservation furrow was accepted by more number of farmers, due to easiness in adoptability.

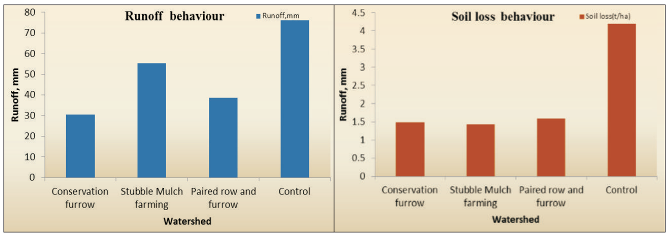


Fig. 3.16: Runoff and soil losses from various treatments

चित्र 3.16: विभिन्न उपचारों से अपवाह और मृदा ह्रास

Photo 3.14: Green water harvesting techniques for rainfed crops in farmers' fields

फोटो 3.14: किसानों के खेतों में वर्षा आधारित फसलों के लिए ग्रीन जल संचयन तकनीकें

***Furrow irrigation techniques under limited water supply situations for Fennel crop in rabi season*:** In rainfed districts of Gujarat farmers are cultivating maize in *kharif* season. Few farmers, those are having irrigation facilities are cultivating fennel crop, in *rabi* season. They are applying huge amount of water and the farmers those does not have irrigation facilities are paying 1/3rd of profit towards irrigation water. Keeping these considerations in view an experiment was conducted to enhance water productivity with various furrow irrigation techniques, *viz*; plough furrow, alternate furrow and furrow irrigation with and without surge flow were conducted (Photo 3.15). Alternate furrow with surge flow saved irrigation water upo 78% (Table 3.21) and without much yield reduction in comparison to farmers practice (basin method).

Table 3.21: ***Water applied for each irrigation method***
तालिका 3.21: प्रत्येक सिंचाई विधि के लिए प्रयुक्त जल

Type of irrigation method applied	Water applied (m^3 ha^{-1})	Water saving % compare to farmer's method	Yield (kg ha^{-1})
Plough Furrow	4118	43	1863
Surge Flow- Plough Furrow	3033	58	1933
Alternate Furrow	2890	60	1816
Surge Flow-Alternate Furrow	1632	78	1924
Furrow	5758	21	1980
Surge Flow-Furrow Irrigation	4113	44	2034
Farmer's Method (basin)	7280	-	1969

***Green water harvesting techniques for horticultural crops*:** An experiment was conducted for evaluating the cost effective and adoptable green water use options for prominent horticultural crop (mango). For this crop the green water use techniques such as mango plants with V-shape micro catchment, crescent shaped bunds, saucer shaped basins and crop reside and gravel mulch techniques (Photo 3.16) were evaluated in farmers' fields of Panchmahal district for their modification, evaluation, demonstration and popularization for wider adoptability. Higher survival and better growth of the mango plants were observed in the treatment having mango plants with V shaped micro catchments (Table 3.22).

Photo 3.16: V-shaped micro catchment techniques for mango plants
फोटो 3.16: आम के पौधों के लिए वी–आकार की सूक्ष्म जलग्रहण तकनीकें

Table 3.22: ***Survival and growth of mango plants under various treatments***
तालिका 3.22: विभिन्न उपचार के तहत आम के पौधों की जीवितता और वृद्धि

Treatments	Survival (%)	Height (m)	Stem girth (cm)
Mango plants with V-shaped catchment	92	0.87	1.0
Mango plants with crescent shaped bund	85	0.74	0.8
Mango plants with saucer shaped bund	85	0.63	0.8
Control	76	0.46	0.7

***Design and development of 'Blue' water use techniques*:** Cost effective and innovative check dams with plastic materials, HDPE embedded stone check dams for different flow regimes and recharge filters (Photo 3.17) were developed and these were evaluated in the famer's fields of Panchmahal district Gujarat. It was observed that plastic check dams with PP sheets are more effective and durable. Cost of PP check dams has decreased by 3 times in comparison to brick/stone masonry check dams. HDPE embedded stone check dams store the runoff water in the streams and can be easily adopted by farmers due to simple design with minimum cost.

Photo 3.15: Various irrigation techniques for water saving in the farmers' fields
फोटो 3.15: किसानों के खेतों में पानी की बचत के लिए विभिन्न सिंचाई तकनीकें

Photo 3.17: Cost effective check dams and recharge filters for water harvesting in farmers' fields
फोटो 3.17: लागत प्रभावी चैक डैम और किसानों के खेतों में जल संचयन हेतु पुनर्भरण फिल्टर

Strategies for Rainwater Harvesting and its Multiple Uses in Rainfed Agriculture in Central Gujarat (P.R. Bhatnagar, B.K. Rao, Gopal Kumar (till Aug. 2015) and V.C. Pande) - Vasad

In order to develop strategies for rainwater harvesting under different conditions of central Gujarat (mostly characterised under Semi-arid climatic conditions) based on already developed techniques and its efficient utilisation using multiple use concept, the project was conceived and started in 2015-16. Techniques of small water tanks (*Jalkunds*) for establishment of horticulture in higher topo sequences, runoff recycling based plastic film lined ponds with provisions of multiple commodity production both spatially and temporally are envisaged to be evaluated with strategic implementation to ensure sustainable water availability for each component as per need, production and income.

In 2015-16, evaluation of small water ponds (*Jalkunds*) was taken up for establishment of horticultural plants with custard apple as target. A *Jalkund* of 3.0m x 1.5m x 1.0m size was conceptualised for collection of direct falling rainwater as no runoff is available on top lands, although the catchment (collection area) was considered larger than top dimension using bunds, so that water depth collection of 1.0 m is ensured. For Vasad, an annual rainfall of 700-800 mm is expected. Hence, rainwater collection area of 3.5 m x 2.0 m is required for collection of 1000 mm of water with 10-15% direct evaporation losses.

However, keeping a goal to provide sustainable water availability to meet water requirement till onset of next monsoon (i.e. till 15th July), analysis was undertaken using long-term rainfall and evaporation of Vasad. Seepage loss is to be arrested using LDPE film. Expected period of water availability is indicated in Fig. 3.17 and Table 3.23. It indicates that even without any withdrawal of water for irrigation, *Jalkund* will be fully empty by 10th May if it is kept open (pan factor, PF=0.8). But, if it is covered using a grass-bamboo frame thatch with polythene cover (PF=0.25), a reasonable depth of water (56 cm) remains in the pond until 15th July, which can be utilised productively for plants (Photo 3.17). To evaluate the *Jalkunds*, a feasibility testing trial was executed with eight treatments (Table 3.23). A total of 24 *Jalkunds* were constructed for three replications of each treatment in three different blocks. Water utilisation pattern should vary as per expected water losses and water withdrawal pattern. A total of eight plants are expected to be irrigated using bucket and mug system and water is withdrawn through a small hole of 50cm x 50cm size for covered *jalkunds*. The evaluation is under progress.

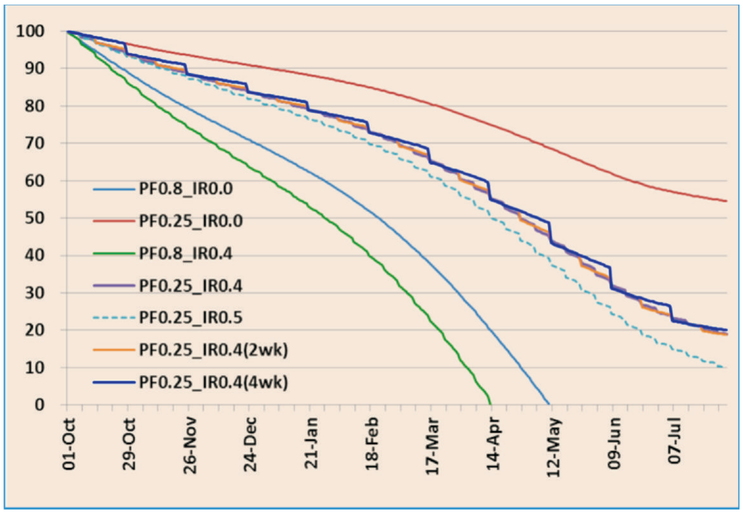


Fig. 3.17: Expected temporal water level pattern in *Jakund* with different treatments (PF-Pan factor - 0.8 for open, 0.25 for covered; IR – Irrigation required, with three levels 0.0, 0.4 and 0.5 times of cumulative pan
चित्र 3.17: जल कुण्ड में अपेक्षित लौकिक जल स्तर के स्वरूप का विभिन्न उपचारों के साथ, पीएम–पैन कारक–0.8 खुले हेतु, 0.25 कवर हेतु, IR–सिंचाई की आवश्यकता उस्तरों 0.0, 0.4 और 0.5 गुणा क्यूमुलेटिव पैन के साथ

Table 3.23: ***Details of treatments applied with expected water availability under each treatment***
तालिका 3.23: प्रयुक्त उपचारों के विवरण के साथ प्रत्येक उपचार के अंतर्गत अपेक्षित जल उपलब्धता

Treatment	Covering of Jalkund	Irrigation water to be applied (fraction of CPE)	Frequency of water application	Mode of water application	Water Ava ilabilty
T_1: PF0.8_IR0.0	Open	0.0	Weekly	Ring Basin	No water on 10 May
T_2: PF0.25_IR0.0	Cover	0.0	Weekly	Ring Basin	56 cm water on 15 July
T_3: PF0.8_IR0.4	Open	0.4	Weekly	Ring Basin	No Water on 13 April
T_4: PF0.25_IR0.4	Cover	0.4	Weekly	Ring Basin	21 cm water on 15 July
T_5: PF0.25_IR0.5	Cover	0.5	Weekly	Ring Basin	13 cm water on 15 July
T_6: PF0.25_IR0.4 (2Wk)	Cover	0.4	2- week	Ring Basin	21 cm water on 15 July
T_7: PF0.25_IR0.4 (4wk)	Cover	0.4	4- week	Ring Basin	21 cm water on 15 July
T_8: PF0.25_IR0.4 (P)	Cover	0.4	Weekly fill	Pitcher	To be analysed

Photo 3.17: Open and bamboo frame grass thatch cover with opening for water removal Jalkund
फोटो 3.17: खुले और पानी निकालने को खोलने के लिए घास फूस के साथ ढके बांस फ्रेम के जलकुंड

Socio-economic implications and vulnerability of farmers to groundwater exploitation in hard rock regions of the Deccan (Suresh Kumar and A. Raizada) - Bellary

This project aims to examine the externalities of groundwater over-extraction, and assess the vulnerability to groundwater exploitation in the hard rock regions of the Deccan. A representative sample of 72 farmers was selected from Chitradurga district of Karnataka for collecting primary data on cropping pattern, status of irrigation bore-wells, coping or mitigation strategies adopted including the changes made in cropping pattern by farmers in response to depleting groundwater. Of the total farmers, around 29.2, 25.0, 27.8 and 18.1% are marginal (< 1 ha), small (1-2 ha), medium (2-4 ha) and large farmers (>4 ha), respectively. Size of landholding is 0.84, 1.58, 2.78 and 6.45 ha, respectively for marginal, small, medium and large farmers, and in the study area as whole the average size of land holdings is 2.58 ha. Net irrigated area varies from 0.33 to 1.45 ha per farm.

As per the bore-well profiles, marginal, small, medium and large farmers, on an average, own 1.57, 2.06, 2.65 and 3.08 numbers of bore-wells at their farms. However, nearly half of these were not working at the time of survey (Table 3.24). In the study area, average life of bore-wells is 6.87 years. There is a wide variation in the depth of bore well (ranging from 27 to 283 m) depending upon the location of the bore-well. Similarly, farmers are using different HP motor for irrigation ranging from 2 to 15 HP depending up on the depth of bore-wells and irrigation requirements.

Extant methodology for estimating negative externality is the difference between amortized cost of all bore-wells (working + failed) and amortized cost of functional wells. This method captures the effect of reduction in the average working life of bore-well. With increase in well interference due to higher density of

Table 3.24: ***Physical parameters of the working and failed bore-wells (BW)***
तालिका 3.24: कार्यशील और विफल बोरवेलों (BW) के भौतिक मापदंड

Particulars	Marginal	Small	Medium	Large	Overall
Number working bore-wells	0.76	0.94	1.45	1.69	1.17
Life of bore-wells (years)	6.9 (1-20)	8.38 (1-34)	6.5 (1-39)	6.02 (1-18)	6.87 (1-39)
Number failed bore-wells	0.81	1.11	1.20	1.38	1.10
Total bore-wells	1.57	2.06	2.65	3.08	2.26
Depth of bore-wells (m)	164 (260-83)	112 (250-27)	131 (283-32)	144 (260-30)	137 (283-27)
Pump capacity (HP)	5.30 (2-7.5)	6.62 (2-10)	6.36 (3-15)	6.75 (3-15)	6.50 (2-15)
Year of installation (range)	1994-2013	1980-2013	1975-2013	1996-2013	1975-2013

Note: Figures in parentheses indicate the.range bore-well, bore-wells starts failing because of over extraction (in relation of capacity of aquifer) of groundwater, which eventually leads to lesser life of bore-wells. Under such conditions, farmer behaves in the following ways: (a) installs new bore-wells (some drilling efforts might not be successful, which are termed as failed attempts), (2) deepens exiting bore-well, (3) uses of high power irrigation pump set. Keeping this in view, there is need for customizing the existing methodology to instill actual investment behaviour of farmers while estimating negative externality, by separately adding the cost incurred by farmers for the failed attempts and adaptation measures i.e. use of high power motors and deepening of existing bore-wells.

Hence, we have estimated the total negative externality as a sum of negative externalities rendered by (A) due to bore-well failures; (B) due to failed attempt and (C) because of adaptive measures. Negative externality due to failure of bore-wells A is estimated to the tune of ₹ 3677, 6879, 9863 and 15772 for marginal, small, medium and large farmers, respectively (Table 3.25). Relatively higher negative externality costs for medium and large farmers can be attributed to relatively higher proportion of failed bore-wells as well as relatively less life of working bore-wells on their farmers. In hard rock areas, the probability of failed attempts was estimated to be 65% in the Chitradurga district. This compels famers to go for more than one attempt (average 4-5 attempts) for installing a successful bore-well. These unsuccessful attempts cannot be considered as *failed bore-wells* since these are not used for irrigation purpose due to no water yield or/and too low water yield. It has been observed that farmers are incurring a sizable amount of losses for such failed attempts and, such attempts are increasing with corresponding depletion of groundwater resources. The increasing number of failed attempts can be considered as an adverse implication of groundwater depletion. Therefore, they must be quantified and, need to be treated as negative externality.

Estimated amortized cost of failed attempts using average life of failed bore well as a frequency of recurring such investments. Negative externality of failed attempts (B) was estimated to the extent of ₹ 4168, 3549, 5629 and 5853 for marginal, small, medium and large farmers, respectively. Further, with depleting groundwater table some farmers deepen their exiting bore-well and use high powered motors to compensate the reduction in bore-well yields. Such investments are also treated as a part of negative externality C, and were measured to the tune of ₹ 1502, 576, 514 and 366 for marginal, small, medium and large farmers. Higher amount of negative externality of adaptive measures for marginal farmers can be attributed to the fact that these resource-poor farmers first try to rejuvenate their existing bore-well instead going for new bore-wells. Total value of negative externality (A+B+C) is estimated to be ₹ 9347, 11004, 16006 and 21991 for marginal, small, medium and large farmers, which is significantly higher than the earlier estimates. Overall, it can be said that society is losing ₹ 14,120 yr^{-1} $farmer^{-1}$ due to groundwater depletion.

***Coping strategies adopted by the farmers to moderate the impact of groundwater depletion*:** In response to groundwater depletion, farmers adopt strategies that help minimizing their losses occurring due to bore-well failure or /and poor bore-well water yield. Analysis shows that growing of high value crops, *viz*; floriculture and vegetables with drip irrigation is being opted by

Table 3.25: ***Negative externality occurring due to bore well failures and failed attempts in Chitradurga district of Karnataka***

तालिका 3.25: कर्नाटक के चित्रदुर्ग जिले में बोरवेल विफलताओं और असफल प्रयासों के कारण होने वाली नकारात्मक बहिर्मुखताएं

Particulars	**Negative externality occurring due to bore well failures and failed attempts (₹)**				
	Marginal	**Small**	**Medium**	**Large**	**Overall**
Amortized cost (All bore-wells)	10682	10127	13280	18220	12843
Amortized cost (working Bore-wells)	8343	6781	9558	13094	9491
Negative externality per farm (due to less life) - A	3677	6879	9863	15772	7589
Negative externality per bore-well	2339	3346	3722	5126	3352
Negative externality per farm due to failed attempt - B	4168	3549	5629	5853	5742
Negative externality per attempt	4387	2553	3632	3048	4101
Negative externality adaptive measures - C	1502	576	514	366	789
Grand total of negative externality (A+B+C)	**9347**	**11004**	**16006**	**21991**	**14120**

most of farmers (Table 3.26). However, for this, adoption rate is higher in medium to large farmers as they can allocate land for vegetables and floriculture after meeting their food grain requirements, and also have capacity to bear risk of price volatility, especially in vegetables.

Leasing-in irrigated lands, sharing of bore-wells (with neighbour and family members), buying irrigation water, switching to livestock centric occupation are the other key strategies adopted by resource-poor farmers. Surprisingly, check dams and recharge filters / percolation tanks were adopted by a very few farmers (3-4%) that too with the financial help from the state government under any scheme. Generally, it has been observed that in case of failure of working bore-well farmers tend to spend ₹ 25000-45000 for an attempt for installing a new bore-well in spite of knowing the high risk involved given the condition of groundwater exploitation and higher probability of failures-leading to huge financial losses. There is, therefore, need to educate farmers that in the event of bore-well failure, they must invest in making a recharge filter which costs nearly the amount equivalent to the cost of one failed attempt, and recharge filters are likely to help in rejuvenating defunct bore-well or/and improve the well yield.

3.3 Decision support systems (DSS)

Development of a user-friendly Decision Support System application for planning of watershed development project (P.R. Ojasvi, P.K. Mishra, Charan Singh, N.K. Sharma and D.V. Singh) - Dehradun

A GIS based analytic framework was developed for the DSS software to be developed under this study started during 2011-12. Various software modules (Automatic watershed delineation module; Cross-section and longitudinal profile extraction module; Identification of hotspots of erosion in watershed, and Design of structures) were developed for extracting important topographic, morphometric and hydrologic parameters from DEM, rainfall, landuse and soil database of the watershed and utilizing the extracted information in design of structures.

30 m resolution ASTER as well as CARTOSAT data was used in testing the developed modules. Database and decision rules for selection of engineering measures, agronomic measures and agro-forestry measures were also compiled. Automatic watershed delineation module has been tested on the Almas watershed. By a click on any point on the drainage line (outlet), watershed is delineated from DEM (Fig. 3.18) along with watershed features like area, perimeter, min./max. mean slope, min./max. elevation, max. flow length, which are required for designing structure. A comparison of these parameters with manual estimated values is presented in Table 3.27, which shows that watershed characteristics can be obtained from DEM with desired accuracy. Similarly, longitudinal profile module and cross-section module have also been developed. The level of detail contained in

Table 3.26: ***Coping strategies adopted by farmer to moderate the impact of groundwater depletion in Chitradurga district***
तालिका 3.26: चित्रदुर्ग जिले में भूजल कमी के प्रभाव को संतुलित करने हेतु किसान द्वारा अपनाई गई रणनीतियाँ

Strategies	Impact of groundwater depletion (%)				
	Small	Marginal	Medium	Large	All
Use higher power pump	23.8	22.2	25.0	23.1	23.6
Deepening of existing BW	28.6	16.7	15.0	7.7	18.1
Growing Vegetables	23.8	16.7	30.0	53.8	29.2
Floriculture cultivation	4.8	11.1	25.0	38.5	18.1
New Plantation (Areca nut)	4.8	8.3	22.5	26.9	14.6
Micro-irrigation (Drip)	9.5	16.7	30.0	61.5	26.4
Lease in irrigated lands	14.3	11.1	0.0	0.0	6.9
Increase Livestock	14.3	13.9	12.5	0.0	11.1
Buying irrigation water	7.1	15.0	5.0	0.0	7.2
Casual labour	12.4	12.8	0.0	0.0	6.8
Small check dam	0.0	0.0	5.0	15.4	4.2
Recharge filters/percolation tank	0.0	0.0	5.0	7.7	2.8
Sharing of water	14.3	11.1	0.0	0.0	6.9

Note: Base year is 2008-2009.

the DEM channel x-section representation is limited due to coarse 30 m resolution data.

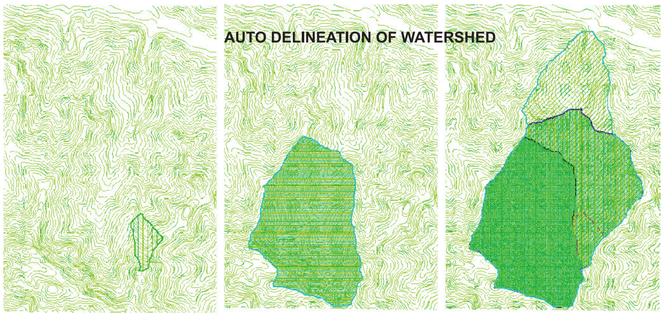


Fig. 3.18: Auto delineation of watersheds of any shape and size from DEM
चित्र 3.18: डिजिटल एलिवेशन मॉडल (डीईएम) से किसी भी आकार और आकृति की वाटरशेड का स्वतः चित्रण

Table 3.27: ***Comparison of some watershed characteristics obtained from DEM***
तालिका 3.27: डिजिटल एलिवेशन मॉडल (डीईएम) से प्राप्त कुछ जलग्रहण विशेषताओं की तुलना

Parameter	Value	
	Manual	Automatic (DEM)
Area (ha)	628	633
Perimeter (km)	11.7	11.3
Max. Flow Length (km)	5.5	5.3
Min. elevation (m)	1400	1320
Max. elevation (m)	2612	2612

It is often required to identify and prioritize the erosion control works in farmer's field and drainage line treatment based on the areas prone to erosion in a watershed. A different approach which has been increasingly pursued involves the modelling of patterns of soil erosion and deposition instead of the computation of absolute values of erosion fluxes. This process is known as identification of hotspots of erosion which need most attention for treatment instead of treating entire watershed. Modelling of such erosion/deposition patterns does not allow the evaluation of actual sediment dynamics but just the relative strength or intensity of the phenomena and it makes available a rationale for the ranking of intervention priorities and maintains the possibility of comparing different management scenarios. The module for hotspot identification computes both soil erosion and sediment deposition as the change in sediment transport capacity in the direction of flow. Application of this model to Almas watershed was comparable to visual estimates of soil erosion and deposition in the field (Fig. 3.18). Most of the high erosion area in this watershed is found in the riparian zone (stream banks) along streams, rainfed terraces (outward sloping) and landslide prone hill slopes (lower portion of watershed). This technology can be considered successful if the model estimates agree with visual estimates more than 80% of the time (Fig. 3.19).

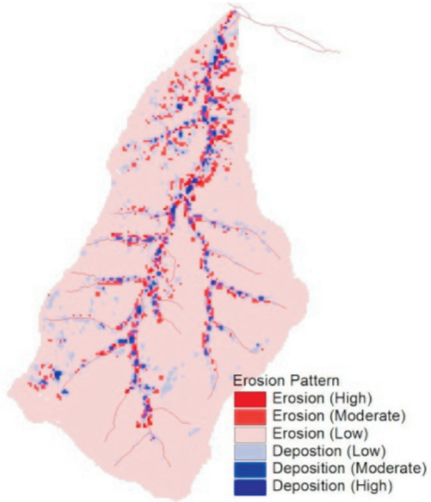


Fig. 3.19: Identification of hotspots of erosion in Almas watershed
चित्र 3.19: अलमास जलागम में क्षरण के संवेदनशील केंद्रों की पहचान

Decision rules for selection of bio-engineering measures such as land levelling, contour bunding, terracing, trenching, stonewall, vegetative barriers, retaining wall, revetment, etc. based on the land slope, soil and rainfall were standardized. Input parameters for selection of these measures were obtained from the GIS database and modules that have been developed for hydrological and geo-morphological analysis of a watershed. Similarly, decision rules for selection of best agronomic measures namely conventional tillage, minimum tillage, zero tillage, crop residues management, plantation density, mulching, intercropping, strip cropping, contour cultivation etc. based on land slope, rainfall, landuse, and runoff and soil loss reduction potential were standardized (Table 3.28).

Table 3.28: ***Runoff, soil loss and nutrient losses under different tillage practice***
तालिका 3.28: विभिन्न जुताई पद्धति के अंतर्गत अपवाह, मृदा ह्रास और पोषक तत्व हानि

Practice	Runoff (% of rainfall)	Soil loss ($t\ ha^{-1}\ yr^{-1}$)	Nutrients losses ($kg\ ha^{-1}\ yr^{-1}$)		
			N	P	K
Conventional tillage	23.3	17.95	32.1	0.566	13.3
Conventional tillage + crop residues	20.3	15.72	27.4	0.503	12.1
Minimum tillage	23.9	14.39	21.7	0.490	9.9
Minimum tillage + crop residues	20.6	13.58	18.5	0.408	8.8