Journal of SOIL AND WATER CONSERVATION

Vol. 11, No. 2 ISSN 0022-457X APRIL-JUNE 2012

Soil Conservation Society of India
New Delhi

SOIL CONSERVATION SOCIETY OF INDIA

(Registered under Act XXI 1860 of 1952-53)

Founded 1951

National Societies Block A/G-4
National Agricultural Science Centre Complex (NASC)
Dev Prakash Shastri Marg, Pusa, New Delhi 110 012

SOIL CONSERVATION SOCIETY OF INDIA

Journal of
Soil and Water Conservation

Volume 11 No. 2 ISSN 0022–457X April–June 2012

Contents

Journal of Soil and Water Conservation, Vol. 11, No. 2, pp 3–8 (2012)
Received: 28 December 2011; Accepted: 8 April 2012

Soils of Lower Shiwalik of Himalayas - Their Degradation Status and Land Management

G. S. SIDHU[1], JAYA N. SURYA[2], TARSEM LAL[3], D.K. KATIYAR[4], AND J. P. SHARMA[5]

ABSTRACT

Shiwaliks in India represent most fragile eco-system of Himalayas. Particularly, the study area in Balachur tehsil representing Lower Shiwalik in Punjab are one of the highly degraded areas of the state with soil erosion losses as high as 400 t ha^{-1} yr^{-1}. Rivulets (Choes) originating in Shiwaliks cause extensive damage in piedmont plain. Soils development shows various pedogenic stages (AC to AB-Bt), good soil-physiographic relationship are belong to soil orders Inceptisols and Entisols. Lithic/Typic Ustorthents found to occur on steep hill slopes, Typic Ustipsamments on choe belts, Typic Haplustepts on piedmont plains and Typic Haplustepts/ Haplustalfs and Fluventic Ustifluvents on recent and active flood plains. More than 80% of total area is affected by moderate to severe erosion and constitute the principal factor for soil degradation in the region. Major soil problems identified in the area are limited soil depth, low water holding capacity due to coarse/gravelly texture and low fertility status which restrict the productivity of this region. The poor vegetative cover in the hills is the major cause of higher amount of run-off, reduced infiltration, accelerated soil erosion, siltation of river/*choes* beds and flash floods. Based on soil resource data generated during present studies soil conservation measures like gully plugging, stream bunding, continuous contour trenching, construction of check dams etc are recommended to check the soil erosion. Besides these measures, cultivation across slope, cultivation of monocots, vegetative bunds, contour vegetative hedges and plantation activities are also needed to control further soil erosion losses. The development of forestry and silvi-horticulture under protective grazing is recommended to conserve and restore the soils on these degraded hilly areas.

Key words: Soil resource data, Shiwaliks, Himalayas, degradation, soil and water conservation measures, land management

INTRODUCTION

Natural resources in mountainous terrain are profoundly affected by land degradation. Shiwaliks in India represent most fragile eco-system of Himalayas. Because of peculiar geological formations, this most fragile eco-system of mountainous range threatened by massive soil erosion hazards. Shiwaliks are highly prone to soil erosion (Sidhu *et al.* 2010). Soil erosion is being accelerated in this region due to intensive Shiwaliks due to erosion up to 400 t ha^{-1} yr^{-1} has been reported (Dhruvanarayana and Ram Babu, 1983), deforestation, terrace farming on steep slopes, and mining, etc. (Bhumbla,1976; Sidhu *et al.* 2000). Shiwaliks locally known as *Kandi* areas are extended from north-west to east direction. To minimize land degradation due to soil erosion, numbers of measures are being taken by various agencies. In spite of all these efforts, the soil erosion in the area is going on unabatedly.

Soil resources information is pre-requisite for assessment of erosion and demarcations of degraded areas are essential for conservation/planning agricultural, developmental and watershed management programs. These degraded areas can be brought under cultivation after reclamation/ conservation measures. In view of this, an attempt has been taken to generate soil resource information, land degradation assessment, and factors responsible for land degradation and measures required for proper management of soils of lower Shiwalik as a case study in Balachaur tehsil of Shahid Bhagat Singh Nagar district (Nawanshahr), Punjab state.

[1-5] National Bureau of Soil Survey and Land Use Planning, Regional Centre Delhi, IARI Campus, New Delhi -110 012

MATERIALS AND METHODS

The study area, Balachaur tehsil representing the Lower Shiwaliks (Sub-mountainous) lies between $31^{0}00'$ to 32^{0} 052 N latitude and $75^{0}302$ to $76^{0}322$ E longitude and covers an area of about 48691 ha. The river Sutlej flowing in the southern side whereas entire north - eastern boundary passes along the Shiwalik range. Geology of the area consists of Shiwalik deposits which are composed primarily of upper tertiary river deposits of alluvial detritus from sub-aerial wastes of mountain swept and their deposits (Wadia, 1975). Natural vegetation of the Shiwaliks is mainly northern tropical dry deciduous forest and Himalayan sub-tropical forest species. Climatically, the area is semi-arid sub-tropical and experience extreme summer and winter seasons. The maximum and minimum temperature range from 34 to 36 ^{0}C and 6 to 12 ^{0}C, respectively with mean annual temperature of 22.7 ^{0}C and an annual precipitation of 1098 mm. The area qualifies for ustic soil moisture regime and hyperthermic soil temperature regime. About 11 per cent area is occupied by forest, 67 per cent area is under cultivation, 8.9 per cent area is wasteland, 3.4 per cent area is uncultivable lands and rest of the area is under miscellaneous uses (Agriculture statistics, 2009). The natural vegetation comprises of a wide variety of dry deciduous mixed trees like Babul *(Acacia arabica)*, khair *(Acacia catechu)*, ber *(Zizipus jujube) etc.* The common grasses are kans *(Sachharum spontananeum)*, Doob *(Cynodon dactylon)*, Nut grass *(Cyprus rotundus) etc.* A large stretch of the area is cultivated to rice *(Oryza sativa)*, maize *(Zea mays indica)* in *kharif* and wheat *(Triticum aestivum)*, mustard *(Brassica juncia L.)*, potato *(Solanum tuberosum L.)* and *sugarcane (Saccharum officineram)* in rabi as on residual moisture/ assured irrigation.

Satellite data of IRS-P6, LISS-III for the year 2005/ 2006 on 1:50,000 scale were interpreted for physiography, land use, slope and drainage density of the area (on 50,000 scale) by using remote sensing data, survey of India (SOI) toposheets and other ancillary data. On the basis of interpretation of physiographic and land use units, reconnaissance soil survey of the study area on 1:50,000 scale was carried out. Soil profiles were exposed in each physiographic unit and studied for morphological properties (Sarma *et al*., 1987; AIS&LUS, 1971) and classified as per Soil Taxonomy (Soil Survey Staff, 2006) by following USDA classification system. Soil samples collected from representative typical pedons were processed and analyzed for different physical and chemical properties as per standard procedures (Black, 1965; Jackson, 1967). The soils were grouped under different land capability sub classes (Klingebiel and Montgomery, 1966), land irrigability sub-classes (AIS&LUS 1971) and soil unit wise problems, /potentials and conservation measures were suggested (Wischmeier and Smith, 1978; Larson and Piece, 1991).

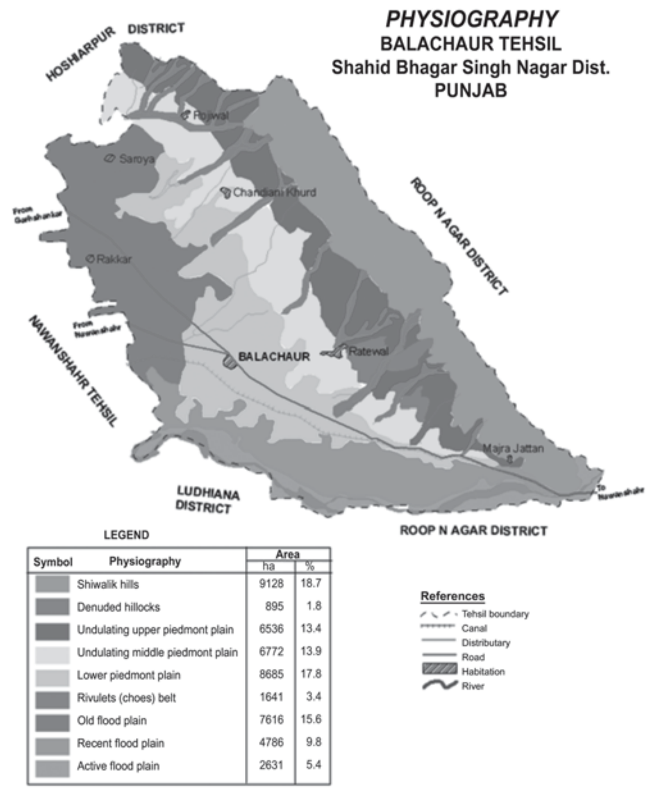
RESULTS AND DISCUSSION

Land form analysis

The interpretation of satellite imageries in conjunction with ground checking categorized the study area into three main distinct physiographic units *viz.*, Shiwaliks hills, piedmont plain and flood plain (Map 1). These units were further sub-divided into 9 sub-units *i.e.* (i) Shiwalik hills with steep slopes (ii) denuded hillocks with moderately steep slopes, (iii) undulating upper piedmont plain with moderate slopes, (iv) undulating middle piedmont plain with gentle to moderate slopes, (v) lower piedmont plain with gentle slopes, (vi) rivulets (*Choes*) belt, (vii) old flood plain, (viii) recent flood plain, and (ix) active flood plain. Shiwalik hills covers 18.7 per cent area of TGA, while denuded hillocks cover 2 per cent area. The upper piedmont occupies 13.4 per cent area while middle and lower piedmont covers 13.9 and 17.8 per cent area respectively. Old flood plain occupies 15.6 % while area under recent and active flood plain covers 15.2 percent. The area under rivulets is 3.4 per cent. The spatial distributions of different physiographic units were shown in Map.1.

Land use analysis

Land use classification was delineated by using digital data. Shiwalik hills are covered with dense forest, whereas denudated hillocks are mostly under fairly dense shruby forest. Undulating upper piedmont plains are under fairly dense to thin shruby forest and waste land with patches of cultivated land. Middle piedmont plains are under moderately cultivated land with forest and waste land intermittently, rivulets (*Choes*) are under waste lands with few patches under cultivation. Old flood plain, recent flood plain and active flood plains are under dense cultivation with social forestry occurring at few places.



Map 1. Physiographic Map of Balachuar Tehsil, Nawanshahr District, Punjab

Soil Resource Characterization

The soil development of the mountainous terrain is mainly governed by landform reflecting good soil-physiographic relationship. *Soils of Shiwalik hills* are shallow, medium deep to deep, excessively drained, loamy-skeletal to coarse-loamy (with rounded boulder/stone on >15% slopes). They are slightly acidic to slightly alkaline soils with very low electrical conductivity (EC) (< 0.13 dS m^{-1}), with low to moderate organic carbon status and low available water capacity (AWC) (Table 1). They are classified as Lithic/Typic Ustorthents. These soils are severely eroded.

The soils developed on moderately sloping *upper piedmont plain* are having almost similar soil properties as that of Shiwaliks hills except that these soils are relatively finer in texture. These soils are placed under Typic Haplustepts/Ustorthents. These soils are moderately to severely eroded.

The *soils of middle piedmont plain* occurring on moderately to gently sloping lands are deep to very deep, well to excessively drained, coarse-loamy with moderately erosion. They are moderately alkaline with low EC. These soils are classified as Typic Haplustepts.

The s*oils of lower piedmont plain* with gentle slopes are very deep, well to excessively drained, fine-loamy with moderate to slight erosion. They are moderately alkaline (pH 8.2), with low EC (< 0.20 dS m^{-1}). These soils are finer in texture with cambic B horizon and are placed under Typic Haplustepts. The soils of *rivulets (Choes)* occurred on narrow dissected gullies are coarse-loamy, strongly alkaline (pH 8.8) with low EC (< 0.10 dS m^{-1}) and are classified as Typic Ustipsamments. Productivity of these soils is very low. These soils are severely eroded on account of high runoff and causes narrow dissected gullies.

Soils of *old flood plain* are classified as very deep, moderately well drained, fine loamy, calcareous, moderately alkaline with Fe-Mn nodules and argillans with medium EC (< 0.15 dS m^{-1}) and classified as Typic Haplustepts. These are slightly eroded soils. Productivity of this soils is good. Soils of *recent flood plain* are very deep, fine loamy, calcareous, moderately alkaline with medium EC (< 0.15 dS m^{-1}) and classified as Fluventic Haplustepts. These are slightly eroded soils.

The *soils of active flood plain* are classified as very deep, fine-loamy, Typic/Udic Haplustepts. These soils are low to moderately productive. Some soils on active flood plain are stratified soils and classified as Typic Ustifluvents (Table 1). These soils are suggested slight to moderate erosion.

Degradation Status and factors

The numerous problems encountered in the study area due to topography, drainage pattern and inherent characteristics of soils have been identified. The degradation was mainly due to soil erosion which is governed by physiography and also by anthropogenic nature. The sheet erosion and gully formation are mostly the main causes of degradation in this area. Slight erosion class portrays minimum risk of erosion whereas severe erosion (under Shiwalik hills slopes/*choes*) shows maximum risk. The denudation of Shiwaliks, *choe* lands with coarse texture leads to severe erosion. High erratic runoff loaded with heavy silts causes siltation problems in lower areas. About 24.5 per cent area is under severe to very severe erosion, 58.5 per cent area under moderate erosion and 17 per cent area is under slight erosion. Deposition of sand by stream in the plains

Table 1. Physico-chemical properties of soils of lower Shiwalik terrain

Depth (cm)	Horizon	Particle size class (mm)			O.C. (%)	$CaCO_3$ (%)	pH(1:2.5)	E.C. (dSm^{-1})	CEC [$Cmol(p^+)kg^{-1}$]
		Sand (2-0.05)	Silt (0.05-0.002)	Clay (0.002)					
Soils of Shiwalik Hills - Typic Ustorthents									
0-12	Ap	78.3	14.3	7.4	0.36	Nil	7.8	0.13	5.44
12-30	A12	84.6	11.2	4.2	0.18	Nil	8.1	0.06	6.00
30-60	C1	80.2	11.1	8.7	0.18	Nil	8.2	0.04	8.16
60-90	C2	81.4	11.5	7.1	0.13	Nil	8.2	0.04	7.61
90-130	C3	82.1	15.0	2.9	0.06	Nil	8.5	0.04	7.07
130-160	C4	77.5	15.1	7.4	0.04	Nil	8.5	0.08	10.33
Soils of Piedmont Plain - Typic Haplustepts									
0-14	Ap	75.4	15.4	9.2	0.34	4.87	8.1	0.21	5.15
14-40	Bw1	47.4	36.1	16.5	0.29	6.51	8.3	0.04	10.33
40-79	Bw2	37.1	41.1	21.7	0.39	5.64	8.4	0.19	15.12
79-99	Bw3	50.3	31.5	18.2	0.32	5.79	8.4	0.11	12.95
99-147	BC	69.3	18.3	12.3	0.13	3.95	8.5	0.11	6.33
147-175	C1	66.1	23.6	10.2	0.20	3.20	8.6	0.11	5.51
Soils of Rivulets (Choes) - Typic Ustipsamments									
0-13	Ap	87.9	5.3	5.8	0.21	1.85	8.6	0.06	4.35
13-40	C1	94.1	5.1	0.8	0.09	8.99	8.8	0.07	3.26
40-70	C2	95.2	3.5	1.3	0.04	5.00	8.8	0.07	3.26
70-100	C3	92.0	4.9	3.1	0.03	7.30	8.8	0.08	3.80
100-160	C4	92.3	5.1	2.6	0.04	4.10	8.8	0.12	3.88
Soils of Old Flood Plain - Typic Haplustepts									
0-19	Ap	43.1	39.9	17.0	0.62	1.35	7.9	0.22	10.2
19-45	A2	42.0	39.2	18.7	0.36	1.13	8.3	0.18	10.0
45-68	Bt1	29.1	38.35	32.5	0.36	0.45	8.0	0.13	17.0
68-98	Bt2	30.2	37.3	32.5	0.27	0.68	7.8	0.14	18.0
98-125	Bt3	31.2	33.8	35.0	0.27	0.68	8.1	0.10	20.0
125-150	BC	30.1	36.1	33.7	0.23	0.45	8.0	0.10	19.0
Soils of Recent Flood Plain - Fluventic Haplustepts									
0-20	Ap	82.2	12.9	5.0	0.56	Nil	8.2	0.14	3.5
20-50	Bw1	66.6	15.9	17.5	0.31	Nil	8.0	0.11	9.8
50-86	BW2	66.6	16.0	17.5	0.25	Nil	7.8	0.10	9.8
86-112	BW3	66.0	16.5	17.5	0.21	Nil	7.8	0.08	10.0
112-138	BW4	71.0	16.5	17.5	0.19	Nil	7.9	0.06	7.0
138-150	BC	70.0	15.0	15.0	0.15	Nil	7.8	0.07	8.5
Soils of Active Flood Plain - Typic Ustifluvents									
0-25	Ap	77.3	12.5	10.2	0.27	3.46	8.0	0.16	1.8
25-55	C1	85.5	8.8	5.7	0.06	2.92	7.9	0.12	0.6
55-80	C2	86.7	8.7	4.6	0.04	2.92	8.1	0.10	0.2
80-110	C3	88.5	7.8	3.7	0.04	2.97	8.1	0.11	0.2
110-150	C4	89.8	6.7	3.5	0.04	3.60	8.0	0.13	0.2

by colluvial activities converting good lands into sandy wastes. Beside this anthropogenic activities such as deforestation, overgrazing, steeply sloping lands put under cultivation after clearing forests leads to severe soil and water erosion. Untapped rainwater for irrigation, causes problems of number of seasonal streams (*choes*); extended cultivation even to the fringes of *Choes* damaging the natural embankment formed over time. (NBSS & LUP, 1986).

Conservation Measures/ Suggestions

The Shiwalik area needs immediate attention to check further degradation of natural resources. Soil conservation measures (like mechanical, vegetative, terrace cultivation, etc.) were suggested to restore the eroded area on sustainable basis (Table 2). *Shiwalik hills and piedmont plain* having shallow soils are subjected to moderate to severe erosion which

Table 2 : Soil unit wise problems and potential and conservation measures for Balachur tehsil

Slope (%)	Land Capability	Land Irrigability	Soil Problems /potentials	Conservation measures
Soils of Shiwalik Hills and Denuded Hillocks				
10-15	VIIe	6t	Highly broken Shiwalik hills, severely eroded, slopes restrict continued cultivation	Terraced bunding, check dams, gully plugging, permanent vegetation through raising forest and grasses
10-15	IIIes - IVes	4st	Moderately to strongly sloping lands, susceptible to runoff losses, erosion and droughtiness	Need intensive soil conservation measures like check dams, permanent vegetation through plantation of growing tree species and grasses besides contour bunding
Soils of Rivulets (*Choe belts*)				
8-5	VIIw	6t	Undifferentiated soils in the choe and river beds and surrounding areas, subjected to seasonal floods and water stagnation.	Suited for afforestation; cultivation of vegetables; sand mining, strengthening of stream banks.
Soils of Piedmont Plain				
3-5	IIc-IIIs	2t	These soils are good except that problems due to free calcium carbonate and slight erosion	Suggested to grow climatically suitable crops with good management practices; and plantations across the slopes; Soil and water conservation measures like field bunding, leveling of land; contour bunding in undulating lands
1-3	IIc-IIIs	2st-3st	These soils are good except problem due to free calcium carbonate and slight erosion; topography; extensive percolation losses, leaching losses and less nutrient retention capacity.	Suggested to grow climatically suitable crops with good management practices; and plantations across the slopes; slight and frequent irrigation; judicious integrated nutrient management
Soils of Old Flood Plain				
0-1, 1-3	IIcIIIs	2s, 2t	Very deep, well to somewhat excessive drained soils. Sufficient moisture to grow crops, relatively potential and productive soils of the area	Grow climatically adapted crops with improved management practices; Adaptation of improved water management and integrated nutrient management.
Soils of Recent flood plain				
0-1, 1-3	IIc	1s, 1-2d	Very deep, well to somewhat excessive drained stratified soils. Sufficient moisture to grow crops, relatively potential and productive soils of the area	Grow climatically adapted crops with improved management practices; Adaptation of improved water management and integrated nutrient management.
1-3	IIc-IIIs	1-2s, 2t	These soils are good except problem of free calcium carbonate and slight erosion; loss of irrigation water due to percolation because of high infiltration rate and loss of nutrients due to leaching.	Suggested to grow climatically suitable crops with improved management practices: plantation on marginal lands, improved water management like mulching, light and frequent irrigation. Soils of Active Flood Plain
1-3	IIIe-IIIs	3st-4st	Very deep coarse loamy soils, susceptible to erosion, stratified as well as soil deposition in low lying areas and droughtiness	Green manuring and row cropping of legume across slopes; light and frequent irrigation and integrated nutrient management.

Subclass level land capability limitations : 'e' - limitations for wind and water erosion; 'w'- drainage difficulties; 's'- soil limitations affecting plant growth; 'c' – limitations due to climate ; Irrigability limitations : 's' - soil; 'd'- drainage; 't'- topographic.

leads to high runoff losses. These areas support thin forest, scrubs and single cropping in patches. Lands under these areas require soil conservation measures like gully plugging, stream bunding, continuous contour trenching and construction of check dams. Cultivation across slope, cultivation of monocots, vegetative bunds, contour vegetative hedges and plantation activities are also needed to control soil erosion losses. In *choe* lands, soils are sandy subjected to severe erosion and high erratic runoff. Contour trenching, gully plugging, leveling of lands, walting, and construction of masonary check dams along with planting *Agava spp*. Vetivar, Bhaber grass *(Eulaliopis binata*), ber (*Zizypus Jujuba*), etc. are the major soil conservation measures in these lands. In *old*, *recent and active flood plain* where soil is mainly deep to very deep is subjected to slight to moderate erosion. Soil conservation measures like strengthening the stream bunding and construction of percolation tanks are required to reduce soil erosion and increase soil moisture status of the lands. Cultivation of climatically suitable crop, land leveling, vegetative bunds, crop rotation and mixed cropping are essential in such areas to reduce soil erosion.

CONCLUSIONS

The findings of the study area highlight the settings, problems and potential of soils on various landforms of the Shiwalik system. The remedial measures for every soil-physiographic unit were suggested as per their problems and to improve the degraded soils. Soil resource information system is vital for development of an area with respect to rectification of problem faced by specific and in situ problems.

REFERENCES

Agriculture Statistics, District Nawanshahr. 2009. Agriculture Department, Nawanshahr, Punjab State.

AIS & LUS (All India Soil and Land Use Survey). 1971. *Soil Survey Manual*, Revised Edition. IARI., New Delhi. 57-64.

Bhumbla D R. 1976. Soil Conservation in Siwaliks. *Indian Farming*. **25** (12): 3-5.

Black C A. 1965. Methods of Soil Analysis, Part 1 & 2. *American Society of Agronomy*, *Madison*, Wisconsin, USA.

Dhruvanarayana V V and Ram Babu.1983. Estimation of soil erosion in India. *Journal of Irrigation and Drainage Engineering. ASCE*, **109 (**4): 419-434.

Jackson M L. 1967. *Soil Chemical Analysis*, Prentice Hall of India Pvt. Ltd., New Delhi.

Klingebiel A A and Montgomery P H. 1966. Land Capability Classification. Agricultural Handbook No. 210, Soil Conservation Service, USDA, Washington, D.C.

Larson W E and Piece F J. 1991. Conservation and enhancement of soil quality. In evaluation for sustainable land management in the developing World (Eds. Daumanaski J., Pusharajanh E., Latahm M., and Myera R.), **2**, Technical papers. Proceedings of International Workshop, Chang Rai, Thailand. International Board for Soil Research and Management, Bangkok, Thailand, 175-203.

NBSS & LUP. 1986 Soil survey and land use plan of Hoshiarpur District, Punjab. Report No. 485 (ICAR)., 59.

Sarma V A K, Krishnan P and Budhihal S C. 1987. Laboratory methods. Soil resources mapping of different states in India, *NBSS Publ*. **14**, Nagpur.

Sidhu G S, Walia C S, Sachdev C B, Rana K P C, Dhankar R P, Singh S P and Velayutham M. 2000. Soil resource of N-W Shiwaliks for prospective land use planning. In Fifty years of research on sustainable resource management in Shiwaliks (Eds S.P. Mittal, R.K. Aggarwal and J.S. Samra), CSWCRTI, RC, Chandigarah. pp. 23-34.

Sidhu G S, Yadav R P, Singh S P, Sharma J P, Aggarwal R K, Tiwari A K, Gajbhiye K S, Sarkar Deepak and Sharda V W. 2010. Soil erosion status of Himachal Pradesh. NBSS & LUP Publi. *Technical Bulletin* No **132**, 53.

Soil Survey Staff. 2006. *Key to Soil Taxonomy*: 6th Edition, SCS, USDA, Washington DC, USA. pp 326.

Wadia D N. 1975. *Geology of India*. Tata Mcgraw Hill. pp 582.

Wischmeier W H and Smith D D. 1978. Predicting rainfall erosion losses – A guide to conservation planning, USDA: *Agriculture Handbook 537*, Washington, DC.

Journal of Soil and Water Conservation, Vol. 11, No. 2, pp 9–13 (2012)
Received: 17 November 2011; Accepted: 22 March 2012

Rainfall Runoff Study for a Watershed Using SCS-CN Method and GIS Technologies

M.C. SASHIKKUMAR[1] AND S. SANGEETHA[2]

ABSTRACT

Water is a prime natural resource, a basic human need and precious natural asset. Surface runoff is the major source for all the surface water bodies such as tanks and reservoirs. In our country the availability of accurate information on runoff is scarcely available in few selected locations. Accurate estimation of depth and rate of runoff are the key parameters for watershed management. In the present study, Soil Conservation Service Curve Number (SCS-CN) method has been applied to assess the runoff for Nambiyar sub-watershed of Thamiravaruni River Basin, Tirunelveli District, Tamil Nadu State. The SCS-CN method is a versatile and widely used procedure for runoff estimation. Geographic Information System (GIS) technique is used in this study to create the database and arises as an efficient tool for the preparation of most of the input data required by the SCS-CN method. The complexities of the data make GIS, a valuable tool for use in the planning and management of surface water.

Key words: Runoff, sub-watershed, GIS, SCS-CN method

INTRODUCTION

Surface water flow resulting from the runoff is the major source for all surface water bodies and it is one of the most important natural resource of a country. The watershed management programme for conservation and development of natural resources management necessitated the runoff information. In order to conserve and manage the runoff for watershed management development program, prediction of runoff is essential. Hence the present study has been undertaken to assess the surface runoff by integrating SCS-CN method and GIS for Nambiyar sub-watershed located in the Thamiravaruni River Basin of Tirunelveli District, Tamil Nadu. Advances in computational power and the growing availability of spatial data have made it possible to accurately predict the runoff. The possibility of rapidly combining data of different types in a GIS has led to significant increase in its use in hydrological applications. The SCS-CN method computes direct runoff through an empirical equation that requires the rainfall and a watershed coefficient as inputs (Nayak et al 2003). The thematic maps such as land use pattern, soil type and drainage pattern were used in the analysis.

MATERIALS AND METHODS

Study area

The present study has been undertaken in the Nambiyar sub-watershed of Thamiravaruni River Basin, Tirunelveli District, Tamil Nadu. The area of Nambiyar sub-watershed is 49,130 ha and is situated between 77º 30′ E to 77º 50' E longitude and 8º 35' N to 8º 20' N latitude. The mean annual rainfall of the study area is about 778 mm. The maximum portion of annual rainfall occurs during Northeast monsoon i.e. October, November and December. So there is a scope of conserving and managing the runoff resulting from rainfall in the study area. The location of the study area is shown in fig. 1. The study area has a sub-tropical climate. It has a hot summer and a mild winter. The period from May to June is generally hot and dry. The weather is pleasant from December to January. The average relative humidity

1 Assistant Professor, Department of Civil Engineering, Anna University Tirunelveli, Tirunelveli.
Email: getsahi_kumar@yahoo.com
2 M.Tech (Remote Sensing) Student, Anna University Tirunelveli, Tirunelveli.

ranges between 79% and 84%. The mean minimum daily temperature and mean maximum daily temperature is 22.9°C and 33.5°C respectively. Cultivation is done almost in the entire area except the hills and ridge portions. Even though small tanks are located inside the sub-watershed area, mainly well irrigation is in practice for cultivation throughout the year. Paddy is mainly cultivated and cereals, pulses and oil seeds have also been the other important crops produced in this area.

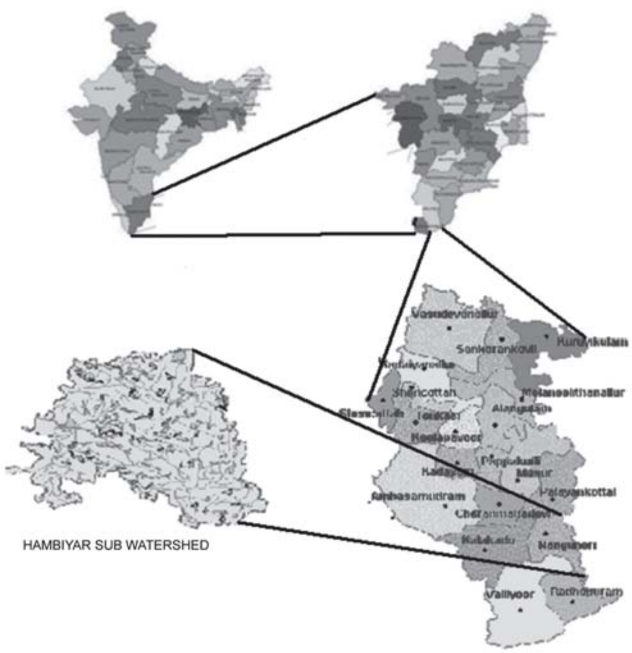


Fig.1 Location map of Study area

Data acquisition

Data acquisition involves with the collection of maps and rainfall data for the study area. The spatial data of study area such as soil type, land use pattern and drainage pattern were collected in the form of maps in the scale of 1:50,000. These maps were collected from Institute of Remote Sensing, Anna University, Chennai. The non-spatial data such as rainfall was also collected from Groundwater Division, Public Works Department, Tirunelveli.

Soil Conservation Service Curve Number (SCS-CN) Method

The Soil Conservation Service Curve Number (SCS-CN) method was developed by United States Department of Agriculture (USDA, 1972). This method computes direct runoff through an empirical equation that requires rainfall and a watershed coefficient as inputs. The watershed coefficient is called as the Curve Number (CN), which represents the runoff potential of the land cover soil complex (Verma et al 2006).

The general equation for the SCS-CN method is as follows:

$$Q = \frac{(P-I_a)^2}{(P-I_a+S)} \qquad (1)$$

Where Q, Runoff in mm; P, Rainfall in mm; S, Potential maximum retention after runoff begins in mm; I_a, Initial abstraction of rainfall in mm.

For the present conditions the initial abstraction I_a may be approximated equal to 30% of the watershed storage (S) and is expressed as,

$$I_a = 0.3S \qquad (2)$$

Therefore, equation reduces to:

$$Q = \frac{(P-0.3S)^2}{(P+0.7S)} \quad (P > 0.3S) \qquad (3)$$

The watershed storage (S) and curve number (CN) are related by,

$$S = \frac{25400}{CN} - 254 \qquad (4)$$

The parameter CN, having a range of values between 0 and 100, called the curve number. It depends on the land use pattern, soil characteristics and the antecedent moisture conditions.

GIS database development

The thematic maps such as soil type, land use pattern and watershed were geo-referenced by latitude and longitude and digitized using Arc GIS software. Using Arc GIS software, the above theme maps have been integrated to derive the attribute database files. MS Access was used for handling the attribute data and Arc GIS for spatial analysis. The daily rainfall was taken into account in the present study and was accessed by MS Access. The Weighted Curve Number (CN) values of intersected polygons of the land use pattern map and hydrological soil group map were assigned to the attribute table. Based on these Weighted CN values, the CN distribution map was prepared for the study area. For each value of CN, the surface retention has been calculated, by taking initial abstraction value as 0.3S. The runoff was calculated for a design rainfall value of 53 mm which is based on the 75% probability of 10-year maximum rainfall event of the study area. The database file consists of CN values for different polygons, daily rainfall and Antecedent Moisture Condition. These database files were combined with SCS-CN method and runoff depth and runoff volume of the study area was calculated.

RESULTS AND DISCUSSION

Land use map

Most of the inhabitants in the watershed are dependent on agriculture and the major part of the land is under cultivable land. Six types of land use pattern were identified in the watershed such as built uplands (6.19%), crop lands (12.63%), cultivable land (45.91%), fallow land (21.94%), waste land (3.71%) and water bodies (9.62%). The areas of land use pattern obtained through GIS are shown in table 1. The land use pattern map of the study area is shown in fig. 2.

Table 1: Land use classification present in the study area

Sl.No.	Land Use Pattern	Area (sq.km)	Area (%)
1.	Built upland	30.39	6.19
2.	Crop land	62.05	12.63
3.	Cultivable land	225.55	45.91
4.	Fallow land	107.80	21.94
5.	Waste land	18.25	3.71
6.	Water bodies	47.25	9.62
	Total Area	491.30	100

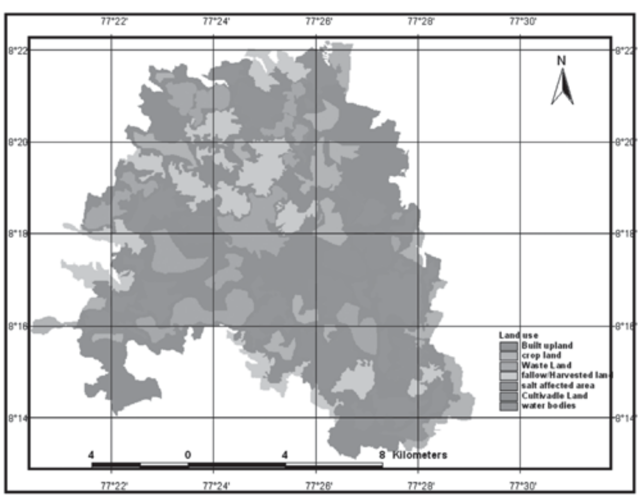


Fig. 2 Land use pattern map of study area

Hydrological soil group

The study area is predominantly covered with red soil. The other types of soils are gravel, lateritic soil, loam, clay, heavy plastic clay and red sandy soil. The area of hydrological soil group A, B, C and D obtained through GIS are shown in table 2. The maximum area of watershed was observed to be under hydrological soil group A (76.93%) followed by hydrological soil group of C (15.24%). The hydrological soil map of the study area is shown in fig. 3.

Table 2: Hydrological soil group present in the study area

Sl.No	Hydrological Soil Group	Area (sq.km)	Area (%)
1.	A	377.98	76.93
2.	B	25.26	5.14
3.	C	74.86	15.24
4.	D	13.19	2.69
	Total Area	491.30	100

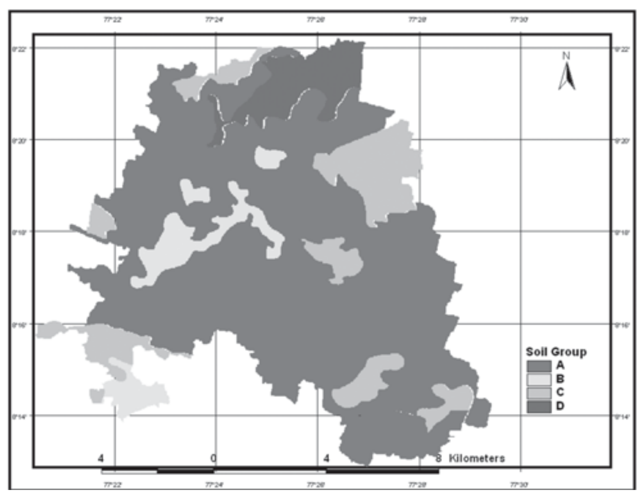


Fig.3 Hydrological Soil group of study area

Surface runoff determination

SCS-CN method is used to assess the surface runoff for the study area using the rainfall data, soil type and land use pattern. Based on the Weighted CN values, the CN distribution map was prepared for the study and is shown in fig. 4. Spatial variation of runoff for the sub-watershed was assessed and is shown in fig. 5. The surface runoff of the study area was classified into low, less moderate, moderate and high. The surface runoff map shows that most of the area in the sub-watershed is having low to less

Table 3: Computation of Runoff Depth of the study area

Hydro-logical Soil Group	Weighted Curve Number	Maximum retention of watershed (S)	Rainfall in mm(P)	Runoff depth in mm(Q)
A	75	84.66	53	6.78
B	86	41.34	53	20.11
C	89	31.39	53	25.33
D	96	10.58	53	41.09

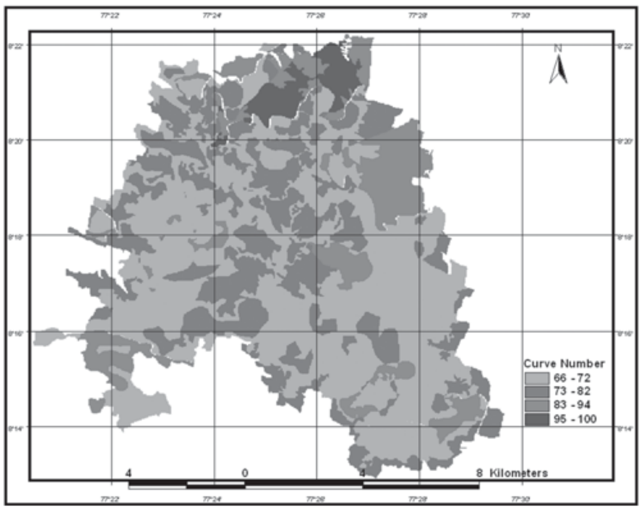


Fig. 4 Curve Number Map of study area

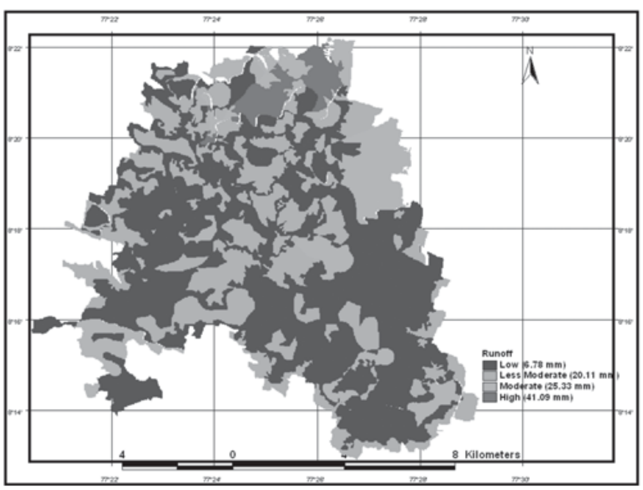


Fig. 5 Runoff Map of study area

moderate surface runoff potential. This is due to the presence of hydrological soil group A (76.93%) and land use classification of cultivable land (45.91%) predominately covering the study area and having higher infiltration capacity and water retention property. The moderate and high runoff potential covers only smaller portion of the study area. This is due to the presence of hydrological soil group C (15.24%) & D (2.69%) and land use classification of built upland (6.19%) & water bodies (9.62%) covering the smaller portion of the study area. These areas are having lower infiltration capacity and water retention property. So the portion of excess runoff in these areas can be used for groundwater recharge.

CONCLUSIONS

The proper assessment of runoff resulting from rainfall is an important factor for developing efficient soil and water conservation plan in a watershed. The surface runoff was assessed for Nambiyar sub-watershed using SCS-CN method and GIS. The thematic maps such as Land use map and Soil map were prepared and used as input data in GIS environment. The data integration, management and visualization in GIS environment were relatively efficient. The surface assessment is very essential to quantify the water that flows out of the watershed. The result of surface runoff map indicates that most part of the area in sub-watershed is having low to less moderate surface runoff potential. A portion of the surplus flow in these areas can be used for conservation within the sub-watershed. The combination of GIS and SCS-CN method makes the runoff estimate more accurate and fast.

ACKNOWLEDGEMENT

I wish to convey my immense gratitude to our Vice Chancellor Dr.S.Kaliappan, M.Tech., Ph.D (Illinois), Anna University Tirunelveli, Tirunelveli for extending his esteemed support and encouragement to carry out the present study.

REFERENCES

Benedict M. Mutua and Andreas Klik 2003. Development of a physically based model for estimation of spatial sediment delivery ratio for large remote catchments, Journal of Spatial Hydrology, 5(2): 45-59.

Debashis Chakraborty, Dibyendu Dutta and Chandrasekharan, H. 2001. Spatial modelling for hydrological response behavior of an arid watershed, India by Remote Sensing and GIS approach, Journal of Spatial Hydrology, 5(1): 47-66.

Manivannan, S., Ramaswamy, K. and Shanthi, R. 2001. Predicting runoff from tank catchments using green-Ampt and SCS runoff curve number models, International Journal of Agricultural Engineering, 10 (1&2): 57-69.

Nayak, T.R. and Jaiswal, R.K. 2003. Rainfall-Runoff modelling using satellite data and GIS for Bebas River in Madhya Pradesh, Institution of Engineers (I), 84: 47-50.

Qihao Weng 2001. Modeling urban growth effects on surface runoff with the integration of Remote Sensing and GIS, Journal of Environmental Management, 28(6): 737–748.

Sreenivas Kandrika and Venkataratnam, L. 1999. A spatially distributed event-based model to predict sediment yield, Journal of Spatial Hydrology, 5(1): 1-19.

Verma, S.K., Singh, J., Tiwari, S.C. and Ranade, D.H. 2006. Runoff estimation by using remote sensing and GIS from watershed, Journal of Soil and Water Conservation, 5(3): 49-53.

Journal of Soil and Water Conservation, Vol. 11, No. 2, pp 14–17 (2012)
Received: 28 November 2011; Accepted: 14 May 2012

Performance of Rainwater Harvesting Structures in a Watershed of Junagadh District (Gujarat)

R. S. SIKARWAR [1], M.K. KHANDELWAL[2] AND SANJAY ARORA[2]

ABSTRACT

Water in rainfed agriculture is the most valuable input deciding success/failure of agricultural crop production. To mitigate problem of water scarcity the Gujarat State Land Development Corporation (GSLDC) constructed 5 small check dams and 5 marginal check dams across the river Ambakai in the district Junagarh. The temporal variation of water levels in the reservoirs and the wells were observed periodically to study impact of structures on the arrest of water table decline. The impact of water harvesting on cropping pattern, net revenue and socio-economic status of the farmers was evaluated. The cost of water storage was estimated to be Rs 5.60 and Rs 33.30 per m^3 for small and marginal check dams. Construction of the check dams enhanced the crop yields and corresponding benefits.

Keywords: Check dams, rainfall, rainwater harvesting, water table, cropping pattern, net revenue

INTRODUCTION

The topography of the Saurasthra region of Gujarat is having the shape of inverted saucer. All the rivers in region originate from Chotila and flows in to the Arabian Sea in short span. The scope for construction of large dams in these small and seasonal rivers are further limited due to less suitable catchment features. Since the region experiences advance rainstorm and so much of rainwater flows waste to sea. It also enhances soil erosion of top productive soil surface. The existing water resources are stressed to increase more area under irrigated agriculture to meet the increasing demand of population. Farmers of the region largely depend on ground water as the surface water resources are limited. Excessive withdrawal of limited ground water resulted in intrusion of sea water and deteriorated ground water quality and thus hamper overall agricultural production.

In order to arrest further deterioration of ground water and worsening of surface water resources, it was imperative to harvest rain water in all possible places i.e., nalas, and fluvial channels by constructing small and marginal check dams in the study area. The paper presents efforts undertaken to some of the issues in this direction.

Study area

The Ladudi watershed falls in Maliya taluka of Junagadh district in Saurastra region of Gujarat state. It is about 70 km away from the Junagadh towards the Arabian sea. The climate of the watershed is semi arid. The average rainfall in the watershed is 750 mm. The soil of the region is medium black cotton soils and loamy in texture with depth varying from 0.50 to 0.80m. The water table had gone beyond 50 m from the ground surface. The wells within the area are scarcity will not run more than one hour. Due to lack of water resources the farmers were not getting the water in required quantities for drinking. This caused many villagers engaged in agriculture to migrate to other area for their livelihood. The major crops of the study area are groundnut, wheat, bajra.

DRDA, Junagadh selected the watershed project under the DPAP-4 rural development programme, GOI New Delhi. The implementation of watershed development was assigned to AKRSP, Gadu during 1999-2000. Later on the scheme was handed over to GSLDC Junagadh during 2002-2003 by the DRDA Junagadh. The GSLDC constructed a series of 5 small check dams and 5 marginal check dams.

[1]Gujarat State Land Development Corporation Limited, Bhavnagar, Gujarat
[2]Central Soil Salinity Research Institute, Regional Research Station, Bharuch 392012, Gujarat

METHODOLOGY

An extensive and precise survey was made for impounding appropriate quantity of water to be stored by the water harvesting structure. The rainfall data from collected from the meteorological observatory at Agricultural University, Junagadh for the past 20 years. The average monthly rainfall and PET of the district is presented in Fig. 1. The daily runoff from the study area was calculated using the SCS curve number approach. The harvesting structures were designed at five year recurrence interval. Using the standard procedures the water harvesting structure were designed. The details of existing cropping pattern and crop revenue pattern were collected from agriculture department Government of Gujarat.

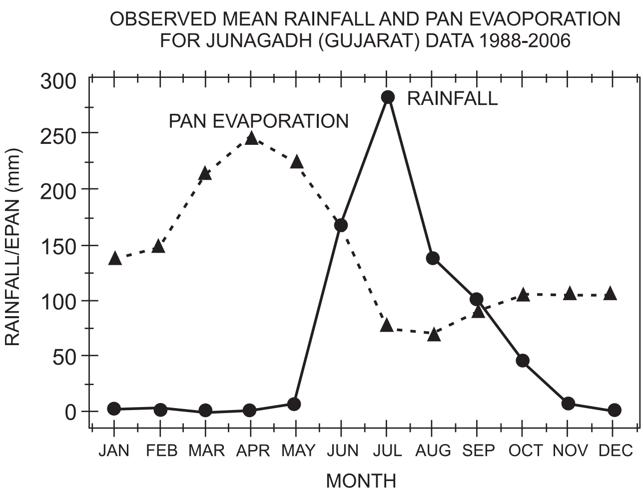


Fig 1. Rainfall and PET for Junagadh district of Gujarat

The runoff was observed using the stage level recorder. The daily water level observation in the storage and in the nearby wells were recorded using water level indicator. The amount of water infiltrated was determined by subtracting evaporation from the drop in the water level of storage. The pan evaporation method (Doorenbos and Pruitt, 1977) is adopted for estimating evaporation in view of data availability and relative accuracy. Doorenbos and Pruiitt (1979) presented values of pan coefficients for different wind speeds (U), relative humidity (H), and windward ground cover conditions for class pan evaporation pans and Colorado Sunker Pans (F). Many regression models were developed to these table values of pan coefficient by Cuenca (1989) and Snyder (1992) as a function of mean relative humidity, H, mean 24 hr wind speed, U, and fetch, F in the present analysis the Snyder's regression model is adopted and presented by :

$$Kp=0.482+0.024 \ln (F) -0.00376 U+0.0045 H$$

The duration of water storage and availability of water from the selected wells in the watershed area were observed wells.

RESULTS AND DISCUSSIONS

Analysis of daily rainfall data for the period of about 20 years at Maliya, showed that area received seasonal average and annual average rainfall of 843 mm and 886 mm respectively. Earliest and latest onset of effective monsoon at 50 per cent probability would be around June 8-9. Similarly, earliest and latest onset of effective monsoon at 68 per cent probability would be around July 10- July 12. Withdrawal of south west monsoon is around September 20. It experiences three critical spells of 19, 23 and 30 days starting on Jul 7, August 1, and August 24, respectively. Annual potential evapotranspiration for the watershed is estimated to be 2144 mm. Using Thornthwaite and Mather book keeping procedure it is noticed that it may be possible to harvest runoff in order of 408, 223, 121 and 55 mm during first, second, third and fourth wet spells respectively in above normal rainfall years.

The evaluation of water storage structures were one on two aspects. The first aspect includes the change in the cropping pattern, the increase in the crop productivity the increase in the water table and the additional land brought under cultivation. The second aspect includes the improvement in the standard of living and lifestyle and economic improvement before and after constructing the watershed structures. Nearly five small and five marginal check dams were constructed to prevent the soil erosion and to tap the runoff water. A series of marginal check dams across the drain passing through the watershed were constructed. The dams were filled two to three times in a year. The total storage capacity of five marginal and five small structures were found to be 22500 m^3 and 720 m^3, respectively. During the year about 109500 m^3 and 8000 m^3 was harvested by five medium and five small water harvesting structures. The unit cost of harvested water worked to be Rs 5.60 and Rs 33.3 per m^3. The ground water recharge due to medium and small structure was estimated to be 61500 m^3 and 4200 m^3, respectively.

It was observed that the small harvesting structure constructed across small stream on he upper part of the watershed were empty by second week of October. This may be due to higher seepage rate towards lower side of structure and due to excessive pumpage from groundwater to cater the needs of rabi crops. It was found that the time availability of water in small structure increased when a storage structure is constructed at the down stream. This may be due to water storage at the down stream side created a saturated zone, which restricted the hydraulic gradient of the seepage from the upstream structure. The water storage in the main drain remained for 255 days after first filling (June 30 to Mar 15) where as in small check dams the water storage time was 120 days only (Table 1). The total hours of irrigation possible from a well has increased by 32% after recharge structures are constructed. An average of 6-7 m increase in water table depth was observed in the wells.

The benefits derived from 5 small and 5 marginal dams were evaluated through the information acquired from the surrounding farmers. The major crops along with their respective area and production are presented in Table 2. The results indicate that the number of crops grown by an average farmer had increased with the construction of the structures. The area under kharif ground nut was increased after watershed treatment. The irrigation intensity during rabi was considerably increased by 28% and accordingly the overall profit/ productivity was also enhanced. The farmers near by the structure started taking crops during summer season also due to availability of water (Table 2). The individual farmer preferred more number of crop in small area than few irrigated crops in large areas in winter after watershed structure are construed. It can also be concluded that increase in irrigation potential increase the area under the kharif and rabi season crops. This can help in improving the socio-economic status of the farming community in the region.

Table 1. Details of masonry structure storage capacity and expenditure (Village Laduli, taluka Maliahatina, District-Junagadh)

S. No.	No. of structures	Weir length (m)	Weir height (m)	Direct water storage (cum)	Storage period (days)	Approximate percolation quantity (cum)	Total runoff harvested (cum)	Expenditure (Rs. lakh)	Storage cost (Rs/m^3)	Well depth (m)	Water table depth (m, bgl)	Month
1.	C.D.2	30.00	1.20	12000	240	24000	36000	1.93	5.36	14.00	7.00	Apr
2.	WHS.5	8.00	1.05	720	120	780	1500	0.05	33.30	19.50	6.20	Jan
3.	C.D.3	22.00	1.65	10500	270	23000	33500	2.00	5.97	20.00	13.00	May

Table 2. Details of crops and production in command area of structure

S. No.	Structure	Beneficiary	Area (ha)	Crops	Before Work			After Work			Additional income (Rs. Lakhs)	Income per ha (Rs.)
					Area (ha)	Production (q)	Income (Rs. Lakhs)	Area (ha)	Production (q)	Income (Rs. Lakhs)		
1.	CD2	Meraman	6.50	Groundnut	6.50	100.00	1.20	6.50	120.00	1.44	0.67	10307
		Punja		Wheat	5.90	183.00	1.28	5.90	212.40	1.48		
				Bajra	0.60	10.00	0.06	0.60	11.00	0.07		
				Groundnut	-	-	-	1.00	18.00	0.22		
2.	WHS5	Jina	1.50	Groundnut	1.20	18.00	0.22	1.20	22.00	0.26	0.11	7333
		Bhima		Mango	0.30	6.00	0.12	0.30	7.00	0.14		
		Rathod		Wheat	1.20	35.00	0.24	1.20	42.00	0.29		
3.	CD3	Bhikha	6.30	Groundnut	6.30	98.00	1.18	5.50	105.00	1.26	0.81	12857
		Pola		Wheat	0.80	24.00	0.17	-	-	-		
		Parmar		Garlic	0.80	20.00	0.30	0.80	24.00	0.48		
				Banana	-	-	-	0.80	80.00	0.40		
				Castor	-	-	-	0.80	16.00	0.24		
				Bajra	0.80	12.00	0.07	0.90	18.00	0.11		
				Groundnut	1.80	24.00	0.29	2.00	30.00	0.36		

CONCLUSIONS

The watershed needs recharging of aquifers to arrest the declining water table and to prevent the further deterioration of ground water quality at deeper aquifers by seas water ingress. The structure are being filled 2-3 times in a year water storage remained up to 255 days and 120 days in marginal and small check dams after filling. The productivity, net profit, watering intensity was enhanced after watershed treatment. There was an increase of 6-7 m in the water table depth during the observed period.

REFERENCES

Cuenca, R.H. 1989. Irrigation System Design: An engineering approach. Prentice Hall, Englewood Cliffs, N.J., pp. 133.

Doorenbos, J. and Pruitt, W.O. 1977. Guidelines for prediction of crop water requirements. Irrigation and Drainage, Paper No. 24, FAO, Rome, Italy, pp. 144.

Snyder, R.L. 1992. Equation and evaporation pan to evapotranspiration conversions. Journal of Irrigation and Drainage Engineering 118: 977-980.

Journal of Soil and Water Conservation, Vol. 11, No. 2, pp 18–23 (2012)
Received: 21 October 2011; Accepted: 19 March 2012

Spatial andTemporal Variations of Rainfall and Its Application to Crop Production in Jharkhand

PRAGYAN KUMARI[1], A.WADOOD[1], BINOD KUMAR[2] AND AKHILESH SAH [3]

ABSTRACT

Probability analysis of rainfall offers a better scope in crop planning and strategies by predicting the assured weekly rainfall in rainfed regions like Jharkhand state. In addition, annual, seasonal and coefficient of variability of rainfall has been estimated to compare the rainfall variability in places with different mean. The study area was divided into its three agro-climatic sub-zones to suggest the optimal cropping plans. Result of the study revealed that station Chiyanki recorded highest coefficient of variation in annual as well as seasonal rainfall, whereas it was lowest for Kanke. Assured rainfall (AR), predicted by using an incomplete gamma distribution model for carrying out rainfall characteristics for any week showed that at every probability levels it was found lowest for Chiyanki and highest for Dumka. Then optimal crop plans for various probability levels were worked for each agro-climatic sub-zone.

Key words: Assured weekly rainfall, Incomplete Gamma distribution, rainfall variability, Crop planning, Jharkhand

INTRODUCTION

The amount of rainfall received over an area is an important factor in agricultural and for hydrological planning. Therefore, the study of the variability in quantum and distribution of rainfall with time and space is very important for assessing the amount of water available to meet the various demands of agriculture.

Agriculture in Jharkhand state is mainly rainfed having rice based cropping system with only 10-12 % irrigation potential. Undulating terrain with a slope of one to ten percent, shallow soil depth, low water retentive capacity, poor soil fertility and fragmented holdings are the most important constraints in agriculture.

To enhance the productivity, minimise the risks and facilitate need based, location specific suitable cropping strategies in this area knowledge of the characteristics of rainfall is a must.

Proper information about normal rainfall, start and end of rainfall, their duration, seasonal rainfall variability and assured weekly rainfall at different probabilities for a particular time and place plays a decisive role in proper agricultural management and development. In regions of uncertain precipitation like Jammu & Kashmir or in an arid /semiarid climate, one cannot fully depend on averages (Hasan, 1999). Estimates of probable rainfall can be used to assess the chances of occurrence of rain and potential of a place to grow the crops in a particular time. The gamma distribution was found to provide the best fit for rainfall analysis in climatological study of the south-western region of Saudi Arabia (Abdullah & Al-Mazroui, 1998). It is useful in the identification of periods favourable for sowing different crops and for determining the quantum of moisture that would be available during different phases of crop growth.

MATERIALS AND METHODS

Very little work has been done on regional basis to characterize rainfall and its variability for the Jharkhand state. Jharkhand state extends from $21^0 28'$ to $25^0 30'$ N and $83^0 22'$ to $87^0 40'$ E with an altitude up to 1142 m above msl and having humid to sub

[1]Department of Agril. Physics & Meteorology, B.A.U. Kanke, Ranchi - 834006
[2] Zonal Research Station, Darisai
[3] Zonal Research Station, Chiyanki
* E mail: pragyanbau@yahoo.com

humid tropical monsoon type of climate. For conducting the study, four stations viz. Kanke, Dumka (sub-zone IV), Chiyanki (sub-zone V) and Darisai (sub-zone VI) were selected (Fig. 1). Daily rainfall data was collected from the Meteorological observatory of Birsa Agricultural University, Kanke, Ranchi (1961-2008) and its three zonal stations Dumka (1986-2008), Darisai (1989-2008) and Chiyanki (1986- 2008) and converted into weekly data for analysis. Annual and seasonal variation in rainfall with start and end of rainfall as well as weekly assured rainfall at different probability levels (10, 25, 50, 75 and 90%) has been worked out for selected stations and discussed. Seasons are divided into four group viz. winter season (January-February) summer season (March-May), monsoon (June-September) and post monsoon (October-December). Highest, lowest and coefficient of variation (CV %) were calculated on seasonal basis. The start and end of rainy season were computed by forward and backward accumulation of weekly rainfall data (Morris & Zandstra, 1979).

Fig 1: Agro climatic sub zones of Jharkhand with selected stations. Not to scale

In estimating probability, two different methods were tried viz., a) past frequencies are directly taken to delimit future expectations and b) a theoretical distribution may be found out from such a distribution. As the frequency distribution of rainfall over shorter period is mostly skewed, and because of some other important limitations of the available data on weekly totals (abnormally high total rainfall for any week, occurrence of a number of zero rainfall cases, etc.), an incomplete gamma distribution was used for carrying out weekly rainfall probability analysis. This is expressed as

$$H(X) = q + pF(X)$$

Where F(X) is the gamma distribution function, q is the probability of zero precipitation cases, and p = 1-q. The distribution function F(X) of the two parameter Gamma distribution is:

$$F(X) = \frac{1}{\Gamma(\gamma).\rho^{\gamma}} . \int_{o}^{x} X^{\gamma-1.} e{-}(x/\beta) . dx$$

Where, $X, \gamma, \beta > 0$

$F(X) = 0$ when $x\ d \leq 0$

γ , β are shape and scale parameters of the distribution, respectively and $\Gamma(\gamma)$ is the Gamma function of g .The distribution is bounded at the left side by zero. H(X) is the probability of rain < X. To obtain the rainfall probabilities, the two parameters γ and β of the Gamma distribution have to be estimated from the observed data.

Fitting of incomplete gamma distribution to this kind of skewed data has been suggested by several researchers (Krishnan & Kushwaha 1972; Khambete & Biswas 1978; Biswas and Basarkar 1982).

RESULTS AND DISCUSSION

Mean Annual and Seasonal Rainfall Distribution of the Study area

Rainfall, annual as well as seasonal, is probably the most important simple climatic indicator of productivity. Mean annual and seasonal rainfall has been analysed for the area of the study (Table 1). A lot of variations in rainfall is observed within the state. The western side of the state (zone V) receives less rainfall than the eastern side. The maximum mean annual rainfall appears on region IV, specifically at Ranchi (1424 mm) followed by Dumka (1278 mm). However , highest annual rainfall at Dumka has been recorded up to 2256 mm**.** Chiyanki (zone V) receives the lowest mean annual rainfall of 1002 mm. Monsoon season rainfall contributes about 82 % of total rainfall followed by summer rain (8%) with meagre rain in winter (3%) for all the three zones. Monsoon season rainfall also ranges from 884 mm at Chiyanki to 1169 mm at Kanke (Ranchi) and reflects a wide variation in rainfall at regional scale.

Rainfall Variability

The ecology of any region is not only dependent on how much rainfall occures but also on how it varies from year to year. Coefficient of variability

Table 1: Annual and seasonal rainfall (mm) at selected stations

		Zone IV		Zone V	Zone VI
Season		**Kanke**	**Dumka**	**Chiyanki**	**Darisai**
Annual	Lowest	951	731	588	795
	Highest	2065	2256	1632	1859
	Average	1424 (19)	1278 (30)	1002 (31)	1200 (25)
Summer	Lowest	13	0	2	45
	Highest	243	348	106	242
	Average	108 (46)	107 (70)	34 (77)	118 (48)
Monsoon	Lowest	705	520	523	565
	Highest	1771	2055	1478	1515
	Average	1169 (21)	1033 (39)	884 (32)	961 (28)
Post monsoon	Lowest	0	2	0	3.8
	Highest	363	281	110	234
	Average	99 (77)	117 (74)	44 (86)	92 (74)
Winter	Lowest	0	0	0	0
	Highest	145	67	316	148
	Average	48 (72)	21 (92)	40 (169)	29 (118)

Figures in parenthesis are coefficient of variation (CV%).

Table 2: Onset, withdrawl and duration of rainy season at different stations

Station	Onset of rainy season (SMW)				Withdrawl of rainy season (SMW)				Duration of rainy season (Weeks)			
	Early	Late	Mean	CV%	Early	Late	Mean	CV%	Max.	Min	Mean	CV%
Kanke	23	27	24	4.6	38	52	45	9.8	29	13	21	20.5
Dumka	23	26	24	4.2	39	52	45	7.0	29	15	21	17.2
Chiyanki	23	28	25	4.4	36	52	44	13.0	29	8	19	30.5
Darisai	23	26	24	4.2	39	52	45	10	29	14	21	21.0

makes it possible to compare the variability of rainfall in places with different mean annual and seasonal rainfall. As it is generally the case, variability increases with decreasing rainfall. The maximum annual variability of 31% is shown at Chiyanki, while the minimum of 19% is calculated for Kanke. Chiyanki shows lowest rainfall associated with high coefficient of variation for all seasons. Seasonal rainfall variability was more for winter season as compared to other season at all selected stations (72-169%). Dumka shows its highest rainfall variability (39%) in monsoon season as compared to Chiyanki (32%).

Onset, Withdrawl and Duration of Rainy Season

Proper planning and scheduling of cropping activities in rainfed areas can effectively be done only when the farmers have some idea of normal date of monsoon onset, its withdrawal and length of the rainy season. A perusal of data in table 2 reveals that the normal Standard Meteorological week (SMW) of start of rainy season is observed in 24th SMW (11-17 June) for zone IV and VI while it is 25th SMW (18-24 June) for zone V. Latest onset of monsoon was observed at 28th SMW (9-15 July) at Chiyanki followed by 27th SMW (2-8 July) at Kanke. Mean week for end of rainy season ranges from 44 SMW (Chiyanki) to 45 SMW (Kanke and Darisai). Station Chiyanki showed its earliest end of rainy season by 36th SMW (3-9 Sept). Normal duration of rainy season available was 21 weeks at Kanke, Dumka and Darisai whereas it is 19 weeks at Chiyanki. Minimum duration of rainy season varies from 8 weeks (56 days) with highest CV% (30.5) at Chiyanki to 15 weeks (105 days) with 17.2% of CV at Dumka. Variability in terms of start, end and duration of rainfall was highest for Chiyanki station. This type of uncertainty with regard to the duration of monsoon season puts a major limitation, before the scientists and farmers, in choosing right crops and varieties of appropriate duration.

Assured Weekly Rainfall Analysis

The weekly assured rainfall values at different probability levels for a particular place over specified weeks have been analysed (Table 3). Assured rainfall amounts decrease with the increase in probability level from 25% to 90%. A zonal analysis of representative stations showed different trends. Magnitude of assured rainfall at all probability level is found to be lowest at Chiyanki during entire monsoon season.

To find out the spatial and temporal distribution, assured rainfall values for all the probability levels have been plotted against the standard weeks for all the selected regions (Fig. 2). A minor peak is observed during the 23rd standard week with more than 15 mm assured rainfall (A.R.) at 50% probability level, which indicates the early onset of monsoon at Kanke, Dumka and Darisai station. The major peak is observed during 29th standard week for Kanke and Dumka station when A.R. is 78 and 62 mm at 50% probability level, respectively. At Darisai and Chiyanki, major peak is observed after an interval of two week, during 31st and 33rd week, when the A.R. is 70 and 56 mm at 50% probability level, respectively.

Table 3: Probability of assured weekly rainfall (mm) during *kharif* season

Station	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
(a) At 25% probability level																					
Kanke	17	49	59	101	111	99	114	121	126	107	96	103	92	100	98	98	81	59	36	30	19
Dumka	29	58	57	95	91	80	128	108	80	72	63	70	85	67	66	82	116	110	61	38	39
Chiyanki	5	20	39	99	74	88	91	83	87	91	93	104	76	91	55	78	36	31	15	13	11
Darisai	26	53	65	98	87	88	92	95	91	117	82	92	52	74	80	60	53	44	40	18	23
(b) At 50% probability level																					
Kanke	7	19	27	54	61	58	71	78	65	64	60	63	57	53	48	51	34	26	14	11	7
Dumka	12	29	26	51	51	47	57	62	45	47	30	41	46	32	39	44	44	45	23	16	12
Chiyanki	2	8	15	42	30	53	54	46	43	50	50	56	37	38	27	32	14	12	6	5	4
Darisai	10	24	29	41	50	48	54	54	64	70	49	47	28	37	45	28	21	17	17	7	8
(c) At 75% probability level																					
Kanke	2	5	10	25	29	30	41	47	29	35	35	35	32	24	19	22	11	9	4	3	2
Dumka	4	12	10	24	25	25	20	31	23	28	11	22	21	12	20	21	12	13	6	5	2
Chiyanki	1	2	4	14	9	29	29	23	18	23	23	26	15	12	11	10	4	3	2	1	1
Darisai	3	8	10	13	26	22	28	28	43	38	26	20	13	15	23	11	6	5	6	2	2
(d) At 90% probability level																					
Kanke	1	1	3	11	13	15	23	28	11	18	20	19	17	10	7	9	3	2	1	1	0
Dumka	1	5	3	10	12	12	6	15	11	17	4	11	9	4	10	9	2	3	1	1	0
Chiyanki	0	0	1	4	2	15	15	10	7	10	9	11	5	3	4	2	1	1	0	0	0
Darisai	1	2	3	3	13	10	14	13	28	20	13	8	6	6	11	3	1	1	2	0	0

Monsoon is normally well established over the whole state by the 24th SMW (11-17 June). The region of highest rainfall is observed in Darisai where it is 65, 29, and 10 mm at 25, 50 and 75% levels, respectively. Chiyanki is found as a lowest rainfall zone where assured rainfall is in the order of 39, 15 and 4 mm at 25, 50 and 75% levels, respectively. One can expect rainfall of 15 mm in 5 out of 10 years in Chiyanki in that 24th week.

Considerable increase in rainfall is noticed after 24th week in all selected stations and the highest rainfall belt shifted to Kanke, where it is 78 and 47 mm at 50 and 75% probability levels by the 29th week, respectively. After 37th week, assured rainfall amount shows a decreasing trend in all regions. Shifting of highest rainfall belt towards Dumka is observed during the end of monsoon which is clearly seen at 50% level. In this region, it is 45 and 13 mm by 39th SMW at 50 and 75% levels, respectively.

A gradual decrease in A.R. is noticed up to 42nd week at Kanke but a marked secondary peak is observed during 39th week at Dumka when the A.R. is 45 mm at 50% probability level. At Darisai and Chiyanki, secondary peak is also observed during 26th and 28th week at 50% probability level, respectively.

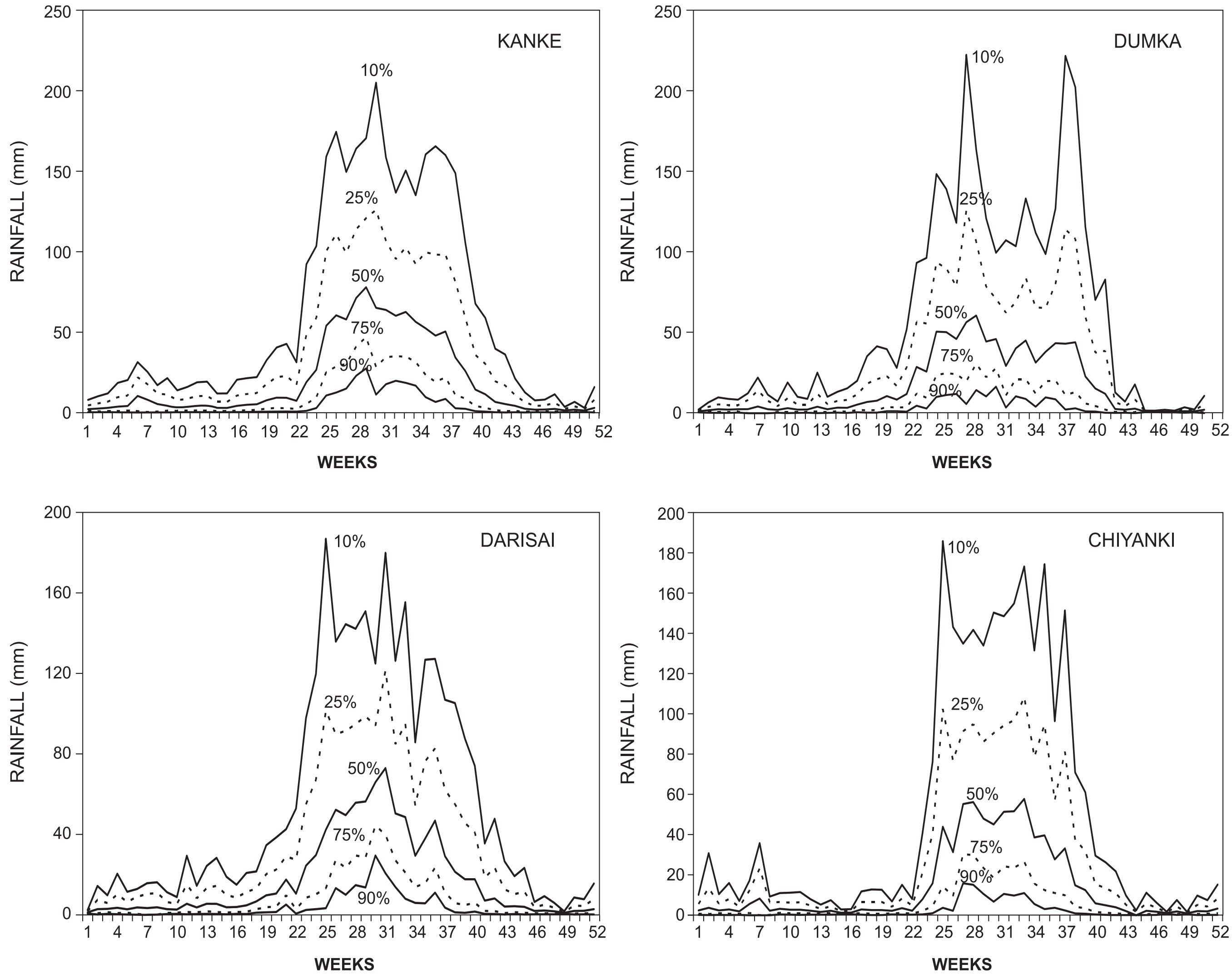


Fig. 2: Assured weekly rainfall at different probability levels for selected stations

At least10 mm of weekly rainfall is required for land preparation, sowing work and other cultural practices in agriculture and at Chiyanki rainfall duration is short varying from 7 to 16 weeks (90 to 50% probability levels). Magnitude of assured rainfall and its duration is found highest for Dumka followed by Kanke and Darisai. Rainfall duration ranges from 13-21 week for Dumka and 11-19 weeks for Kanke and Darisai at 90-50% probability levels, respectively. Crop duration and the critical stages of crops can be adjusted accordingly with distribution of assured rainfall to minimise the risk and increase agricultural production at each stations.

CONCLUSION

Crop Planning and Strategy

Many agricultural operations revolve around the probability of receiving a definite amount of rainfall, and such an analysis can be useful for land use planning, identification of crop growing periods, choice of cropping pattern, and resource allocation. The above analysis of various aspect of rainfall reveal that the North-western part of the state (sub zone v) comprising six districts are ill privileged having most severe agro climatic constraints compared to other two zones- the North eastern and central plateau sub zone IV(15 districts) and Southern plateau zone VI

(3 districts). Rainfall analysis of Jharkhand region brought out that the chances of getting assured rains for sowing of *kharif* crops is around 25th SMW (18-24 June) at Kanke and Dumka , 26th SMW (25-31 June) at Darisai and 27th SMW (1-7 July) at Chiyanki , respectively.

With least assured rainfall (AR) and shortest growing period, Chiyanki (sub zone v) needs more attention towards appropriate and précised crop planning, particularly the selection of right crops and their varieties. In this sub zone, short duration, low water requiring but high value crops like maize, pulses and oilseeds should be promoted. Rice requires large quantity of water need to be cultivated differently. It is possible to produce rice with lot less water and other inputs by adopting it to System of Rice Intensification kind of farm based methods. Rice cultivation in sub zone IV and VI needs encouragement with the adoption of drought mitigation techniques like (i) selection of short duration drought tolerant varieties with low water requirement (ii) In situ rain water conservation by improving the water storage capacity of soils and (iii) rain water harvesting during its plenty and re-use as life saving irrigation during its scarcity. Toria/Sarson/rai/Chickpea/ lentil /linseed/ groundnut/wheat can be grown in *rabi* season with some assured irrigation.

REFERENCES

Abdullah,M.A. and Al-Mazroui,M.A. 1998, Climatological study of southwestern region of Saudi Arabia. I. Rainfall analysis.*Cim.Res.* 9:213-223.

Biswas, B.C and Basarkar, S.S. 1982. Weekly rainfall probability over dry farming tract of Gujarat. *Annals of Arid Zone* 21(3).

Hasan,B. 1999, Rainfall climatology of Jammu and Kashmir State, India. *Drought Network News.* 11 (1) 14-17.

Khambete, N.N and Biswas, B.C. 1978. Characteristics of short period rainfall in Gujarat. *Indian J. Met. Hydrol. Geophysics*. Vol. 29 (3).

Krishnan, A and Kushwaha, R.S. 1972. Mathematical distribution of rainfall in arid and semi-arid zones of Rajasthan. *Indian J. Met. Geophys*. Vol 23 (2).

Morris, R.A and Zandstra, H.G. 1979. Land and climate in relation to cropping pattern .*In :rainfed low land rice*. Selected papers. Int. Rice Res. Inst. Manila. Pp 255-274.

Journal of Soil and Water Conservation, Vol. 11, No. 2, pp 24–28 (2012)
Received: 13 December 2011; Accepted: 26 May 2012

Portable Micro-sprinkler Based Rainfall Simulator for In-situ Soil Erosion Studies

M. J. SINGH[1] AND K.L. KHERA[2]

ABSTRACT

Portable rainfall simulator using micro-sprinkler nozzles was designed, fabricated and calibrated. Provision was made for the variable rainfall intensity, plot size and simulator height. Uniformity of rainfall was calculated from uniformity coefficient which was observed to be 84, 83 and 73 per cent at 25, 50 and 75 mm h^{-1} rainfall intensities, respectively. Simulated rainfall studies for in-situ determination of runoff and soil erosion were conducted using this rainfall simulator at four locations i.e. Ballowal Saunkhri – I, Ballowal Saunkhri – II, Kokowal Majari and Saleran in submontaneous tract of lower Shiwaliks of Punjab with four land uses and three replications. Rainfall was applied at three intensities of 25, 50 and 75 mm h^{-1} and three antecedent soil moisture conditions i.e. dry, field capacity and wet were maintained. Similar studies were conducted under natural rainfall conditions. Significant correlation was observed for soil sediment yield (r^2 = 0.81) and runoff (r^2 = 0.75) when these were compared for natural and simulated rainfall studies. So this rainfall simulator can be used satisfactorily for in-situ soil erosion evaluation and for various other soil erosion and hydrologic studies.

Key words: Natural rainfall, runoff, simulated rainfall, soil erosion

INTRODUCTION

Rainfall simulator, a device to produce rainstorms of desired characteristics, has been widely used as a research tool in soil erosion studies because of unpredictable, infrequent and random nature of natural rainfall (Shrivastva and Das, 1998). Designing of rainfall simulators is done to duplicate as closely as possible the physical characteristics of natural rainfall and to fit the device for the area to be studied and resources available.

Soil erosion studies can be carried out in laboratory set up using single drop techniques and with micro plots using disturbed soil samples or can be carried out in micro plots (< 5 m^2), small scale plots (about 100 m^2) or in field plots (about 1 ha) (Hudson, 1993). Sprays often deliver rainfall in pulses to the ground, whilst rotating sprays can deliver rainfall over a relatively large surface area, but the rainfall intensity usually decreases with distance from the rotating nozzle. Attempts to reduce this spatial variability frequently rely on multiple rotating nozzles, with the overlap distance between the sprayers being determined by the area over which the simulation is to be performed. Micro-sprinkler based rainfall simulator has been successfully used for laboratory studies of soil erosion (Kohli and Khera, 2008). Frauenfeld and Truman (2004) used rainfall simulator to produce variable rainfall intensity pattern and studied their impact on soil loss and observed that although runoff may be same for different rainfall patterns for the same amount of rainfall but the soil losses might be quite different. In recent years, greater use has been made of field experiments combined with rainfall simulation. These have virtually replaced the natural runoff plots as the major research tool throughout the world (Morgan, 2005). Keeping in view the conflicting results of the performance of rainfall simulators and lack of simple portable rainfall simulator for field level in-situ soil erosion studies, a micro-sprinkler based rainfall simulator was fabricated, calibrated and tested under field conditions.

[1] Extension Specialist (Soils), FASS (PAU), Room No. 208, Kheti Bhawan, Hoshiarpur, Punjab - 146001
[2] Retired Senior Soil Physicist

MATERIALS AND METHODS

Fabrication of Rainfall Simulator

Rainfall simulator using micro-sprinkler nozzles was designed and fabricated (Fig. 1). Structure of rainfall simulator consisted of rectangular iron frame (2.5 m x 1.0 m) with four supporting pipe legs of 2.2

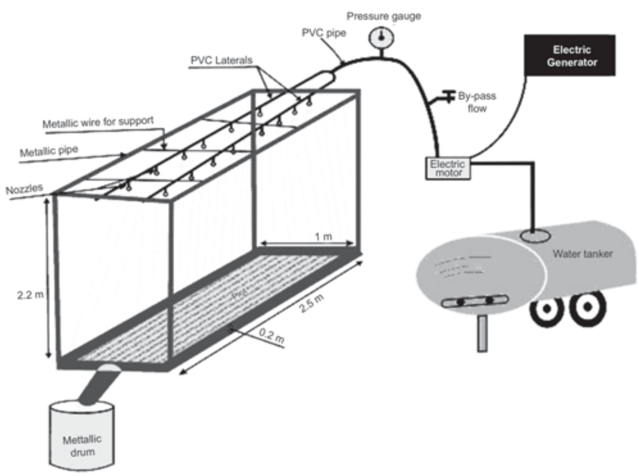


Fig. 1 Isometric view of the rainfall simulator

m length each. Galvanized iron sheets of 22-gauge thickness and 20 cm width were fixed on all sides on the lower end of structure to channelize runoff water. An opening with an outlet was provided in the sheet on one end to collect runoff water. On the top of the structure, two PVC lateral pipes with nozzles were fixed. Iron wire was used to support and fix these laterals on the structure and to maintain water supply a mono-block electric motor of 0.5 HP capacity was used. Power supply source was a portable electric generator and water supply source was tractor mounted water tanker. A pressure gauge was fixed to control the water pressure in the laterals on the main pipe supplying water from motor to the laterals. A uniform pressure of 1.0 kg cm^{-2} was maintained in all the runs. A by-pass pipe with tap was provided to control the pressure in the laterals. Provision was made to fix plastic sheet on three sides of rainfall simulator structure to minimize wind effect. An outlet made from galvanized iron sheet was fixed to channelize the flow of runoff from plots to the collecting reservoir made of iron drums of 200 l capacity fixed at the lower end of each plot.

Calibration of Rainfall Simulator

Three rainfall intensities i.e. 25, 50 and 75 mm h^{-1} were used in simulating the rainfall events. These intensities were maintained by changing the number and size of micro-sprinkler nozzles. Calibration was done in such a way that when only first lateral was attached, rainfall intensity of 25 mm h^{-1} was achieved, when only second lateral was attached rainfall intensity of 50 mm h^{-1} was achieved and when both the laterals were attached, the rainfall intensity of 75 mm h^{-1} achieved (Table 1). To calibrate rainfall intensity, water was collected on plastic sheet

Table 1. Calibration of rainfall simulator at different rainfall intensities

Runs	Low Intensity (25 mmh^{-1})	Medium Intensity (50 mmh^{-1})	High Intensity (75 mmh^{-1})
	Rainfall Intensity (mm hr^{-1})		
1	25.0	48.0	75.3
2	24.6	49.2	72.9
3	24.0	50.5	76.9
4	26.1	49.5	76.0
5	23.7	51.6	75.3
Mean	24.7	49.8	75.3
SE	0.94	1.36	1.48

from whole plot area in fixed time interval when simulator was run on. The simulated rainfall intensity was calculated from volume of water and time of run. Uniformity of rainfall was calculated from uniformity coefficient (UC). Twenty-five beakers of equal sizes were kept in grids of 25 x 25 cm^2 throughout the plot area. After each run of the simulated rainfall, the water collected in all the beakers was measured and UC was calculated as:

$$UC (\%) = (1-d/x)* 100$$

Where d is deviation from mean and x is mean water collected in the beakers. Five replicated runs were used to calculate UC for each rainfall intensity. The UC of rainfall simulator was observed to be 84, 83 and 73 per cent at 25, 50 and 75 mm h^{-1} rainfall intensities respectively.

Simulated Rainfall Studies

Simulated rainfall studies were conducted at four locations i.e. Ballowal Saunkhri – I, Ballowal Saunkhri – II, Kokowal Majari and Saleran under four land uses with three replications. The plot size kept was 2.5 m x 1.0 m. Rainfall was applied at three intensities of 25, 50 and 75 mm h^{-1} and three antecedent soil moisture conditions i.e. dry, field capacity and wet were maintained. The initial run of 30 minutes on dry soil was termed as dry run. Immediately after this run, the simulator was run for 30 minutes on the same site and this run was termed as wet run. Then after one day, another run of 30 minutes duration on the same site was termed as field capacity run. Soil samples were taken for moisture determination before each run and moisture was determined gravimetrically. Antecedent soil moisture (ASM) content differences between different locations were non significant (Table 2). However, among different land uses, higher moisture content was observed under cultivated and grassland conditions. As compared to the two levels of rainfall intensities i.e. 50 and 75 mm h^{-1}, ASM was significantly lower at the rainfall intensity of 25 mm h^{-1}. Mean ASM under dry, field capacity and wet conditions was observed to be 7.6, 17.6 and 29.2 per cent, respectively. After each rainstorm, the depth of runoff water in drums measured in depth units was converted to total runoff volume. A 2-litre representative runoff sample was collected in PVC containers from each collecting reservoir after stirring its contents thoroughly. The collecting reservoirs were emptied and cleaned after each rainstorm manually and plots tilled and cultivated again.

Table 2: Antecedent soil moisture content (%, weight basis) as affected by land use, rainfall intensity and antecedent soil moisture conditions under simulated rainfall conditions

Location	Land Use				Rainfall Intensity			Antecedent Soil Moisture Condition			
	Barren	Cultivated	Grassland	Forest	Low	Medium	High	Dry	Field capacity	Wet	Mean
Ballowal Saunkhri–I	17.6	19.7	17.9	17.6	18.0	18.2	18.4	8.0	16.9	29.6	**18.2**
Ballowal Saunkhri–II	17.5	18.5	18.7	18.4	17.6	18.7	18.5	8.4	17.9	28.5	**18.3**
Kokowal Majari	17.8	18.9	17.4	17.9	17.5	18.4	18.1	5.7	17.9	30.3	**18.0**
Saleran	17.4	18.0	19.3	17.3	17.2	18.7	18.0	8.2	17.5	28.3	**18.0**
Mean	17.6	18.8	18.3	17.8	17.6	18.5	18.3	7.6	17.6	29.2	

CD (0.05) Land Use = 0.44, Rainfall intensity = 0.31, Antecedent soil moisture condition = 0.33, Location = NS
Location X Land Use = 0.88, Location X Intensity = NS, Location X Antecedent Soil Moisture Condition = 0.65

Natural Rainfall Studies

Natural rainall studies were conducted at two locations Ballowal Saunkhri – I and Ballowal Saunkhri - II under four land uses viz. barren, cultivated, grass and forest with three replications under each. Plots measuring 5 m x 1.5 m were prepared with an average slope of 4 %. The duration of different rainstorms varied from 45 to 375 minutes. The amount of rainfall for different storms varied from 14.2 to 96.0 mm. The maximum 30-minute and 15-minute rainfall intensities varied from 18.4 to 76.0 and 26.0 to 120.0 mm h^{-1}, respectively. After each rainstorm, the depth of runoff water in drums measured in depth units was converted to total runoff volume. A 2-litre representative runoff sample was collected in PVC containers from each collecting reservoir after stirring its contents thoroughly. The collecting reservoirs were emptied and cleaned after each rainstorm manually and plots tilled and cultivated again. Automatic recording rainguage was used for getting data on rainfall amount and intensity.

RESULTS AND DISCUSSION

Runoff and Soil Loss Under Natural Rainfall Conditions

Runoff (%) was significantly affected by location and land use (Table 3). Runoff was significantly higher at Ballowal Saunkhri – I as compared to

Table 3: Runoff (%) for natural rainfall conditions

Location	Barren	Culti-vated	Grass-land	Forest	Mean
Ballowal Saunkhri–I	50.1	50.3	43.6	41.9	46.5
Ballowal Saunkhri–II	38.0	36.1	32.7	31.9	34.7
Mean	44.1	43.2	38.2	36.9	

CD (0.05) Land use = 2.4, Location = 1.0, Location x Land Use = 1.4

Ballowal Saunkhri – II location. Runoff was lower under grassland and forest land uses as compared to barren and cultivated land uses.

Soil sediment yield was higher at Ballowal Saunkhri – II as compared to Ballowal Saukhri – I (Table 4). Among different land uses it was in the order of Barren > cultivated > grassland > forest land use.

Table 4: Soil sediment yield (t ha^{-1}) under natural rainfall conditions

Location	Barren	Culti-vated	Grass-land	Forest	Mean
Ballowal Saunkhri–I	28.9	25.2	21.5	18.6	23.6
Ballowal Saunkhri–II	32.4	29.1	23.6	20.6	26.4
Mean	30.6	27.1	22.6	19.6	

CD (0.05) Land use = 1.3, Location = 1.2, Location x Land Use = 1.9

Runoff And Soil Loss Under Simulated Rainfall Conditions

Runoff was significantly affected by location, land use as well as antecedent soil moisture conditions (Table 5). The percent runoff was observed to be highest at Kokowal Majari (28.3) followed by Ballowal Saunkhri-I (21.8), Ballowal Saunkhri-II (11.3) and Saleran (10.4). Under different land uses, forest soils were having the lowest runoff (16.2 %). The difference of runoff percent under other three land uses was non-significant and it varied from 18.1 to 18.8. Runoff increased with increase in rainfall intensity at all the locations. The mean values of percent runoff were observed to be 6.1, 17.3 and 30.5

Table 5: Runoff (%) at four locations as affected by land use, rainfall intensity and antecedent soil moisture under simulated rainfall conditions

Location	Land Use				Rainfall Intensity			Antecedent Soil Moisture Condition			
	Barren	Cultivated	Grassland	Forest	Low	Medium	High	Dry	Field capacity	Wet	Mean
Ballowal Saunkhri – I	20.8	27.9	20.7	17.5	7.3	20.4	37.6	12.6	24.2	28.5	**21.8**
Ballowal Saunkhri –II	10.2	9.9	14.4	10.8	0.5	10.7	22.8	5.2	12.8	15.9	**11.3**
Kokowal Majari	31.4	26.4	28.5	27.0	14.9	28.1	41.9	15.1	31.9	37.9	**28.3**
Saleran	9.8	10.8	11.5	9.5	1.5	10.0	19.7	4.0	10.9	16.2	**10.4**
Mean	18.1	18.8	18.8	16.2	6.1	17.3	30.5	9.2	20.0	24.6	

CD (0.05) Land Use = 0.59, Rainfall Intensity = 0.92, Antecedent Soil Moisture Condition = 0.38, Location = 0.68
Location X Land Use = 1.19, Location X Intensity = 1.84, Location X Antecedent Soil Moisture Condition = 0.77

Table 6: Soil loss (t ha^{-1} storm^{-1}) at four locations as affected by land use, rainfall intensity and antecedent soil moisture under simulated rainfall conditions

Location	Land Use				Rainfall Intensity			Antecedent Soil Moisture Condition			
	Barren	Cultivated	Grassland	Forest	Low	Medium	High	Dry	Field capacity	Wet	Mean
Ballowal Saunkhri-I	1.94	1.46	1.55	1.32	0.19	1.34	3.21	0.85	1.77	1.84	1.58
Ballowal Saunkhri-II	1.90	1.71	1.69	1.35	0.03	1.23	3.72	1.25	1.79	1.95	1.67
Kokowal 1.41 Majari	1.29	1.24	1.16	0.20	1.06	2.58	1.01	1.33	1.48	1.28	
Saleran	1.68	1.60	1.54	1.32	0.10	1.28	3.22	1.37	1.47	1.77	1.54
Mean	1.75	1.52	1.50	1.29	0.13	1.23	3.18	1.12	1.59	1.77	
CD (0.05)	0.07	0.03	0.03	0.06							

Location X Land Use = 0.12 Location X Intensit = 0.07 Location X Antecedent Soil Moisture Condition = 0.07

percent for rainfall intensities of 25, 50 and 75 mm h^{-1}, respectively. The increase in runoff was about three times when rainfall intensity was doubled (from 25 to 50 mm h^{-1}) and was about 5 times when rainfall intensity was increased three times (from 25 to 75 mm h^{-1}). Under low rainfall intensity conditions, the mean values of runoff were very low at all locations except Kokowal Majari because at this rainfall intensity almost no runoff was observed under dry and field capacity soil moisture levels. The runoff was observed to be quite low under dry conditions (9.2 %) as compared to field capacity (20.0%) and wet (24.6 %) soil moisture conditions.

Soil sediment yield was significantly affected by location, land use, rainfall intensity and antecedent soil moisture conditions (Table 6). Mean sediment yield was significantly lower at Kokowal Majari (1.28 t ha^{-1}) as compared to other locations. Among different land uses, barren soils were having significantly higher sediment yield per storm (1.75 t ha^{-1}) as compared to other land uses with forest soils having minimum soil loss (1.29 t ha^{-1}). The sediment yield increased with increase in rainfall intensity and it was observed to be 0.13, 1.23 and 3.18 t ha^{-1} per storm under low, medium and high rainfall intensity conditions, respectively. Sediment yield also increased with increase in antecedent soil moisture content.

Simulated vs. Natural Rainfall Evaluations

Significant positive correlation (r^2 = 0.75) was observed between runoff obtained under natural and simulated rainfall conditions (Fig. 2). Similarly significant positive correlation (r^2 = 0.77) was observed between soil sediment yield obtained under natural and simulated rainfall conditions (Fig. 3). The results indicate that for qualitative or semi-quantitative soil erosion studies this type of micro-sprinkler based rainfall simulator may be used.

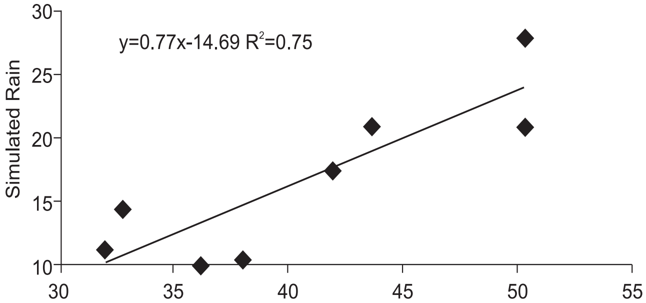


Fig. 2: Runoff (%) under simulated vs. natural rainfall conditions

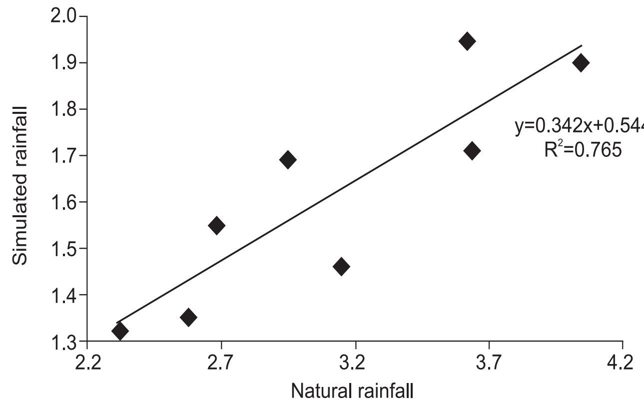


Fig.3: Soil sediment yield per storm under simulated vs. natural rainfall condition

SUMMARY AND CONCLUSIONS

This rainfall simulator can easily be fabricated, calibrated and used with minimal skills under field conditions. The total weight of the simulator excluding water tanker, generator and water pump may be around 15-20 kg depending upon the material used and total cost may vary from Rs. 2500 to 5000. Folding pipes can be used for easy portability. Aluminum or PVC pipes may further reduce the weight. The system may be used from 1 m^2 plots to even up to 5 m^2 plots and rainfall intensity can be varied from 20 to 100 mm h^{-1}. Although rainfall simulator experiments cannot replace the natural rainfall field experiments but for preliminary studies on soil conservation measures, hydrologic studies etc. this type of rainfall simulator may be used with confidence.

REFERENCES

Frauenfeld B and Truman C. 2004. Variable rainfall intensity effects on runoff and interrill erosion from two coastal plain ultisols in Georgia. *Soil Sci.* **169**: 143-54.

Hudson N W.1993 *Field measurement of soil erosion and runoff*. FAO Soils Bulletin 68, Rome pp 139.

Kohli A and Khera K L. 2008. A micro-sprinkler based portable rainfall simulator for hydrologic studies. *Indian J. Soil Cons.* **36**: 67-69.

Morgan R P C.1995. *Soil Erosion and Conservation*. 2nd Edition. Longman Group Limited, UK.

Shrivastava P K and Das G. 1998. A review of rainfall simulators for soil erosion studies. *Indian J Soil Cons* **26**: 26-80.

Singh M J and Khera K L. 2009. Nomographic estimation and evaluation of soil erodibility under simulated and natural rainfall conditions. Land Degradation Dev. **20**: 471-480.

Journal of Soil and Water Conservation, Vol. 11, No. 2, pp 29–38 (2012)
Received: 19 November 2011; Accepted: 23 May 2012

Morphometric Analysis of Moolbari Watershed in Sub-Himalayan Region of India: A Remote Sensing and GIS Approach

A K MISHRA[1] AND K S RAWAT[2]

ABSTRACT

Remote sensing and GIS techniques are being extensively used since quite some time in watershed related studies as very effective tools in determination of the basin geometry i.e, morphpmetric analysis or quantitative description of watershed morphologic characteristics. In the present study, an attempt has been made to use the capabilities of GIS (ESRI-Arc-View) to quantify the morphology of the Moolbari Watershed. The watershed was studied for its size and shape, drainage and relief characteristics to develop a thorough understanding of the watershed for future planning to avert the land degradation. Twenty seven morphometric parameters of the Moolbari Watersheds situated in Mashobra block of Shimla District (Himachal Pradesh), have been quantified. They comprise: Stream Order, Stream Length (L_u), Mean stream length (L_{sm}), Stream Length ratio (R_L), Bifurcation ratio (R_b), Mean bifurcation ratio (R_{bm}), Length of main channel (L_m), Drainage Density (D_d), Length of overland flow (L_g), Basin length (L_b), Basin perimeter (P), Fineness ratio (R_{fn}), Basin/drainage area (A), Constant of channel maintenance (C), Stream frequency (F_s), Circulatory ratio (R_c), Elongation ratio (R_e), Form Factor (R_f), Unity shape factor (R_u), Watershed shape factor (W_s), Drainage Texture (R_t), Total relief (H), Relief ratio (R_h), Relative relief (R_p), Ruggedness number (R_n), Shape index (S_w),Watershed slope (%) and Hypsometric Integral. On the basis of the morphometric studies it was concluded that the hydrologic response of the Moolbari watershed is dependant on surface characteristics significantly due to its being a "Fan Shaped" one. The watershed is in active stage of degradation. Its quantification is being done based on the field measurements and recording of soil erosion. The result suggests that the ratio between cumulative stream length and stream order is constant throughout the successive orders of the basin.

Key words: Morphometric analysis, GIS, hilly watershed, Remote Sensing, Sub-Himalayan Region

INTRODUCTION

Watershed development implies conservation and management of natural resources on the watershed basis. A watershed is considered as the surface area drained by a part or the totality of one or several given water courses and can be taken as a basic erosional landscape element where land and water resources interact in a perceptible manner (Hortan, 1932, Hortan, 1945 and Kumar et al., 2000). Watersheds are studied well for developing their management plans and morpohometric parameters help the planners in achieving the desired goals. Evaluation of the morphometric parameters requires preparation of drainage map, ordering of various streams, measurement of the catchment area and perimeter, channel length, drainage density and a host of other parameters which help in understanding the nature of the drainage basins. Remote sensing and Geographical Information System (GIS) techniques are being extensively used since quite some time in watershed related studies as very effective tools in determination of the basin geometry i.e, morphpmetric analysis or quantitative description of watershed morphologic characteristics (Sebastian et al., 1995; Nag, 1998; Vijith & Satheesh, 2006). More recently, Narendra and Nageswara Rao

1-2 Senior Scientist (Soil and Water Conservation Engineering), and Research Associate, respectively; SAC-ISRO Project on 'Space Technology Applications for Assessment and Sustainable Utilization of Water Resources". Water Technology Centre, Indian Agricultural Research Institute, New Delhi -110012. Tel: 91 11 25846790, Fax.: 91 11 25848380, Email: akm_wtc@iari.res.in. ks_rawat2002@yahoo..com

(2006) have carried out morphometric analysis of Meghadrigedda watershed, Andhra Pradesh, using GIS and Resourcesat-I data, while, Vijith and Satheesh (2006) used GIS analysis techniques to evaluate the linear, relief and aerial morphometric parameters of two major upland sub-watersheds of Meenachil River in Kerala for future developmental planning of the watersheds.

Watershed management is the process of formulation and carrying out a course of action involving modification of the natural system of, watershed to achieve specified objectives of resources conservation and management. It implies the proper use of land and water resources of a watershed for optimum production with minimum hazard to natural resources. Remote Sensing and GIS techniques have emerged as powerful tools for watershed management programmes. Consequently remote sensing and GIS techniques are being extensively used since quite some time in watershed related studies as very effective tools in determination of the basin geometry i.e, morphpmetric analysis or quantitative description of watershed morphologic characteristics (Sebastian et al., 1995; Nag, 1998; Vijith and Satheesh, 2006) etc. as well as planning and management tools. The quantitative analysis of drainage system is an important aspect of characterisation of watershed (Strahler, 1964). Earlier studies indicated a relationship between cumulative stream length and stream order and also bifurcation ratio, drainage density, texture ratio and relief ratio for assessing the level of soil erosion (Nautiyal, 1994, Chaudhary and Sharma, 1998). Misra et al. (1984) studied the effect of different topo-elements such as area, drainage density, form factor etc.

Millar (1953) and Morisawa (1958) highlighted the use of watershed topographic parameters and their effects on the hydrologic characteristics of the watersheds or watershed hydrologic response. Singh (2006) used the drainage morphological approach to develop the water resources of Sur river catchment in India. In the present study, the Moolbari experimental watershed (MEW) situated near Shimla in Himachal Pradesh, falling in the Sub-Himalayan Region of India, has been considered for morphometric analysis (Fig. 1). This watershed was taken as a representative sample for the studies, which were supposed to be used by a larger user group for drawing meaningful inferences for other similar watersheds located in the Sub-Himalayan region identified by the Department of Science and Technology, G.O.I.

Fig. 1. Location map of Moolbari Experimental Watershed in Sub-Himalayan Region of India near Shimla in H.P. State (India)

METHODOLOGY

Study Area

The study area was situated near Shimla, the state capital of Hmachal Pradesh, Inida. The selected watershed was Moolbari Experimental Watershed (a watershed adopted by the DST, Min. of Science and Technology under its Bio-Geodatabase Development Programme under NRDMS), in which the measurements were later on continued by the Water Technology Centre and SAC (ISRO). The watersheds is enveloping the Mashobara Block, and a small portion of Shimla District of Himachal Pradesh, which lies between 31º7'-30"-31º15' N latitudes and 77°00'-77°7'30" E longitudes. The total area of the watershed is approximately 13.9 sq km with a perimeter of 16297.27 m. This information was generated using Arc-View ver. 9.3 by a projected map of the watershed in WGS-84 projection system of the SOI topo-sheet No. 53 E/15 NW. The watershed delineation was carried out using SOI topo-sheet No. 53E/4/NW of 1 :50,000 scale (Fig. 2).

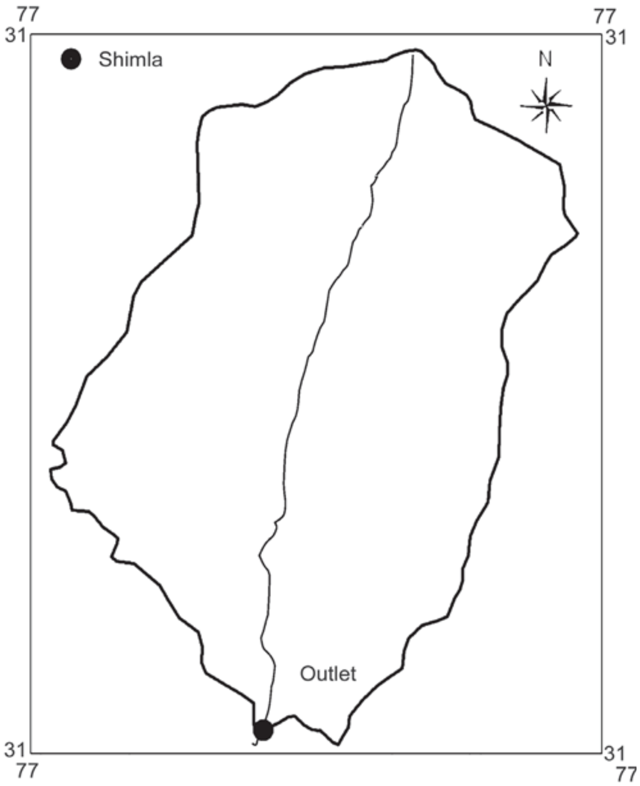


Fig. 2 Delineated boundary map of Moolbari experimental watershed in Sub-Himalayan Region

The climatic characteristics of the watershed are of tropical monsoon type. The block experiences oppressive cold with minimum temperature going below freezing point in the winter while summer temperatures rises up to 25°C. The relative humidity in rainy and summer seasons rises as high as 98 % with minimum up to 55 %.

Data used

Remote sensing data acquisition and preparation

LANDSAT data acquired on February, 18, 1997 was used with Survey of India (SOI) topo-sheets No. 53E/4/NW of 1:50,000 scale as collateral data. LANDSAT 7ETM$^+$ (path/row: 231/67) was acquired on 27 June 2009. The specifications of remote sensing data from the satellite LANDSAT-7 ETM$^+$ as used in the present study have been presented in Table 1. The image was converted to apparent reflectance through an image-based calibration method using the gain, offset, and sun elevation angle. This image was geometrically rectified using control points

Table 1: Specifications of LANDSAT-7 ETM$^+$ remote sensing data of satellite using in the present study

Spectral bands	Spatial resolution	Spectral resolution
Band	ETM+	ETM+
1 (Blue)	30 m	0.45-0.52 µm
2 (Green)	30 m	0.53-0.61 µm
3 (Red)	30 m	0.63-0.69 µm
4 (Near IR)	30 m	0.78-0.90 µm
5 (Middle IR)	30 m	1.55-1.75 µm
6 (Thermal IR)*	60 m	10.4-12.5 µm
7 (Middle IR)	30 m	2.09-2.35 µm
8 (Panchromatic)**		0.52-0.90 µm

collected from SOI topographic maps (topo-sheets No. 53E/4/NW of 1:50,000) so that the image can be accurately linked to ground reference data and other ancillary data, such as soil type map and DEM data. The nearest-neighbourhood resampling technique was used and a root-mean-square error with less than 0.5 pixels was obtained during the geometric rectification of the remote sensing image. The field data collection and ground truth work was conducted in August 2009 with help of hand held GPS device (Garmin (eTrexH), 15 meter accuracy).

The watershed boundary and the associated drainage network were delineated form the Survey of India topo-sheets of 1:50,000 scale, digitized using the ArcGIS software (Ver. 9.3) and the attributes were assigned to create a digital database (Fig. 1 and 2). The watershed was delineated manually from the database based on the established principles (Fig 2). A 5 m contour map of the watershed was generating using the algorithms of Arc-GIS (ver. 9.3) after digitizing the base map (SOI topo-sheet of 1:15,000 scale which has a 10 m contour interval (C.I.)) and a drainage map was also developed thereafter (Figs. 3 and 4).

Various other thematic layers of the watershed were generated such as DEM, slope and aspect maps etc. (Fig. 5, 6 and 7 respectively) for the analysis.

The soil information generated by point scale survey and data analysis in the Soil Physics Laboratory of the Water Technology Centre, Indian Agricultural Research Institute, New Delhi and supported by the data generated by the NBSSLUP, Delhi Centre have been used to prepare textural soil map of the Moolbari watersheds (Fig. 8).

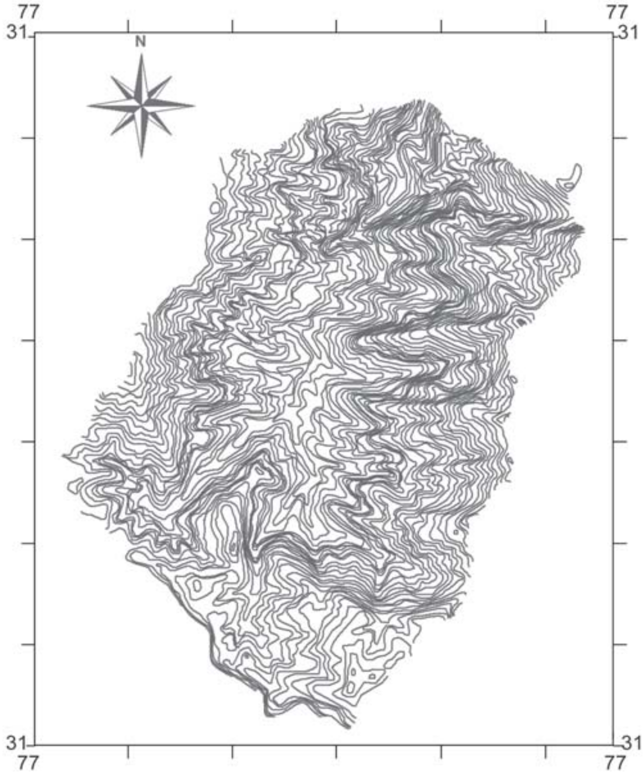


Fig. 3 Contour map of Moolbari experimental watershed, Shimla, H.P. (India)

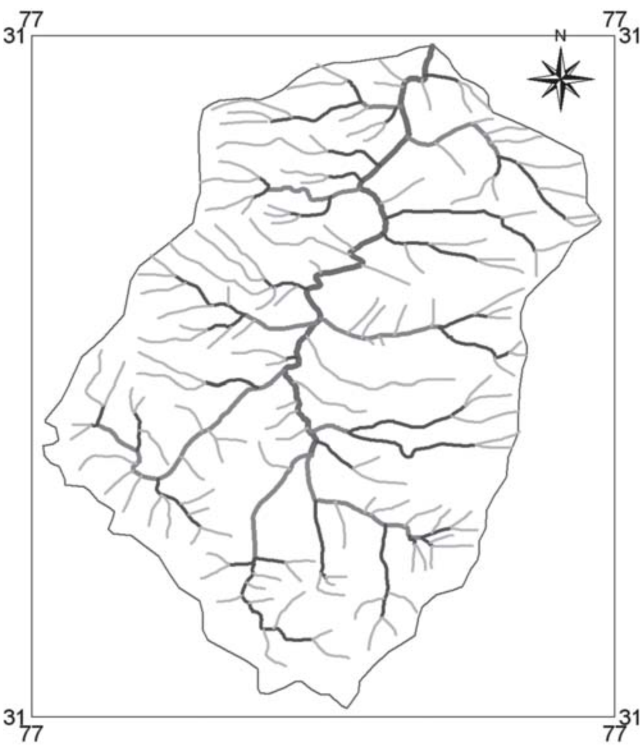


Fig. 4. Drainage map of Moolbari experimental watershed in Sub-Himalayan Region of India near Shimla in H.P. state

Correction and upgradation of the Drainage Pattern of the Watershed

The LANDSAT image was geometrically rectified with respect to the Survey of India (SOl) topographical maps on 1 : 50,000 scale. The drainage pattern that was initially derived from SOI topo-sheets was updated using Linearly Stretched FCC (Fig. 5). The updated drainage pattern watershed was exported to ILWIS 3.4 software for morphometric analysis. The drainage density, stream frequency, texture ratio and basin shape (form factor, circularity ratio. elongation ratio, etc.) were estimated as per the formulae given in Table 1 (Strahler, 1964). The infor-mation about area, perimeter, stream length and number of stream was obtained from the watershed layers and basin length was calculated from stream length. Bifurcation ratio was calculated from the number of streams. The other parameters were calculated from area, perimeter, basin length and stream length.

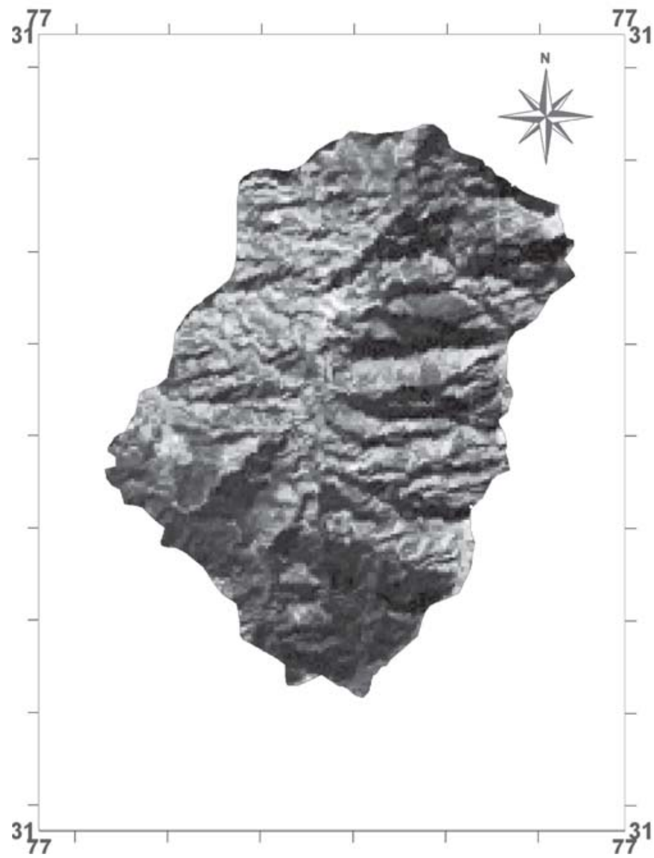


Fig. 5. LANDSAT FCC image of Moolbari experimental watershed, Shimla (H.P.), India

Estimation of Morphometric Parameters

Using the hierarchical ranking method (Strahler, 1964) the stream orders were assigned and the digital database was updated with stream order as one of the attribute data for the drainage layer (Figure 4). The information on watershed area, perimeter, basin length, relief, length of streams, stream order was then used to compute the morphometric parameters of the watershed using the standard formulae (Horton,1932, 1945; Miller, 1953; Schumm, 1956; Strahler, 1964; Chopra *et al*., 2005; Singh, 2006). Some of the morphometric parameters were estimated from the measured quantities using the formulae and references as given in table 1 viz., stream order, stream length (L_u), km; mean stream length (L_{sm}), stream length ratio (R_L), bifurcation ratio (R_b), mean bifurcation ratio (Rbm), length of main channel (L_m), km, drainage density (D_d), length of overland flow(L_g), basin length (L_b) km, basin perimeter (P) Km, fineness ratio (R_{fn}), basin/drainage area (A), constant of channel maintenance (C), stream frequency (F_s), circulatory ration (R_c), elongation ratio (R_e), form factor (R_f), unity shape factor (R_u), watershed shape factor (W_s), drainage texture (R_t), total relief (H), relief ratio (R_h), relative relief (R_p), ruggedness number (R_n), shape index (S_w), watershed slop (%) and hypsometric integral. The parameters namely bifurcation ratio, drainage density, stream frequency, texture ratio, form factor, circularity ratio and elongation ratio are also termed as erosion risk assessment parameters were used during prioritization of sub-watersheds for conservation measures.

RESULTS AND DISCUSSION

The results of the morphometric analysis are presented in Table 2. The ranking of streams into different orders is the first step in drainage basin

Table 2: General formulae for estimation of morphometric parameters for watershed characterization their sources

S.No.	MorphometricParameters	Formula	Reference
1.	Stream Order	Hierarchical	Strahler (1964)
2.	Stream Length, Km (L_u)	Length of stream	Horton (1945)
3.	Mean stream length (L_{sm})	$L_{sm}=L_u/N_u$Where, Lu=total stream length of order'u 'Nu=total number of stream segments of order'u'	Strahler (1964)
4.	Stream Length ratio (R_L)	$R_L=L_u/L_{u-1}$Where, Lu=total stream length of order'u' L_{u-1}=total no of stream segments of its next lower order	Horton (1945)
5.	Bifurcation ratio (R_b)	$N_b=N_u/N_{u+1}$Where, Nu=total stream length of order'u' N_{u+1}=Number of segments of next higer order	Schumn (1956)
6.	Mean bifurcation ratio (R_{bm})	Average of bifurcation ration of all orders	Strahler (1957)
7.	Lenth of main channel (L_m) Km	Length along longest water course form the outflow point of designated sub-basin to the upper limit of catchment boundary	Horton (1945)
8.	Drainage Density (D_d)	$D_d=L_u/A$Where, D_d= Drainage Density Lu=Total stream length of all orders, km and A=Area of the Basin, km^2	Horton (1932)
9.	Length of overland flow (L_g)	$Lg=1/D_d*2$Where, L_g=Length of Overland flowand D_d=Drainage Density	
10.	Basin length (L_b) Km	Distance between outlet and farthest point on basin boundary	
11.	Basin perimeter (P) Km	Length of watershed divide which surround the basin	
12.	Fineness ratio (R_{fn})	$R_{fn}=L_b/P$, Where, L_b=Basin length, kmP=Basin perimeter, km	Melton (1957)
13.	Basin/drainage area (A)	Area enclosed within the boundary of watershed divide	
14.	Constant of channel maintenance (C)	$C=1/D_d$, D_d =Drainage Density, km/km^2	
15.	Stream frequency (F_s)	Fs=Nu/AWhere, Fs=Stream Frequency Nu=total number of stream segments of all order A=Area of the Basin, km^2	Horton (1932)
16.	Circulatory ration (R_c)	$R_c=2*pi*A/P^2$ Where, Rc=Circularity Ratio, Pi=Pi value i.e., 3.14A=Area of the basin, km^2	Miller (1953)
17.	Elongation ration (R_e)	$R_e=[(4.A/pi)]^{1/2}/L_b$A=Area of the basin,km^2 Pi=Pi value i.e.,3.14L_b=Basin length	Schumm (1956)

S.No.	MorphometricParameters	Formula	Reference
18.	Form Factor (R_f)	$R_f=A/L_b^2$A=Area of the basin,km^2 andL_b=Basin length	Horton (1932)
19.	Unity shape factor (R_u)	$R_u=L_b/(A)^{1/2}$$L_b$=Basin lengthA=Area of the basin	
20.	Watershed shape factor (W_s)	$W_s=L_m/D_c$Where, $D_c= 4A/ð^{1/2}$	Wu et. al.(1964)
21.	Drainage Texture (R_t)	$R_t=N_u/P$	Horton (1932)
22.	Total relief (H)		
23.	Relief ration (R_h)	$R_h=H/L_b$	Schumm (1956)
24.	Relative relief (R_p)	$R_p=H/P$	
25.	Ruggedness number (R_n)	$Rn=H*D_d$	Melton (1957) and Strahler (1958)
26.	Shape index (S_w)		
27.	W/S slope (%)		

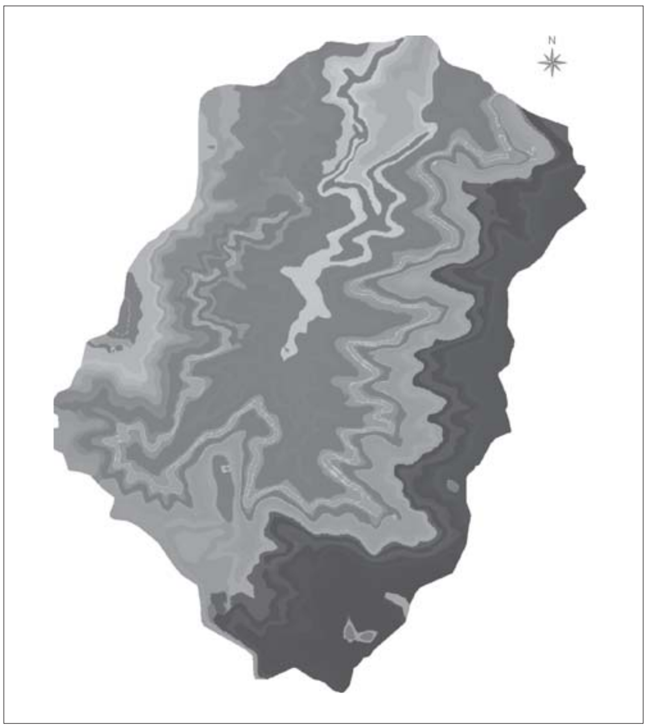


Fig. 6. DEM generated from the 10 m contour map of Moolbari experimental watershed, Shimla (H.P.), India

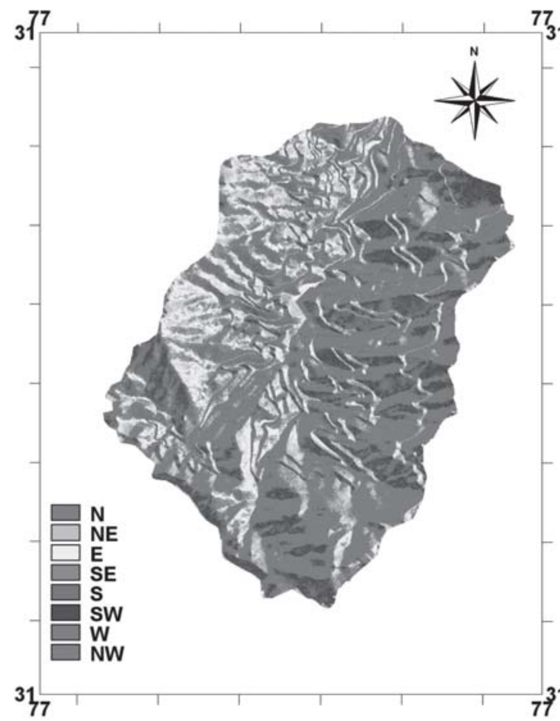


Fig. 7. Aspect map of Moolabri experimental watershed, Shimla (H.P.), India

analysis and was carried out based on the hierarchical method proposed by Strahler (1964). A perusal of Table 2 indicates that there are 187 stream segments of different orders and the Moolbari watershed can be designated as a fourth order watershed having sub-dendritic drainage pattern. The order of streams is closely governed by the slope conditions. Higher the order of streams, lower is the slope value while lowest order of streams exhibit highest slope conditions. This has corroborated the fact that lower the stream order higher is the number of streams (Singh, 2006). The plot of the logarithms of the number of streams of a given order against the order as shown in figure 9, show a linear relationship which is in accordance with the law proposed by Horton (1945). The fitted equation of the most appropriate trend line the form of which is given below:

$$Y = -0.5594 X + 2.6764 \quad ....(1)$$

$$R^2 = 0.9967$$

This can be rewritten as:

$$Log_{10} N_n = -0.5594 N_u + 2.6764 \quad ....(2)$$

$$R^2 = 1$$

where N_n is the number of streams in km and N_u is the order of streams.

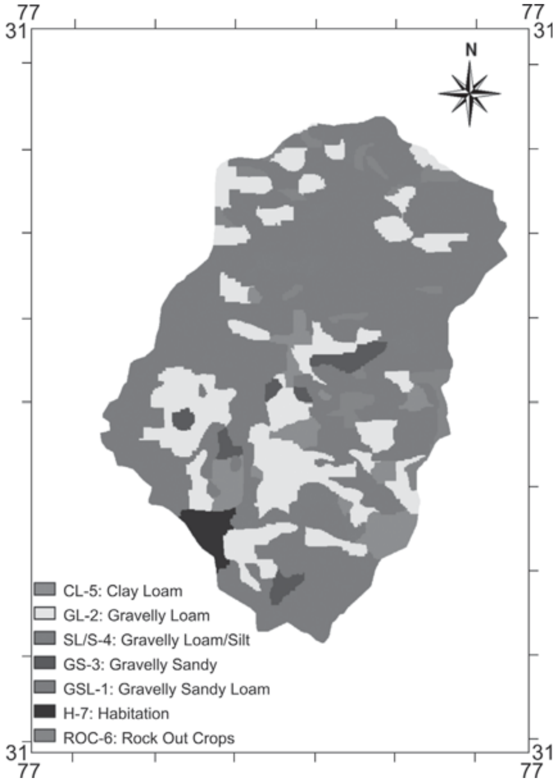


Fig 8. Soil texture map of Moolabri experimental watershed, Shimla (H.P.) India

The above relationship indicated that there are large numbers of streams of lower order which get reduced as the stream order increases to three. Lower stream length of the order 2 and 3 represents the fact that the watershed is having very steep gradient to certain length which makes it a leaf shaped one to a certain extent. Later on the increase in the number of streams of higher order indicated that the watershed has assumed a small gradient and has become a fan shaped. Thus it is a mixture of highly steep and mild watershed characteristics. Moolbari watershed has the main drainage channel *Bari Ka Khadd* that starts almost from the midway while one traverses from one end to the other.

The stream length (N_L) is the total length of streams in a particular order. Generally, the total length of stream segments in the first order is highest and decreases as the stream order increases. A relationship between the logarithms of Stream Length (N_L) Vs. Stream Order (N_u) has also been plotted. The fitted equation of the most appropriate trend line is given below:

$$Y = 0.22 X^3 - 0.7258 X^2 - 1.3077 X + 6.425 \quad ....(3)$$

$$R^2 = 1$$

This can be rewritten as:

$$\text{Log}_{10} N_L = 0.22 N_u^3 - 0.7258 N_u^2 - 1.3077 N_u + 6.425 \quad ...(4)$$

$$R^2 = 1$$

where L_u is stream length and N_o is stream order, respectively.

Using this equation, it is possible to find out the length of streams of a given order for other estimations in the watershed. The plot of the logarithm of stream length of a given order versus stream order (Figure 10) showed a curvilinear pattern indicating that the watershed has not developed over a homogeneous rock material subjected to weathering and erosion (Narendra & Nageswara Rao, 2006). The mean stream length of a channel is a dimensional property and reveals the characteristic size of drainage network components and its contributing basin surfaces (Strahler, 1964). Table 2 indicates that the mean stream length for the

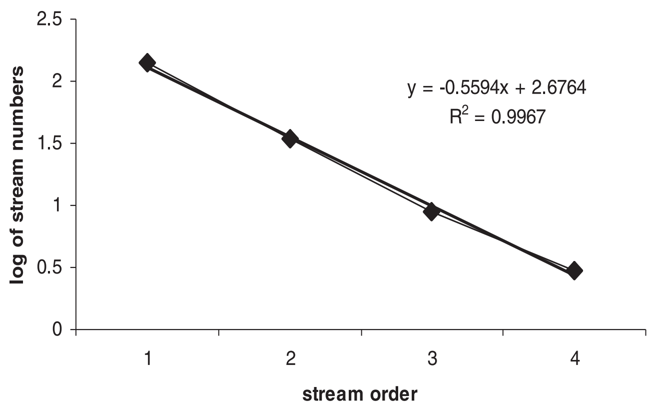


Fig. 9. The relationship between stream number (N_n) (logarithmic scale) vs. stream order (N_u) of Moolbari experimental watershed, Shimla (H.P.), India

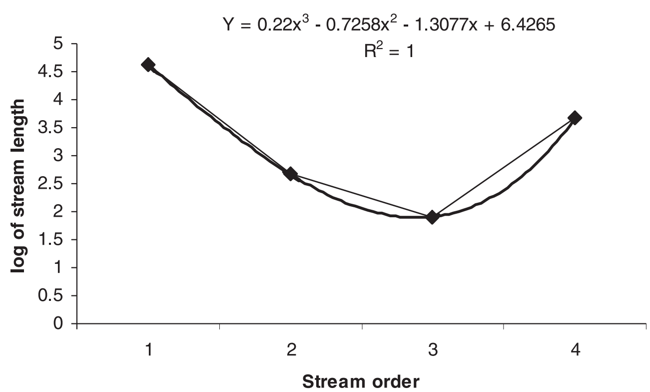


Fig. 10. The relationship between stream length (N_L) (logarithmic scale) vs. stream order (N_u) of Moolbari experimental watershed, Shimla (H.P.), India

Table 3: Morphometric analysis of Moolbari watershed, Shimla (H.P.), India

S. No.		Morphometric Parameters		
1.	Stream Order, No. & Length	Hierarchical rank	No.	Length (Km)
		I^{st} Order	141	41.029
		II^{nd} Order	34	0.466
		III^{rd} Order	9	0.082
		IV^{th} Order	3	4.612
		Total	**187**	**46.188**
2.	Mean stream length (Lsm), kM		0.291	
			0.014	
			0.009	
			1.537	
3.	Stream Length ratio (RL)		88.094	
			5.707	
			0.018	
4.	Bifurcation ratio (Rb)		0.241	
			0.265	
			0.333	
5.	Mean bifurcation ratio (Rbm)		0.280	
6.	Length of main channel (Lm) , Km		7.134	
7.	Drainage Density (Dd)		0.343	
8.	Length of overland flow (Lg)		1.459	
9.	Basin length(Lb) Km		0.581	
10.	Basin perimeter P) Km		16.297	
11.	Fineness ratio (Rfn)		0.036	
12.	Basin/drainage area (A), Km^2		134.773	
13.	Constant of channel maintenance (C)		2.918	
14.	Stream frequency (Fs), Km^{-2}		1.388	
15.	Circulatory ration (Rc)		6.373	
16.	Elongation ration (Re)		147.660	
17.	Form Factor (Rf)		398.768	
18.	Unity shape factor (Ru)		0.002	
19.	Watershed shape factor (Ws)		0.021	
20.	Drainage Texture (Rt), Km^{-1}		11.474	
21.	Total relief(H)		724.400	
22.	Relief ration (Rh)		1246.054	
23.	Relative Relief (R_p)		44.449	
24.	Ruggedness Number (R_n)		248.259	
25.	Shape Index (S_w)		0.378	
26.	Watershed Slope (%), S		537.496	

watershed ranges from 0.00906 to 1.53. Such lower values of stream length are characteristics of leaf shaped watersheds which will result into the higher peak flows at shorter durations. The mean stream length of any given order is greater than that of lower order. However in the present study there was a deviation from the trend which may be due to variation in slope and topography. The stream length ration was very high for first order streams (88.09) while very low for fourth order stream (0.017). This can also be used as a model for sub-Himalayan region for a limited extent to study the drainage characteristics although the drainage is unique characteristics of every watershed thereby a general understanding can be made regarding the watersheds of sub-Himalayan regioin due to the similar geologic and climatologic nature.

The bifurcation ratio (R_b) is an index of relief and dissections (Horton, 1945) and lower values are characteristics of structurally less disturbed watersheds without any distortion in drainage pattern (Nag, 1998). In the present study the mean bifurcation ratio of 0.28 indicates the absence of strong structural control on the drainage pattern and that the watershed is structurally less disturbed.

The relief ratio (R_h) is the ratio of the maximum relief to the horizontal distance along the longest dimension of the basin parallel to the principal drainage line (Schumm, 1956). It is a measure of the overall steepness of a drainage basin and is an indicator of the intensity of the erosion processes operating in the basin. Its value normally increases with decreasing drainage area and size of a given drainage basin. For Moolbari watershed the value of R_h was found to be 1246.0544. Very high R_h has indicated that the watershed is having a high slope as well as is highly prone to soil erosion consequent upon high rainfall intensities.

The drainage density (D_d) expresses the closeness of spacing of channels and is affected by factors which control the characteristic length of streams like resistance to weathering, permeability of rock formation, climate, vegetation, etc. It also provides a numerical measurement of land dissection and runoff potential. In general, low value of D_d is observed in regions underlain by highly permeable material with vegetative cover and low relief. High drainage density is observed in regions of weak and impermeable subsurface material with sparse vegetation and mountainous relief (Chopra *et al*., 2005). Smith (1950) has classified drainage density into five different textures i.e. very coarse (<2), coarse (2-4), moderate (4-6), fine (6-8) and very fine (>8).

The watershed has a very low drainage density of 0.3427 km/km^2 but with strong and impermeable subsurface materials, dense vegetation, and mountainous relief with moderately low to medium runoff potential. According the Smith (1950) criterion the Moolbari watershed has been ranked as having a very coarse drainage density.

As shown in table 2, that the Moolbari watershed has very high values of Form Factor (398.77), Elongation Ratio (147.66) and a Circulatory Ratio (6.37). This indicates that the watershed is elongated with sharper peak flow for short duration. Flood flows of such basins are very difficult to manage than those of a circular basin (Nautiyal, 1994). Ruggedness number (R_n) of 248.259 indicates that the area has extremely high undulating and rugged topography. It also implies that the area is prone to severe soil erosion.

The stream frequency (F_s) is closely related to the permeability, infiltration capacity and relief. The value of F_s for the watershed was found to be 1.39 indicating low relief and high infiltration of the bed rock as reported by Vijith and Satheesh (2006). As a consequence, despite having sharper peak flow, the runoff potential of the watershed is low which is further supported by the fact that it does not have a very high drainage density. This means that the watershed is a leaf shaped watershed having steep gradients and less elaborate drainage network. The parent material being the rocks; the watershed is not bisected by the drainage despite the heavy rainfall as expected; rather the narrow deep gorges have become the characteristics feature of the drainage network. High value of Drainage Texture (11.47) suggests that there is adequate scope for surface and ground water development (Singh 2006).

CONCLUSIONS

Remote sensing and GIS techniques were used to study the morphpmetric of Moolbari watershed Shimla (H.P.). On the basis of the morphometric studies it was concluded that the hydrologic response of the Moolbari watershed is dependant on surface characteristics due to its being a leaf shaped one. The watershed is in active stage of degradation. The stream length ratio was very high for first order streams (88.09) while very low for fourth order stream (0.017). It has very high values of Form Factor, Elongation Ratio as well as Circularity Ratio indicating that the watershed is elongated with sharper peak flow for short duration. This fact has been corroborated with low drainage density also. The mean bifurcation ratio indicates the absence of strong structural control on the drainage pattern and that the watershed is structurally less disturbed. In general the watersheds of Sub-Himalayan region are characterized for having very rugged terrain which result into sharper peak of relatively short duration. Such high peak flows are much difficult to manage. However, due to the presence of dense forests, decayed biomass and high drainage texture the effect of surface flow usually gets moderated. So much so that there is low or no surface flow and all the rainfall either gets intercepted or seeps into the ground flow so as to join the underground water through base flow or inter flow.

In the light of above it can be safely concluded that the watershed in the study represents the Sub-Himalayan watershed in true sense and also the results obtained therein can be extraploted the other watersheds following in the same agro-climatic settings. Also, the present study can be used as a model for Sub-Himalayan region to a limited extent to study the drainage characteristics and flow behavior through the morphometric parameters. The results obtained in the [present study can further be analyzed and extrapolated to arrive at Morphometry based runoff models corresponding to a given rainfall which need further analysis.

REFERENCES

Chaudhary R S and Sharma P D 1998. Erosion hazard assessment and treatment prioritisation of Giri river catchment, North Western Himalayas. *Indian J. Soil Conserv.*, **26(1)**: 6-11.

Chopra R, Dhiman R D and Sharma P K 2005. Morphometric analysis of sub-watersheds in Gurdaspur district, Punjab using remote sensing and GIS techniques. *J. Indian Soc. Remote Sensing*, **33**, 531-539.

Horton R E 1932. Drainage basin characteristics. *Trans. Am. Geophys. Union*, **13**, 350-361.

Horton R E 1945. Erosional development of streams and their drainage basins: Hydrophysical approach to quantitative morphology. *Geological Society of America Bulletin*, **56**, 275-370.

Miller V C 1953. A quantitative geomorphic study of drainage basin characteristics in the Clinch Mountain area, Virginia and Tennessee. Proj. NR 389-402, *Tech. Rep*. **3**, Columbia University, Department of Geology, ONR, New York.

Morisawa M E 1958. Measurement of drainangc basin outline form. *J. Geol*. **66**: 587-591.

Nag S K 1998. Morphometric analysis using remote sensing techniques in the Chaka sub-basin, Purulia district, West Bengal. *J. Indian Soc. Remote Sensing*, **26**, 69-76.

Narendra K and Nageswara Rao K 2006. Morphometry of the Meghadrigedda watershed, Visakhapatnam district, Andhra Pradesh using GIS and Resourcesat data. *J. Indian Soc. Remote Sensing*, **34**, 101-110.

Nautiyal M D 1994. Morphometric analysis of a drainage basin using aerial photographs: A case study of Khairkuli basin, district Dehradun, U. P. *J. Indian Soc. Remote Sensing*, **22**, 251-261.

Sebastian M, Jayaraman V and Chandrasekhar M C 1995. Space technology applications for sustainable development of watersheds. *Technical report: ISRO-HQ-TR*-**104-95**. ISRO. Bangalore: pp 1-41.

Schumm S A 1956. Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. *Geological Society of America Bulletin*, **67**, 597-646.

Singh S R 2006. A drainage morphological approach for water resources development of the Sur catchment, Vidharbha region. *Indian Soc. Remote Sensing*, **34**, 79-88.

Smith K G 1950. Standards for grading textures of erosional topography. *American J. Sci*., **248**, 655-668.

Strahler A N 1957. Quantitative geomorphology of drainage and channel networks. *Handbook· of Appliecl Hydrology.* (Ed) Ben Te Chow, McGraw Hill Book Company. New York. pp 4-39-4-76.

Strahler A N 1964). Quantitative geomorphology of basins and channel networks. (In) Chow V T. (ed.), *Handbook of Applied Hydrology*, McGraw Hill Book Company, New York, 75-94.

Vijith H and Satheesh R 2006. GIS based morphometric analysis of two major upland sub-watersheds of Meenachil river in Kerala. *J. Indian Soc. Remote Sensing*, **34**, 181-185.

Wu I.P., Delleur., J.W. and Diskin, M.H. 1964, Determination of peak discharge and design hydropraphs for small watersheds in Indiana, Bulletin Indiana flood Control Resources commission at Purdu University.

Journal of Soil and Water Conservation, Vol. 11, No. 2, pp 39–45 (2012)
Received: 23 November 2011; Accepted: 4 April 2012

Reservoirs – Sink or Sources of Greenhouse Gases?

SOMEN ACHARYA[1], TARUN ADAK[2] AND R B SRIVASTAVA[3]

ABSTRACT

Reservoir surfaces were widely viewed as a carbon-free source of energy during past few centuries because of non availability of data on CO_2 and CH_4 emissions from reservoirs. However, recent development and research studies indicated that greenhouse gas production per unit of power generated is not zero and should depend on the amount of organic carbon flooded to create the electricity. Henceforth, global effect of all types of reservoirs surfaces (both tropical and temperate reservoirs) on the atmosphere needs to be evaluated and these fluxes should be included in greenhouse gas inventories by each country and in models of global carbon cycling. A first estimate indicated that for a global large dams area of $1.5x10^6$ km^2, about $10x10^{14}$ g/yr of CO_2 and 69.3 Tg CH_4 (1 Tg=10^{12}g) can be annually released by bubbling and diffusive processes. Based on a theoretical model, bootstrap resampling and data provided by the International Commission on Large Dams (ICOLD), it was estimated that global large dams might annually release about 104±7.2 Tg CH_4 to the atmosphere through reservoir surfaces, turbines and spillways. In view of novel technologies to extract CH_4 from large dams, it was further estimated that roughly 23±2.6, 2.6±0.2 and 32±5.1Tg CH_4 could be used as an environmentally sound option for power generation in Brazil, China and India, respectively. For the whole world this number may increase to around 100±6.9 Tg CH_4. Although there are uncertainties in both flux measurement and surface area information, however based on initial available data globally, these emissions may be equivalent to 7% of the global warming potential of other documented anthropogenic emissions of these gases. Therefore, a thorough rethink is essentially required for a newly established reservoirs and the process of reservoir development for the mitigation options available. Innovative engineering technologies are essentially needed to avoid these emissions, and to recover the non-emitted CH_4 for power generation.

Key words: Reservoirs, global emission estimates, Indian scenario, techniques of flux measurements, emission process and dominant factors

Global climate is changing and is believe to be changing slowly yet progressively than our imagination. Although, the green house effect makes the Earth suitable for living, release of excessive amount of greenhouse gases (GHGs) into the atmosphere due to anthropogenic activities cause global warming. According to an estimate (Sharma et al., 2006), total amount of GHGs emitted in India, was 1228 million tonnes, which accounted for only 3% of the total global emissions, and of which 63% was emitted as CO_2, 33% CH_4, and the rest 4% as N_2O. Moreover, the projected trends of GHGs emissions in India in 2020 will be below 5% of global emissions and the per capita emissions will still be low compared to most of the developed countries as well as the global average. However, the problem lies in Indian estimate is that emissions from reservoirs and large dams are not included as these sources were thought to be emission free resources.

The general impacts of climate change on water resources indicate an intensification of the global hydrological cycle affecting both ground and surface water supply (Gosain et al., 2006). Significant changes in total amount, frequency, intensity and distribution of precipitation have also been predicted. Such spatio-temporal changes may create

[1] Address: Scientist, Defence Institute of High Altitude Research (DIHAR), DRDO, C/o 56 APO, Leh Ladakh-901205.
[2] Address: Scientist, Division of Crop Production, CISH, Rehmankhera, Lucknow; email: tarunadak@gmail.com).
[3]Address: Director, Defence Institute of High Altitude Research (DIHAR), DRDO, C/o 56 APO, Leh Ladakh-901205.

drought-like situations and will have drastic impact on ground water recharge, reservoir storage capacity and thereby emissions of gases.

Reservoirs or dams are generally man-made bodies of open water serving as public water supply sources, as winter storage for crop irrigation or as flood storage facilities in association with river corridors. Upland reservoirs are commonly known as impounding reservoirs since they are built across river valleys. A common form of lowland reservoir is known as a pumped storage reservoir since water is pumped from a nearby river source rather than filling naturally as in the case of an impounding reservoir. Water supply reservoirs have developed into important nature conservation assets.

Reservoirs are believed to be the sources of greenhouse gases to the atmosphere and their surface areas have increased to the point where they should be included in global inventories of anthropogenic emissions of GHGs (Keller and Stallard, 1994; Fearnside, 1997; Duchemin et al., 1999). Recent research indicates that reservoirs and hydroelectric dams (Table 1) may be significant sources of GHGs since these gases are emitted from both natural aquatic (lakes, rivers, estuaries, wetlands) and terrestrial ecosystems (forest, soils) as well as from anthropogenic sources (Cole et al., 1994; Lima, 2005). Hydropower is generally considered "clean" in comparison with fossil fuel combustion which since well ago is acknowledged an important source of GHGs (IRN, 2002). However, dams are know to produce large environmental and social problems, particularly the larger ones (Rashad and Ismail, 2000). Dams may emit considerable amounts of GHG as CO_2 and CH_4 (Fearnside, 2004; Bambace et al., 2007).

Table 1: Global warming impact of various electricity options

Power plant type	Emissions (g CO2-eq/kwh)
Hydro (tropical)	200 – 3000*
Hydro (temperate/boreal)	10 – 200*
Coal (modern plant)	790 - 1200
Heavy oil	690 - 730
Diesel	555 - 880
Combined cycle natural gas	460 - 760
Natural gas cogeneration	300

*Represents gross emissions and does not include emissions produced when water is released from the reservoir
Source: International River Network (IRN)

The first studies of greenhouse gas fluxes from reservoirs focused on hydroelectric generation (Kelly et al., 1994; Duchemin et al., 1995) because it was, and still is, widely viewed as a carbon-free source of energy (Hoffert et al., 1998). This view likely originated because before 1994, there were no data available on CO_2 and CH_4 emissions from reservoirs, even though it was well known that oxygen depletion resulting from active decomposition of flooded organic matter was common in waters of newly constructed reservoirs (Baxter and Glaude, 1980). The first discussion of greenhouse gas emissions from reservoirs pointed out that greenhouse gas production per unit of power generated (e.g., in kWh) is not zero and should depend on the amount of organic carbon flooded to create the electricity.

Estimation of global flux of GHGs from reservoirs

Estimation of the global surface area of reservoirs and average flux of GHGs is itself a very difficult task due to incomplete databases of the International Commission on Large Dams (ICOLD, 1998). Non registering of dams and reservoirs by different countries is attributed to the possibility of fair estimation of surface area. However, considering both the incomplete listing of large dams in many countries and the overall lack of data on small reservoirs, the global surface area of all reservoirs today is estimated to be approximately 1.5 million km^2, or approximately three times the documented area behind large dams and this area is equivalent to the estimated global surface area of natural lakes (Shiklomanov, 1993). Thus, combining the average areal fluxes with the estimated surface area of reservoirs in temperate and tropical regions yields annual global fluxes of 10×10^{14} g/yr of CO_2 and 0.7×10^{14} g/yr of CH_4 (Abril et al., 2005; Soumis et al., 2005). It was estimated that a total of approximately 70% and 90% of global reservoir fluxes of CO_2 and CH_4, respectively, occurred from tropical reservoirs even though these reservoirs were only accounted for approximately 40% of the global surface area. On a global basis, the CO_2 flux from reservoirs was only equivalent to 4% of other anthropogenic emissions of CO_2, but the CH_4 flux was equal to approximately 20% of other anthropogenic CH_4 emissions. These large estimated CH_4 fluxes from reservoirs exceed estimated fluxes from rice paddies or biomass burning worldwide. When CO_2 and CH_4 fluxes are combined and converted to a flux of total carbon to the atmosphere, the fluxes from reservoir surfaces are equal to 0.3 Gt/yr of carbon, or 4% of other documented anthropogenic fluxes of carbon as CO_2 and CH_4. Average emission fluxes of GHGs from different ecosystems are tabulated in the table 2 and 3 to indicate the mean emission rate, net emission and net consumption by the ecosystem (Aselmann and Crutzen, 1989; Kelly et al., 1997).

Table 2: Average emissions of CH_4 from natural areas (Kelly et al., 1997)

Category	Emission mean rate (mg CH_4-C/m^2/day)	Period of production (days)
Wetlands with decomposing vegetation	11 (11-38)*	178
Marsh	60 (21-162)	169
Swamp	63 (43-84)	274
Bog	189 (103-299)	249
Floodplains	75(37-150)	122
Lakes	32(13-67)	365

* the numbers in brackets are the range

Table 3: Average fluxes of CO_2 and CH_4 from the surfaces of different ecosystems

Ecosystem	Areal flux (mg/m^2/d)	
	CO_2	CH_4
Temperate reservoirs	1500↑	20↑
Tropical reservoirs	3000↑	100↑
Boreal/temperate forests	2100↓	1.0↓
Tropical forests	710↓	0.2↓
Northern peatlands	230↓	51↑
Lakes (worldwide)	700↑	9↑

[a]Downward arrows indicate net consumption by ecosystem. Upward arrows indicate net flux to the atmosphere. [b]Averaged over 365 days assuming 1.5 million km^2 of lake surface area globally.

(Kelly *et al*, 1997)

Indian Scenario

Indian reservoirs represent the whole spectrum of different reservoir types found in the world. Some are located in alpine environments and shares the same features that are typical of northern temperate reservoirs, i.e., can be assumed to release insignificant amounts of greenhouse gases. On the other extreme one finds reservoirs in arid environments, where sequestration probably dominates over release of carbon. Between these extremes are reservoirs located in wet, humid or dry tropical environments.

The major dams and water reservoirs in India include:

- Nagarjuna Sagar Dam, Andhra Pradesh
- Sardar Sarover Project build on river Narmada, Gujarat
- Bhakra Nangal Dam build on river Sutlej, Himachal Pradesh
- Maharana Pratap Sagar Dam, Himachal Pradesh
- Krishna Raja Sagara Dam on Cauvery River, Karnataka
- Tunga Bhadra Dam
- Neyyar Dam, Kerala
- Narmada Dam Project, Madhya Project
- Hirakund Dam Build on Mahanadi River, Orissa
- Farakka Barrage

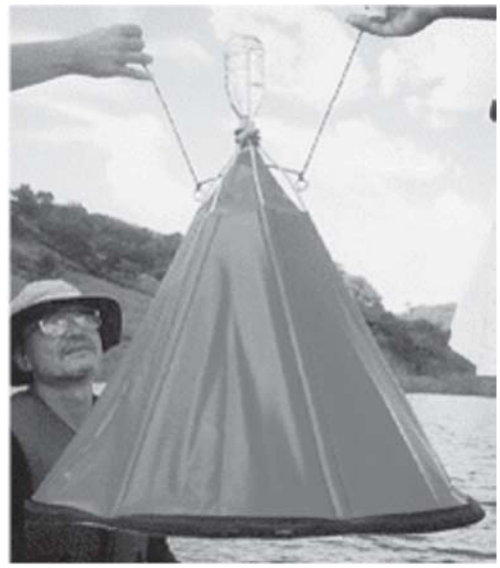
Ocular inspections of satellite photos (Google Earth) in combination with information on prevalent climatic conditions indicate that reservoirs in Uttarakhand, Tamil Nadu, Sikkim, Rajasthan, Punjab, Karnataka, Jammu/Kashmir, Himachal Pradesh, Gujarat, and Arunachal Pradesh represent categories of surface waters where net emissions of greenhouse gases, to judge from experiences from other parts of the world, are generally low, and probably comparable to those from natural lakes. These reservoirs represent about 40 percent of the total storage capacity occupied by reservoirs in the country.

On the other hand, latest scientific estimates show that large dams and reservoirs in India are responsible for about a fifth of the countries' total global warming impact (Lima et al., 2008). Study conducted by National Institute for Space Research, Brazil estimates that total methane emissions from India's large dams could be 33.5 million tonnes (MT) per annum, including emissions from reservoirs (1.1 MT), spillways (13.2 MT) and turbines of hydropower dams (19.2 MT). Total generation of methane from India's reservoirs could be 45.8 MT. The difference between the figures of methane generation and emission is due to the oxidation of methane as it rises from the bottom of a reservoir to its surface. The methane emission from India's dams is estimated at 27.86 % of the methane emission from all the large dams of the world, which is more than the share of any other country of the world. Brazil comes second with the emission of methane from Brazil's reservoirs being 21.8 MT per annum, which is 18.13% of the global figure. Looking at the available figures for dams in India, total emission of methane from Indian dams may be somewhat over estimated, but it is still likely to be around 17 MT per annum. Even this more conservative figure means that India's dams emit about 425 CO_2 equivalent MT (considering that global warming potential over 100 years of a T of methane is equivalent to GWP of 25 T of CO_2, as per the latest estimates of IPCC). This, when compared to India's official emission of 1849 CO_2 MT in year 2000 (which does not include emission from large dams), the contribution of methane emission from large dams is 18.7% of the total CO_2 emission from India. Based on a theoretical model, bootstrap resampling and data provided by the International Commission on Large Dams, it was estimated that global large dams might annually release about 104 ± 7.2 Tg CH_4 to the atmosphere through reservoir surfaces, turbines and spillways. In view of novel technologies to extract CH_4 from large dams (Table 4), it was further estimated that roughly 23 ± 2.6, 2.6 ± 0.2 and 32 ± 5.1 Tg CH_4 could be used as an environmentally sound option for power generation in Brazil, China and India, respectively (Lima et al., 2008). For the whole world this number may increase to around 100 ± 6.9 Tg CH_4. Researchers are in opinion that Indian dams are the largest global warming contributors compared to all other nations. The problem lies in Indian estimate is that emissions from reservoirs and large dams are not included even in the IPCC estimation as these sources were thought to be emission free sources. Henceforth, there is an urgent need to set up a coordinated research programme and its implementation owing to have an idea of GHGs emission from our own reservoirs so that any discrepancies/claims by other sources are sorted out effectively and in an efficient scientific manner.

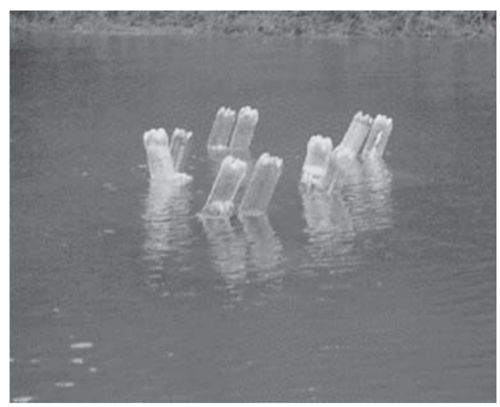
Techniques for Measuring Emissions from Reservoirs

Fluxes of greenhouse gases from water surfaces can be quantified using a number of techniques:

1. Gas Sampling Method for Bubbles Using Funnels



Funnel Bubble Collector Coupled to a Gas Collecting Bottle



Group of Collecting Funnels Placed in a Shallow Region

Table 4. Estimation of CH_4 production (emission + oxidation) and potential recovery from large dams in the world, Brazil, China and India

Country	Upstream Tg CH_4	Downstream Tg CH_4	Total Production Tg CH_4	Potential Recovery Tg CH_4
Brazil	8.28 ± 0.72	25.12 ± 3.027	33.41 ± 3.752	23.38 ± 2.626
China	0.45 ± 0.06	3.248 ± 0.235	3.703 ± 0.300	2.592 ± 0.210
India	5.33 ± 1.91	40.49 ± 5.402	45.82 ± 7.312	32.07 ± 5.118
World	17.4 ± 1.15	125.9 ± 8.730	143.4 ± 9.880	100.4 ± 6.916

Tg- Terra gram (10^{12} gram)

2. Sampling of Gases by Diffusion Chambers

A static floating chamber measuring the rate of buildup of CO_2 and CH_4 gases over time inside the chamber

Floating static chambers have been used to estimate the diffusive flux of CO_2 and CH_4 from the surface of reservoirs by calculating the linear rate of gas accumulation in the chambers over time. Diffusive flux of CO_2 and CH_4 from reservoir surfaces has also been estimated using the thin boundary layer method.

Gas Emission Process in Tropical Reservoirs

The pattern of gas emissions from a hydroelectric reservoir is totally different from a fossil-fuelled power plant. While CO_2 emissions from the combustion of fossil fuels in a thermal power plant are released uniformly over the entire period of operation of the plant, important part of the production of both CH_4 and CO_2 from the bacterial decomposition of organic matter in a hydroelectric reservoir can be concentrated in time and can decay over a period much shorter than the lifespan of the reservoir. There will also be CH_4 and CO_2 long-term emissions due to the (Delmas et al., 2004)

1. decomposition of residual stored biomass remaining in the reservoir after an initial intense degradation,
2. new biomass produced over time inside the reservoir
3. alocthonous organic matter from the watershed.

The bottom of the reservoir contains flooded biomass that after decomposition emitted principally CO_2, CH_4 and N_2 resulting from anaerobic decomposition. In aerobic decomposition only CO_2 and N_2 are emitted. Along with the gases emitted, during decomposition biologically inert residues are formed (humus, humic and fulvic acids) can be leached out and carried by the water. These inert compounds (phenol polymers) originate principally from lignin, present in woody material. Thus part of the carbon is emitted as gas, and another part is carried by the water as humic and fulvic acids. There is also the insoluble and inert phenol residue, the humus, that can be incorporated into the bottom of the reservoir as sediment, and which, together with the silica and clay sediments, can proceed to fossilization.

At the bottom of the reservoir, there are the flooded terrestrial biomass, the organic matter that coming from the watershed and some fresh sediment formed by plankton detritus. The decomposition of sediment, carried out principally by bacteria, demands oxygen at higher rates than diffusion can supply, and an anaerobic regime is established. In the first stage of decomposition, organic acids released, which are then decomposed leading to the formation of CH_4 and CO_2, as can be exemplified with acetic acid subject to methanogenesis.

$$CH_3 - COOH = CH_4 + CO_2$$

The gas emitted from the decomposition of flooded biomass constitutes only a fraction of the total of gas emitted by the reservoir, because there is another source of gas emissions: the zooplankton and phytoplankton contained in the water of the reservoir. Phytoplankton, consisting principally of algae, carries out photosynthesis using carbon dioxide dissolved in the water. The phytoplankton biomass grows at a typical rate of 80 mg of carbon per m^2 per day, a value confirmed in the large Amazon reservoirs.

The decomposition of the flooded biomass progressively reduces the stock of carbon, and because of the resulting biological inertia, its proportion of the emissions of gases diminishes over time. The gas emitted as a result of plankton has an essentially constant rate over time because its source is constantly renewing.

Factors Affecting Emissions from Existing Reservoirs

The range of average fluxes from reservoirs around the world is expected because fluxes of CO_2 and CH_4 depend on a number of factors (Bastviken et al., 2004), including the amount of organic carbon flooded, age of the reservoir, mean annual temperature etc.

1. Organic carbon: The flux per unit area of GHGs from reservoir surfaces should be proportional to the amount of decomposable organic carbon that is flooded to create the reservoir. The largest

amounts of organic carbon per unit area are found in peatlands. CH_4 fluxes in temperate regions were highest in reservoirs that flooded at least 80% peatlands.

2. Age: The age of reservoirs also affect GHGs fluxes because newly flooded labile carbon, such as that found in leaves and litter, should decompose rapidly, followed by slow decomposition of older, more recalcitrant organic carbon such as soil carbon and peat (Kelly et al., 1997).
3. Water temperature: Higher rates of decomposition in tropical reservoirs because of annual water temperatures are much higher as compared to temperate environments.
4. Water residence time
5. Size and nature of watershed
6. Climate and hydrological fluctuations
7. Primary production
8. Operating regime of dam
9. Depth of the reservoir
10. Size and shape of reservoir (bathymetry)
11. Anthropogenic activities around the reservoir and in the catchments

Alternative Energy Generation Options

Alternative future energy sources for electricity generation have become an increasingly popular subject as more emission of GHGs into the atmosphere due to anthropogenic causes. Many sources of alternative energy have been proposed due to global concern for cleaner electricity production. The most important of these are solar, wind, geothermal and nuclear energy. According to recent projections, alternative energy will become increasingly more important over the next 50 to 100 years. For developing countries, nuclear energy promise to produce the most electricity with practically no CO_2 emissions. For rural parts of developing and undeveloped countries wind, solar, wave and tidal channel power are the most viable alternatives to fossil fuels for electricity production. These simple technologies can be implemented cheaply and quickly without the investment and planning required for nuclear and hydroelectric.

CONCLUSION

Reservoirs were widely viewed as a carbon-free source of energy since most reservoirs are developed not for hydroelectric production but rather for flood control, water supply, irrigation, navigation, recreation and aquaculture purposes. However, a recent concern is whether reservoirs emits significant amount of GHGs and contributing to global climate change; is of practical significance. The slow yet steady accumulation of scientific data on GHGs emissions indicates that reservoirs can emit GHGs due to the anaerobic decomposition of biomass and CO_2. Tropical reservoirs that are shallow and unclear of biomass appear most at risk. The uncertainty lies in the estimates; the main scientific controversy centres on the extrapolation of measured emissions per m^2 in selected parts of the reservoir to the whole reservoir area. Emissions almost certainly vary according to depth and the distribution of the submerged biomass. They also vary through time, with a rapid peak occurring shortly after submersion after which they tail off at an unknown rate. Studies have not yet been carried out over long periods to characterize the full life-cycle curve of the emissions. Thus, this has to be assessed on a case by case basis. Although, the science base is not yet able to give accurate guidance to planners on whether a new reservoir will or will not emit GHGs. More research is needed in order to be able to do this, and this should focus on the following areas: i) spatio-temporal variability of CO_2, CH_4 and N_2O fluxes in reservoirs, ii) correlation of trace gas emissions with the major environmental variables (water levels, temperature, air pressure, nutrients) and the key biogeochemical process (primary production, denitrification, methane generation and oxidation), iii) application of remotely sensed data and new techniques to evaluate trace gas fluxes and biogenic chemical process from reservoir and lake ecosystems and finally iv) to build a GHG emission network including reservoirs and lakes in different agro-climatic zones involving study on carbon budgeting in reservoirs.

REFERENCES

Abril G, Gue´rin F, Richard S, Delmas R, Galy-Lacaux C and Gosse P. 2005. Carbon dioxide and methane emissions and the carbon budget of a 10 year old tropical reservoir (Petit Saut, French Guiana). *Global Biogeochem Cycles* **19:** 1-16.

Aselmann I and Crutzen P. 1989. Global Distribution of Natural Freshwater Wetlands and Rice Paddies, Their Primary Productivity, Seasonality and Possible Methane Emissions. *Journal of Atmospheric Chemistry* **8:** 307-358.

Bambace L A W, Ramos F M, Lima I B T and Rosa R R. 2007. Mitigation and recovery of methane emissions from tropical hydroelectric dams. *Energy* **32:** 1038-1046.

Bastviken D, Cole J, Pace M and Tranvik L. 2004. Methane emissions from lakes: Dependence of lake characteristics, two regional assessments, and a global estimate, *Global Biogeochemical Cycles* **18:** 1-12.

Baxter R M and Glaude P. 1980. Environmental effects of dams and impoundments in Canada: Experience and prospects. *Canadian Bulletin of Fisheries and Aquatic Sciences* **205:** 1-34.

Cole J J, Caraco N F, Kling G W and Kratz T K. 1994. Carbon dioxide supersaturation in the surface water of lakes. *Science* **265:** 1568-1570.

Delmas R, Richard R, Guérin F, Abril G, Galy-Lacaux C, Delon C and Grégoire A. 2004. Long term greenhouse gas emissions from the hydroelectric reservoir of Petit Saut (French Guiana) and potential impacts. In: Greenhouse Gas Emissions: Fluxes and Processes. Hydroelectric Reservoirs and Natural Environments. A. Tremblay, L. Varfalvy, C. Roehm and M. Garneau (Eds) Environmental Science Series, Springer-Verlag, Berlin, Heidelberg, New York. pp 293-312.

Duchemin E, Lucotte M and Canuel R. 1999. Comparison of static chamber and thin boundary layer equation methods for measuring greenhouse gas emissions from large water bodies. *Environmental Science and Technology* **33:** 350-357.

Duchemin E, Lucotte M, Canuel R and Chamberland A. 1995. Production of the greenhouse gases CH4 and CO2 by hydroelectric reservoirs of the boreal region. *Global Biogeochemical Cycles* **9:** 529-540.

Fearnside P M. 2004. Greenhouse gas emissions from hydroelectric dams: controversies provide a springboard for rethinking a supposedly 'clean' energy source. *Climatic Change* **66:** 1-8.

Fearnside P M. 1997. Greenhouse-gas emissions from Amazonian hydroelectric reservoirs: The example of Brazil's Tucuruí Dam as compared to fossil fuel alternatives. *Environmental Conservation* **24:** 64-75.

Gosain A K, Rao S and Basuray D. 2006. Climate change impact assessment on hydrology of Indian river basins. *Current Science* **90:** 346-353.

Hoffert M I et al. 1998. Energy implications of future stabilization of atmospheric CO2 content. *Nature* **395:** 881-884.

ICOLD. 1998. International Commission on Large Dams. World Register of Dams, Paris: International Committee on Large Dams.

IRN. 2002. Flooding the land, Warming the Earth. Greenhouse gas emissions from dams. International River Network (IRN).

Keller M and Stallard R F. 1994. Methane emission by bubbling from Gatun Lake. *Panama. J Geophys Res* **99:** 8307-8319.

Kelly C A, Rudd J W M, St. Louis V L and Moore T. 1994. Turning attention to reservoir surfaces, a neglected area in greenhouse studies. *EOS* **75:** 332-333.

Kelly C A, Rudd J W M, Bodaly R A, Roulet N P, St. Louis V L, Heyes A, Moore T R, Schiff S, Aravena R, Scott K J, Dyck B, Harris R, Warner B and Edwards G. 1997. Increases in fluxes of greenhouse gases and methyl mercury following flooding of an experimental reservoir. *Environmental Science and Technology* **31:** 1334-1344.

Lima I B T. 2005. Biogeochemical distinction of methane releases from two Amazon hydroreservoirs. *Chemosphere* **59:** 1697-702.

Lima I B T, Ramos F M, Bambace LW A and Rosa R R. 2008. Methane Emissions from Large Dams as Renewable Energy Resources: A Developing Nation Perspective. *Mitig Adapt Strat Glob Change* **13:** 193-206.

Rashad S M and Ismail M A. 2000. Environmental impact assessment of hydro-power in Egypt. *Applied Energy* **65:** 285-302.

Sharma S, Bhattacharya S and Garg A. 2006. Greenhouse gas emissions from India: A perspective. *Current Science* **90:** 326-333.

Shiklomanov I A. 1993. World fresh water resources. Pages 13-24 in Gleick PH, ed.Water in Crisis: A Guide to the World's Fresh Water Resources. Oxford University Press.

Soumis N, Lucotte M and Canuel R. 2005. Hydroelectric reservoirs as anthropogenic sources of greenhouse gases. In: Lehr JH, Keeley J (eds) Water encyclopedia: Surface and agricultural water. Wiley-Interscience, Hoboken, N. J. pp 203-210.

Journal of Soil and Water Conservation, Vol. 11, No. 2, pp 46–49 (2012)
Received: 30 October 2011; Accepted: 11 April 2012

Effect of Integrated Use of Organic Manure and Nitrogen Fertilizer on Grain Yield, Nutrients Uptake and Use Efficiency in Wheat (*Triticum aestivum* L.) in Northern India

RAMESH SHARMA[1], JITENDER BAMEL[2], J. P. SINGH[3] AND B.RATH[1]

ABSTRACT

A field experiment was conducted during two consecutive rabi seasons of 2006-07 and 2007-08 on loamy sand soil of KVK farm, Sonipat, Haryana (INDIA) to study the effect of integrated use of farm yard manure (FYM) and urea on grain yield, nutrient uptake and their use efficiency in wheat (*Triticum aestivum* L.). The experimental design was split plot having four levels of FYM (0, 7.5, 15 and 30 t/ha) in the main plots and five levels of N (0, 75, 150, 187.5 and 225 kg/ha) in the sub-plots. The results indicated that the increasing levels of FYM increased the wheat grain yield and nutrient uptake (N, P and K) at all levels of applied N. The agronomic efficiency, partial factor productivity and apparent N recovery were highest at 15 t FYM/ha and 150 kg N/ha application. However, application of 187.5 kg N/ha along with and 15 t FYM/ha produced optimal yields of 5.3 and 5.2 t/ha during the year 2006-07 and 2007-08, respectively. Regarding economic of production, the higher net monetary return was obtained with combined application of 187.5 kg N/ha along with and 15 t FYM/ha with a highest B: C ratio as compared to other treatment combination, irrespective of wheat growing year.

Key words: FYM, fertiliser N, wheat, yield, nutrient use efficiency

Wheat is one of the major food crops in the world cultivated over an area of about 226.45 m ha with a production of 161.9 m tones. In India, the wheat production is about 72 m tonnes from an area of around 25 m ha (Chanda et al., 2008). Although, India is well placed in meeting its needs for food grains, yet the major objective of food and nutritional security for its entire population has not been achieved. The demand for wheat in India by 2020 has been projected to be between 105 to 109 m tonnes as against 72 m tonnes production of present day. Most of this increase in production will have to come from increased productivity, as the land area under wheat is not expected to expand.

Like Haryana, yields in other areas of the country have started declining because of decrease in factor productivity (Yadav, 1998) and farmers are now using greater than recommended levels of fertilizer nitrogen to maintain the yield levels which they were getting a few years back. Therefore, one of the most promising means for increasing wheat yield is to develop alternative nutrient management practices for increasing factor productivity. The integrated use of organic materials and inorganic nitrogenous fertilizers has received considerable attention in the past with a hope of meeting the farmer's economic need as well as maintaining favorable ecological conditions on long-term basis (Kumar et al., 2007). The integrated nutrient management helps to restore and sustain fertility and crop productivity. It may also help to check the emerging deficiency of nutrients secondary and micronutrients. Further, it brings economy and efficiency in fertilizers. The integrated nutrient management favorably affects the physical, chemical and biological environment of soils. Integrated use of FYM and inorganic N increases the productivity and monetary returns of wheat by maintaining or improving soil fertility (Sarma et al., 2007)

[1]Department of Agriculture & Cooperation, Ministry of Agriculture, Govt. of India, New Delhi-110001
[2]CCS Haryana Agricultural University, Krishi Vigyan Kendra, Sonipat-131001, Haryana
[3]Deptt. of Soil Science, CCS Haryana Agricultural University, Hisar-125004, Haryana

Limited availability of land for additional crop production, along with declining yield of major food crops like wheat have heighted concerns to focus on using available nutrient resources more efficiently. In views of these facts, this study was designed to study the effect of combined use of FYM and fertilizer N on crop yield, nutrient uptake and N use efficiency in wheat crop grown on an alluvial soil in Haryana, India.

MATERIALS AND METHODS

A field experiment was conducted during 2006-07 and 2007-08 at the farm of Agriculture Science Centre (KVK), Sonipat, Haryana approximately 50 KM North West of New Delhi. The soil was loamy sand, alkaline in pH (8.3) with low organic carbon (0.34%), N (120.4 kg/ha), P (18.4kg/ha) contents and medium in available K (150.0kg/ha). The precipitation received during the crop seasons (November to April) of 2006-07 and 2007-08 was 37.0 and 94.9 mm, respectively. The experiment was conducted with Split Plot Design consisting of four levels of farm yard manure (FYM) - 0, 7.5,15.0 and 30 t/ha as main plots and five levels of N - 0, 75,150, 187.5 and 225 kg/ha as sub plots with three replications. Well decomposed FYM (0.58 and 0.62% N and 0.25 and 0.30% P and 0.72 and 0.74% K during the year 2006-07 and 2007-08, respectively) was applied uniformly and incorporated in soil 15 days before the sowing of the crop. Recommended dose of P (60kg/ha), K (30 kg/ha) and Zn SO_4 (25 kg/ha) was applied at sowing time while N as top dressing was applied in three split doses -1/3 each at sowing, 1^{st} irrigation and 2^{nd} irrigation. Wheat WH-711 was sown on 15^{th} and 12^{th} December in 2006-07 and 2007-08, respectively at 20 cm row to row distance with 125 kg seed/ha. Surface soil samples were collected before sowing and after harvesting of the crop and were analysed for N content. Wheat crop was harvested at maturity and grain samples were analysed for N by Nessler's Reagent method (Linder, 1944), P by Vanadomolebdo phosphoric acid yellow colour method (Koenig and Johnson, 1942) and K by flame photometer method. The data was subjected to economic analysis and the following computations were used-

Agronomic efficiency (kg/kg): {Yield (N) – Yield (N_0)} / applied fertiliser N

Apparent Recovery of N (%): {Uptake (N) – uptake (N_0)} / applied fertiliser N

Partial factor productivity of applied (kg/kg): Yield (N) / applied fertiliser N

RESULTS AND DISSCUSSION

Grain yield of wheat

The results suggest that the average grain yield of wheat increased significantly with the increasing levels of N and FYM (Fig 1). The magnitude of increase in yield with N was higher as compared to applied FYM. In general, the application of N up to 187.5kg /ha and FYM up to 15 t /ha increased the grain yield significantly. The application of FYM @7.5 and 15 t /ha increased the grain yield significantly by 17.1 and 25.2 during 2006-07 and 12.7 and 23.7% during 2007-08 over control. The average grain yield increased significantly with successive increase in N levels up to 225kg N /ha being 69.0, 117.4, 129.6 and 136.2% with 75, 150, 187.5 and 225 kg /ha, respectively, over control. The improvement in yield with the application of N and FYM might be due to balanced nutrition supplied by treatments. The interaction between N and FYM was found to be synergistically significant in improving the grain yield during both the years. Similar kind of synergistic interaction between N and FYM has also been reported by (Singh and Aggarwal, 2005). The optimum yield (5.3 and 5.2t /ha) of wheat was obtained with the application of 187.5 kg N /ha and 15 t FYM /ha during 2006-07 and 2007-08, respectively. The optimal wheat yield obtained on plots receiving 187.5 kg N /ha and 15 t FYM /ha were possibly caused by the better nutrient supply pattern and improved physical conditions (Yadvinder-Singh et al., 2004). Mundra et al., 2003 also reported higher grain yield with 125% of recommended N, P and K (120+60+30) application along with 10 t FYM /ha.

Nutrient uptake

The total uptake of N, P and K was significantly enhanced by the application of farm yard manure and nitrogen (Table 1). The application of 7.5 and 15 t FYM /ha increased the total N, P and K uptake by 28.2 and 43.8%, 27.5 and 43.5%, 24.3 and 38.3% during 2006-07 and 22.5 and 40.1%, 20.7 and 40.0%, 16.5 and 34.2% during 2007-08, respectively over control. The total N, P and K uptake was enhanced significantly and subsequently with the application of N up to 225kg /ha. The increase in total uptake of

N, P and K was 94.6, 83.8 and 78.7% with 75kg N / ha, 172.5, 147.5 and 145.5% with 150kg N /ha, 198.3, 157.5 and 171.2% with 187.5 kg N /ha and 213.9, 168.8 and 187.8% with 225kg N /ha, respectively during the year 2006-07. The corresponding increase during 2007-08 was 76.5, 68.1 and 66.8% with 75kg N /ha, 136.9, 117.0 and 119.7% with 150kg N /ha, 158.0, 124.5 and 139.0% with 187.5kg N /haand 171.7, 134.0 and 149.7% with 225kg N /ha, respectively. The increase in N, P and K uptake with the application of FYM lies in the fact that apart from supply of nutrients, it also enhanced the availability of these nutrients to the plants. It also improved the soil environment, which encourage proliferous root system resulting in better absorption of moisture and nutrients and thus resulted in higher biomass production. Singh et al. (2011) reported that wheat crop needs to be fertilized with organic and inorganic sources of |N to have higher wheat yield and nutrient uptake. These results are in conformity with those of Paikaray et. al. 2002 and Singh and Agarwal, 2005.

Nutrient Use Efficiency

Agronomic efficiency

Agronomic efficiency increased from 14.6 and 14.5 to 20.4 and 19.3 with the application of FYM only upto 15 t/ha during 2006-07 and 2007-08, respectively (Table 2). Reduced losses of N and balanced availability of nutrients with the application of FYM might lead to improvement in grain yield of wheat and consequently the higher agronomic efficiency. On the other hand agronomic efficiency decreased with increasing levels of N because of low utilization of applied N which is supported by low apparent recovery and partial factor productivity of applied N. Reduced losses of N and higher availability of nutrients with the application of farm yard manure might lead to improvement in grain yield of wheat and consequently the higher agronomic efficiency. Sharma, 2002 also observed similar results in wheat.

Apparent recovery of N

Apparent recovery of N increased with the application FYM but decreased with the application of N fertilisation (Table 2). Higher apparent recovery of fertilizer N with FYM application might be attributed to lower nitrogen losses and synchronization of N supply as per crop need. Dwivedi et. al., 2003 and Singh and Agarwal, 2005 also reported higher agronomic efficiency and apparent N recovery in wheat with the use of organic manures.

Partial factor productivity of applied N

Partial factor productivity increased only upto 15t/ha of FYM and then dropped in both the growing years (Table2). The maximum average partial factor productivity of 43.5 and 45.3 was recorded at 75kg N /ha ˉand it decreased by 32.6, 41.4 and 50.3 per cent during 2006-07 and 36.0, 44.8 and 52.3 percent during 2007-08 at 150, 187.5 and 225 kg N/ ha over 75kg N /ha application.

Physiological use efficiency

In general, the physiological use efficiency of N, P and K decreased with application of N and FYM at all levels. Physiological use efficiency of N,P and K decreased by 8.9, 8.2 and 5.4% during the year 2006-07 and 12.8, 10.8 and 5.3 during the year 2007-08 with the application of 7.5 t FYM /ha over no FYM application, respectively (Table 3). The highest physiological efficiency of N and K was recorded at 150 kg N /ha. Increasing level of N from 150 to187.5kg /ha reduced the physiological efficiency of N and K significantly in both the years where as the physiological efficiency of P increased with the application of N up to 187.5 kg /ha and further increase in N levels, the physiological efficiency of P reduced. Increasing levels of farmyard manure in combination with N also reduced the physiological efficiency of N, P and K. Similar results were also observed by Singh and Aggarwal 2005 in wheat.

Economic analysis

The data suggested that the highest average benefit: cost ratio of 2.23 and 2.54 was obtained at 15 t FYM /ha during 2006-07 and 2007-08, respectively (Table 4). Likewise the benefit cost ratio increased from 1.23 and 1.58 with no N applied to 2.48 and 2.73 at 187.5kg N /ha application during 2006-07 and 2007-08, respectively. However the highest benefit: cost ratio of 2.63 and 2.91 was obtained at 15 t FYM ha and 1875kg N /ha application during the year 2006-07 and 2007-08 respectively as compared to all other treatments. Increase in FYM beyond 15 t /ha reduced the benefit cost ratio due to higher cost of these inputs. The increase in net returns by application of organic manure is attributed to increase in yield as a consequence of combined use of FYM and N application

CONCLUSIONS

The present investigation highlights the importance of combined use of organic and mineral fertilisers in supplying judicious and balanced plant nutrition for profitable and sustainable cropping systems. Our study has suggested that a combined use of 187.5kg of fertiliser N and 15 t of FYM/ ha produced the highest grain yield and ultimately the highest net returns in what crop.

REFERENCES

Chanda, T.K. Sati, K. and Robertson, C. 2008 *Fertiliser Statistics* (2007-08) 53rd Ed. Pp II-11, (Published by The Fertiliser Association of India, New Delhi).

Dewivedi, B.S., Shukla, A.K., Singh, V.K. and Yadav, R.L. 2003 Improving nitrogen and phosphorus use efficiencies through inclusion of forage cowpea in the rice-wheat system in the Indo-Gangetic Plains of India. *Field Crops Research*, **80(3),** 167-93.

Koening, R.A. and Johnson, C. R. 1942 Colorimetric determination of phosphorus in biological materials, *Indian Engineering Chemistry (Analytical)*, **14**, 155-6.

Kumar, A., Tripathi, H.P. and Yadav, D.S. 2007. Correcting nutrient for sustainable crop production. *Indian Journal of Fertilizers.* **2**:37-44.

Linder, R. C. 1944 Rapid analytical methods for some of the most common inorganic constituents of plant tissues. *Plant Physiology*, **19(1),** 76-8.

Mundra, M. C., Singh, B. P., Rinwa, R. S. and. Gupta, S. C 2003 Crop productivity, returns and soil sustainability under rice (Oryza sativa)-wheat (Triticum aestivum) cropping system. *Indian Journal of Agronomy*, **48(4),** 247-50.

Paikaray, R. K., Mahapatra, B. S. and Sharma, G. L. 2002 Integrated nitrogen management in rice (Oryza sativa)-wheat (Triticum aestivum) cropping system, *Indian Journal of Agricultural Science*, **72(8),** 445-8.

Sarma, A., Harbir, S. and Nanwal, R.K. 2007. Effect of integrated nutrient management on productivity of wheat (Triricum aestivum) under limited and adequate irrigation supplies. *Indian Journal of agronomy*, **52**: 583-586.

Sharma, S. N. 2002 Nitrogen management in relation to wheat (Triticum aestivum) residue management in rice (Oryaza sativa), *Indian Journal of Agricultural Science,* **72(8)**, 449-52.

Singh, C.M., Sharma, P.K., Kishor, P., Mishra, P.K., Singh, A.P., Verma, R. and Raha, P. 2011. Impact of integrated nutrient mamgmnement on growth, yield and nutrient uptake by wheat (*Triticum aestivum* L.). *Asian Journal of Agricultural Research*, 5: 76-82.

Singh, R. and Agarwal, S. K. 2005 Effect of levels of farm yard manure and nitrogen fertilization on grain yield and use efficiency of nutrients in wheat (*Triticum aestivum*), *Indian Journal of Agricultural Sciences*, **75(7),** 408-413.

Yadav, R.L. 2001. On-farm experiments on integrated nutrient management in rice-wheat cropping systems. *Experimental Agricultural,* 37: 99-113.

Yadvinder-Singh, Bijay-Singh, Ladha, J.K., Khind, C.S., Gupta, R.K., Meelu, O.P. and Pasuquin, E. 2004. Long-term effects of organic inputs on yield and soil fertility in the rice-wheat rotation. *Soil Science Society of America Journal,* **68**: 845-853.

Journal of Soil and Water Conservation, Vol. 11, No. 2, pp 50–58 (2012)
Received: 20 October 2011; Accepted: 28 May 2012

Influence of Microbial Inoculants on Yield, Economics and Nutrient Uptake by Basmati Rice and Soil Properties

Y.V. SINGH[1], IMTIYAJ AHMAD[1] AND K. K. SINGH[2]

ABSTRACT

Field experiments were conducted during *kharif* seasons of 2009 and 2010 at the research farm of the IARI, New Delhi to study the influence of integrated nutrient management through chemical fertilizer and N_2-fixing and P-solubilising micro-organisms on productivity, economics and nutrient uptake of rice (cv. 'Pusa Basmati 1121') and soil properties. In the experiment, 12 treatments including microbial inoculants like Blue Green Algae (BGA), *Azolla, Azotobacter,* Phosphate Solubilizing Bacteria (PSB) and AM fungi were inoculated alone or in combination along with a common fertilizer dose of $N_{90}K_{60,}$ and these were compared with recommended dose (N_{120}+ P_{60}+ K_{60}) of fertilizers. Microbial-inoculants were applied as per their recommendation to rice crop. It was found that the crop yield was significantly influenced by combined inoculation of BGA and *Azolla* with PSB and AM fungi with 90 kg N + 60 Kg K_2O ha^{-1} and these inoculants showed *at par* yield as given by $N_{120}P_{60}K_{60}$. Combined inoculation of BGA with AM fungi and PSB gave the highest net return and cost: benefit ratio and these were statistically *at par* with the return given by chemical fertilizer. Inoculation with N_2-fixing and P-solubilising micro-organisms enhanced the concentration and uptake of N in grain as well as straw, and the response was higher due to the combined application of these bio-inoculants. Concentration and uptake of P in grain was significantly increased due to the combined application of microbial inoculants, however, it did not increase P concentration and uptake in straw. Concentration and uptake of K was not significantly influenced in grain but same parameters in straw were significantly influenced due to those inoculants. Fe concentration and uptake in grain and straw were significantly increased due to microbial inoculants. Content of Zn and Mn was not significantly affected in grain but same parameters were significantly increased in straw. Physico-chemical (pH, EC and OC) properties of soil were not significantly influenced due to the microbial inoculation during experimental period. However, microbial biomass C and enzymatic activities of soil were significantly influenced due to the microbial inoculants.

Key words: Basmati rice, N, P and K uptake, N_2-fixing micro-organisms, P-solubilising micro-nutrient uptake

INTRODUCTION

Rice (*Oryza sativa* L.) plants require large amounts of mineral nutrients including N for their growth, development and grain production. Rice crop removes around 16-17 kg N for the production of each ton of rough rice including straw (Sahrawat 2000). However, most of the rice soils of the world are deficient in N, so fertilizer N applications are required to meet a rice crop's N demand. Generally, urea is applied as the N source for rice production. But the efficiency of added urea-N is very low, often only 30-40%, in some cases even lower (Choudhury and Kennedy 2004). This low N-use efficiency is mainly due to denitrification, NH_3 volatilization and leaching losses (De Datta and Buresh 1989). NH_3 volatilization and denitrification cause atmospheric pollution through the production of greenhouse gases like N_2O and NH_3 (Reeves *et al.* 2002). In addition to these environmental problems, the long-term use of urea depletes the soil organic matter. These problems are of great concern to the scientists around the world. So, alternate sources of N should

[1]CCUBGA, [2]SPU, Indian Agricultural Research Institute, New Delhi 110 012
(Email: yvsingh63@yahoo.co.in)

be applied to minimize these problems. Biological N fixation (BNF) technology can play an important role in substituting for commercially available N fertilizer use in rice culture, thus reducing these environmental problems to some extent. Use of biofertilizers can prevent the depletion of the soil organic matter (Jeyabal and Kuppuswamy 2001). Rice crops are grown in both wetland and upland cultures. However about 85% of the total rice-cropped area is under wetland culture. In upland culture aerobic bacteria can fix atmospheric N while in wetland culture both aerobic and anaerobic bacteria can fix N. Aerobic bacteria like *Azotobacter* can live in the oxygenated rhizosphere of the rice plant and can fix atmospheric N. *Azotobacter* has been reported to fix 15-20 kg N ha^{1} year^{-1} (Paul and Verma 2005). A wetland rice ecosystem is the favourable habitat for aquatic biota like *Azolla* and blue-green algae (BGA). *Azolla* can fix a substantial amount of N in symbiotic association with *Anabaena* (Mian 2002), while blue-green algae, cyanobacteria, can fix atmospheric N_2 as free living aquatic biota (Hashem 2001). An increase of 10-30 % in grain yield of rice due to BGA incorporation was reported (Pabbi *et al.* 2000). P solubilising micro-organisms can help in increasing the availability of accumulated phosphates for plant growth by solubilization (Kucey *et al*. 1989; Richardson 1994). In addition, the micro-organisms involved in P-solubilization as well as better scavenging of soluble P can enhance plant growth by increasing the efficiency of biological N_2-fixation, enhancing the availability of other trace elements, such as Fe, Zn etc. and by production of plant growth promoting substances (Kucey *et al*. 1989). The arbuscular mycorrhizae (AM) fungi includes various bacteria and fungi that mobilize insoluble mineral phosphate complexes especially those of calcium phosphate complexes (Lekberg *et al.* 2008; Sheng *et al.* 2008). A number of studies on different bio-fertilizers have been conducted in India and abroad, but informations are mostly lacking on consolidated effects of these bio-fertilizers on the uptake of macro and micro nutrients by rice crop and their effects on physico-chemical properties of soil. With such background this experiment was conducted to study the response of basmati rice to inoculation of microbial inoculants on productivity, economics, nutrient uptake and soil properties.

MATERIALS AND METHODS

Field experiments were conducted during wet (*kharif*) seasons of 2009 and 2010 at the research farm of Indian Agricultural Research Institute, New Delhi, situated at a latitude of 28º 40′N and longitude of 77º 12′ E, altitude of 228.6 m above the mean sea level. The mean annual rainfall of Delhi is 650 mm and more than 80% generally occurs during the south-west monsoon season (July-September) with mean annual evaporation 850 mm. The soils of the experimental field was sandy clay loam and its initial soil sample had 234 kg ha^{-1} alkaline permanganate oxidizable N, 18.0 kg ha^{-1} available P, 286 kg ha^{-1} 1N ammonium acetate exchangeable K and 0.56% organic C. The pH of soil was 7.4 (1: 2.5 soil and water ratio). In the experimental area rice-wheat cropping system was followed and wheat was grown under recommended dose of fertilizers.

The experiment was laid out in randomized block design (RBD) with twelve treatments comprising, T_1: BGA; T_2: *Azolla;* T_3: *Azotobacter;* T_4: Phosphate Solubilizing Bacteria (PSB); T_5: AM fungi; T_6: *BGA* + PSB; T_7*: Azotobacter* + PSB; T_8*: Azolla + PSB;* T_9*: BGA* + AM fungi; T_{10}: *Azolla* + AM fungi; T_{11}*: Azotobacter* + AM fungi and T_{12}: N_{120}+ P_{60}+ K_{60} (Recommended dose). *Azolla filiculoides* @ 1000 kg ha^{-1} and multani mitti based blue green algae (BGA) having composite culture of four species viz., *Anabaena sp.*, *Nostoc sp.*, *Tolypothrix sp.* and *Aulosira sp.* were applied @ 1.5 kg ha^{-1} as top dressing 2 days after transplanting and for proper growth of these bio-fertilizers, standing water (3-5 cm) was maintained in rice crop. Both *Azolla* and BGA multiplied for about 25-30 days and later decomposed when good mat developed and rice crop canopy developed shading effect. Biomass of *Azolla* (on dry-weight basis) contained 3.7% N, 0.75% P, 4.2% K, 755 ppm Fe, 85 ppm Zn, 174 ppm Mn and 17 ppm Cu; while dry biomass of BGA contained 4.1% N, 0.88% P, 4.7 % K, 695 ppm Fe, 74 ppm Zn, 165 ppm Mn and 21 ppm Cu.

Azotobacter and PSB were applied @ 500 g ha^{-1} through seedling root dip for 30 minute at the time of transplanting. AM fungi were applied @ 10 kg ha^{-1} as basal application at the time of transplanting. This AM fungi inoculant had around 70 % spore inoculation level per root system. A common dose of 90 kg N and 60 kg K_2O ha^{-1} was applied in all treatments except T_{12}.Twenty-four days old seedling of rice variety 'Pusa Basmati 1121' were transplanted at 20 cm × 10 cm spacing keeping 2 seedlings hill^{-1}. The gross plot size was 5.0 m × 2.5 m for each treatment.

At the time of maturity, the net plots (leaving 2 border rows on each side and 4 hills from each side of the length) were harvested and sun-dried for three days in the field and then the total biomass yield was recorded. After threshing, cleaning and drying the grain yield was recorded at 14% moisture. Straw yield was obtained by subtracting grain yield from the total biomass yield.

Plant samples were collected at the time of harvesting and dried in hot air oven at 60±2ºC for 6 hours. The oven dried samples were sieved by passing through 40 mesh sieve in a Macro-Wiley Mill. From each replication 0.5 g dry matter samples and grain and straw samples were taken for chemical analysis to determine the P, K, Zn, Mn, Cu and Fe concentrations in grain and straw of rice. N concentration in grain and straw of basmati rice samples were determined by modified Kjeldahl method. Total K in grain and straw of rice were estimated by flame photometry method on a tri-acid digest of plant material. The Zn, Mn, Cu and Fe in grain and straw of rice crop were determined by wet-digestion (di-acid digestion) procedure (Prasad *et al*., 2006). The uptake/accumulation of various major and micronutrients in grain and straw of rice were calculated by multiplying the grain and straw yield of rice with their respective concentrations and expressed in kg ha^{-1} and g ha^{-1}.

Soil samples were collected before beginning of the experiment and after harvest of rice crop from a depth of 0-15 cm and were analyzed for organic C by wet digestion method. pH and EC were estimated as per the procedure described by Prasad *et al*. (2006). For microbial analysis soil samples were taken at mid season stage (60 DAT) and analysed for microbial biomass C (Nunan *et al*. 1998) and microbial activity (Green e*t al*. 2006). All the data obtained were statistically analyzed using the *F*-test procedure and LSD values at 5% used for determining the significance of differences betweens means.

RESULTS AND DISCUSSION

Yield and economic returns

Grain and straw yields of Basmati rice increased significantly with combined inoculation of *Azolla* + PSB, *Azolla* + AM fungi, BGA + AM fungi and BGA + PSB as compared to single inoculation of *Azotobacter* during both the years (Table 1). However this yield was statistically *at par* with application of recommended dose of chemical fertilizer ($N_{120}P_{60}K_{60}$). Grain and straw yield with single inoculation with *Azolla*, BGA, PSB and AM fungi was higher as compared to the single inoculation of *Azotobacter*. The increase in grain and straw yields due to inoculation of microbial inoculants can be explained on the basis of their effect on yield attributes like effective tillers, panicle length and no. of grains panicle^{-1}. The increase in yields might be attributed to slow release of applied N and P due to the inoculation of N_2-fixing and P-solubilising micro-organisms (Singh and Mandal 1997), which might have led to increased photosynthetic activity for longer period and finally increased dry matter accumulation. The ratio of grain to straw was high and harvest index of 20-22% was recorded among different treatments. This might be due to the semi-tall stature of rice variety and its vigorous growth under integrated nutrient management.

Table 1. Effect of different treatments on grain and straw yield of basmati rice

Treatment	Grain yield (t ha^{-1})		Straw yield (t ha^{-1})	
	2009	2010	2009	2010
BGA	4.29	4.14	16.58	16.12
Azolla	4.13	4.02	16.06	16.45
Azotobacter	3.74	3.61	15.91	16.45
PSB	4.04	4.12	16.25	17.12
AM fungi	4.26	4.31	16.22	17.14
BGA + PSB	4.63	4.55	16.74	17.55
Azotobacter + PSB	4.31	4.41	16.54	17.12
Azolla + PSB	4.58	4.67	16.72	16.16
BGA + AM fungi	4.71	4.77	16.75	17.23
Azolla + AM fungi	4.59	4.82	16.87	17.43
Azotobacter + AM fungi	4.49	4.50	16.44	16.98
N_{120}+ P_{60}+ K_{60}	4.75	4.83	16.87	17.36
LSD (P= 0.05)	0.56	0.61	0.54	0.39

Combined inoculation of BGA with AM fungi and PSB gave the highest net return and this return was *at par* with the return given by sole chemical fertilizer application (Table 2). Among the treatments having single inoculation of different bio-inoculants, BGA gave the highest return followed by AM fungi.

Benefit: cost ratio due to inoculation of different bio-fertilizers was comparable to application of chemical fertilizers. Benefit cost ratio varied between 1.58 and 2.07 and the lowest ratio was recorded due to the inoculation of *Azotobacter*. Combined application of N_2-fixing and P-solubilising micro-organisms gave higher cost: benefit ratio as compared to their single application.

Table 2. Effect of different treatments on economics of bio-inoculants and chemical fertilizers in rice cultivation

Treatment	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	Benefit : cost Ratio (Rs ha^{-1})
BGA	59453	38771	1.87
Azolla	57337	36595	1.76
Azotobacter	53343	32676	1.58
PSB	56647	35980	1.74
AM fungi	58857	37715	1.78
BGA + PSB	63307	42560	2.05
Azotobacter +PSB	59643	38951	1.88
Azolla + PSB	62553	41786	2.01
BGA + AM fungi	63850	42668	2.01
Azolla + AM fungi	62807	41565	1.96
Azotobacter + AM fungi	61503	40336	1.91
N_{120}+ P_{60}+ K_{60}	64347	43390	2.07
LSD (P= 0.05)	2785	5295	0.26

Concentration and uptake of N, P and K

Concentration of N in grain and straw of basmati rice was the highest when bio-inoculants like *Azolla* + PSB, *Azolla* + AM fungi, BGA + AM fungi and BGA + PSB were inoculated and concentration with these treatments was statistically *at par* with application of recommended dose of chemical fertilizer (Table 3). Combined inoculation of *Azolla*, BGA, PSB and AM fungi showed higher increment as compared to single inoculation of N_2-fixing and P-solubilising micro-organisms. Similar trend was recorded in the concentration of protein in grain and N in straw. Higher uptake of N in grain and straw was found due to the combined inoculation of *Azolla* + PSB, *Azolla* + AM fungi, BGA + AM fungi and BGA + PSB as compared to single inoculation of bio-inoculants (Table 3). However, the uptake of N in grain and straw with combined inoculation of 2 bio-inoculants was statistically *at par* with application of $N_{120}P_{60}K_{60}$. Concentration of N with inoculation of *Azotobacter* was the lower as compared to single inoculation of *Azolla*, BGA, PSB and AM fungi. Inoculation of microbial inoculants increased OC content of soil, which might also be responsible for higher nutrient availability (Mandal *et al*. 2003 and Dwivedi *et al*. 2005). Due to the inoculation of bio-fertilizers, amount of fixed atmospheric N_2 and organic matter content in to soil was enhanced. Organic matter is considered a reservoir of nutrients in soil and it is also a good indicator of available N into the soil. Similar findings were reported by Chaphale *et al*. (2000) and Singh *et al*. (2002). Marginal increase in N content of rice straw due to inoculation of N_2-fixing and P-solubilising micro-organisms has been reported (Singh and Mandal 1996). This might be due to increase in the N availability through synchronized released from the inoculation of microbial inoculants which increased the N concentration proportionately in grain and straw and finally led to higher N uptake with highest level of N (Shivay *et al*. 2008).

Table 3. Effect of different treatments on the concentration and uptake of N by rice grain and straw

Treatments	N concentration (%)		N uptake (kg ha^{-1})		Total N uptake (kg ha^{-1})
	Grain	Straw	Grain	Straw	
BGA	1.38	0.58	58.4	96.5	157.0
Azolla	1.39	0.59	56.6	93.5	152.1
Azotobacter	1.37	0.58	50.4	90.5	143.2
PSB	1.38	0.60	55.4	98.5	155.8
AM fungi	1.40	0.61	62.0	97.6	158.6
BGA + PSB	1.41	0.61	67.0	100.6	170.0
Azotobacter + PSB	1.41	0.58	60.1	99.4	158.8
Azolla + PSB	1.42	0.61	63.3	101.5	169.1
BGA + AM fungi	1.38	0.63	63.3	106.4	171.4
Azolla + AM fungi	1.41	0.62	64.4	107.0	170.4
Azotobacter + AM fungi	1.40	0.60	63.5	98.6	161.6
N_{120}+P_{60}+K_{60}	1.40	0.60	64.0	101.4	168.5
LSD (P=0.05)	0.04	0.03	7.3	8.5	12.2

The variation in concentrations of P in rice straw in different treatments was non-significant, however in grain highest concentration of P was found at $N_{120}P_{60}K_{60}$ and this concentration was statistically *at par* with the treatments having inoculation of PSB or AM fungi alone or in combination with *Azolla* and BGA (Table 4). Variation in uptake of P in grain was highest in treatment having application of $N_{120}P_{60}K_{60}$ but it was statistically *at par* with the treatments having inoculation of PSB or AM fungi alone or in combination with *Azolla* and or BGA. Uptake in treatment having *Azotobacter* inoculation had lowest P uptake. Single application of *Azolla*, BGA, PSB and AM fungi also increased P uptake and it was higher than *Azotobacter* inoculation. Increase in concentration and uptake of P due to application of *Azolla* and BGA has been reported by Singh and Mandal (1996).

The concentration of K in grain was not statistically different among different treatments though, it varied between 0.28 to 0.31 % among different treatments (Table 4). The K concentrations in straw were different among different treatments. The lowest K concentration was recorded in the treatment having inoculation of *Azotobacter* (1.20%), this concentration was significantly lower than all the other treatments and even with the treatment having single inoculation of BGA, *Azolla*, PSB and AM fungi. Uptake of K in grain was found to be non-significant among all the treatments though it varied between 10.9-14.1 kg ha^{-1}. K uptake by straw was significantly different among treatments. The highest K uptake was seen in treatment having recommended dose of chemical fertilizer (247.2 kg ha^{-1}). This concentration was statistically *at par* with the treatment having BGA + AM fungi, *Azolla* + AM fungi, *Azolla* + PSB and BGA + PSB. K concentration in straw increased with increasing levels of N application and this was favourably complementd by bio-inoculants inoculation and resulted in enhanced K concentration (Singh and Mandal 1996; Shivay *et al*. 2001).

Concentration and uptake of Fe, Zn, Mn and Cu

The highest concentration (92.1 mg kg^{-1}) of Fe was recorded in the treatment having inoculation of BGA + PSB and this concentration was significantly higher than all other treatments (Table 5). Fe concentration in straw was recorded to be statistically different among different treatments. The highest Fe concentration (440.6 mg kg^{-1}) was recorded with BGA + AM fungi and it was statistically *at par* with BGA + PSB and recommended dose of chemical fertilizer. Inoculation of BGA, *Azolla*, AM fungi also recorded higher Fe concentration as compared to *Azotobacter* inoculation. Fe uptake in rice grain was recorded to be statistically different. The highest Fe uptake (429.6 g ha^{-1}) was recorded with BGA + PSB which was statistically higher than all the other treatments. The recommended dose of chemical fertilizer gave Fe uptake 386.2 g ha^{-1} and it was statistically *at par* with other treatments. Fe uptake in straw was the highest with recommended dose of chemical fertilizer (7376.5 g ha^{-1}) which was statistically *at par* with the Fe uptake with BGA + AM fungi and BGA + PSB. Total uptake of Fe by grain and straw also showed similar trend. The highest total Fe uptake was recorded with the

Table 4. Effect of different treatments on concentration and uptake of P and K by rice grain and straw

Treatments	P concentration (%)		P uptake (kg ha^{-1})		K concentration (%)		K uptake (kg ha^{-1})	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
BGA	0.24	0.12	10.5	12.6	0.29	1.47	12.3	216.1
Azolla	0.24	0.12	9.9	12.4	0.31	1.37	12.6	198.1
Azotobacter	0.22	0.12	8.3	12.6	0.29	1.20	10.9	180.7
PSB	0.30	0.14	11.9	14.2	0.30	1.37	12.1	195.9
AM fungi	0.28	0.12	11.9	13.3	0.31	1.40	13.2	211.4
BGA + PSB	0.32	0.13	14.7	14.9	0.29	1.67	13.5	240.9
Azotobacter+ PSB	0.27	0.13	11.5	14.2	0.30	1.50	12.8	216.2
Azolla + PSB	0.26	0.13	12.1	15.1	0.29	1.67	13.5	234.3
BGA + AM fungi	0.28	0.11	13.2	12.9	0.28	1.70	13.2	245.7
Azolla+ AM fungi	0.33	0.12	15.2	12.4	0.28	1.60	12.9	242.7
Azotobacter + AM fungi	0.27	0.12	12.3	13.3	0.28	1.60	12.5	226.9
N_{120}+ P_{60}+ K_{60}	0.32	0.12	15.2	13.6	0.30	1.63	14.1	247.2
LSD (P=0.05)	0.04	NS	2.2	NS	NS	0.20	NS	38.4

recommended dose of chemical fertilizer which was closely followed the uptake by the treatments having inoculation of BGA + PSB and BGA + AM fungi.

The concentration of Zn in grain of rice was not significantly different among treatments though it varied between 22.3-27.7 mg kg^{-1}(Table 5). Zn concentration in straw was recorded to be significantly different among different treatments. The highest concentration of Zn was recorded with inoculation of BGA + AM fungi (164.7 mg kg^{-1}) and it was statistically *at par* with the concentration with BGA + PSB, recommended dose of chemical fertilizer and *Azolla* + AM fungi. Single inoculation of BGA, *Azolla* and AM fungi also increased the Zn concentration as it was higher than the concentration due to the inoculation of *Azotobacter*. The highest Zn uptake was seen with inoculation of *Azolla* + PSB (127.1 g ha^{-1}) and it was *at par* with the uptake at recommended dose of chemical fertilizer, inoculation of *Azolla* + AM fungi and BGA + PSB. The lowest Zn uptake was found with the inoculation of *Azotobacter*. Total uptake of Zn in grain and straw also showed the similar trend. The highest total Zn uptake (288.5 g ha^{-1}) was reported with recommended dose of chemical fertilizer at it was *at par* with combined inoculation of N_2 -fixing and P-solubilising micro-organism.

The variation in concentration of Mn in grain of rice was not significant among different treatments though it varied between 20.0 to 22.0 mg kg^{-1}(Table 6). Mn concentration in straw was recorded to be significantly different among different treatments.

Table 5. Effect of different treatments on the concentration and uptake of Fe and Zn by rice grain and straw

Treatments	Fe concentration (mg kg^{-1})		Fe uptake (g ha^{-1})		Zn concentration (mg kg^{-1})		Zn uptake (g ha^{-1})	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
BGA	83.1	396.1	22.3	159.5	22.3	159.5	95.5	2645.5
Azolla	82.0	391.2	25.3	159.1	25.3	159.1	104.4	2555.3
Azotobacter	81.1	381.9	22.7	156.0	22.7	156.0	84.5	2482.4
PSB	80.6	383.7	22.3	157.4	22.3	157.4	90.6	2556.5
AM fungi	79.4	396.7	22.7	159.4	22.7	159.4	96.6	2585.6
BGA + PSB	92.1	439.4	24.0	164.7	24.0	164.7	112.6	2746.4
Azotobacter+ PSB	79.1	399.2	24.3	159.8	24.3	159.8	105.0	2643.8
Azolla + PSB	82.1	413.3	27.7	163.0	27.7	163.0	127.1	2726.0
BGA+ AM fungi	79.3	440.6	22.3	164.7	22.3	164.7	104.8	2759.2
Azolla+ AM fungi	81.5	415.6	26.0	163.3	26.0	163.3	119.2	2760.2
Azotobacter + AM fungi	80.2	410.6	25.7	162.6	25.7	162.6	115.6	2699.5
N_{120}+ P_{60}+ K_{60}	81.3	438.1	25.7	164.3	25.7	164.3	122.5	2766.0
LSD (P=0.05)	5.6	7.8	NS	2.7	NS	2.7	24.3	105.6

Table 6. Effect of different treatments on the concentration and uptake of Mn and Cu by rice grain and straw

Treatments	Mn Concentration (mg kg^{-1})		Mn uptake (g ha^{-1})		Cu concentration (mg kg^{-1})		Cu uptake (g ha^{-1})	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
BGA	21.3	61.5	91.5	1019.8	11.3	38.1	48.5	633.9
Azolla	22.0	60.9	90.7	977.8	11.0	37.7	45.3	605.7
Azotobacter	21.3	59.5	80.4	947.3	10.3	35.2	38.9	560.5
PSB	21.0	60.7	84.4	986.5	10.7	36.7	43.0	596.3
AM fungi	20.0	61.1	85.1	991.1	10.3	38.0	43.8	616.2
BGA + PSB	21.7	64.7	100.4	1078.5	10.0	40.4	46.5	673.5
Azotobacter+ PSB	20.7	61.5	89.4	1017.4	11.7	38.2	50.5	632.1
Azolla + PSB	20.7	62.3	94.7	1042.6	11.0	40.0	50.4	669.0
BGA + AM fungi	21.3	64.7	100.7	1083.9	10.7	41.2	50.0	689.8
Azolla+ AM fungi	20.3	62.6	93.3	1058.4	12.0	39.6	55.2	669.5
Azotobacter+ AM fungi	20.7	63.9	92.8	1061.5	11.0	38.3	49.3	635.7
N_{120}+ P_{60}+ K_{60}	21.7	64.3	102.8	1082.3	11.7	40.8	55.2	686.5
LSD (P=0.05)	NS	2.4	NS	58.1	NS	NS	NS	75.6

The highest concentration (64.7 mg kg^{-1}) of Mn with BGA + PSB and BGA + AM fungi was statistically *at par* with recommended dose of chemical fertilizer and *Azotobacter* + AM fungi. Uptake of Mn in grain was also recorded to be statistically *at par* among different treatments. And it varied between 80.4 to 102.8 g ha^{-1}; Mn uptake by straw was significantly different among all the treatments. The highest Mn uptake was with the inoculation of BGA + AM fungi (1084.0 g ha^{-1}) statistically *at par* with recommended dose of chemical fertilizer and BGA + PSB. Total uptake of Mn by grain and straw was also significantly different among different treatments.

The differences in concentration of Cu in grain and straw were not significant among treatments (Table 6). Concentration of Cu in grain varied between 10.3 to 12.0 mg kg^{-1} while in straw between 35.2 to 41.2 mg kg^{-1}. Cu uptake in grain was also not significantly different among different treatments. Cu uptake varied between 38.9 to 55.2 g ha^{-1}. Cu uptake in straw was significantly different among treatments being highest Cu uptake with BGA + AM fungi (690 g ha^{-1}) which was statistically *at par* with the concentration of recommended dose of chemical fertilizer, *Azolla* + AM fungi and *Azolla* + PSB. Total Cu uptake was found significantly different among treatments, the highest Cu with recommended dose of chemical fertilizer *at par* with *Azolla* + AM fungi, *Azolla* + PSB and BGA + PSB. The lowest (594 g ha^{-1}) Cu was recorded due to inoculation of *Azotobacter*. Increased micronutrient uptake might be governed by increased root surface area (longer and thinner roots), the ability to change chemistry and biology of rhizosphere by releasing phyto-siderophores from roots (Cakmak *et al*., 1996; Regel, 1999).

Soil-physico-chemical and microbial properties

Data on soil pH, EC and organic C content in soil at crop harvest showed that the treatments did not have significant influence on the pH, EC and organic C content of soil. pH of soil varied between 7.3-7.4 among different treatments(Table 7). The EC values varied between 2.21 to 2.29 dS m^{-1}. Organic C level in soil varied between 0.54-0.60 percent. The soil Microbial biomass C (MBC) at mid-season stage of C was found to be significantly different among different treatments. The highest MBC was recorded with *Azotobacter* + PSB which was statistically *at par* with BGA + PSB. Recommended dose of chemical fertilizer recorded 257.4 µg C g^{-1} soil which was statistically *at par* with the MBC at BGA + AM fungi and *Azolla* + PSB. Alkaline phosphatase activity at mid-season stage was significantly different among treatments. The highest alkaline phosphatase activity was recorded with *Azotobacter* + PSB which was statistically *at par* with *Azolla* +PSB. The FDA hydrolysis was significantly different in treatments. The highest FDA hydrolysis (1.34µg Fluroscein rel g^{-1} hr^{-1}) was found with the *Azolla* + PSB inoculation and it was statistically *at par* with single BGA inoculation. Less difference in soil physical properties were recorded in treatments. This might be due to the short period of experimentation while longer period is required to have considerable change in soil physical properties. Buresh and Datta (1990) also reported less changes in physical

Table 7. Effect of different treatments on physical and microbial parameters of soil after crop harvest stage

Treatment	pH	EC(dS m^{-1})	Organic C (%)	Microbial biomass C (µg C g^{-1} soil)	Alkaline phosphatase (µg PNP rel g^{-1} hr^{-1})	FDA Hydrolysis (µg Fluroscein rel g^{-1} hr^{-1})
BGA	7.4	2.21	0.55	241.1	244.5	1.28
Azolla	7.3	2.32	0.55	276.7	248.3	0.85
Azotobacter	7.3	2.21	0.54	243.9	237.0	0.89
PSB	7.4	2.30	0.54	246.4	243.3	1.13
AM fungi	7.3	2.21	0.55	260.3	244.5	0.59
BGA + PSB	7.4	2.27	0.57	281.7	240.0	1.13
Azotobacter+PSB	7.3	2.35	0.56	287.5	253.6	0.66
Azolla + PSB	7.5	2.34	0.58	269.9	253.0	1.34
BGA+ AM fungi	7.2	2.29	0.60	264.6	239.4	0.81
Azolla+ AM fungi	7.4	2.27	0.58	262.9	242.5	0.90
Azotobacter + AM fungi	7.4	2.28	0.54	253.8	242.6	0.78
N_{120}+ P_{60}+ K_{60}	7.4	2.25	0.56	257.4	241.1	0.79
LSD (P=0.05)	NS	NS	NS	20.3	4.9	0.38

properties of soil due to the application of biofertilizers on short term basis. Singh *et al.* (2006) reported change in microbial properties in soil due to the application of microbial inoculants like *Azolla*, BGA and PSB. Change in microbial properties in soil have been reported by other workers (Paul and Verma, 2005; Singh and Rana, 2005; Prasanna *et al.*, 2008).

CONCLUSIONS

The study concluded that inoculation with N_2-fixing and P-solubilising micro-organisms enhanced the crop productivity, net return, concentration and uptake of N in grain as well as straw, and the response was higher due to the combined application of these bio-inoculants. Concentration and uptake of P in grain and K in straw was significantly influenced due to the combined application of microbial inoculants. Iron concentration and uptake in grain and straw was significantly influenced due to the inoculation of microbial inoculants. Soil microbial properties were significantly influenced due to the inoculation of N_2-fixing and P-solubilising micro-organisms while physico-chemical properties were not significantly influenced.

REFERENCES

Buresh RJ and De Datta SK.1990. Denitrification losses from puddled rice soils in the tropics. *Biol. Fertil. Soils.* **9:**1-13.

Cakmak I, Sari N, Marschner H, Kalayci M and Yilmaz A.1996. Phytosiderophore release in bread and durum wheat genotypes differing in zinc efficiency. *Plant Soil* **180**:183-189.

Casida LE Jr, Klein DA and Santoro T. 1964. Soil dehydrogenase activity. Soil Sci. **93**:371-376.

Chaphale SD, Chaphale BS, Yeerne AZ and Laniewar AD.2000. Effect of green manuring on soil properties and yield performance of rice. *J. Soil Crops* **10**(1):136-140.

Choudhury ATMA and Kennedy LR.2004. Prospects and potentials for systems of biological nitrogen fixation in sustainable rice production. *Biol Fertil Soils* **39**:219-227

De Datta SK and Buresh RJ.1989. Integrated nitrogen management in irrigated rice. *Adv Soil Sci* **10**:143–169

Dwivedi CP, Tiwari ON, Nayak R, Dwivedi S, Singh A and Sinha SK.2005. Effect of green manures *Sesbania* and *Vigna radiata* and biofertilizers on the soil sustainability and crop productivity in rice-wheat cropping system. *Physio. Mol. Bio. Plants* **11**(1):141-147.

Green VS, Ctott DE and Diack M. 2006. Assay of Fluorescein diacetate hydrolytic activity- optimization of soil samples. *Soil Biol. Biochem*. **38**: 693-701.

Hashem MA.2001. Problems and prospects of cyanobacterial biofertilizer for rice cultivation.*Aust J Plant Physiol* **28**:881– 888

Jeyabal A and Kuppuswamy G. 2001. Recycling of organic wastes for the production of vermicompost and its response in rice-legume cropping systems and soil fertility. *Haryana J. Agron.,* **15**: 153-170.

Kucey RMN, Jenzen HH and Leggett ME.1989. Microbially mediated increases in plant available phosphorus. *Adv. Agron*.b,:199–228.

Lekberg Y, Koide RT and Twomlow SJ.2008. Effect of agricultural management practices on arbuscular mycorrhizal fungal abundance in low-input cropping systems of southern Africa: a case study from Zimbabwe. *Biol Fert Soils* **44**: 917–923.

Mandal UK, Gurcharan S, Victor US and Sharma KL.2003. Green manuring: its effect on soil properties and crop growth under rice-wheat cropping system. *European J. Agron.* **19**(2): 225-237.

Mian MH .2002. Azobiofer: a technology of production and use of *Azolla* as biofertiliser for irrigated rice and fish cultivation. In: Kennedy IR, Choudhury ATMA (eds) Biofertilisers in action. Rural Industries Research and Development Corporation, Canberra, pp 45–54

Nunan N, Morgan MA and Herlihy M.1998.Ultraviolet absorbance (280 nm) of compounds released from soil during chloroform fumigation as an estimate of the microbial biomass. *Soil Biol. Biochem*. **30**(12): 1599-1603.

Pabbi S, Prasanna, R, Dhar, DW and Singh PK.2000. Algal biofertilization to rice: Potential and constraints. In : Biofertilizers, Blue green algae and *Azolla*. Singh, P.K, Dhar, DW, Pabbi, S and Prasanna, R and Arora, A, IARI, New Delhi. pp. 83-99.

Paul S and Verma OP.2005. *Azatobacter* bio-inoculants in sustainable agriculture. Advances in Microbiology at IARI 1961-2004. Division of Microbiology, IARI, New Delhi. 135-146.

Prasad R, Shivay YS, Kumar D and Sharma SN.2006. Learning by Doing Exercise in Soil Fertility-A Practical Manual for Soil fertility, Division of Agronomy, IARI, New Delhi.

Prasanna R, Jaiswal, P, Singh YV and Singh PK.2008. Influence of biofertilizers and organic amendment on nitrogenase activity and phosphatase biomass on soil under wheat. *Acta Agronomica Hungarica*. **56**(2):149-159.

Rengel Z.1999. Physiological responses of wheat genotypes grown in chelatorbuffered nutrients solutions with increasing concentrations of excess HEDTA. *Plant Soil* **215**: 193-202.

Reeves TG, Waddington SR, Ortiz-Monasterio I, Bnziger M and Cassaday K.2002.

Removing nutritional limits to maize and wheat production: A developing country perspective. In: Kennedy IR, Choudhury ATMA (eds) Biofertilisers in Action.

Rural Industries Research and Development Corporation, Canberra, pp 11–36

Richardson AE.1994. Soil micro-organisms and phosphate availability. In soil biota management in sustainable agriculture. Eds. CE Pankhurst, BM Doube, VVSR Gupts and PR Grace pp.50–62. CSIRO, Melbourne, Australia.

Sahrawat KL .2000. Macro and micronutrients removed by upland and lowland rice cultivars in West Africa. *Commun Soil Sci Plant Anal* **31**:717–723

Sheng M, Tang M, Chen H, Yang BW, Zhang FF and Huang YH .2008. Influence of arbuscular mycorrhizae on photosynthesis and water status of maize plants under salt stress. *Mycorrhiza* **18**: 287–296.

Shivay, YS, Kumar D and Prasad R. 2008. Effect of zinc-enriched urea on productivity, zinc uptake and efficiency of an aromatic rice-wheat cropping system. *Nutrient Cycling in Agroecosystems.* **81**(3):229-243.

Shivay YS, Prasad R, Singh S and Sharma SN.2001. Coating of prilled urea with neem (*Azadirachta indica* Juss) for efficient nitrogen use in lowland transplanted rice. *Indian J. of Agron.* **46**(3):453-457.

Singh CS and Rana JPS. 2005. Arbuscular mycorrhizal fungi. Advances in Microbiology at IARI (2004). Division of Microbiology, IARI, New Delhi. 123-133.

Singh, G., Kumar, T., Kumar, V., Kumar, R.G. and Sharma, R. 2002. Effect of integrated nutrient management on transplanted rice and its residual effect on succeeding wheat in rainfed lowlands. *Indian J. Agron.* **47**(3):311-317.

SinghYV and Mandal BK.1996. Manuring of rice through organic sources in combination with Urea. *J. Andaman Sci.Assoc.* **12**(1&2): 1-8.

Singh YV and Mandal BK.1997. Nutrition of rice (*Oryza sativa*) through *Azolla*, organic materials and urea. *Ind. J. Agron.* **42**(4):626-633.

Journal of Soil and Water Conservation, Vol. 11, No. 2, pp 59–65 (2012)
Received: 6 November 2011; Accepted: 9 April 2012

Remote Sensing and GIS Application for Rainfed Agriculture Management

ARUN CHATURVEDI[1], G.P. OBI. REDDY[2], RAJEEV SRIVASTAVA[3] AND A.K. MAJI[4]

ABSTRACT

In view of the high emphasis on watershed development projects in rain-fed areas of India, the emerging tools modern tools such as satellite remote sensing and Geographic Information System (GIS) need to be used, which provide newer dimensions to effectively monitor and manage land resources in an integrated manner particularly in sustainable development of rainfed agriculture. Remote sensing data are widely used to monitor vegetation cover and drought assessment throughout the world. Green leaves commonly have larger reflectances in the near infrared than in the visible range. As the leaves come under water stress, become diseased or die back, they become more yellow and reflect significantly less in the near infrared range. NDVI (normalised difference vegetation index) calculated from remote sensing satellite data has been found highly correlated with vegetation parameters such as green-leaf biomass and green-leaf area and, hence, is of considerable value for vegetation discrimination.In the present study, the utility of remote sensing and GIS along with conventional methods have been followed in field survey, soil sampling and physico-chemical analysis were followed for evaluation and planning of natural resources in the selected watershed in rainfed region as a case study. The AWiFs satellite data has been used to assess the biomass status in Nagpur district to monitor the drought conditions.

Keywords: Geographic Information System, Remote Sensing, Physico-chemical Rainfed Green Leaf, Drought

INTRODUCTION

The Rainfed agriculture plays an important role in Indian economy as 68 percent of total net sown area (136.8m.ha) comes under rainfed lands, according to the Union Ministry of Agriculture. Area under rainfed crops account for 48 percent under food crops and 68 percent of the area under non-food crops. Nearly 50 percent of the total rural workforce and 60 percent of livestock in the country are concentrated in the dry districts. But uncertainty in production due to fluctuations in total rainfall and changes in its distribution, decrease in relative productivity in rainfed lands etc. affect the livelihoods of many poor and marginalised farmers and remain a major national concern. Rainfed areas are highly diverse, ranging from resource-rich areas with good agricultural potential to resource-poor areas with much more restricted potential. Developing strategies for rainfed areas is difficult because of their diversity in terms of agroecological characteristics, infrastructural development, and other socioeconomic variables.

Concepts and Definition of rainfed Agriculture

Most definitions of 'rainfed' areas are unable to distinguish between rainfed and irrigated agriculture. Agriculture scientists have explained rainfed areas from various perspectives. Shah and Shah (1993) define rainfed areas as those with percentage of gross cropped area under irrigation of less than 25 per cent, and an average rainfall of 400-750 mm. According to the Central Research Institute for Dryland Agriculture, those areas, which receive an annual rainfall of 750-800 mm, and have less than 30 per cent irrigated land, are rainfed. The Union Ministry of Agriculture classifies areas, which receive less than 750 mm rainfall annually, and have less than 30 per cent land under irrigation (both surface and ground water) as drylands. Some of the definitions for rainfed areas are listed in Table 1.

[1-4] National Bureau of Soil Survey & Land Use Planning, Amravati Road, Nagpur – 440 033

Table 1. Alternative criteria to define rainfed agriculture

Authors	Criteria used
Rangaswamy (1981)	Percentage of gross cropped area under irrigation (less than 30 percent) and average annual rainfall (between 375 and 1125 mm)
Jodha (1984)	Percentage of gross cropped area under irrigation (less than 25 percent) and average annual rainfall (between 500 mm and 1500 mm)
Subbarao (1985)	Percentage of gross cropped area under irrigation (less than 25 percent) and average annual rainfall (less than 970 mm)
Shah and Sah (1993)	Percentage of gross cropped area under irrigation (less than 25 percent) and average annual rainfall (between 400 and 750 mm)
Thorat (1993)	Percentage of gross cropped area under irrigation (less than 10 percent) and average annual rainfall (between 375 and 750 mm) (high intensity dry farmaing area)

Technologies, Tools and Investigations

The latter part of the 20th century has seen emergence of many technologies, which directly or indirectly help us in understanding our natural resource base, appreciating their limitations and potentials, and guiding us towards their optimum exploitation for sustained use. Computer based Digital Mapping Techniques of Remote Sensing and Geographic Information System (GIS) are examples of this category.

It is now increasingly being realized that utilization of natural resources with ignorance of their properties/characteristics creates mis-utilization that eventually may lead to their degradation, sometimes to the extent of irreversibility. There is, therefore, a greater emphasis on studies and surveys directed towards understanding of the resources and their basic properties. Inventorying of natural resources is, therefore, becoming a very crucial aspect of any resource management programme (Chaturvedi, 1992). The data originating from such inventories usually include, geographical distribution of natural resources, their characteristics (physical, chemical and biological properties), their limitations and potentials, and in some cases technologies and techniques for their optimum utilization.

The crucial aspect of any planning exercise is to handle complex problems of resource allocations and decision-making. Any attempt at resource evaluation for development planning requires data on various aspects both bio-physical and socio-economic and their integration. While data on socio-economic parameters points out the people, for whom the planning is required and their status, it also suggests the infrastructure and other limitations of any developmental plan. The bio-physical attributes, however point out the physical setting of the landscape and the problems and potentials of the natural resource base of the region. The latter has its importance in defining the sustainability of the suggestions made during the planning process.

The need for a "Management Information System" to the planners has been widely recognized. There is now an urgency to incorporate a "Decision Support System" so that Planners may be able to take suitable decisions in tune with the ground realities. Integration of Remote Sensing and GIS technologies provides an opportunity for the same. Any development plan should meet the aspirations of people within the resource paradigm set for the area. Therefore resource evaluation should be the first step in any planning process. Various datasets are available for the bio-physical as well as socio-economic aspects in spatial as well as non-spatial format. Digital analysis of multi-sensor, multi-temporal remotely sensed data are useful in discrimination of large number of unique spectral classes for accurate and faster map updating related to resource base in rainfed areas.

Role of Rainfed Areas in India's Food Security

Food security and productivity growth in agriculture in the coming years will increasingly depend on improved utilization of natural, human, financial and material resources and productivity growth in rainfed regions. According to the national agriculture policy, India must achieve a growth rate of 3- 4 per cent per annum in the sector. For maintaining food security even at the current nutritional levels, about 100 million tonnes of food grains need to be produced additionally by 2020. The total cropped area in India has remained static at around 140 million ha since 1970. The increased yield must come from areas with the least irrigation potential. Even then, there is likely to be a shortfall of 38 million tonnes of food grain in 2020. Further, the total contribution of irrigated agriculture to food grain production from both area expansion and yield improvement put together is likely be around 64 million tonnes in 2020, leaving a shortfall of 38 million tonnes. This implies that even in the best possible scenario of irrigation development, about 40 per cent of the additional supply of food grain needed to match future rise in demand will have to come from the unirrigated segment of Indian agriculture, most of which is located in dryland areas. And this demands that productivity of drylands be raised through intensive watershed work.

Overview of Soil Resources in Rainfed Areas

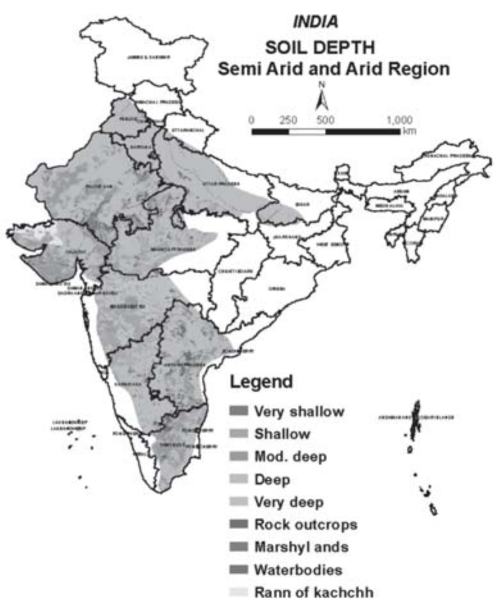
Maintaining this valuable resource in a state of high productivity is most important for providing ever increasing population with their basic needs on sustainable basis. Therefore, basic and reliable data on soil resources have become the imperative need for their scientific utilization. Since, semi-arid and arid regions in the country are closely associated with the rainfed areas, the soils of these regions were demarked from the 1:1 M soil resource map (NBSS&LUP, 2002). The thematic soil maps of the semi-arid and arid regions in the country are useful for regional scale planning. Some of the major soil properties that have direct bearing on agricultural productivity are briefly discussed hereunder.

Soil depth: Effective soil depth is an important soil parameter, which decides the growth and performances of crops and other vegetations. In the semi-arid and arid regions, shallow and very shallow soils are mainly associated with upland areas and undulating plains in the different parts of the region. Moderately deep soils occur in western and southern parts of the region. The majority of the area in the northern parts is under deep soils. Very deep soils are found in the black soil region of central Maharashtra (Fig.1a).

Soil drainage: Drainage refers to internal drainage through the soil pedons. It is governed by soil properties (viz. texture, structure, permeability, etc.), landform and depth to groundwater. The poorly and imperfectly drained soils are mainly associated with Indo-Gangetic plains in the northern parts of the region (Fig.1b). Moderately well drained soils have been noticed in central parts of the region particularly in Madhya Pradesh and Maharashtra. A majority of the area in the region is under well drained soils. Excessive drained soils have been noticed in isolated pockets.

Soil erosion: Slight erosion has been noticed in indo-gangetic plains in the northern parts of the region (Fig 2a). Moderately eroded soils occupy majority of the area in semi-arid and arid regions of the country. Severe erosion has been noticed in the uplands and undulating areas, which are critical in agricultural production.

Soil reaction (pH): Soil reaction is also an important limiting factor in crop growth. It governs the uptake of the nutrients held in exchange site of soil colloids. The slightly acidic soils have been noticed in the isolated pockets in semi-arid and arid regions in the country (Fig.2b). Slightly alkaline soils have occupied majority of the area. Strongly alkaline



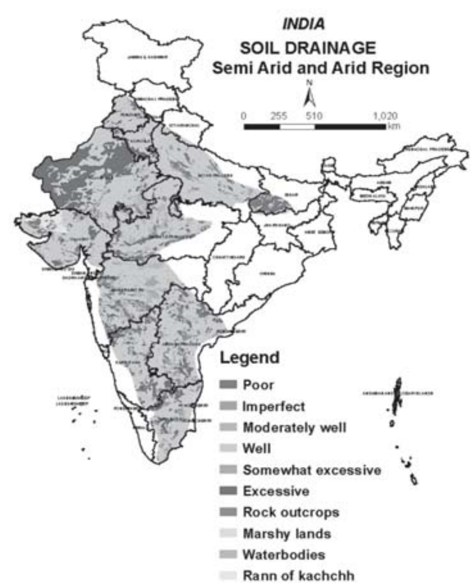
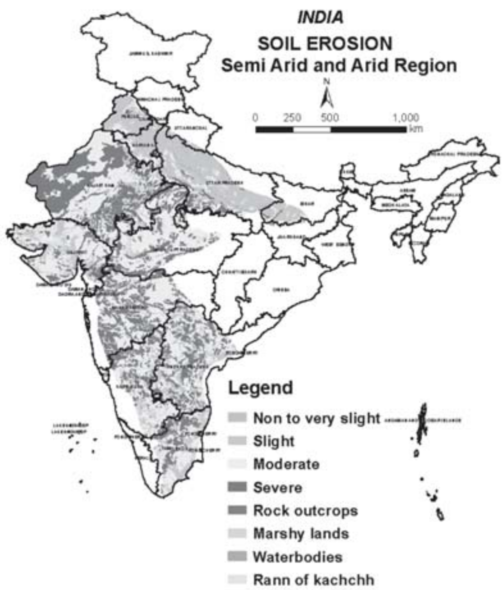


Fig. 1a and 1b: Soil depth and soil drainage in semi-arid and arid regions of India



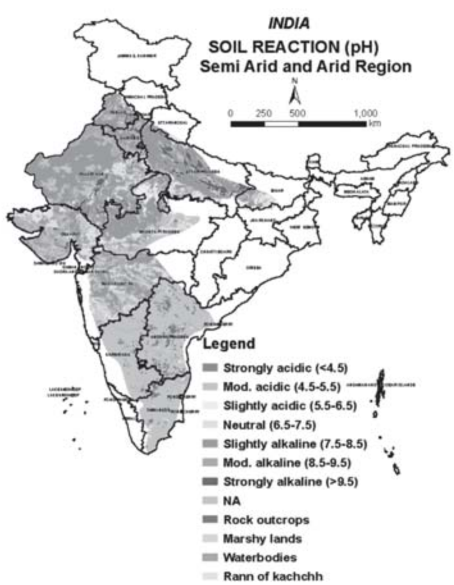


Fig. 2a and 2b: Soil erosion and soil reaction (pH) in semi-arid and arid regions of India

soils are mainly associated with the Indo-Gangetic plains in the northern parts of the region.

Importance of Resources Management in Rainfed Agriculture Areas

Sustainable agricultural development in rainfed areas requires a systematic effort towards the planning of land, water resources and land use activities in the most appropriate way, apart from several other institutional and policy programmme initiatives. Watershed base approach is one of the most important for natural resources management and agricultural developmental planning.

Remote sensing and GIS Application

Watershed Development Program was initiated in 1980s (MoRD 1994; Hanumantha Rao 2000; Planning Commission, 2002, 2005). The emphasis and approach of the projects vary from region to region depending upon the priority and resources availability. In India watershed-based development has been the strategy for growth and sustainability of agriculture in the vast semi-arid and dry sub-humid regions popularly called rain-fed regions. Watershed Development Projects have been undertaken to enhance agricultural production, conserve natural resources base and ensure rural livelihood. Initially soil and water conservation was the primary objective of the program which attracted large public investments in the last 25 years. Subsequently, providing sustained rural livelihoods through management of land and water resources and environment has gained emphasis. To achieve these goals large investments have been assigned for watershed based development in the National Five-Year Plans since 1990s. In view of the high emphasis on watershed development projects in rain-fed areas of India, the emerging modern tools such as satellite remote sensing and Geographic Information System (GIS) were adopted. They provide newer dimensions to effectively monitor and manage land resources in an integrated manner for sustainable development of rainfed agriculture.

Remote Sensing and GIS Application in Natural Resource Management-A case study

The capabilities of remote sensing and GIS applications in resources inventory, monitoring temporal change, creation of spatial and non-spatial databases for evaluation and management of natural resources in rainfed areas have been demonstrated by several workers. As a case study, the application of IRS 1C-LISS-III (Fig 3a) data in characterization and evaluation of Jhilpi watershed is briefly discussed below.

The watershed is located between 21° 02′ to 21° 06′ N latitude and 78° 50′ to 78° 58′E longitude in Hingna tehsil of Nagpur district Maharashtra covering an area of 4850 ha. It is located at about 25 km south-west of Nagpur town. The study area falls in the Survey of India Toposheet no. 55 K/16. The mean elevation of area varies from about 300 to 450m above the m.s.l. The general slope of the watershed is in east direction. Jhilpi Nala and its tributaries mainly drain the area. The climate is subhumid (dry) with mean annual temperature of 26.6ºC and mean annual rainfall is 1050 mm.

The study (Fig. 3b) revealed that notified forest comprises 1571.4 ha area of which 46.1 per cent is under dense forest (>40% canopy), 22.5 per cent under thin forest (10-40%) and 31.4 per cent under degraded forest (<10% canopy). Teak (*Tectona grandis*) is the dominant tree in the forest area. Other tree species are Palas (*Butea monosperma*), Charoli (*Buchanania latifolia*), *and* Anjan (*Hardwickia binata*). The total cropped area is 2773.5 ha of which only 44.9 per cent is under double crop. The dominant crops grown in the area are sorghum, cotton,

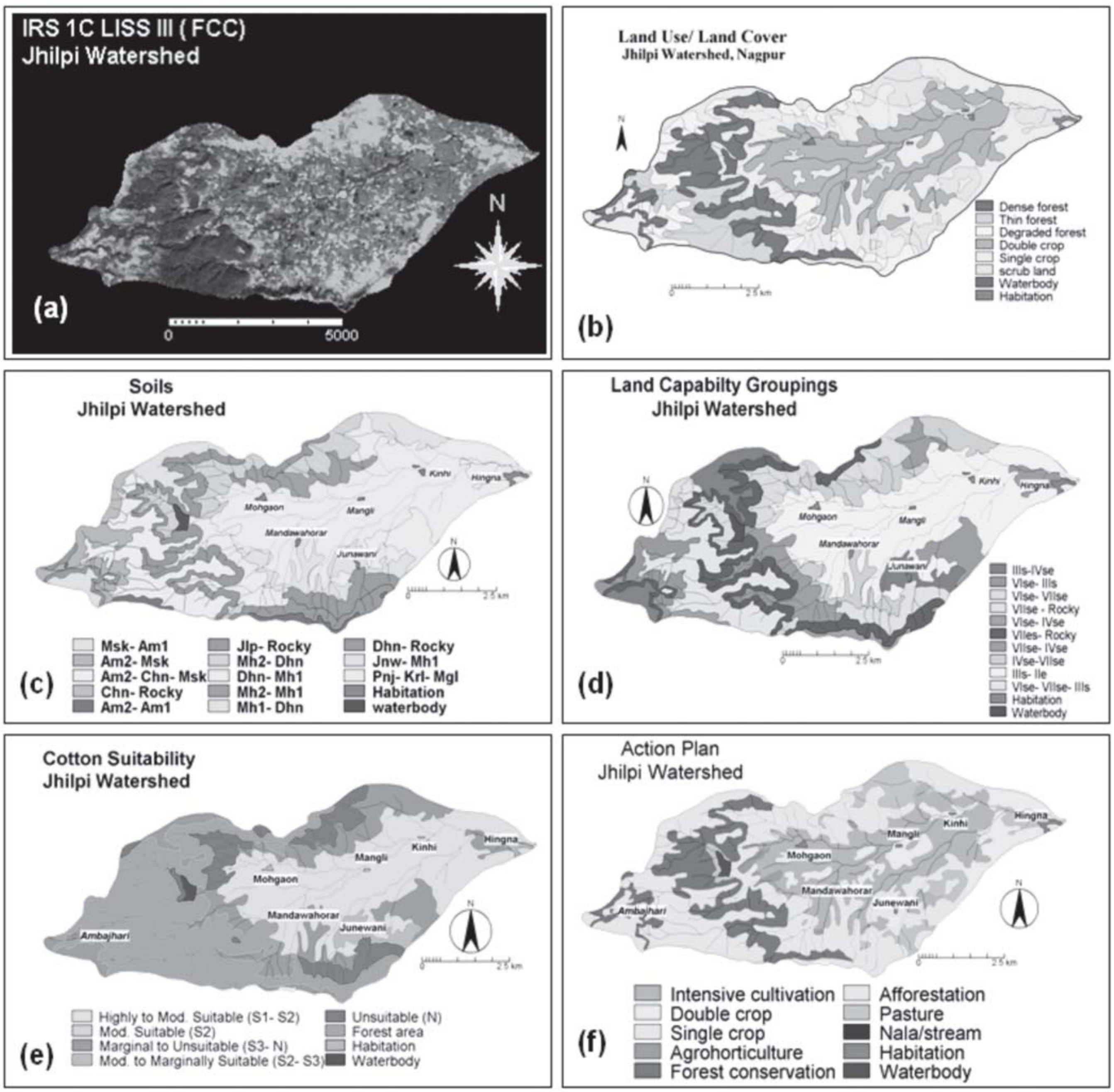


Fig. 3: Thematic maps of Jhilpi watershed, Nagpur

pigeonpea, mungbean and soybean in k*harif* and wheat and gram in *rabi*. The scrub lands, habitation and waterbodies constitute 9.5, 0.6 and 0.4 per cent, respectively of the total watershed.

Physiographically, the watershed has been divided into four dominant physiographic units *viz*. plateau top, escarpments, pediments and alluvial plains. These units were further subdivided based on slope and image characteristics. Based on physiography – soil relationship twelve soil series were identified and mapped as association of soil series. The soil map of the area showing association of soil series as mapping unit was prepared (Fig. 3c). The soils on plateau top, escarpments and pediments are, in general, very shallow to shallow, well to excessively drained, non-calcareous, loamy-skeletal to clayey, severely eroded Lithic Ustorthents (Chn and Dhn series), Typic Ustorthents (Am1, Am2, Jlp, Mh1, Mh2 series) Vertic Haplustepts (Msk series) and Typic Haplustepts (Jnw series) whereas the soils developed in alluvial plains are deep to very deep, moderately well drained, calcareous, fine to very fine, and slightly to moderately eroded. Due to dominance of smectitic group of clay minerals, they develop deep and wide cracks on drying. These soils are classified as Typic Haplusterts (Pnj series), Sodic Haplusterts (Mgl series) and Vertic Haplustepts (Krl series).

Based on climate, soil and site characteristics, the soils were grouped under different land capability classes. The land capability subclasses identified in the watershed are IIe, IIIs, IVse, VIse, and VIIes. The land capability map of the watershed is presented in Fig. 3d. Based on land capability groupings, it is observed that nearly 52.9 per cent of the total area is fit for cultivation and the rest is suitable for forestry and other uses.

Soil-site characteristics of each soil unit were evaluated for their suitability to cotton. The analysis of data indicates that nearly 33 per cent of the total watershed area is highly to moderately suitable (S1-S2), 2.3 per cent as moderately to marginally suitable (S2-N) and 20.8 per cent as marginally suitable to unsuitable (S3-N). The rest of the area is either unsuitable for cultivation or under miscellaneous categories (forest, habitation, waterbodies). It is observed that the soils of undulating plateau, escarpment and gently sloping pediments are unsuitable for cotton due to limitations posed by shallow solum, moderate surface stoniness and steep slopes. The soils of very gently sloping plateau and pediment are marginally suitable (Fig. 3e) because of shallow depth and moderate to severe erosion. The deep to very deep soils occurring in valleys are moderately suitable (S2) for cotton due to limitations posed by low content of organic carbon and high calcium carbonate.

The action plan map (Fig. 3f) of the watershed has been prepared taking into consideration the physiography, soils, land use/land cover, slope and land capability of the area.

CONCLUSIONS AND SUGGESTIONS

The watershed based approach using the modern techniques of remote sensing and GIS is most appropriate to inventory, analysis, planning and management of natural resources in rainfed regions of India. The available resources need to be planned and managed for onsite water harvesting and recharge of groundwater. In case of moderate annual rainfall regions, water harvesting and surface storage through farm ponds need to be given priority to enhance productivity of rain-fed crops. The remote sensing and GIS based studies help to suggest suitable sites for soil and water conservation structures (S&WC) viz., check-dam, stone weirs, contour bunding, live bunds, vegetative cover, key-line plantation, grassed water ways, etc. to provide impediments to overland runoff, which induce soil erosion and deplete nutrients from agricultural fields. The structures like farm ponds and tanks for water harvesting on surface besides impounding water for facilitating deep percolation for groundwater recharge.

REFERENCES

Chaturvedi Arun 1992. Recent Trends in Computerization of Natural Resource Inventories. ANNALS of National Association of Geographers, India Vol. XII (2)

Dvorak. 1988. Indigenous soil classification in semi-arid tropical India. Economics Group Progress Report No. 84, Resource Management Program. Patancheru: ICRISAT.

Hanumantha Rao, C.H. 2000. Watershed Development in India – Recent experience and emerging issues. Economic & Political Weekly, 35 (32) 3943 – 3947.

Jodha, N.S. 1984. Agricultural tenancy in semi-arid tropical India. In *Contractual Arrangements, Employment, and Wages in Rural Labor Markets in Asia*, eds. H.P.

MoRD, 1994. Report of the Technical Committee on DPAP and DDP. MoRD (GoI) -New Delhi..

NBSS&LUP. 2002. Soils of India. NBSS Publication No.94. National Bureau of Soil Survey and Land Use Planning, Nagpur, India pp 130 + 11 sheet maps.

Planning Commission, 2002. Report of the Committee on India Vision 2020. Planning Commission (GoI) - New Delhi. Dec. 2002. pp. 28-79..

Planning Commission, 2005. Mid-term Appraisal of the 10 Five-year Plan (2002-2007), (GoI) - New Delhi. pp. 187 – 236..

Rangaswamy, P. 1981. Economics of dry farming in drought prone areas: A case study of Hisar in Haryana. Research Study No. 81/1. Agricultural Economics Research Centre, University of Delhi.

Shah A. and D.C. Sah 1993. Dry land Farming under the changing source environment"A case study of Gujrat" *Artha Vignana* 35(3).

Subbarao, K. 1985. Institutions, infrastructure and regional variations in India's input delivery system. In Agricultural Markets in the Semi-Arid Tropics: Proceedings of the International Workshop, October 24-28, 198. Patancheru, India: ICRISAT.

Thorat, S.K. 1993. *Technological Change and Regional Differentiation*. New Delhi: Khanna Publishers.

SCSI PLEDGE

J.S. Bali

I pledge to conserve Soil,
that sustains me.
I pledge to conserve Water,
that is vital for life.
I care for Plants and Animals and the Wildlife,
which sustain me.
I pledge to work for adaptation to, and mitigation of
Global Warming.
I pledge to remain devoted,
to the management of all Natural Resources,
With harmony between Ecology and Economics.

Journal of Soil and Water Conservation, Vol. 11, No. 2, pp 66–73 (2012)
Received: 29 October 2011; Accepted: 27 April 2012

Impact of SWC Works under MNREGS on Rural Livelihoods in Rainfed Areas

K.S. REDDY[1], K. KAREEMULLA[2] , C.A. RAMA RAO[2] AND B.UMESHA[3]

ABSTRACT

The Mahatma Gandhi National Rural Employment Guarantee Scheme (MNREGS) is under implementation since 2006 and is currently covering all the rural districts of India. Besides providing wage employment opportunities locally, the scheme is creating assets in agricultural lands with major emphasis on soil and water conservation (SWC) works. A study was conducted with the prime objective of assessing the impact of SWC works on rural livelihoods in agriculture, in 16 villages spread across 4 major states, where the scheme is implemented in successful scale. There was significant reduction in the level of migration in the sample villages as a result of MNREGS implementation. Both the weaker sections and women got greater opportunities for employment under the scheme. The wage earnings were primarily used for ensuring food and health security besides education. The impact of SWC in farmers' lands through construction of farm ponds, open wells, field bunds and land leveling was visible in the study areas. The development of Common Property Resources (CPRs) like renovation of village tanks, construction of check dams/earthen dams were also prominent. An assessment of the impact of major soil and water conservation structures indicated that the annual return on investment was satisfactory in Anantapur (4.3%) followed by Yevatmal district (2.4%). The scheme can be effectively implemented with preparation of developmental plans on watershed basis for executing the SWC works particularly farm ponds, open wells, check dams. etc, so that the investment is fruitful in creation of assets for water resource development in rainfed agriculture followed by appropriate mechanism in place for its operation & maintenance.

Key words: MNREGS, Soil and water conservation, farm ponds, rainfed agriculture, CPR

INTRODUCTION

The Mahatma Gandhi National Rural Employment Guarantee Scheme (MNREGS) came into existence after the enactment of a parliament act 'National Rural Employment Guarantee Act' (2005) in September 2005. The Scheme was launched on 26 February from Anantapur in Andhra Pradesh. The Scheme initiated in 200 districts was subsequently extended twice to cover all the 593 rural districts of the country. The goals of the scheme provide strong social safety net for the vulnerable groups by providing a fall-back employment source, empowerment of rural poor through the processes of a rights-based law and new ways of doing business, as a model of governance reform anchored on the principles of transparency and grass root democracy (GoI, 2008).

The primary objective of the Scheme is to provide 100 days of guaranteed wage employment in a financial year to every household whose adult members volunteer to do unskilled manual work. The scheme has a systematic approach with regard to identification of works, issue of job cards to the eligible and execution of works, provision for social audit and transparency in payment among others. The scheme in the last four years of its existence has brought in a noticeable change in the rural areas with regard to employment opportunities particularly in the field of soil and water conservation works executed under the scheme.

[1] Principal Scientist (SWCE), Div. of Resource management, CRIDA, Hyderabad 500059
ksreddy@crida.in; ksreddy.1963@gmail.com
[2] Principal Scientists (Agril.Economics), CRIDA, Hyderabad
[3] Sr. Research Fellow (SWCE), CRIDA, Hyderabad

Many studies have documented the processes followed in NREGS implementation (Dreze, 2009, Ambasta *et al*., 2008). Change in the consumption pattern and purchase behavior of household durables among employment beneficiaries were reported (IAMR, 2008). Similarly, socio-economic issues, especially on the level of women participation in the scheme have also been studied (RTBI, 2009). NREGS activities, apart from providing employment and income, provided multiple environmental services such as, increased ground water recharge, enhanced water storage in tanks, increased soil fertility, reclamation of degraded lands and carbon sequestration (Raveendranath *et al*,.2009). However, all these studies indicated the impacts on social benefits only.

Therefore, the present study was conducted in four major states of the scheme implementation which also happened to be the major rainfed states with a specific focus on the use of soil and water conservation structures for agriculture, besides the impact on livelihoods of the employed beneficiaries.

METHODOLOGY

The study was conducted in four states *viz* Andhra Pradesh, Karnataka, Rajasthan and Maharashtra, as these are key states in terms of implementation of the scheme, besides being states with large rainfed areas. For the survey and field work, one district from each of these states was selected based on the lead in the implementation of MNREGS, i.e. the number of works as the criterion. From each such selected district, three mandals/ blocks were further selected randomly. At the next stage, from each of the selected mandal / block, two gram panchayats (GPs) were selected adopting the same criterion (Table 1). At the GP level, employment beneficiaries, farmers (both beneficiaries and non-beneficiaries) and work sites were selected and studied using pre-tested questionnaires as per the sample framework. Similarly, secondary data was collected from the websites www.nrega.nic.in and from the scheme implementing state line departments with respect to NRM works undertaken in the scheme.

TYPE OF WORKS IN STUDY STATES

Water conservation and water harvesting followed by land development were the major work categories in Andhra Pradesh, Karnataka and Maharashtra, whereas, provision of irrigation followed by rural connectivity comprised of the major work categories in Rajasthan (Table 2).

CLIMATE AND AGRICULTURE IN STUDY DISTRICTS

The sample districts in the study states were primarily chosen based on the maximum number of works. Majority of these districts fell into semi-arid climate. The incidence of drought was more frequent in Udaipur (25 out of 100 years) followed by Anantapur (24 out of 100 years) compared to 18 years each in Bellary and Yevatmal districts, which naturally affects the rural livelihoods, especially, by way of malnutrition and poverty, ultimately leading to migration (Gore, Thakur and Hatwar, 2010). The annual rainfall of the selected districts varies from 536 mm to 1032 mm (Table 3) and has ample scope of contributing swc works in drought proofing in the districts under the scheme.

Two of the study districts, viz., Yevatmal and Anantapur had comparatively lower cropping intensity (105 and 106%) indicating agricultural backwardness compared to Bellary (127%) and Udaipur (146%) (ICAR-ICRISAT Database (2008).

Table 1 : Study sample framework

Sample unit	Number per sample village (2 per block)	Number per mandal/block (3 per district)	Number per District / State (1 per state)	Total (4 states)
Employment Beneficiary				
- Men	5	10	30	120
- Women	5	10	30	120
Beneficiary Farmers* (< 5 acres)	6	12	36	144
Non-beneficiary farmer (> 5 acres)	6	12	36	144
Work-sites				
- Farmers	6	12	36	144
- CPRs	3	6	18	72

* As per norms of NREGS

Table 2: Share (%) of different works across study states

Work category	Type of works	Andhra Pradesh	Karnataka	Maharashtra	Rajasthan	India
Rural Connectivity	Rural connectivity, etc	2.9	5.4	3.4	22.5	15.9
Flood Control and Protection	Drainage in water logged areas, construction & repair of embankment	0.8	4.3	3.3	0.9	3.6
Water Conservation & water Harvesting	Digging of new tanks/ ponds, percolation tanks, small check dams	35.2	22.8	68.8	12.4	29.0
Drought Proofing	Afforestation and tree plantation	4.0	8.1	5.7	2.4	4.8
Minor Irrigation Works	Minor irrigation canals, others, etc to be indicated separately	14.1	6.2	0.4	3.1	6.6
Provision of Irrigation facility	SC's and ST's, beneficiaries of land reform, IAY's, small & marginal farmer	9.2	21.0	5.8	47.5	16.2
Renovation of Traditional Water bodies	Desilting of tanks/ ponds, desilting of old canals, desilting of traditional open well	6.6	4.5	5.2	8.9	7.1
Land Development	Plantation, land leveling, etc.	27.1	23.5	7.5	2.3	15.0
Others	Any other activity, approved by MRD, etc to be indicated separately	0.0	4.1	0.0	0.0	1.8
	Total Works (No.)	532673	38549	10613	87023	2084505

Source: www.nrega.nic.in

Table 3. Average annual rainfall of selected districts under MNREGS

Name of the district	Annual rainfall, mm	Annual Runoff potential, mm*
Anantapur (Andhra Pradesh)	536	42.88
Bellary(Karnataka)	632	50.56
Yavatmal (Maharashtra)	1032	165.12
Udaipur (Rajasthan)	653	26.12

*Average runoff coefficient of 8% for Anantapur and Bellary, 16% in Yavatmal and 4% in Udaipur were considered based on soils and slope conditions

A scheme like MNREGS with soil and water conservation works is expected to address this problem by way of bringing in climate resilience in cropping systems.

NUMBER OF MNREGS WORKS IN SELECTED DISTRICTS

Among the sample districts studied, Anantapur topped the list with maximum number of completed works (74929) which was about 14 per cent of the total works completed in Andhra Pradesh. Bellary accounted for 56 per cent of the completed works in Karnataka (Table 4).

Table 4: District - wise progress of NREGS works in study states (2006-10)

District	Completed works	District's Share (%)	Total no. of works in the state
Anantapur, A.P.	74929	14	532673
Bellary, Karnataka	21588	56	38549
Udaipur, Rajasthan	22622	26	87023
Yevatmal, Maharashtra	724	7	10613

Source: www.nrega.ap.gov.in

TYPE OF WORKS IN SELECTED DISTRICTS

Water conservation works (56%) dominated in Anantapur followed by land development (29%) (Table 5). On the other hand, provision of irrigation facilities (62%) dominated the work types in Bellary district, while drought proofing and renovation of traditional water bodies accounted for majority of the works in Yevatmal district. In Udaipur district land development was the major work category.

Table 5: Type of NREGS works (%) of total works across study districts

SWC Works	Anantapur	Bellary	Udaipur	Yevatmal
Water conservation / harvesting	56	3	8	19
Drought proofing and plantation	3	3	3	32
Micro and minor irrigation works	1	5		-
Provision of irrigation facilities	4	62	7	-
Renovation of traditional water bodies	3	1	5	32
Land development	29	5	39	1
Rural connectivity	3	12	13	6
Flood control and others	0	9	25	10
Total number of works	74929	21588	22622	724

Source: Records of scheme implementing departments

MODULUS OPERANDI OF WORKS IDENTIFICATION AND IMPLEMENTATION

Generally, works to be carried out under MNREGS, are identified at the grass root level. Depending on the sphere of work, viz., under the purview of Gram Panchayat, Mandal / Block Panchayat and District Panchayat, the works are categorized and reserved in the shelf of works. Proposals of such works related to community or individuals are prioritized in the Gram Sabha and then sent to mandal/block which will be finally approved at the district level by the implementing agency. For instance, in Andhra Pradesh, the District Water Management Agency (DWMA) is the nodal agency for implementing the MNREGS works while in the other three states, viz., Karnataka, Maharashtra and Rajasthan, the Zilla Panchayat is the nodal agency. The line departments like PWD, forests, minor irrigation are involved for planning and executing the works in community / government lands, especially in states like Rajasthan and Maharashtra. However, in Andhra Pradesh almost all the works are directly executed by DWMA with their field staff with active involvement of the Gram Panchayats.

RESULTS AND DISCUSSION

The site and household study was conducted in four purposively selected states, namely, Andhra Pradesh, Rajasthan, Maharashtra and Karnataka. Anantapur, Udaipur, Yevatmal and Bellary districts, respectively represented the selected states in the sample. A comparative status and impact of MNREGS on the livelihood and utility of NRM measures implemented across the study villages in the selected districts of four sample states is presented and discussed in this section.

IMPACT OF SWC WORKS ON RAINFED AGRICULTURE IN SAMPLED DISTRICTS

Majority of the works taken up under MNREGS are related to NRM and are mostly soil and water conservation works. Based on the field visits at the ground level, the technical soundness and utility of these interventions was evaluated by the multi-disciplinary study team. The summary of such evaluations across the four study districts is presented in table 6.

Anantapur, Andhra Pradesh

Farm ponds and earthen field bunds dominated the NRM works in the study villages. Some of the farm ponds, especially made in black soils, are being put to use for purposes like supplemental irrigation to crops (sunflower, chickpea, etc.) and some are serving as dugout / seepage wells. The average size of farm ponds with dimensions of 10 mx10 mx1m are dugout by using labor which accounts for creation of 100 m^3 capacity of water storage .In order to convert most of these structures into durable farm assets, certain alterations like proper pitching for the inlet / outlet and some lining, say with silt in the case of ponds in red soils; matching the catchment area with the pond size are required. The works are mainly contributing to ground water recharge than used for supplemental irrigation. On an average, the water level in bore wells increased by 5-6 m.

Bellary, Karnataka

Soil and water conservation works formed the majority of the MNREGS works in Bellary supporting the protection to resource base from erosion in the rainfed areas. Majority of the works included the construction of check dams and earthen dams in the area whose capacity ranged from 1000

Table 6: Success rate of works assessed at the site level (no. of works)

Name of the work	Anantapur		Bellary		Udaipur		Yevatmal	
	Total works	Works in use	Total works	Works in use	Total works	Works in use	Total works	Works in use
Checkdams, earthern dams			9	8	6	6	22	22
Farm ponds/ percolation tanks	16	13	2	2	-	-	24	14
Open Wells					14	14	2	2
Renovation of tanks	3	3	2	1				
Earthen/ Stone bunds	17	17			2	2		
Gully plugs					2	2		
Bush clearance	3	3	4	4				
Irrigation channels			9	9	10	8		
Plantations	7	6			6	4	**2**	**0**
Land Leveling					12	5		
Roads / drainage	4	4	3	3	2	2	4	4
Others	4	4						
Total	54	50	29	27	54	43	54	21

to 3000 m^3 which are being used for both irrigation and ground water recharge. Such tructures helped the farmers to improve the productivity in rainfed crops through supplemental irrigation. There are also a few cases where the MNREGS support was being utilized to lay pipelines to convey irrigation water to private properties and a few cases where some soil and water conservation structures were being taken up.

Yevatmal, Maharashtra

The major NRM interventions done as part of MNREGS in the study villages of Yevatmal district are farm ponds, cement plugs (a type of check dam) and earthen dams. Almost half of the farm ponds made lacked technical touch, as a result of which, they are not being utilized by the farmers. Nevertheless, the design and size of the farm ponds are optimal given the soil and rainfall pattern in the region. The district has good potential of water harvesting through farm ponds where 750 m^3 farm ponds are dugout in the farmers fields. Such structures indeed helped the farmers for supplemental irrigation to cotton crop by increasing the yields by 2.5 times as compared to rainfed.

Udaipur, Rajasthan

Land leveling, formation of field channels and open wells are the three major NRM works carried out as part of the MNREGS in Udaipur district. Wherever the crops are grown in the elevated areas, and are not supported by rains, lifting water and irrigating them from the valleys is a costly affair especially for the resource-poor farmers. After the introduction of MNREGS, water harvesting structures, especially check-dams were built along the natural drains in the valleys. The water collected in these structures was lifted and put in the field channels for irrigating the field crops. The lifting of water and distribution is managed by the community. The maintenance charges of the lift irrigation are borne by the farming community, whereas the initial investment for pump set comes from the Irrigation Department. Similarly, wherever there is a technical feasibility for digging open wells in the farmers' fields, the same were carried out in the MNREGS. Open wells would be very useful assets for the farmers. Field channels with cement and bricks were made connecting water harvesting structures (checkdams) or traditional village tanks through main canals.

IMPACT OF SWC WORKS ON RURAL LIVELIHOODS

Profile of Employment Beneficiaries

Farmers out numbed the employment beneficiaries in the study districts with exception of Yevatmal, where landless dominated the job seekers under the NREGS (Table 7). This indicates that the scheme has been particularly useful to the resource poor farmers who otherwise might have stayed unemployed after attending to their own farm operations.

Table 7: MNREGS Employment beneficiary profile in the study districts

Particulars	Anantapur (Andhra Pradesh)	Bellary (Karnataka)	Udaipur (Rajasthan)	Yevatmal (Maharashtra)
Average family size	4	5	5	5
Landless (No. & %)	23 (38)	29 (48)	41 (68)	1 (2)
Marginal / small farmers (No. & %)	31 (51)	31 (52)	16 (27)	59 (98)
Others farmers (No. & %)	6 (11)	0	3 (5)	0

Among the farmers' category, the marginal and small farmers took advantage of the scheme for augmenting their livelihood sources. Only in agriculturally distressed districts like Anantapur and Yevatmal even other farmers (>2 ha) participated in the MNREGS as wage earners.

Migration Status

One of the major concerns in rainfed areas, especially that are typically drought prone, is distress seasonal migration. Schemes that provide local opportunities for manual work like MNREGS are expected to bring down the level of such migration. It was noted that in almost all the study districts, the migration level has come down drastically due to the implementation of MNREGS (Table 8). The reduction in migration was the highest in Anantapur. The number of family members engaged in migration was higher in districts like Anantapur and Udaipur, which also came down in the MNREGS period. Accordingly, the income from migration was less in the MNREGS period compared to the pre-MNREGS period.

Household Employment and Share of MNREGS

The number of days in employment for the wage seekers was the highest in Anantapur with 107 person days per main worker. The share of MNREGS employment was also highest (27%) in Anantapur district followed by Yevatmal. Employment obtained in MNREGS per household was the highest in Udaipur district compared to the other three districts. Nevertheless, other wage opportunities including non-farm and non-agriculture employment dominated the share of employment for the households (Table 9).

Gender and Employment Pattern

Women obtained employment in MNREGS more or less on par with their men counterparts in all the study areas. Similarly, opportunities for them in rural areas were on par with that of men, except in Udaipur (Table 10). Because of assured minimum wage rates, women are getting equal wages depending on the work output.

Table 8: Impact of MNREGS on degree of migration (n = 60 per district)

Particulars	Anantapur		Bellary		Yevatmal		Udaipur	
	Before	After	Before	After	Before	After	Before	After
% of households in migration	55	13	30	12	12	8	47	15
No. of family members in migration	1.3	0.3	0.3	0.1	0.4	0.3	1.1	0.6
Income from migration	14791	10877	25222	17714	7813	6502	12214	7452

Table 9: Source-wise household employment status

District	Per person			Per household	
	NREGS	Other works	Self employment	NREGS	Total
Anantapur	29 (27)	50 (47)	28(26)	52	182
Bellary	15(16)	67(70)	13(14)	66	207
Yevatmal	25 (25)	55(55)	21 (21)	46	180
Udaipur	44(23)	94(49)	53(28)	94	422

Note: Figures in parentheses are percentages

Table 10: Employment pattern across gender in the study villages (No. of days/household/yr)

Source of employment	Anantapur		Bellary		Yevatmal		Udaipur	
	Men	Women	Men	Women	Men	Women	Men	Women
NREGS	63	64	34	38	51	40	46	42
Other outside employment	53	55	30	30	18	16	61	45
Household job including agri.	143	125	127	128	139	127	96	92

Household Income Vs MNREGS Earnings

The annual household income was the highest (Rs.62,357) for the wage seekers in Bellary district while it was the least (Rs.25,893) in Yevatmal district. Agricultural wages was the major source of livelihood in three out of the four study districts with an exception in Anantapur where MNREGS wages accounted for the major share (33%) of family income (Table 11). This indicates that the scope for MNREGS works is higher in districts with agricultural labour opportunities. MNREGS wages accounted for a share of 12-18% in the other three study districts. In Udaipur district non-agriculture labour, especially construction work in the nearby urban areas provided a considerable share of family income compared to the other three districts.

UTILITY OF MNREGS WAGE EARNINGS

Based on the survey of wage earners of MNREGS, the data was obtained on the purposes for which the wages were used (Table 12). It was learnt that ensuring food security was the major use across all the districts. Considerably higher share of wage earners (60%) in Udaipur reported use of the NREGS wages for that purpose. The other major uses of MNREGS wages were education of the dependents and family health. Some of the wage earners have even gone for savings (13%) in a distressed district like Yevatmal which also happens to be the poorest in terms of household income. This probably indicates that the propensity to save is better in a poor district compared to a relatively rich district, at least among the rural labour. The MNREGS wages played a crucial role in the survival and food security of the beneficiary households because these wages were available when they did not have access to other source of employment locally.

Table 11: Composition of household income of rural labour Rs & (% per year)

Source	Anantapur	Bellary	Udaipur	Yevatmal
Crops	11779 (27.5)	14093 (22.6)	4546 (14.2)	5438 (21)
Small ruminants	1499 (3.5)	499 (0.8)	288 (0.9)	0 (0)
Dairy	171 (0.4)	935 (1.5)	160 (0.5)	2330 (9)
Bullock hiring	300 (0.7)	374 (0.6)	288 (0.9)	0 (0)
Agricultural wages	10665 (24.9)	32924 (52.8)	10596 (33.1)	11134 (43)
Non-agricultural wages	4155 (9.7)	5862 (9.4)	10244 (32)	3107 (12)
MNREGS wages	14263 (33.3)	7670 (12.3)	5890 (18.4)	3884 (15)
Total income/yr	42833 (100)	62357 (100)	32012 (100)	25893 (100)

Table 12: Use of MNREGS wage earnings (% households)

Purpose	Anantapur	Bellary	Udaipur	Yevatmal
Food security	32	27	60	33
Education	18	20	8	5
Health	13	12	20	7
Debt repayment	8	12	2	8
House construction	7	8	0	13
Purchase of household assets	3	5	0	5
Clothing	7	9	6	12
Purchase of land	5	1	0	3
Savings	7	7	3	13

CONCLUSIONS

Majority of the works under MNREGS identified pertain to creation of soil and water conservation structures that have a bearing on the production capacity of rainfed lands to reduce the resource losses due to erosion. The present study which was conducted at micro level in four major states of MNREGS implementation, viz., Andhra Pradesh, Karnataka, Maharashtra and Rajasthan has drawn the following conclusions:

- The employment beneficiaries are both landless and farmers indicating that the resource poor farmers are also willing to get employed in public schemes to augment their livelihood sources
- Introduction of a large scale scheme like MNREGS has significantly brought down the migration levels in rural areas, thus, retaining the rural labour for use in the local areas.
- The beneficiary households utilized earnings from MNREGS for purposes like food and health security, education, repayment of debts, construction / purchase of house, etc. This indicates that the rural poor only need opportunities for them to participate and grow to come out of the vicious cycle of poverty and lead a decent and dignified life
- Given the degraded nature of resources in the rainfed regions of the country, the type of NRM works implemented in the study areas match the corrective steps required to improve their status. However, the success of these measures will largely depend on adequate technical supervision and greater farmer involvement in turning them into productive assets. In fact, the NRM works like farm pond done under NREGS should be taken up as a package, facilitating the provision of water lifting, micro irrigation, planting material, etc. in convergence with other schemes like NHM
- Some good success stories of proper utilization of MNREGS assets were seen in the case of farm ponds in Andhra Pradesh and Maharashtra and in respect of open wells in Rajasthan. It is imperative that the implementing agencies upscale such successful models
- The rural labour markets have been influenced by the massive MNREGS and have had a decisive impact on agriculture, which needs to be studied in depth to bring out the labour availability and implications on cost of cultivation
- From the study it is being observed that the program could be made more effective and efficient if the Soil and Water Conservation activities are being preplanned on watershed basis and then implemented along with proper supervision.

REFERENCES

AFPRO 2009. Infrastructure development and beyond : Exploring the scope for sustainable livelihood – support under NREGA. A study of schemes in Chainpur block, Gumla district, Jharkhand. Action for Food Production. pp. 36.

Ambasta Parmatesh, Vijay Shankar, P. S. and Shah Mihir 2008. Two years of NREGA: The Road Ahead. Economic & Political weekly – February 23-29, 2008, 43(8): 41-50.

Dreze, Jean 2009 NREGA is not artificial employment. Civil Society. May 2009 : 7-8

GoI 2008. The National Rural Employment Guarantee Act 2005 (NREGA). Operational Guidelines, 3rd Edition, Ministry of Rural Development. Government of India, New Delhi. pp. 194.

Gore, PG, Thakur Prasad, HR Hatwar 2010. Mapping of Drought areas Over India. NCC Res Report of IMD, Pune. pp 22.

IAMR 2008. All-India Report on Evaluation of NREGA: A Survey of Twenty Districts. Prepared with Financial Support and Research Inputs from Programme Evaluation Organisation (PEO), Planning Commission. Institute of Applied Manpower Research, Delhi. pp.24

ICAR - ICRISAT Database 2008. District level database, ICAR-ICRISAT collaborative research and development project. February, 2008.

Joshi Varsha, Surjit Singh and K.N. Joshi 2008. Evaluation of NREGA in Rajasthan. Institute of Development Studies, Jaipur, A Monograph, pp. 79.

Planning Commission 2010. Data tables – Statistics. www.planning commission.gov.in.

Ravindranath, N.H., V.R. Ramakrishna Parama, M.S. Mohan Kumar, Joyashree Roy, Narayanan, Sandhya Rao, H.I. Somashekhar, Rakesh Tiwari, B.K. Mohan Kumar, Harshad Parate, Murari Varma, Indu K Murthy, Sumedha Malaviya, Ananya S Rao and Asmita Sengupta 2009. Environmental Services, Vulnerability Reduction and Natural Resource conservation from NREGA Activities - Case study of Chitradurga District. Indian Institute of Science, Centre for Sustainable Technologies, Bengaluru.

RTBI 2009. Evaluation of National Rural Employment Guarantee Act in Cuddlore, Dundigal, Kanchipuram, Nagai, Thiruvallur. RTBI. Indian Institute of Technology, Chennai, pp.115.

Journal of Soil and Water Conservation, Vol. 11, No. 2, pp 74–80 (2012)
Received:16 January 2012; Accepted: 4 June 2012

Approach in Managing Development Communication in Agricultural Research

V.K. BHARTI[1], HANS RAJ[2] AND SURAJ BHAN[3]

ABSTRACT

The Information and Communication Technology (ICT) is playing a key role in agricultural growth and development in the country by providing timely and useful information in demand-driven mode. There are considerable resources of knowledge and information in the ICAR system that can be harnessed for realizing full potential of technological interventions developed so far. Several ICT-driven information delivery mechanisms have been developed for quick and cost-effective dissemination of information to masses. Keeping pace with the latest global trends and increasing importance of knowledge in the technology-driven agriculture, the Directorate of Knowledge Management in Agriculture has expended its knowledge dissemination programme vibrantly. By adopting knowledge-management initiatives, the Directorate is technologically and administratively empowered to systematically capture, organize, store, retrieve and communicate the development communication in agricultural research to a wide range of stakeholders, which include policy-makers, institutions, researchers, extension workers and above all, the farmers. For enhancing visibility and brand image of the ICAR at the national level through development communication has assumed great importance in the present era of digital world.

Key words: Information and Communication Technology, Print communication, Electronic communication

INTRODUCTION

Most of the comprehensive knowledge generated in National Agricultural Research System is reflected through the ICAR publications. The Council's publications have a stamp of quality and they are nationally and internationally recognized for their content and print quality. The Directorate of knowledge Management in Agriculture is a window of the ICAR through which the research and other activities are revealed to the world. It brings out a variety of publications in English and Hindi for the use of scientists, researchers, students, policy planners, extension personnel, farmers and the general public. Research journals, popular magazines, scientific monographs, technical and popular books, handbooks, low-priced books, bulletins, reports, proceedings of conferences and a variety of miscellaneous titles are brought out regularly, along with certain special publications from time to time.

Development Communication via Print mode

ICAR brings out regularly a number of books of topical interest for students/ farmers/ extension officers/ research workers. These include monographs, technical books, technical bulletins, low priced publications etc.

The publications brought out by ICAR are; Indian Farming, *Kheti*, Indian Journal of Agricultural Sciences, Indian Journal of Animal Sciences, Indian Horticulture, *Phal Phool*, *ICAR Mail, ICAR Chitti, Agbiotech Digest*, ICAR News, ICAR Reporter, Indian Animal Sciences Abstracts, Indian Agricultural Sciences Abstracts. Some of highly saleable non-serial publications of ICAR are: Handbook and Textbook series on Agriculture,

[1] Chief Production Officer
[2] Information System Officer, Directorate of Knowledge Management in Agriculture, Indian Council of Agricultual Research, Krishi Anusandhan Bhavan, Pusa, New Delhi-110012
[3] President, Soil Conservation Society of India, New Delhi-110012

Horticulture, Fisheries and Aquaculture, Animal Husbandry discipline apart from popular books. Most of these publications are the result of the scientific contribution made by the experienced scientists, technicians and agricultural managers of National Agricultural Research System.

In order to promote agricultural research in Hindi regions of India, the ICAR is launching a research magazine "Krishika" in Hindi along with its regular research journals namely *The Indian Journal of Agricultural Sciences, the Indian Journal of Animal Sciences.*

Since its inception in July 1929, the ICAR took up the publication of journals and other titles as early as 1931. Now the ICAR is the leading publishing house of development communication on agricultural research, providing the overall position of research conducted throughout the country under varied agro-climatic conditions, diverse crops as well as major livestock's, poultry and fisheries, including agricultural technology. The Directorate is the nodal centre of the ICAR for implementation of the National Knowledge Network, which aims at sharing of knowledge resources for collaborative research and development work. So far, 20 ICAR institutes/ SAUs have been connected and remaining institutes will be connected steadily. To enhance greater visibility and brand imaging of the ICAR across the country, initiative like technology-based news and features are regularly published at national and regional level through print and electronic media.

Development communication via electronic mode

Keeping in line with the growth of information technology and multi-fold options put forward by the e-publications, ICAR publication programme underwent a sea change. The publications programme was restructured to reap the rich benefits and enormous advantages offered by the electronic products. Some of databases/ publications of ICAR were identified for digitalization. Various databases/publications on Research project, Handbook of horticulture, ICAR Vision 2020, digital photo Library, Annual Reports, and Indigenous Technology of Knowledge in Agriculture (ITK) etc. were digitalized using suitable formats and technologies through active links.

The Directorate has produced first corporate film on the ICAR, *Drivers of Change* and is very effective and popular in creating the brand image of the ICAR at national and international forums. In the fast changing knowledge intensive era, the directorate has promoted ICT-driven technology and information dissemination system for quicker and more effective delivery of messages. Besides, ICAR Reporter, ICAR News, ICAR Mail, Agbiotech Digest and ICAR *Chitthi* (Hindi) are available in open access along with print editions for wider circulation. Hosting of e-Books, especially designed to make available information on the farmer-friendly technologies and data, on the website is a value-added feature for enhancing sharing of knowledge among stakeholders. The well illustrated e-Book, Making a Difference in Indian Agriculture -The Journey of the ICAR, was released in presence of the Prime Minister of India on the Foundation Day of the ICAR, 16 July 2011.

The research journals and popular periodicals of the Council, namely *The Indian Journal of Agricultural Sciences, The Indian Journal of Animal Sciences, Indian Farming and Indian Horticulture,* and Journals of five professional societies are available in free open-access mode for on-line sharing of knowledge. The on-line versions of these journals have extended to reach across the globe with nearly 13,000 registered users in 180 countries. Inspiring success stories of enterprising farmers and entrepreneurs drawn from across the country are regularly published.

Radio

Farmers need to be informed and educated about improved agricultural practices to enable them increase their productivity and income. Several channels such as extension agents, individuals, farmer-to-farmer contact, print media (newspapers, magazines, newsletters, leaflets, pamphlets, and posters) and electronic media (radio, television, film, slides and film strips) have been widely used to disseminate information to farmers so vast that only effective use of the information multipliers, the mass media, can provide information at the rates driven by pressure of time, population, geographical constraints, and shortage of trained extension personnel in developing countries. Radio is one broadcast medium which almost all experts identify to be the most appropriate for rural emancipation programme. It beats distances, and thus has immediate effect. It has been identified as the only medium of mass communication the rural population is very familiar. This is because a radio set is cheap to obtain and is widely owned in the rural areas. This is made possible by the advent of the battery-operated transistorized sets. Furthermore, radio is favoured as a medium of communication in rural communities because of the advantages ascribed to it in form of (i) transcending the barriers of illiteracy, and (ii) demanding less intellectual exertion than the print media messages.

Rural Radio in Agriculture Extension

Radio is a powerful communication tool. Experience with rural radio has shown the potential for agricultural extension to benefit from both the reach and the relevance that local broadcasting can achieve by using participatory communication approaches. The importance of sharing information locally and opening up wider information networks for farmers is explored with reference to the specific example of vernacular radio programmes based on research on soil and water conservation.

There is a need for greater utilization of Radio for improving the overall effectiveness such as:

- Rural radio can be used to improve the sharing of agricultural information by remote rural farming communities.
- Participatory communication techniques can support agricultural extension efforts especially using local languages and rural radio to communicate directly with farmers and listeners' groups.
- There is a need for national communication and media strategies which incorporate pluralistic approaches to the media within the more traditional centralized broadcasting and information systems and promote the cross-sectoral importance of information and communication in budgetary planning processes.
- The national policy environment in many developing countries could be improved through legislation to encourage independent community broadcasting, including streamlined licensing and subsidies for new information services such as FM stations, internet providers and rural telecommunication services.

Radio as an educational media: Impact on agricultural development

The radio has proved to be the most effective media in promoting agriculture and development in rural areas, particularly as a tool for the delivery of quick information Radio remains a vital part of development and farming systems; agricultural education intervention programmes will be more fruitful if they are conveyed through the radio.

Community Radio-Medium for real empowerment of people

It is now well understood around the world today that community communication offers unique opportunities for real empowerment of people. Community Radio is a low cost medium that carries the promise to protect and promote the cultural linguistic and ethnic diversity of the country. Community Radio can be a powerful medium for development due to its focus on local concerns and aspirations and involvement of the local people in preparations, selection of programmes. Rural Community Radio is particularly relevant in India where our ethnic linguistic and cultural diversity is to be nurtured and preserved as an asset.

Community Radio is defined as radio that is owned by the community and air programs designed and produced by it especially for its development needs. It is a significant departure from the primarily centralized and radio broad casting paradigm that India has been following for decades. Philosophically there are two distinct approaches to Community Radio. One stresses service or community model focused on what the station can do for community. The other stresses involvement and participation. Within the access or participatory, the participation of community members in producing content is seen as a good in itself. Community radio is a type of radio service that caters to the interests of certain area, broadcasting material that is popular among local audience. The government of India on November 18, 2006 decided to broad base the policy concerning the setting up of Community Radio Stations by bringing 'non-profit' organizations like, civil society and voluntary organizations under its ambit on issues relating to development and social change.

Mobile phones

Mobile phones significantly reduce communication and information costs for the rural poor in developing countries. This not only provides new opportunities for rural farmers to obtain access to information on agricultural technologies, but also to use ICTs in agricultural extension systems. Since 2007, there has been a proliferation of mobile phone based applications and services in the agricultural sector, providing information on market prices, weather, transport and agricultural techniques via voice, short message service (SMS). Mobile phones can improve access to and use of private information about agricultural technologies, thereby potentially improving farmers' learning. As previously discussed, farmers have information needs at various stages and on various topics for the agricultural production process. Traditionally, farmers obtained such information from personal visits, radio and to a lesser extent, landlines and newspapers. Mobile phones, by contrast, can reduce costs of obtaining this information as compared with other information mechanisms. Mobile phones are significantly less expensive than the equivalent per-search opportunity and transport costs or obtaining the same information from a newspaper. While they are more expensive than landlines or radio, these two search mechanisms are not readily available in most regions of the country, or only provide specific information. This reduction in search costs suggests that mobile phones could increase farmers' access to (private) information, especially via their social networks.

KISSAN KERALA in its attempt to redefine the services provided to the farming community has introduced a new feature to cater to the needs of the farmers to its full potential. The mobile-based agricultural information service is a giant leap of KISSAN towards becoming an epitome of complete Agri-information systems. This new venture, which offers a plethora of services, could very well be positioned as a right tool for information dissemination that leverages on the modern technology. The information regarding various mobile-based services like SMS based information services, voice based Agri-advisory services, and videos though the mobile etc. Mobile or smart phones are becoming an essential device for all types of users irrespective of the age group. In India mobile technology has unleashed a paradigm shift in the communication medium to reach out to the masses. As per statistics, Kerala is one of the states in the country where the mobile penetration is very high with a growth rate of 3.2%. To tap this vast potential medium, KISSAN has introduced several mobile based services via SMS (PUSH and PULL), voice and video based services to the farming community.

SMS based weather information

This service is a novel concept which helps the farmers in exploring the intricate details of weather of a particular location. The farmer can avail the details like rainfall, max temperature, min temperature, total cloud coverage, max relative humidity, min relative humidity, and wind speed and wind direction of any district on the given day. The farmers can also have the privilege of knowing the weather predictions in advance of three days which would help them in taking timely decisions. The database covers all the districts of Kerala. The database is updated on a daily basis from IMD.

Soil information on mobile

A soil test result through mobile is a novel feature of KISSAN mobile-based information services. This will help the farmers in decision-making regarding the fertilizer to be used for each crop. Through this service, the farmers can easily procure the test results in the least possible time, which otherwise would have got delayed through the conventional means. Once the farmer submit the soil sample to the district level soil testing laboratory, after the analysis, the results along with fertilizer recommendations are made available online through KISSAN Online Fertilizer recommendation System. The same soil test results will be available to the farmers through their mobile. The database is updated daily by all the district level soil testing laboratories directly and real-time updation of database is ensured. This is the first such initiative in the country where such information is made available to farmers through mobile. Currently the database has more than 28000 farmers' soil sample details from across the state.

KISSAN provides a golden opportunity for the farmers to access hundreds of high quality videos on agriculture and allied topics through your mobile. This service is being provided in collaboration with Google You Tube. KISSAN has launched a dedicated online video channel **www.youtube.com/kissankerala** for Agriculture and hosted several hundreds of telecasted quality videos on Agriculture, Animal Husbandry, Fisheries and Allied sectors. All these videos can be accessed via mobile phone. Currently there are around 140 videos available on the channel.

Agricultural information via cell phones

Content collected from a variety of agricultural information sources and then distributed through local cell phone networks. Some of the possible services that could offer are: soil testing system, market information via SMS, automated agricultural answering system, and agricultural information audio and video

The cell phone is the most pervasive form of bi-directional communications in the hands of the smallholder farmer. The recent explosion of cell phone access has left agricultural information systems behind. The move to cell phone based systems is a natural and potentially very beneficial. Cell phones have recently started being used for sending SMS-based information. These simple systems have already had a major impact. If data and voice services could be added to SMS, the possible uses would increase greatly. Cell phones could also be used to transmit data, even video files, to cell phones with sufficient memory capacity via the cell phone's data service. The video could be watched on the cell phone's small screen or projected to a common TV set. The system could work along the lines of a podcasting system or on-demand system. A user would have requested information delivered at night when the cell phone company is not otherwise using their infrastructure. If the cell phone company could be convinced to transfer data files at off-peak times for a very low cost, that could transform information delivery to smallholder farmers. Evidence the project can be successful: SMS messaging has already shown great potential. The FAO is using SMS messaging as a data transmission system for field workers wishing to send in agricultural reports. Call-in help centers have become quite popular both because of their immediacy and because one does not need to be literate to access information. This project could help smallholder farmers by creating an automated answering system which would funnel callers to the right language and content area. If, after listening to the most common answers to their question, the farmer still has questions, the automated system could direct the call to the person most able to answer the call based on language, content expertise, length in queue and cost per minute. This project would first look to current efforts to provide call-in centers and offer technical and strategic coordination. Another service could be the creation of a soil-testing network comprised of local women. Like the Garmeen Telcom's pay-cell-phone system, local women could charge for the use of an automated soil-testing device to be sold by the project. This model has worked well for cell phones and it should be an attractive service for smallholder farmers given the significant impact fertilizers and other agricultural inputs can have on crop yields and on soil health.

Internet channel of communication

The Internet is not a panacea for rural and agricultural development, but it does bring new information resources and can open up new communication channels for rural communities and agricultural organizations. It offers a means for bridging the gaps between development professionals, rural people and agricultural producers through the initiation of interaction and dialogue.

Internet services, in conjunction with existing and more widely used communication media such as rural radio, will enable the broadest enhancement of information and communication resources for rural people. For example, national or regional agricultural market information systems or extension information systems hosted on the Internet can be excellent information sources for the staff of rural radio stations throughout a region or nation. Using information on current market prices broadcast by rural radio stations (including national variations and international figures), farmers can negotiate better prices from local buyers. Improved horizontal communication and improved information resources can improve the quality of the decisions and interventions that impact upon rural people. At the same time, these improvements can enhance rural peoples' direct participation in development. Establishing rural Internet access sites and facilities in concert with efforts to enhance horizontal communication networks among the agencies involved in rural and agricultural development. Rural Internet users indicate that the Internet provides them with a very convenient method for quickly accessing a large volume of information without being impeded by geographic barriers.

Role of the media in agricultural development

There is no doubt that agriculture is back on the development agenda. But despite the promises and the rhetoric from governments worldwide, investment in agriculture and rural development is still lagging. Communication for agriculture is also not seen as a major priority at either national or international level and the role of the media as an effective player in agricultural and rural development is undervalued. Reporting on agriculture is largely restricted to natural disasters, food shortages and rising food prices. Some argue, however, that the media has a potentially broader role in raising the profile of agriculture amongst decision-makers as well as the wider public, and in communicating farmers' needs. The role of the media in agricultural and rural development was the topic of the 2009 annual seminar of CTA (Technical Centre for Agricultural and Rural Co-operation), an institution which works in the field of information for development. Similarly, National Institute of Science Communication and Information Resources, National Council for Science and Technology and ICAR has also organized several conferences and Seminars on the role of media in agricultural development in the past.

The ICAR website (www.icar.org.in): Developed by using an open source content management system called DRUPAL, the website is a unique platform for sharing and dissemination of information to a wide range of users and stakeholders in agriculture sector. The *News* section is updated daily with inputs from the centres of National Agricultural Research System across the country. Interesting *Success Stories* of Indian farmers are presented weekly on the homepage of website to inspire and motivate farming community. The *Weather Based Agro-Advisory* developed by subject matter experts is also updated weekly for the direct use of farmers. The website provides links to international agricultural organizations and to ICAR library and other libraries of interest. A useful link connects the visitors to the global agricultural news released from various international agencies. More than 2.05,436 visits are recorded per month from 184 countries.

The ICAR research journals (*The Indian Journal of Agricultural Sciences* and *The Indian Journal of Animal Sciences*) are available in open-access mode and have been downloaded in 184 countries from a knowledge portal developed and hosted by the Directorate of Knowledge Management in Agriculture(DKMA) of the ICAR. The online research journals provide facilities like registration for reviewer, author, reader and manuscript submission for publishing. The status of articles submitted may also be viewed (http://epubs.icar.org.in). A host of other useful publications including newsletters can also be viewed on the website. The *Hindi* (national language) version of the website is also available with regular updates. Around two lakh farmers/visitors are making use of updated information on website every month. The website has proven its potential for sharing and delivering knowledge at national and global level.

eKutir is an innovative approach to develop a eAgro business centre in which basic necessary agriculture services will be made available by connecting the rural farmers to existing islands of expertise, capabilities and markets. The low cost ICT interventions are being leveraged to develop affordable and integrated service centres involving rural institutions and communities.

Knowledge Help Extension Technology Initiative (KHETI) is a participatory ICT Solution developed and experimented with rural poor farmers. The system and its functionalities is speeding-up communications amongst various stakeholders especially agriculture specialists, farmer representatives and farmers. In KHETI, now with the help of mobiles, one could create Short Dialogue Strips **(SDSs)** using 6 images and 1.5 minutes voices on their queries, problems and other areas of interest. The system is generating knowledge bank and spreading it at large for wide usage, benefits and empowerment of the poor agriculture community.

In an initiative having far reaching impact the Government of India is providing internet connectivity in each block of the six identified states for knowledge sharing on agriculture and rural development scheme.

Awarding agricultural journalist/communication expert is a very good initiative of Govt. of India to boost the morale of the person as well as bringing agricultural science research and development closer to the end user. In this direction, the ICAR has instituted Choudhari Charan Singh Award for Journalism in Agricultural Research & Development and conferred this award for year 2007 to Dr. Mahendra Madhup, Senior Journalist and Editor, Sharad Krishi (Hindi). For the first time, a journalist from Rajasthan received this Rs.1.00 lakh award and citation at the hands of Hon'ble Shri Sharad Pawar, Union Minister for Agriculture. Also an award entitled Atmaram Award for development of technical and scientific literature in Hindi Kendriya Hindi Sansthan under the Union Human Resource Development Ministry has also been has instituted and conferred the Rs.1.00 lakh 'Atmaram' Award to Dr. Mahendra Madhup, Senior Journalist and Editor, Sharad Krishi (Hindi). Dr. Madhup received this award and citation at the hands of Her Excellency the President of India Hon'ble Smt. Pratibhatai Devisingh Patil at the Rashtrapati Bhavan.

Challenges to reporting on agriculture

Our media are poorly re-numerated in terms of how they cover farmer's problem. One of the major challenges is resource constraint. If the media have to go to the rural areas to cover agriculture, it is very costly; we think the other major problem is really that of capacity. The media are not built to fully understand this complex issue that we are dealing with i.e. agriculture. The journalists are not specialized enough: they do not know rural issues and are not close to the farmers. It could be useful to train more reporters in local areas because it is a big constraint for reporters that they cannot travel to certain places. So that instead of people travelling, people could just connect to reporters at a local place, maybe by phone or through the internet. We need to have more forums where the media engages with the policymakers.

CONCLUSION

Considering the importance of development communication as critical input in agricultural research and development, the Govt. of India has launched several innovative plans cutting across different department to enhance the penetration of internet and mobile phone connectivity along with very useful value added services. However, many challenges are also in the way, such as creation of rural infrastructure, development of appropriate and farmer friendly content and maintenance of regular flow of development communication in interactive mode. Besides, language and climatic variability also pose challenge in development of location specific information, which is important to agricultural development. The recent efforts made in the development communication with active involvement and participation of all stakeholders raise hopes to fulfill the dream of a knowledge society. More far-reaching, participatory and ICT driven technology delivery systems would be evolved for effectively linking research with its stakeholders.

REFERENCES

Arunachalam, S. 2008. Open Access to Scientific Knowledge, *DESIDOC Journal of Library and Information Technology*, 28(1), p. 7-14.

Bharti, V.K. and Hans Raj 2009: Technologies for agricultural information management in "Bio-industrial Watershed Development", SCSI, New Delhi, pp. 312-324.

Bhatt, V. S. Information Resources in Agricultural Research, In 40 years of Agricultural Research in India. ICAR, New Delhi, 1989. p.272-82.

Chilowa, W. 1998. The impact of agricultural liberalisation on food security in Malawi. *Food Policy.* Vol. 23 (6). pp. 553-569.

Hans Raj and Mitali Gosh Roy 2006: Scientific Publishing and Open Access in Agricultural Sciences in India; paper presented at 1st AGRIS Conference on Open Access in India, ICRISAT, Patancheru, Hyderabad 06-07 November, 2006.

Meera, S.N. 2002 A Critical analysis of information technology in agricultural development: Impact and implications. Unpublished Ph.D thesis, IARI, New Delhi.

Sharma, R.D. 1998. Growth of Agricultural Journalism and Agricultural Research Information Centre atICAR. *DESIDOC Bulletin of Information Technology*, 18(2), p. 21-30.

Shaik. N. Meera, Anita Jhamtani, and D.U.M. Rao (2004) Information and Communication Technology in Agricultural development: a comparative analysis of three projects from India, Agricultural Research & Extension Network *Network Paper No.135,* January 2004.

Swaminathan, M.S. 1993 (ed.) *Information technology: Reaching the unreached.* Chennai: Macmillan India.

Swaminathan, M. S. 1989 Report of the working Group on Agricultural Research and Education for the Formulation of the Eighth Plan. Planning Commission, ICAR, New Delhi, 1989.

Guidelines for Authors

The journal is primarily intended for the publication of papers submitted by the members of the society excepting for specially invited papers.

Types of contribution

Papers should mainly be based on original works/experience or ideology on any aspect of soil and water conservation including the generation and interpretation of basic data for these programmes.

Manuscripts

Manuscripts are required neat and clean in Laser Print or Letter Quality in font size 10/12 point on Bond Paper in English with one Photocopy double spaced, with wide margins and along with one soft copy should be sent to the Cheif Editor, Soil Conservation Society of India, National Societies Block A/G-4, National Agricultural Science Centre Complex, Pusa Campus, New Delhi 110 012. Only two copies of illustrations and plates need to be sent.

Papers should have the following sequence of heads: title, followed by the name(s) of author(s) with affiliation(s). Abstract, Introduction, Text of the paper with sub-heads, if necessary, Summary, Conclusions, Acknowledgement and References. Tables should be compiled separately on separate sheets.

The text should suitably be subdivided; the main heading has to be in capital letters, secondary heading also in capitals but in side position and tertiary heading should be normal typescript in side position. Underline only those words that should be in italics. Use the metric system. The abstract should not be exceed 200 words; it should highlight only techniques ans significant finding and thus be more concise than a regular 'Summary'. References should be written in the form as given below:

Ahuja R L, Garalapuri V N, Manchanda M L and Khanna S S. 1978. Physiography and Soil Association of Haryana, J. Ind. Soc. Soil Sc. 26:261.

The Editorial Board does not hold itself responsible for the opinions expressed by the authors.

Illustrations

These should be kept to the absolute minimum in view of the high cost of reproduction.

Line diagrams and maps should neatly be drawn in Black ink on tracing paper of drawing paper. The original drawings should ordinarily be not more than 35 x 25 cm in size with letter size and spacing so arranged as to permit easy 2/3 reduction.

All photographs should be of good quality, original or printed on glossy paper and should not exceed page (21 x 13 cm.) They should preferably by in squares or rectangles.

If annotated air photos of India are sent, the author(s) should send a certificate tot the effect that Defence Clearance has been obtained for printing.

Length

The paper should not be longer than 16 double space typed A4 size page including Tables and Illustrations.

Reprints

Reprints of articles are supplied on demand at cost price. Request for number of copies of reprints should be made while forwarding the article for publication.

25th National Conference
on
Sustainable Farming Systems and Bioindustrial Watershed Management for Food Security and Enhancing Income of the Farming Community

22–24 November 2012

Sponsored by
State Department of Agriculture
Govt. of U.P., Lucknow

Organized by
Soil Conservation Society of India (SCSI)
New Delhi, India

ADDRESSES FOR CORRESPONDENCE

Dr. Mukesh Gautam
Director (Agriculture)
State Agricultural Department
Govt. of Uttar Pradesh, Krishi Bhawan, Lucknow
Conference Convenor and Chairman
Organizing Committee
Tel: 0522-2205868, 09450627706; *Fax:* 0522-2206582
E-mail: mgautam56@gmail.com

Dr. Suraj Bhan
President
Soil Conservation Society of India
National Societies Block A/G-4
National Agricultural Science Centre Complex
(NASC), DPS Marg (Pusa), New Delhi – 110 012
Telefax: 011-25848244, (M) 09868808980
E-mail : soilcsi@gmail.com, bhan_suraj2001@yahoo.com
Website: www.soilcsi.com

INTERNATIONAL CONFERENCE ON
WATERSHED MANAGEMENT FOR FOOD SECURITY, RURAL LIVELIHOODS AND CLIMATE CONCERNS

From 19-23 November 2014
at
NASC, New Delhi

Organized by
Soil Conservation Society of India
New Delhi

Published by the Secretary General, Soil Conservation Society of India, National Societies Block A/G-4, National Agricultural Science Centre Complex, Dev Prakash Shastri Marg, New Delhi 110 012
E-mail: soilsci@gmail.com, bhan_suraj2001@yahoo.com; Website: http//www.soilcsi.org

Laser typeset by Dot & Design, New Delhi (dotdesign2011@gmail.com) and printed at M/s Chandu Press, D-97, Shakarpur, Delhi-110 092