Journal of SOIL AND WATER CONSERVATION

Vol. 12, No. 1 ISSN 0022-457X JANUARY-MARCH 2013

Soil Conservation Society of India
New Delhi

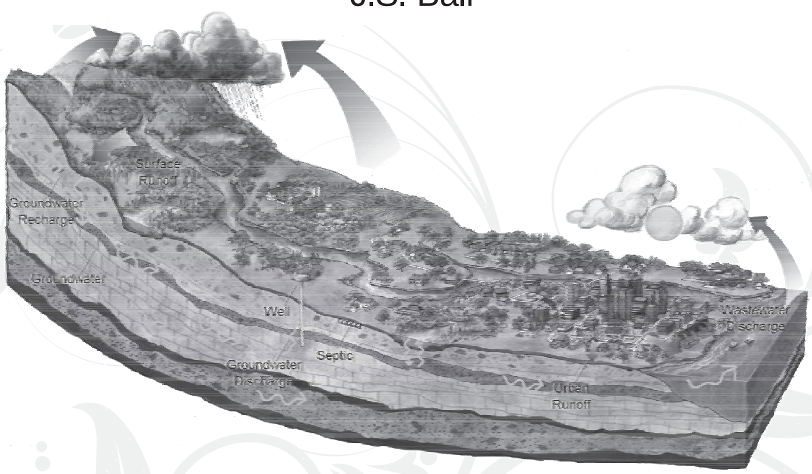
Journal of
SOIL AND WATER CONSERVATION

Volume 12 No. 1 | ISSN 0022–457X | January-March 2013

Contents

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 **12**(1): 3-9, January-March 2013
ISSN: 022-457X

Land capability classification in relation to soil properties representing bio-sequences in foothills of North India

V. K. UPADHAYAYA, R.D. GUPTA and SANJAY ARORA[1]

Received: 24 August 2012; Accepted: 29 December 2012

ABSTRACT

Twenty one soil profiles representing three bio-sequences *viz.*, cultivated lands, forest lands and grasslands were collected to characterize the soils of Kathua district of Jammu region, J&K state, North India. The cultivated soils profiles exhibited comparatively more depth than those under forest and grasslands. Most of the studied soil profiles had angular to sub-angular blocky structure. The soil pH and EC values, irrespective of depth varies, from 4.4 to 7.1 and 0.10 to 0.97 dS m^{-1} with average weighted mean of 4.49 to 6.65 and 0.17 to 0.80 dS m^{-1}, respectively. Organic carbon (OC) and total N content were more in soils of grasslands followed by those of cultivated and forest lands with comparatively low values of C:N ratio in cultivated soils. Cation exchange capacity (CEC) of soil varied widely in horizons ranging from 5 to 19 Cmol (p^+) kg^{-1} with average weighted mean of 5.3 to 16.18 Cmol (p^+) kg^{-1}. The greater values of CEC were observed in case of grassland soils. CEC showed positive correlation both with organic carbon ($r = 0.55^{**}$) and clay content ($r = 0.40^{**}$). The soils belong to order Entisol, Inceptisol and Alfisol. As per land capability classification, cultivated lands were grouped with subclass IIs, IIIw, IVe and IVes, while forest soils were mainly in IIIes, VIe, VIes, and grassland soils in IIIe, VIIes, IIIs and Vs.

Key words: bio-sequences, sub-tropical zone, Jammu, forest, cultivated, grassland

INTRODUCTION

Soil, a natural resource, is storage of water and plant nutrients and as such becomes a medium for biomass production. It serves as a natural filter and detoxification system, preventing deeper geological formations and sub-surface water from various pollutants. Soil is also a high buffering medium controlling unfavourable consequences of different environmental stresses.

Presently, attention is being given to soils due to rapidly declining land area for agriculture, declining soil fertility and increasing soil degradation, wrong land use policies and irrational and imbalanced use of inputs (Kanwar, 2004). There is need for systematic study of morphology and taxonomy of soils which provides information on nature and type of soils, their constraints, potentials, capabilities and their suitability for various uses for sustainable development (Sehgal, 1996). In light of the aforesaid main soil functions in the biosphere, our basic task is to utilize these renewable natural resources judiciously and wisely. For this purpose, a good inventory of soils becomes of an absolute necessity for exploring and exploiting their potentials. Characterization of the soils in terms of physical and physico-chemical properties, therefore, becomes beneficial in understanding the plant and soil relationship. Determination of various physical and chemical properties is also of prime importance for predicting the behaviour of soils in relation to different systems of landuse planning. So, what is required these days is to identify, classify and interpret the soils in respect of resource-knowledge-based decision-making.

The soils of the foothill region of Jammu are prone to water erosion and the area is highly denuded where 4-6 cm of top soil layer is washed every year during monsoons (Arora et al., 2006; Gupta et al., 2009). The Kathua district of Jammu region in J&K state of India has diverse agro-climatic condition and

[1]Senior Scientist (Soils), CSSRI, Regional Research Station, Maktampur P.O., Bharuch 392012, Gujarat, India

had a variety of soils, distributed in different land forms supporting wide variety of vegetation. However, detailed information on morphological, physical and chemical properties is not available for these soils, information so vital for planning sustainable management practices on different soils for various bio-sequences or ecosystems. In this context, characterization of soils of Kathua district in Jammu province was undertaken in relation to bio-sequences including cultivated, forest and grassland ecosystems with an objective to determine morphological, physical and physico-chemical properties of soil profiles and land capability. The present study has also been undertaken to classify the soils of Kathua and suggest land use plan to protect our finite soil resource for sustainable crop production.

MATERIALS AND METHODS

Study area

The Kathua district of Jammu region of Jammu and Kashmir state, located between 32º 17' to 32º 5' latitude and 75º 10' to 75º 21' longitude, is bounded by Ramnagar and Bhaderwah tehsils of Udhampur and Doda districts in the north, Gurdaspur district of Punjab state in the south and Chamba district of Himachal Pradesh state in the east (Fig 1.). In the northern areas of the district lies the Siwaliks that represents the foothill region of Himalayas.

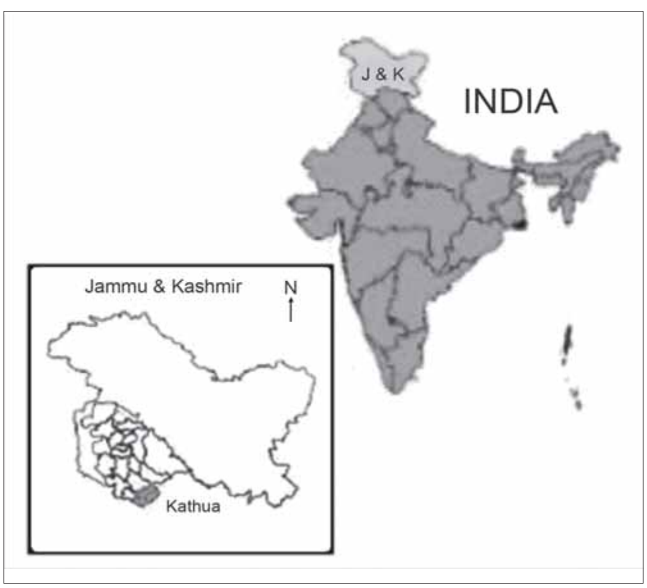


Fig. 1. Map showing the Kathua district of Jammu

The study area has been divided into two natural regions *viz.*, "sub-tropical zone" and "intermediate or sub-temperate zone". The former consists of plains bordering Punjab and Pakistan having irrigation facilities and sub-mountainous areas without irrigation sources. As such this zone is also called subtropical irrigated and subtropical unirrigated or *Kandi* belt. The latter occupies the central portion of the Kathua district, running along the northern parts of Kathua, Hiranagar and Bani as well as southern parts of Basohli and Billawar. The area is mainly drained by the rivers Ravi and Ujh and their tributaries.

The mean annual temperature in sub-tropical region averages to 24.2ºC, whereas in the interior of middle region it is nearly 13.3ºC. The mean annual rainfall of the former is 1069 mm and the latter is 1467 mm bulk of which is received during monsoon.

Soil sampling and analysis

Soil samples from 21 profiles were collected, representing different biosequences *viz.*, cultivated lands (12 profiles), forest lands (4 profiles) and grasslands (5 profiles). The morphological characteristics of the soil profiles were studied *in-situ* in accordance with the procedures given in Soil Survey Staff (1951). The horizon wise soil samples were air-dried, ground and passed through 2 mm sieve for laboratory analysis. Their physico-chemical properties *viz*. pH, EC, organic carbon, particle size distribution, CEC, exchangeable Na, Ca, Mg, K and total N were then determined following the standard procedures (Piper, 1966; Jackson, 1973). Soils were classified as per the Keys to Soil Taxonomy (Soil Survey Staff, 1998). The soils were also evaluated for land capability classification (Klingebiel and Montgomery, 1966).

RESULTS AND DISCUSSION

Soil morphological characteristics

The soil profiles representing cultivated lands, exhibited comparatively more depth than those of forest and grasslands with exception of P_{16} and P_{18} soil profiles. Cultivated soil profiles were deeper owing to their being situated on almost well leveled topography in comparison to forest and grassland soil profiles which were shallower due to being their occurrence on steeper slopes. In respect of moist matrix colour, hue ranged from 5YR to 10YR, value from 4 to 6 and chroma from 1 to 6. The dominant soil colour was found to vary from red to yellow with intensity of colour in midway between absolute white to absolute black. A hue of 10YR depicted uniform conditions of drainage and aeration (Kaushal *et al.*, 1996). A hue of 5YR to 7.5YR in soil profiles of P_{12}, P_{16} and P_{21}, represented weathering of sandstone under aerobic conditions and also due to diffusion of iron content derived from ferro-magnesium silicates (Gangopadhyay *et al.*, 1990). Low values of chroma exhibiting pale brown or dark brown colour showed wetness (Gupta and Tripathi, 1992). Thus, the above said reasons could be attributed to bring wide variability in colour variation in the soils of the present investigation.

Soil profiles of cultivated lands had fine texture in comparison to forest and grassland soil profiles which possessed coarse texture. It is point to mention that stones / pebbles were quite pronounced in soil profiles of forest lands followed by those of grasslands, ranging from 5 to 40 per cent and 2 to 25 per cent, respectively by volume reducing the effective soil volume. Out of 12 cultivated soil profiles, four (P_4, P_5, P_7 and P_{12}) also showed occurrence of these components to the extent of 5 to 15 per cent by volume. These observations are in line with the findings of Gupta *et al.* (2008).

Most of the studied soil profiles showed angular blocky to sub-angular blocky structure, indicating weak to moderate pedality. Granular and crumb or granular / angular blocky structure found in soil profiles of P_4, P_5, P_7, P_{15} and P_{17} revealed more soil aggregation. Gupta and Tripathi (1992) observed the clay, organic matter, wetting and drying, freezing and thawing, adsorbed bases, climate and cultivation were the probable reasons for inducing granular and crumb structures. These factors also seemed to be responsible in bringing granular / crumb structures in soil profiles of P_4, P_5, P_7, P_{15} and P_{17}. Soils of P_{13} and P_{14} profiles were characterized by single grained loose structures which were attributed to massive sand fractions in these soil profiles with weak profile development.

The soils of grassland profiles had consistence of soft to extremely hard, loose to very firm, non-sticky to sticky and non-plastic to plastic under dry moist and wet conditions, whereas those of cultivated and forest land profiles were more hard, more firm and less plastic under similar conditions. Such differences in consistence in various soil profiles appeared to be related with organic carbon and mechanical components.

Soil physico-chemical properties

Soil profiles of cultivated lands were characterized by variable texture ranging from sandy clay loam to silty clay loam in their surface horizons and sandy loam to sandy clay loam and clay in sub-surface layers. On the other hand, forest soil profiles were mostly characterized by sandy loam, sandy clay or silty clay irrespective of their depth. Most of the soils of pasture / grasslands showed silty clay or silty clay loam texture. From the foregoing results, it is emerged that soils of cultivated lands had fine texture having more clay and less sand in comparison to forest grassland soils which had less content of clay and more content of sand (Table 1).

It has been further substantiated by mean weighted average values of sand, silt and clay fraction which were worked to be 29.4, 54.5 and 36.5 per cent, 35.3, 23.4 and 33.2 per cent and 36.8, 23.8 and 31.0 per cent in soils of cultivated, forest and grasslands. The higher contents of clay and silt fractions in soils of cultivated lands could be explained to well leveled or terraced topography which were less prone to erosion hazards. The forest and grassland soils on the other hand, being located on steep slopes were susceptible to more erosion, causing thereby loss of finer fractions, and as such had more content of sand fraction. Gupta *et al.* (2008) also reported high sand contents in soils of eroded barren land. Also, Gupta et al. (2010) also reported erodibility of the soils on different elevations under different land uses in foothills of Jammu.

Soil pH and EC values of the studied profiles irrespective of soil depth varied from 4.4 to 7.1 and 0.10 to 0.97 dS m^{-1}, showing strongly acidic to neutral reaction and no saline or alkaline nature of the soils studied. The average of the weighted mean of different profiles showed soil pH of cultivated, forest and grasslands in the range of 4.94 to 6.65, 5.34 to 6.17 and 4.98 to 5.82, respectively (Table 1). From these values, it was evident that soils of all bio-sequences were moderately to strongly acidic in nature. The principal reason to explain the acidic nature of these soils was leaching of bases due to high average annual rainfall of >1100 mm. However, the role of acidic nature of parent material *i.e.*, granite and / or sandstone in producing acidity cannot be

Table 1. Properties of soils under different bio-sequences*

Soil Profile	Location	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	pH (1:2.5)	EC (dSm^{-1})	OC (%)	Total N (%)
(A) Cultivated lands									
P_1	Burmal	31.11	35.40	10.08	26.48	6.13	0.36	0.18	0.06
P_2	Nihalpur	7.83	22.64	42.80	29.30	6.00	0.38	0.40	0.05
P_3	Kathua	1.81	61.60	18.08	17.79	5.90	0.32	0.20	0.11
P_4	Bacon	3.72	9.12	50.42	40.72	5.25	0.53	0.77	0.09
P_5	Loang	5.42	32.13	37.52	32.75	5.02	0.80	1.81	0.20
P_6	Chandal	4.07	20.96	50.31	29.69	6.10	0.41	0.99	0.11
P_7	Bani	3.07	4.86	26.00	63.71	5.75	0.41	1.33	0.13
P_8	Bhoond	3.90	25.08	24.64	48.60	6.62	0.45	1.08	0.10
P_9	Sahar	6.58	19.87	19.45	57.50	6.35	0.31	0.69	0.07
P_{10}	Basohli	4.21	19.20	36.86	31.14	5.23	0.31	0.42	0.04
P_{11}	Doongara	2.83	15.23	39.43	41.86	4.94	0.33	0.57	0.06
P_{12}	Janota	2.51	9.46	68.35	22.66	6.65	0.48	0.86	0.0
(B) Forest lands									
P_{13}	Bhoond	7.05	62.70	11.70	20.90	5.72	0.35	0.97	0.09
P_{14}	Kardo	10.25	60.25	12.16	16.50	6.17	0.30	0.84	0.07
P_{15}	Parnalla	14.84	57.95	14.92	17.80	6.03	0.24	0.41	0.03
P_{16}	Sukrala	2.33	6.40	54.80	39.87	5.34	0.17	0.68	0.07
(C) Pasture / Grasslands									
P_{17}	Chandal	0.16	4.33	47.33	48.00	5.66	0.65	1.67	0.10
P_{18}	Janota	1.50	37.87	39.46	26.46	4.98	0.21	1.19	0.06
P_{19}	Gagwal	9.33	52.45	10.44	26.44	5.76	0.40	0.40	0.13
P_{20}	Basantpur	5.45	53.88	16.88	22.38	5.82	0.17	0.61	0.10
P_{21}	Mirpur	2.58	15.05	51.75	31.90	5.03	0.23	1.14	0.10

*weighted mean of profiles

ruled out and also of the decomposition of organic matter.

The organic carbon (OC) content in all the soil profiles varied from 0.18 to 1.81 per cent, total N from 0.04 to 0.20 per cent (Table 1). Generally, the surface soils had more content of organic carbon which could be attributed to incorporation of organic matter through leaf litter and decayed organic matter as well as crop residue in agricultural fields in surface horizons. The present findings are in consonance with those obtained by Minhas *et al.* (1997). On the basis of mean weighted averages it has been found that OC and total N contents were generally greater in soils of grasslands owing to presence of most of these profiles at higher elevations followed by cultivated and forestland soils. Like OC content, total N decreased with soil depth. OC content showed significant positive relationship with total N. The C:N ratio in respect of cultivated, forests and grasslands ranged from 3.6 to 19.1, 7.7 to 13.1 and 5.4 to 20.1 with mean weighted averages of 9.5, 10.7 and 12.0, respectively. Comparatively low values of C:N ratio in cultivated soils signified high biological activity and advanced stage of organic matter decomposition in comparison to soils of other bio-sequences (Kaistha and Gupta, 1993).

The average of weighted mean of cation exchange capacity (CEC) of all the soil profiles studied varied from 5.3 to 16.18 Cmol (p^+) kg^{-1}. The mean exchangeable Ca^{2+}, Mg^{2+}, Na^+ and K^+ fluctuated from 1.95 to 5.84, negligible to 3.68, 0.05 to 0.11 and 0.09 to 0.23 Cmol (p^+) kg^{-1} soil in cultivated lands (Table 2) while in forest ecosystem, their content ranged between 1.61 to 2.68, 0.91 to 2.98, 0.04 to 0.14 and 0.09 to 0.11 Cmol (p^+) kg^{-1} (Table 2). Wide variation of CEC and exchangeable cations could be ascribed to the differences of OC and clay content found in these soils. It was further supported by positive and significant correlation of OC ($r = +0.55^{**}$) and clay ($r = +0.40^{**}$) with this parameter. Soils of grasslands had greater CEC followed by those of forest and cultivated lands due to occurrence of more content of clay and organic carbon. On the whole, Ca^{2+} was the principal cation followed by Mg^{2+}, K^+

Table 2. Exchangeable cations* [Cmol (p^+) kg^{-1}] and base saturation of soils of different bio-sequences

Soil Profile	Location	Exchangeable Ca^{2+}	Exchangeable Mg^{2+}	Exchangeable Na^+	Exchangeable K^+	CEC	Base saturation (%)
(A) Cultivated land							
P_1	Burmal	2.69	1.05	0.10	0.09	6.17	63.70
P_2	Nihalpur	3.64	1.72	0.09	0.12	7.68	72.60
P_3	Kathua	2.17	2.78	0.09	0.09	7.75	66.60
P_4	Bacon	3.12	2.87	0.08	0.11	9.41	70.00
P_5	Loang	1.95	2.32	0.09	0.16	11.56	39.10
P_6	Chandal	2.49	1.82	0.05	0.12	9.53	47.30
P_7	Bani	2.50	2.48	0.06	0.12	12.45	41.70
P_8	Bhoond	4.38	3.68	0.07	0.23	8.60	97.20
P_9	Sahar	5.84	2.85	0.07	0.15	12.55	71.30
P_{10}	Basohli	2.85	1.57	0.09	0.09	6.51	70.70
P_{11}	Doongara	2.73	–	0.07	0.14	5.30	55.50
P_{12}	Janota	2.63	2.83	0.11	0.09	8.66	65.50
(B) Forest lands							
P_{13}	Bhoond	1.99	1.15	0.07	0.11	12.7	25.80
P_{14}	Kardo	2.68	0.91	0.04	0.09	7.66	48.80
P_{15}	Parnalla	2.05	1.64	0.14	0.09	7.36	52.50
P_{16}	Sukrala	1.61	2.98	0.08	0.11	16.18	29.40
(C) Pasture / Grasslands							
P_{17}	Chandal	2.40	3.86	0.11	0.18	15.83	41.20
P_{18}	Janota	3.45	0.23	0.10	0.09	8.36	45.40
P_{19}	Gagwal	2.67	0.94	0.07	0.16	11.00	35.50
P_{20}	Basantpur	1.94	0.76	0.09	0.12	9.91	29.50
P_{21}	Mirpur	4.24	3.72	0.07	0.12	15.56	74.80

*weighted mean of profiles

and Na^+ in all soils as well as in soils under cultivated, forest and grasslands.

Soil taxonomy

In the present study, an attempt was made to classify various soil profiles at subgroup level according to "Soil Taxonomy" (1998) by taking resource to physico-chemical and morphological properties *vis-à-vis* diagnostic horizons (epipedons and endopedons), moisture and temperature regimens. The soils of P_1, P_2, P_3, P_4, P_5 and P_{19}, P_{20} were less developed as in these soil profiles no diagnostic horizon other than ochric epipedon and, therefore, classified as Entisols. The soils of profiles P_1 and P_{20} showed loamy fine sand or coarse texture below Ap horizon in all parts to a depth of 1m, so these profiles were placed in "Psamments", "Ustipsamments" and "Typic Ustipsamments" at suborder, great and subgroup level. Soils of P_2, P_{15} and P_{19} profiles had organic carbon less than 1 per cent which decreased with depth reaching a level of 0.35 per cent (<1% or less) and were not permanently saturated with water and lacked of wetness, so these were classified as "Orthents" at suborder level, Ustorthents at great group level and Typic Ustorthents at subgroup level. Soils of profile P_4 qualified for Fluvents, Udifluvents and Typic Udifluvents at suborder, great group and subgroup levels as the texture here was loamy very fine sand or finer in some horizons below Ap and of < 25% and OC content above 0.35 per cent.

The soils of profiles P_5, P_6, P_7, P_8, P_{11}, P_{16}, P_{17} and P_{21} showing incipient profile development with ochric or umbric epipedon coupled with or without cambic endopedon were placed under "Inceptisol Order". Profiles P_5, P_6 and P_{17} were recognized under suborder "umbrepts" great group Haplumbrepts and subgroup Typic Haplumbrepts as their OC content decreased regularly with depth and profiles P_8, P_{11}, P_{16} and P_{21} qualified for ochrepts suborder, ochrepts great group and Typic Ustochrepts for subgroup level.

In soil profiles P_7, P_9, P_{10} P_{12}, P_{13}, P_{14}, and P_{18} there was translocation of clay fulfilling requirement of argllic horizon and, thus, were placed under Alfisols. Soil profile P_7 was classified under Udalf suborder, Hapludalf great group and Typic Hapludalf subgroup level because of Udic moisture regime and absence of fragipan / nitric / argic horizons, while soil profiles P_9, P_{10}, P_{12}, P_{13} and P_{18} were placed under Ustalf suborder, Haplustalf great group and Ultic Haplustalf subgroup level. Profile P_{14} was classified under Udalf, Fragiudalf and Typic Fragiudalf at suborder, great group and subgroup levels due to udic soil moisture regime, presence of fragipan and lack of agric horizon.

Land capability classification

The land capability classification is a broad grouping of soils based on their limitations and serves as a guide to assess suitability of the land for growing of crops, grasses for grazing livestock and raising of forests. The cultivable soils are grouped into class I to class IV and those which are not suitable for agriculture, are grouped under class V to class VIII for several uses like forestry recreation and habitat for wildlife. The land capability classes are further divided into subclasses based on limitations. The subclass is, for example, indicated by symbols like "e" for wind and water erosion hazards, "w" for drainage problems or wetness and many others (AIS&LUS, 1970).

Taking into consideration, the soils of the present study have been grouped into eleven land capability subclasses (Table 3). Soil profiles P_1, P_2, P_8, P_{10} and P_{11} grouped under capability subclass IIs are well drained with deep to very deep in depth, coarse to fine / very fine in texture and 0 to 10 per cent coarse fraction in surface soils by volume. Due to imperfect drainage, soil profile P_3 fell under capability subclass IIIw. Profiles P_4 and P_5 placed under IVes because of being located on undulating / rolling topography (7 to 12% slope), fine surface soil texture with 8-10 per cent gravels by volume and showing moderate /

Table 3. Soil characteristics and land capability classification

Profiles subclass	Sites	Characteristics and limitations	Capability
P_1 P_2 P_8 P_{10} P_{11}	Burmal Nihalpur Bhoond Basohli Doongara	Deep to very deep soils with level to gently sloppy topography; exhibiting negligible to slight erosion. Soil related limitation(s) were coarse or fine or very fine nature of soil texture, with or without preponderance of coarse fragments.	IIs
P_3	Kathua	Deep soil profile with practically no erosion hazards because of being located on nearly flat topography. Limitation(s) pertain to non-proliferation of root zone, due to its being imperfectly drained.	IIIw
P_4 P_5	Bacon Loang	Deep soils with moderately sloppy, rolling topography exhibiting moderate to severe erosion and fine soil texture.	IVes
P_6 P_7	Chandel Bani	Very deep, moderately sloppy lands. The main limitation being soil erosion by rain water due to rolling topography.	IVe
P_9	Sahar	Very deep soils on gently to moderately sloppy undulating and rolling topography. Limitation(s) were soil erosion and very fine soil texture.	IIIes
P_{12} P_{16} P_{21}	Janota Sukrala Mirpur	Deep to very deep soil profiles with gentle to moderately sloppy soil slopes at sites of profiles. The main limitation was moderate to severe soil erosion by rain water.	IIIe
P_{13}	Bhoond	Deep soil profile but on moderately steep, hilly topography. Soil erosion by water and coarse texture / coarse fragments in surface soil was the only hazards.	VIes
P_{14} P_{18}	Kardo Janota	Moderately steep (hilly) to moderately sloppy (rolling) soil slopes contributing moderate to severe soil erosion by water. Soil related hazards being stony / coarse graveled shallow to deep soils, with very coarse soil texture.	VIIes
P_{15} P_{17}	Parnalla Chandel	Moderately sloppy (rolling) to moderately steep (hilly) soil relief, exhibiting moderate to severe soil erosion.	VIe
P_{19}	Gagwal	Very gently sloppy lands showing no erosion hazards by wind or water but for shallow soil and pebbles underlaid by big boulders	IIIs
P_{20}	Basantpur	Very gently sloppy landscape with rounded stones strewn here and there on surface soil, exhibits no erosion hazards.	Vs

severe water erosion. Profiles P_6 and P_7 were classified into subclass IVe which showed severe erosion because of 7 to 11 per cent slope.

Profiles P_9 and P_{12}, and P_{16} and P_{21} were placed under subclasses IIIes and IIIe as the former (P_9 and P_{12} profiles) showed limitations *viz.*, susceptibility to moderate erosion, slope from 7-10 per cent and clayey texture and the latter (profiles P_{16} and P_{21}) had 5 to 10 per cent slope with moderate erosion. Soil profile P_{13} located in steep to very steep slope (15 to 20%) coupled with abundance of coarse fragments in surface soil (10-15% by volume) was classified in VIes subclass. Profiles P_{14} and P_{18} were moderately to severely eroded being located on hilly and rolling topography (12 to 25% slope), shallow soil depth and stoniness in surface soil (upto 50% by volume) and as such were classified under subclass VIIes. Meanwhile, soil profiles P_{15} and P_{17} owing to rolling/hilly topography (15 to 30% slope) were prone to moderate to severe erosion by water and, therefore, were qualified for VIe capability subclass. In case of profile P_{19}, the soil slope was very gentle 2 to 3 per cent only but shallowness of the soil profile due to occurrence of boulders underneath, qualified for subclass IIIs. Profile P_{20} was classified under capability subclass Vs due to stoniness of surface soil (8-10% by volume) with gentle to very gentle slope of 2 per cent.

CONCLUSIONS

In order to understand plant-soil relation, it is essential to characterize and classify the soils on the basis of soil properties and land capability. The soil profiles representing different bio-sequences from different topographical situations in foothill region were explored for the present study. The soils from cultivated ecosystem were less prone to erosion as compared to other bio-sequences. Further, the soil were classified as per their suitability for cultivation of other land use practice which gives an strategic idea for better management of soils in the fragile foothill region. The study helps in better planning of land use for restoring the degraded and erosion prone lands of the region.

REFERENCES

AIS&LUS 1970. *Soil Survey Manual*. All India Soil and Land Use Survey, Indian Agricultural Research Institute, New Delhi, India.

Arora, Sanjay, Sharma, V., Kohli, A. and Jalali, V.K. 2006. Soil and water conservation for sustainable crop production in *Kandi* region of Jammu. *Journal of Soil and Water Conservation, India* 5(2): 77-82.

Gangopadhyay, S.K., Das, P.K., Mukhopadhayay, N., Nath, S. and Banerjee, S.K. 1990. Altitude pattern of soil characteristics under forest vegetation in eastern Himalayan region. *Journal of the Indian Society of Soil Science*, 38 (1): 93-99.

Gupta, R.D., Arora, Sanjay and Sharma, V. 2009. Rainfed Agricultural Production through watershed Management: Success in Jammu region. *Journal of the Soil and Water Conservation* 8(1): 19-24.

Gupta, R.D., Arora, Sanjay, Gupta, G.D. and Sumberia, N.M. 2010. Soil physical variability in relation to soil erodibility under different land uses in foothills of Siwaliks in N-W India. *Tropical Ecology* 51(II): 183-198.

Gupta, R.D. and Tripathi, B.R. 1992. Genesis of soils in wet temperate and subalpine climate zones of north-west Himalayas. *Journal of the Indian Society of Soil Science*, 40: 506-512.

Gupta, R.D., Gupta, G.D., Kher, D. and Sumbria, N.M. 2008. Genesis of soils of *Kandi* belt of Jammu under different landuse pattern. *Journal of Research*, SKUAST-J, 7 (1): 132-144.

Jackson, M.L. 1973. *Soil Chemical Analysis*. Oxford IBH, Publishing House, Bombay, India.

Kanwar, J.S. 2004. Address at 69th Annual Convention, Indian Society of Soil Science, ANGRAU, Hyderabad. *Journal of the Indian Society of Soil Science*, 52 (1): 296-296.

Kaushal, R., Bhandari, A.R., Tripathi, D. and Sharma, J.C. 1996. Soil water retention characteristics of some soils under forest temperate zone of the Himalayas. *Journal of the Indian Society of Soil Science*, 44(1): 9-12.

Klingebiel, A.A. and Montgomery, P.H. (1966). *Land capability classification*. Agricultural Handbook No. 210, USDA, Washington.

Minhas, R.S., Minhas, H. and Verma, S.D. 1997. Soil characterization in relation to forest vegetation in the wet temperate zone of Himachal Pradesh. *Journal of the Indian Society of Soil Science*, 45(1): 146-151.

Piper, C.S. 1966. *Soil and Plant Analysis*. Hans Publications, Bombay, India.

Sehgal, J. 1996. *Pedology: Concepts and Applications*. Kalyani Publishers, New Delhi, India.

Soil Survey Staff 1951. *Soil Survey Manual*. US Department of Agriculture, Handbook No. 18.

Soil Survey Staff 1998. *Keys to Soil Taxonomy*. Eighth edition, Natural Resource Conservation Service, USDA, Blackburg, Virginia.

Journal of Soil and Water Conservation **12**(1): 10-16, January-March 2013
ISSN: 022-457X

Innovative design and layout of Staggered Contour Trenches (SCTs) leads to higher survival of plantation and reclamation of wastelands

R.R. BABU[1] and PURNIMA MISHRA[2]

Received: 10 September 2012; Accepted: 17 February 2013

ABSTRACT

Considering the soil depth, soil type, slope of land, maximum possible 6-hr rainfall and consequent runoff (for 5 year return period), Staggered Contour Trenches (SCTs) were identified as suitable treatment for reclamation of highly degraded upper reaches across different watersheds under Indo-German Watershed Development Programme- Andhra Pradesh (IGWDP-AP). The design of SCTs involved in fixing the horizontal interval and vertical interval between the successive contour lines and spacing between the successive trenches in a row, after selecting the suitable length, width and depth as per site conditions. Contour lines were marked using A-frame. In the new design of SCT, the trench length was either set equal to base width of A-frame or fixed two times of base width of frame. The dug out soil from the trenches is placed in the half moon fashion around the trench. Usually berm of 0.3-0.5 m is maintained between the trench and half moon embankment in the conventional design and layout. However, with a view to improve survival of plants, planting on the berm of excavated trench and bund placed in the half moon fashion around the trench has been incorporated in the layout. Accordingly, berm of 1.5 m was followed between the trench and half moon shaped bund. This innovative SCT design and layout was successfully field tested across 15 watersheds under IGWDP-AP. The length of SCTs varied from 2-4 m. The width of trenches was 0.5- 0.6 m and the depth varied from 0.3-0.6 m. Custard apple, Pongamia, Glyrecidia, Amla, Cashew, etc. were planted on the berm. In case of trenches with 2 m length, single plant on the berm and those with 4 m length 2 plants on the berm were planted. It was observed that simple modification (of restricting the length of SCT to either base width of A-frame or two times of it, increasing the berm space to 1.5 m, placing the dugout soil around the trench in half moon fashion and planting on the berm of excavated trench) in the design and layout of SCTs improved the survival of plants. The data collected from 15 different watersheds revealed that the average survival percentage of plantation was more than 90 per cent. Thus, the modified and innovative design and layout of SCTs helped in situ rain water harvesting and availability of soil moisture for longer period leading to better survival of plantation and reclamation of wastelands.

Key words: Staggered Contour Trench (SCT), rain water, plantation, wasteland and survival of plantation

INTRODUCTION

As per the latest estimates of National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), India, about 45 per cent of total geographical area i.e. 146 m. ha in India is affected by various degradation processes with water erosion being the chief contributor. Large-scale land degradation has long-term environmental and socio-economic implications. The negative environmental implications include loss of biodiversity and ecological stability, frequent occurrence of floods and droughts, silting up of reservoirs and changes in hydrological regimes. Sustainable agricultural production can be achieved by preventing land

[1]Asst. General Manager, Programme Support Unit, IGWDP-AP, 10-1-128/4, Masab Tank X Road, Hyderabad- 500028 (E-mail: drrravibabu@gmail.com)
[2]Department of Horticulture Engineering, College of Horticulture, APHU, Rajendranagar, Hyderabad – 500030

degradation, reclaiming the already affected areas, maintaining soil's productive potential and reducing environmental pollution, while emphasizing reduction in chemical and energy – intensive inputs (Sharda, 2007). In this context, participatory integrated watershed development is now widely recognized as a potential approach for vitalizing rural economy by regenerating the degraded ecosystems. Watershed development aims to bring about the best possible balance in the environment between natural resources on one side and man and grazing animals on the other.

The Indo-German Watershed Development Programme (IGWDP), a bilateral programme of Government of Germany and Government of India is a novel initiative for regeneration of natural resources through participatory approaches that emphasizes on self help, environmental protection and poverty alleviation. The programme is implemented by Village Watershed Development Committee (VWDC- a body nominated by villagers) in association with local Non-Governmental Organization (NGO), known as Project Facilitating Agency (PFA) in each watershed. The Indo German Watershed Development Programme- Andhra Pradesh (IGWDP-AP) was initiated to address the issues concerning the rehabilitation of degraded watersheds in the districts of Karimnagar, Medak, Warangal and Adilabad in Telangana region of Andhra Pradesh. KfW, a German Development Bank is the funding agency on behalf of Government of Germany and NABARD is the legal holder of the projects in India.

The upper reaches of watersheds usually have an undulating topography and are foci for soil erosion. The uncontrolled runoff from these areas causes extensive damage to the adjoining agricultural land. Contour trenching is useful for soil and moisture conservation and afforestation purposes both on hill slopes as well as degraded and bare wastelands (Murty, 1998; Ravi Babu and Mishra, 2005 and Mishra *et al*., 2006). Contour trenching helps in *in situ* conservation of soil moisture and thus facilitates quick establishment of vegetation and rehabilitation of sloping wastelands. However, the field supervisors/engineers in India often adopt thumb rules in layout and design of contour trenches, which leads to either under or over design resulting in their failure or excessive cost (Mishra and Ravi Babu, 2010).

Contour trenching is of two types (1) Continuous Contour Trenching (CCT) and (2) Staggered Contour Trenching (SCT). Considering the field level problems associated with layout and alignment of contours for longer lengths, SCTs are preferred to CCTs. The design of SCT involves fixing the Horizontal Interval (HI) and Vertical Interval (VI) between the successive contour lines and inters spacing between the successive trenches in a row, after selecting the suitable length, width and depth as per site conditions (Ravi Babu, 2009). The step by step procedure described by Ravi Babu, (2009) was used in design of SCTs with the modification that the trench length was either set equal to or fixed two times that of base width of A-frame. Furher, with a view to improve survival of plants, planting on the berm of excavated trench and bund placed in the half moon fashion around the trench has been thought of. Accordingly, berm of 1.5 m was considered between the trench and half moon shaped bund.

This modified SCT design and layout was successfully field tested across 15 watersheds (Shivarvenkatpur, Kasireddipalli, Tigulnarsapur and Mylaram in Medak district; Ayyagaripalli and Chintapalli in Warangal district; Battulapalli in Karimagar district and Settihadapnoor, Sakeda, Kohinoor B, Dhurvaguda, Dharmasagar, Rampur, Yammaikunta and Indervelli in Adilabad district) under IGWDP-AP. The modifications in the design and layout of SCTs and its impact on survival of plantation is presented and discussed in this paper.

MATERIALS AND METHODS

Considering the soil depth, soil type, slope of land, maximum possible 6-hr rainfall and consequent runoff (for 5 year return period), Staggered Contour Trenches (SCTs) were designed for reclamation of highly degraded upper reaches across different watersheds under IGWDP-AP.

The design of SCT involved in fixing the HI and VI between the successive contour lines and spacing between the successive trenches in a row, after selecting the suitable length, width and depth as per site conditions. First, the design depth of rainfall for 5-year return period and for 6-hrs. duration of storm was found. The runoff coefficient duly considering the land use, soil texture and land slope was estimated. Subsequently, the expected runoff depth was calculated using runoff coefficient and design depth of rainfall. The step by step procedure described by Ravi Babu, (2009) as below was used in the design of SCTs.

Assuming rectangular cross-section, the following relationship is used in case of SCTs:

W x D = (Q x HI) (1+ X / L) …(1)

Where, Q= Runoff depth, m

HI = Horizontal interval, m

W = Width of trench, m

D = Depth of trench, m

X = Inter space between trenches, m

L = Length of trench, m

In the improved design of SCT, the length of trench was set equal to base width of A-frame. In case, the base width of A-frame is less than 2 m, the length of trench was set equal to two times that of base width of trench. The spacing between successive trenches (X) in each row is set equal to length of trench (L) for simplicity of calculations. Therefore, the above relationship becomes the following:

W x D = (Q x HI)x (2) …(2)

Depending on the site conditions and available soil depth, the depth of trench was fixed. As rectangular cross-section was assumed, the width of the trench was set as 1.5 – 2 times that of depth of trench. Then, HI was worked out as

HI = (W x D) / (2 x Q) …(3)

Total length of trenches per ha =(1 / 2) x [10000 / ((HI)] …(4)

(Since length of each trench = inter space between successive trenches)

Number of trenches per ha = Total length / length of each SCT …(5)

Volume of earth work per trench = length x cross-section …(6)

Total volume of earth work per ha = no. of trenches per ha x volume of earth work per trench …(7)

Contour lines were marked using A-frame. In the modified design of SCT, the trench length was either set equal to base width of A-frame or fixed two times of base width of frame. The dug out soil from the trenches is placed in the half moon fashion around the trench. Usually berm of 0.3-0.5 m is maintained between the trench and embankment in the conventional design and layout. However, with a view to improve survival of plants, planting on the berm of excavated trench and soil / bund placed in the half moon fashion around the trench. Accordingly, berm of 1.5 m was followed between the trench and half moon shaped bund has been attempted. The point wise comparison of modified design and layout of SCTs with conventional SCTs has been given in Table 1.

Table 1. Modified vs. conventional design and layout of SCTs

S.No.	Parameter / Activity	Modified design and layout	Conventional design and layout
1.	Design procedure followed	(a) Considering the soil depth, soil texture, slope of land, maximum possible 6-hr rainfall and consequent runoff (for 5 year return period), SCTs are designed. (b) The design of SCT involved in fixing the horizontal interval / vertical interval between the successive contour lines and spacing between the successive trenches in a row, after selecting the suitable length, width and depth as per site conditions.	(a) Thumb rules are generally followed. (b) The length, width and depth of trench and horizontal / vertical interval are fixed without considering land use, soil slope, soil texture and expected runoff, etc.
2.	Cross-section (width x depth) of trench	Depending on the site conditions and available soildepth, the depth of trench is fixed. As rectangular cross-section was assumed, the width of the trench was set as 1.5 – 2 times that of	The usual cross section of SCT (in terms of width x depth) is 0.6 m x 0.3 m or 0.5 x 0.5 m
3.	Length of trench	(a) In the improved design of SCT, the length of trench was set equal to base width of A-frame. In case, the based width of A-frame is less than 2 m, the length of trench is set equal to two times that of base width of trench. (b) The length of trench varied between 2-4 m depending on the base width of A-frame.	(a) Staggered trenches are constructed across the slope with lengths varying from 5 to 15 m (Katyal *et al.*, 1995). (b) Under MGNREGA in AP, SCTs of length varying between 7-15 m are found to be made.

S.No.	Parameter / Activity	Modified design and layout	Conventional design and layout
4.	Inter spacing between the trenches in a given row	The spacing between successive trenches in each row is set equal to length of trench facilitating easy layout by even unskilled labour.	As longer trench length is adopted the spacing between trenches in each row is also found to be relatively high.
5.	Horizontal interval between successive trench lines	Proper horizontal interval of 2-10 m is maintained between successive SCTs depending on the soil texture, slope, location, selected cross-section of the trench and design depth of runoff, etc.	Thumb rules are generally followed.
6.	Marking of contour lines and layout of trenches	(a) Contour lines are marked using A-frame / hydromarker (b) Layout of SCTs is very easy as the length of SCTs is limited to base width of A-frame (c) As the length of SCT is linked to base width of A-frame, the errors in layout of contours and SCTs is avoided and trenches are laid exactly on the contours thus facilitating better harvesting of rainwater.	(a) Marking of SCTs is done across the slope (b) As the length of SCT has no relation to base width of A-frame, the layout of contours and SCTs is always prone to errors. (c) Poor alignment of contours s over long length would result in breaches due to concentration of runoff. A breach in one SCT would lead to chain reaction and formation of gullies.
7.	Berm	Minimum berm of 1.5 m was followed between the trench and half moon shaped bund.	Usually berm of 0.3-0.5 m is maintained between the trench and embankment
8.	Placement of soil	The soil excavated (i.e. spoil) is placed in half moon shape at the downstream side of the trench. Thus the trench and half moon shaped bund act as catch pit for the plant.	Excavated soil is placed at the downstream side of the trench.
9.	Bund sectioning	Clod breaking and proper sectioning (as per the design specification) of the soil is carried out.	Required attention is not paid towards clod breaking and proper sectioning of the bund.
10.	Revetment	In highly sloping land, the bund on the downstream side is supported with local stone revetment	This is not attended to in the conventional method
11.	Plantation	(a) Planting is done on the berm of excavated trench and bund placed in the half moon fashion around the trench. (b) It is easy for the plant roots to extract soil moisture from the trenches as it is available within 0.3- 0.5 m radius. Planting on the berm enables shallow root system of plants to absorb trapped rain water, which seeps through the soil from the trenches.	(a) Trench layout is not taken into account while taking up plantation. The plantation is carried out as per the spacing norms. (b) It is difficult for the plants to extract soil moisture (seepage) from the trenches because of shallow root system of plants (in the establishment stage) and relatively possible higher distance of trench and plant.
12.	Availability of catch pit	Separate catch pit for each plant is available facilitating better establishment and survival of plantation and reclamation of wastelands.	Separate catchment pit (trench) may not be available for each plant.

The modified SCT design and layout was successfully field tested across 15 watersheds (Shivarvenkatpur, Kasireddipalli, Tigulnarsapur and Mylaram in Medak district; Ayyagaripalli and Chintapalli in Warangal district; Battulapalli in Karimagar district and Settihadapnoor, Sakeda, Kohinoor B, Dhurvaguda, Dharmasagar, Rampur, Yammaikunta and Indervelli in Adilabad district). Planting was carried out in the year 2010 on the berm of trench and half moon shaped bund across 15 watersheds. The data related to watershed wise number of plants planted and the number of surviving plants as on 30 May 2012 in the SCT treated area was collected and the survival percentage was worked out. Thus the impact of innovative design and layout of SCTs on survival percentage of plantation was assessed and interpretations were drawn.

RESULTS AND DISCUSSION

This innovative SCT design and layout was successfully field tested across 15 watersheds under IGWDP-AP. The design details of SCTs for two selected watersheds (one for red sandy loam soils and the other with black cotton soils) are furnished as sample in Table 2. Based on the width of fabricated A-frame at the base, the length of SCT is fixed s 2 m in Ayyagaripalli watershed and the same in the case of Kohinoor B watershed is 3 m. The spacing of trenches in a line was set equal to length of SCT and the HI between the consecutive lines was 7 and 4 m in Ayyagaripalli and Kohinoor B watersheds, respectively (Table 2).

Table 2. Design details of SCTs for two selected watersheds (Ayyagaripalli, Warangal and Kohinoor B, Adilanad)

S. No.	Item	Ayyagaripalli, Warangal	Kohinoor, Adilabad
1.	Area in ha	2.5	4
2.	Slope of land in %	12	16
3.	Type of soil	Sandy loam	Heavy clay
4.	Estimated depth of runoff (mm)	20	42.6
5.	Cross-section of trench (sq.m)	0.27	0.3
6.	Length of trench in m	2	3
7.	Spacing of trenches in a line in m	2	3
8.	Horizontal interval in m	7	4
9.	Vertical interval in m	0.8	0.6

Across 15 watersheds in which SCTs were executed, the length of SCTs varied from 2 - 4 m. The width of trenches was 0.5- 0.6 m and the depth varied from 0.3-0.4 m. The excavated soil is placed around the trench in half moon fashion leaving berm of 1.5 m. Custard apple, Pongamia, Glyrecidia, Casia siamia, Teak, Bamboo, Amla, Cashew, etc. were planted on the berm. In case of trenches with 2 m length, single plant on the berm and those with 4 m length 2 plants on the berm were planted. The data collected from different watersheds is presented in Table 3. It can be observed from Table 3 that the survival percentage of plantation varied from 61 to 97 % across 15 watersheds in which this activity was taken up. The average percentage of survival of plantation was found to be 91 per cent (Table 3). The views of (treated) area and plantation during pre and post development were depicted in plates 1 to 6. The excavated trench, plantation on the berm and half moon shaped bund around the trench can be seen from the plates. The impact of the SCTs in trapping rainwater, improvement of soil moisture and consequent facilitation of establishment of green grass and plantation in wastelands could be visualized from the plates.

For most of the plants, concentration of moisture absorbing roots is greatest in upper part of the root zone and near the base of plants. Extraction of soil moisture is very rapid in the zone of greatest root concentration and under favorable environmental conditions. Further, the shorter length of SCTs has very less chance of deviating from contours and they are found to be very effective in trapping runoff and as a result increased the soil moisture availability. Thus, better moisture conservation in the soil profile

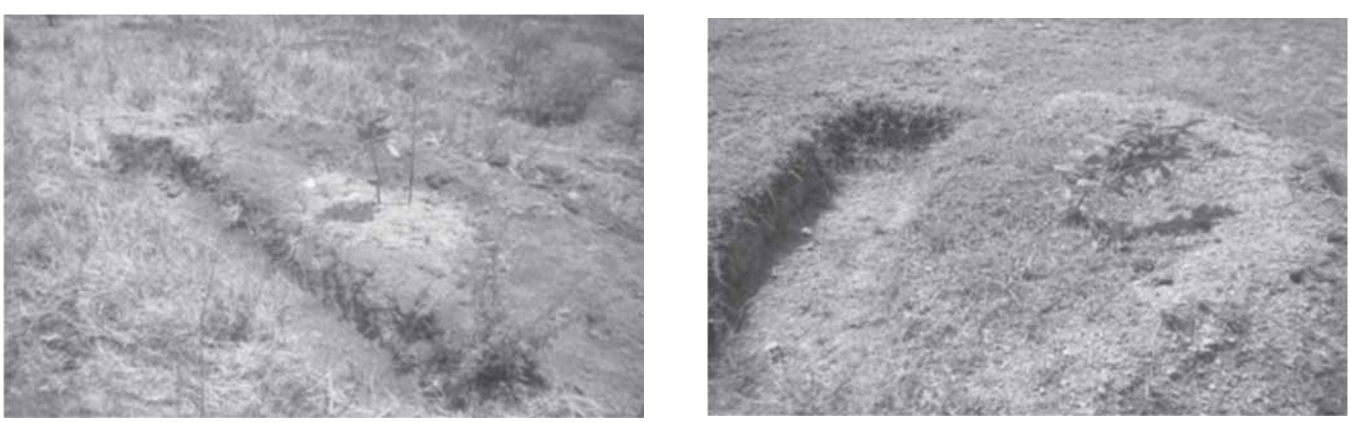


Fig. 1& 2. Close view of Cashew and Custard apple plants surviving only on account of SCTs in Settihadapnoor (Adilabad) and Shivarvenkatpur (Medak) watersheds

Table 3. Watershed wise survival percentage of plantation

S. No. (1)	Name of the watershed (2)	Name of the farmer/owner (3)	Area treated with SCTs (ha) (4)	Average slope (%) (5)	Total No. of plants planted (6)	Species of plants (7)	Total number of surviving plants as on 30.05.2012 (8)	Percentage of survival (9)
1.	Mylaram	Chakali Mallaiah	0.5	8	256	Custard apple, Pongamia	234	91
2.	Mylaram	Chutta Kanakaiah	2	8	321	Custard apple, Pongamia	287	89
3.	Settihadpunoor	Kanaka Jugadhirao	2.83	14	1833	Fruit plants	1685	92
4.	Settihadpunoor	Pendhur ThulasiRam	1	12	180	Fruit plants	171	95
5.	Kohinoor-B	Common land	4.04	16	758	Pongamia, Glyrecidia, Custard apple, Bamboo, etc.	714	94
6.	Sakeda	Marapa Jyothibai	1	8	220	Fruit plants	188	85
7.	Sakeda	Kotrenganagu	1	8	385	Fruit plants	369	96
8.	Dhurvaguda	Common land	20	15	7500	Pongamia, Custard apple, Teak, Amla	7125	95
9.	Dharmasagar	A.Bheemrao and others	12	6	5100	Pongamia, Custard apple, Teak	4590	90
10.	Rampur	Common land, K.Dharmu and others	6	4	4500	Pongamia, Custard apple, Teak	4050	90
11.	Shivarvenkatapur	Gout Land	34	8	12500	Custard apple	11890	95
12.	Kasireddypally	Gout Land	8	5	6000	Custard apple	5824	97
13.	Thigulnarsapur	Gout Land	12	6	6000	Custard apple	4842	81
14.	Ayyagaripally	Govt Land	2.5	12	2040	Custard apple, Pongamia and Casia siamia	1800	88
15.	Chintapally	Govt Land	3	12	1547	Pongamia and Casia siamia	950	61
	Total				49140		44719	91

Fig. 3 & 4. Pre-development (Dhurvaguda, Adilabad) and post-development (Dhurvaguda, Adilabad)


Fig. 4 & 5. Pre-development (Yammaikunta, Adilabad) and post-development (Yammaikunta, Adilabad)

has been observed in the case of modified SCTs. As the planting is done on the berm of excavated trench and bund placed in the half moon fashion around the trench, it is easy for the plant roots to extract soil moisture from the trenches as it is available within 0.3- 0.5 m radius. Planting on the berm thus enabled shallow root system of plants to absorb trapped rain water, which seeps through the soil from the trenches and resulted in facilitating plants to establish and survive in the severely degraded uplands in watersheds.

It was observed that simple modification (of restricting the length of SCT to either base width of A- frame or two times of it, increasing the berm space to 1.5 m, placing the dugout soil around the trench in half moon fashion and planting on the berm of excavated trench) in the design and layout of SCTs improved the survival of plants.

CONCLUSIONS

The modified and innovative design and layout of SCTs helped *in situ* rain water harvesting and availability of soil moisture for longer period leading to better survival of plantation and reclamation of wastelands. This design and layout may be adopted in other degraded upper reaches of watersheds for better establishment and survival of plantation and reclamation of wastelands.

REFERENCES

Katyal, J.C., Singh, R.P., Sharma, S., Das, S.K., Padmanabhan, M.V. and Mishra, P.K. 1995. Field Manual on Watershed Management. pp.18.

Mishra, P., Mazumdar, A. and Ravi Babu, R. 2006. Application of probability analysis of rainfall for design of Continuous Contour Trenches, Contour Bund and Waste Weirs in Bankura. *Journal of Agricultural Engineering*, 43(4): 22-29.

Mishra, P. and Babu, R.R. 2010. Simple User Interface for Design and Cost Estimation of Contour Trenches for Rehabilitation of Non-Arable Degraded Lands in India Paper published in Book Hydrology and Watershed Management. BS Publications, Hyderabad. In: Sarala, C., Rao, B.V., Giridhar, M.V.S.S. and Varalakshmi, V. (ed).pp: 531-541.

Murty, V.V.N. 1998. Measures for erosion control on hill slopes. Land and Water Management Engineering, Kalyani publishers pp: 448-450.

Ravi Babu, R. 2009. Field Manual on design and cost estimation of soil and water conservation measures in watershed development projects. 56 p.

Ravi Babu, R.and Mishra, P. 2005. Design and construction of Staggered Contour Trenches in Paharpur micro-watershed. Hydrology and watershed management, Himanshu publications, Udaipur. In: Kumar, V, Singh, PK and Purohit, R.C.(ed). pp: 261-267.

Sharda, V.N. 2007. Managing Natural Resources. The Hindu Survey of Indian Agriculture. pp: 134-142.

Journal of Soil and Water Conservation **12**(1): 17-22, January-March 2013
ISSN: 022-457X

Prioritization of sub-watersheds for erosion risk assessment - integrated approach of geomorphological and rainfall erosivity indices

RAHUL KAWLE[1], S. SUDHISHRI[2] and J. K. SINGH[3]

Received: 23 August 2012; Accepted: 6 February 2013

ABSTRACT

Watershed prioritization is essential for effective utilization of financial resources. The present study was therefore, undertaken in the Gagas watershed under Ramganga catchment in Almora district of Uttarakhand, covering an area of 634.14 km^2 with the main objective of prioritization of its 19 sub-watersheds. Different thematic maps of the study area were prepared using Survey of India toposheets (1:50,000 scale) and satellite imagery of study area with the help of ARC / INFO 9.0 software. Hypsometric analysis of study area was carried out for determining status of watershed from soil erosion point of view. It was found that out of 19 sub-watersheds, 15 sub-watersheds were in equilibrium stage and remaining 4 were in monadnock geological stage. To ascertain this, morphometric analysis of Gagas watershed and its 19 sub-watersheds was also carried out. Morphometric parameters were integrated with rainfall erosivity index to prioritize the sub-watersheds for erosion risk assessment. Then the compound parameter (C_p) was determined and prioritization of sub-watersheds was carried out for their treatment through soil and water conservation measures. These results confirmed the findings of hypsometric analysis of Gagas watershed barring one sub-watershed (Rf1f).

Key words: watershed; land degradation; geomorphology; erosivity index; prioritization; soil conservation

INTRODUCTION

In India, out of total geographical area (328 Mha), about 188 Mha (57 per cent) area is affected by various land degradation problems of which erosion by water is the major contributor. About 5334 M tonnes of soil are getting eroded annually, which works out to be 16.4 tonnes ha^{-1} $year^{-1}$ (Dhruva Narayana and Ram Babu, 1983). This invokes for the immediate attention to the development, conservation and utilization of soil and water resources in such a way that ensures their high productivity and sustainability. But in India the large financial and manpower commitments involved in treating watersheds require a selective approach for identifying smaller hydrological units for more efficient and better targeted resource management programs. This focus in watershed management has created renewed interest in erosion surveys, sediment yield, and prediction studies to identify problem areas with relatively high sediment yield potential so as to take up conservation measures on priority basis on prioritized erosion prone watershed components. Watershed prioritization is thus ranking of different sub-watersheds according to the order in which they have to be taken for treatment through soil conservation measures.

To determine the geomorphic stages of the watershed many researchers have advocated the use of hypsometric analysis (Chow, 1964; Schumn *et al.*, 1987; Goel and Singh, 2000; Sarangi *et al.*, 2001; Pradhan and Senapati, 2002; Singh, 2009). The hypsometric integral, another indicator of cycle of erosion of a watershed, assumes an important place in geomorphic study because it tells about geological

[1] Ex-M.Tech Student
[3]Ex-Head and Professor, Deptt of SWCE, G.B.Pant University of Agricultural & Technology, Pantnagar, Uttarakhand– 263 145
[2]Senior Scientist (SWCE), WTC, IARI, New Delhi-110012,

stages of development of watershed (i.e. youthful stage, mature stage, old age stage) of watershed (Garg, 1983). After knowing the degradation status of different parts of watershed it is essential to prioritize the sub-watersheds for taking up the soil and water conservation measures as well as other land and non-land based activities. The Sediment Yield Index (SYI) method and Universal Soil Loss Equation (USLE) have been widely used by researchers (Bali and Karale, 1977; Prasd *et al.*, 1993; Rao and Adinarayan, 1994; Sharma *et al.,* 2002) to prioritize the watersheds. However, difficulties have been experienced in applying these method since these require large reliable database like soil, land use, slope length, crop management factor etc., which may need long time to obtain. To overcome this problem, many researchers (Chaudhary and Sharma, 1998; Biswas *et al.*, 1999; Thakkar *et al.*, 2007) advanced the applicability of geomorphological studies in combination with geographic information system (GIS) application for prioritization of watersheds. Other than the geomorphological parameters, rainfall erosivity index also plays a vital role in erosion process.

Keeping the above in view the present study was attempted to prioritize the sub-watersheds of Gagas watershed based on geomorphological and rainfall erosivity indices using GIS tool and compared with result of hypsometric analysis.

MATERIALS AND METHODS

Gagas watershed is situated at South-Eastern part of the Ramganga catchment in middle and outer ranges of Himalayas, covering an area of 634.14 km^2. It lies between $29^0 35'20''$ N to $29^0 51'00''$ N latitude and $79^0 15'00''$ E to $79^0 34'30''$ E longitude in Almora district of Uttarakhand (Fig. 1). It drains into Gagas (a tributary of river Ramganga) from East to West directly or through its tributaries. The watershed is well drained entity due to its coarse textured soils and a number of tributaries spread over entire watershed having dendritic pattern. The maximum elevation of the watershed in the vicinity of upstream end of Gagas river is 2720 m whereas minimum elevation at gauging station (i.e. Bhikiyasen) is 760 m above mean sea level. The climate of watershed is Himalayan sub-tropical to sub-temperate. The mean annual rainfall in the area is 901.78 mm which varies from 755.72 to 1021.42 mm.

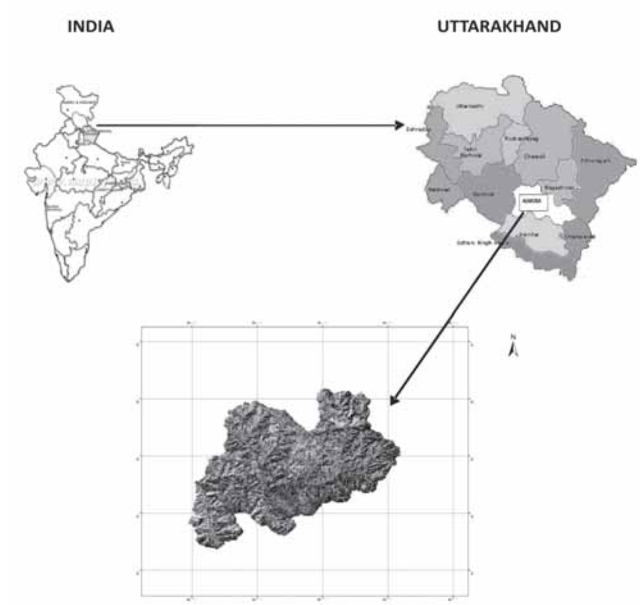


Fig. 1. Location map of Gagas watershed

G.I.S. and remote sensing application for data extraction

Survey of India (SOI) Toposheets (53 O / 5, 53 O / 6, 53 O / 9 and 53 O / 10) at a scale of 1:50,000 scale were scanned (*tiff format*) and geo-referenced and these geo-referenced toposheets were connected to form complete image of the study area using mosaic operation with the help of ERDAS Imagine 8.5 software. The mosaic image was imported from ERDAS Imagine 8.5 software to ARC / INFO 9.0 software and the Gagas watershed boundary was digitized by observing the ridge points from the contours. The study area was divided into 19 sub-watersheds as defined by All India Soil and Land Use Survey (AISLUS), New Delhi and digitization was done accordingly.

Drainage pattern (Fig. 2) was initially digitized from mosaic toposheets and later updated using False Color Composite (FCC) of downloaded LANDSAT data (Bands- 2, 3, 4 ID%039-030, Acquisition date-15 / 10 / 1999, Dataset- ETM+, Producer- Earthsat). Contours were digitized at an interval of 40 m from SOI toposheets using the polyline feature in ARC / INFO 9.0 software. To generate Digital Elevation Model (DEM), 'TIN' was formed using contour layer. Then, using 'TIN' to Raster' option DEM was generated with the help of ARC / INFO 9.0 software. DEM was used to derive relief of sub-watersheds which is the vital parameter in morphometric characterization of watershed.

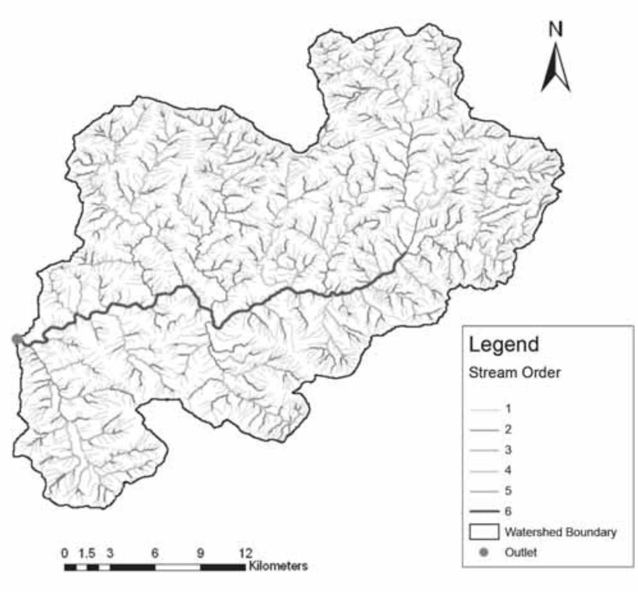


Fig. 2. Drainage map of the Gagas watershed

Hypsometric analysis for erosion status of the watershed

For hypsometric analysis digitized watershed boundary along with contour map of study area was used. The contours of Gagas watershed and its sub-watersheds converted into polygon using 'Feature to polygon' option available in Arc toolbox of ARC / INFO 9.0 software, the attribute table of polygon and contour provide the information of area enclosed by the polygon and the elevation of contours. The hypsometric curves drawn between height ratio and area ratio, plotted along ordinate and abscissa respectively (Chow, 1964). After plotting the hypsometric curves, the values of hypsometric integral (HI) were determined for Gagas watershed and its sub-watersheds which is equivalent to the ratio of area under curve to the area of entire square formed by covering it. Area under the curve was determined by taking the integration of polynomial equation of the curve. Based on these values of hypsometric integral (HI) geologic stages of development of sub-watersheds were fixed.

Computation of R Factor (EI_{1440}) using daily rainfall data

Soil erosion occurs when raindrops act upon the soil particles. Amount of erosion thus depends upon the combination of the power of rain to cause erosion and the ability of soil to withstand it. Potential ability of rain to cause erosion is known as erosivity index (R-factor) which is a function of the physical characteristics of rainfall and the soil. In India, there is the lack of availability of recording rainfall data and therefore, it is a tedious work to calculate erosivity index. To overcome this problem, daily rainfall data is used to calculate erosivity index by considering this as individual storm events. The rainfall storm equal to or more than 12.5 mm was considered as erosive storm for the analysis (Sudhishri *et al.*, 2002). In the present study to determine R-factor daily rainfall data of six raingauge stations i.e. Bhirapani, Bhikiasen, Binta, Ranikhet, Sauni and Tarikhet collected from Divisional Forest Office, Ranikhet, were used and R-factor values for all six raingauge stations were determined as per procedure given by Sudhishri et al., (2002).

A point map of six raingauge stations was prepared in ARC / INFO 9.0 software by locating it on mosaic toposheet. Thiessen polygons were created by nearest point method in ARC / VIEW 3.2 software. Calculated annual average R values (EI_{1440}) for all six raingauge stations were assigned to respective thiessen polygon. Then layer of sub-watersheds was overlaid on thiessen polygon layer and area of sub-watersheds in the respective thiessen polygon zone was determined. The detailed procedure for determination of erosivity index was shown in Fig. 3. The weighted R values for sub-watersheds were determined by taking weighted mean of the rainfall Erosivity and contributed area of a sub-watershed in different thiessen polygons, that is,

Where,

n = number of polygon segments falling in the j^{th} sub-watershed.

Morphometric analysis

Morphometric analysis of sub-watersheds was done for the prioritization of sub-watersheds with the help of ARC / INFO 9.0 software. The stream ordering was carried out using the Strahler's law. The fundamental parameters namely; stream length area, perimeter, basin length and numbers of streams were derived from drainage layer. The morphometric parameters for the watershed and its sub-watersheds were calculated based on the formula suggested by Horton (1945), Strahler (1964), Schumn (1956), and Miller (1953). The morphometric parameters value namely; stream length, bifurcation ratio, drainage density, stream frequency, texture ratio, form factor, circulatory ratio, elongation ratio and average slope were calculated.

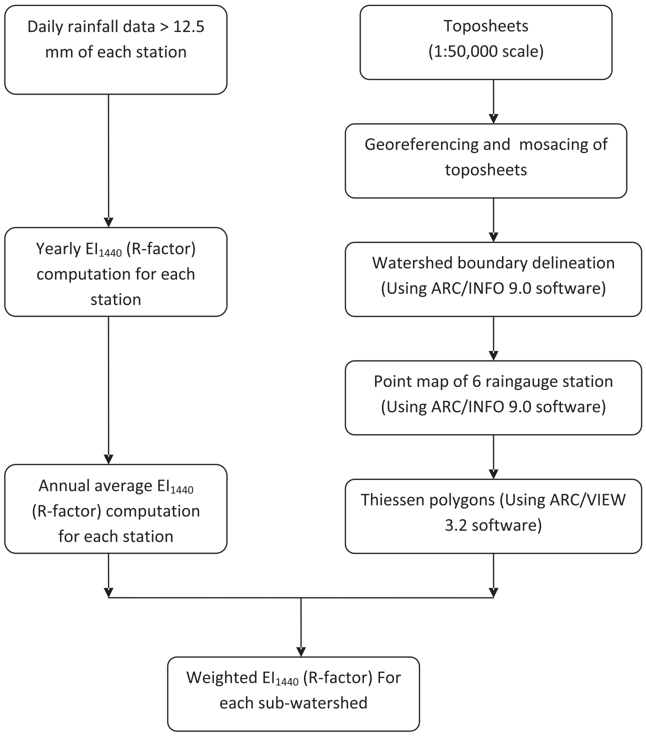


Fig. 3. Flow chart of determination of erosivity index (R-factor)

Prioritization criteria

Since morphological parameters *viz.*, bifurcation ratio, drainage density, stream frequency, texture ratio and average slope are directly related to erosion, their highest values were individually given ranking as 1, next lower value as 2 and so on. The lowest value of particular parameter was ranked last in the serial number. The shape parameters have inverse relation to the erosion. Therefore, for the shape parameter (i.e. form factor, circulatory ratio, elongation ratio), the lowest value was given ranking of 1, next higher value was given ranking of 2 and so on.

As rainfall erosivity index is a very important parameter from soil erosion point of view it has been integrated with morphological parameters to form a compound parameter in present study. Therefore, highest value of erosivity index for sub-watershed was given ranking 1; next lower value was given ranking of 2 and so on. The lowest value was ranked last in the serial numbers. After ranking has been done for individual parameter, the compound parameter was determined for each sub-watershed, by taking average of ranks of nine parameters. Based on values of compound parameter (C_p), the sub-watersheds having the lowest value was assigned highest priority number 1, the next higher value was assigned priority number 2 and so on. The sub-watershed which got the highest value of C_p was assigned the last priority number (Biswas *et al.*, 1999).

RESULTS AND DISCUSSION

It was observed that shape of hypsomeric curve of study area is distorted one having hypsometric integral equal to 0.31, which indicates that the entire watershed is nearer to monadnock stage i.e. a highly eroded watershed got stable and least erosion is possible from the watershed. It was observed from shape of curves and hypsometric integral (HI) values that the 15 sub-watersheds namely, Rc2f, Rc2g, Rf1a, Rf1c, Rf1d, Rf1e, Rf1g, Rf2a, Rf2c, Rf2d, Rf3a, Rf3b, Rf3d, Rf3e, and Rf3f were in equilibrium (mature) stage indicating slow rate of erosion. Whereas, 4 sub-watersheds namely, Rf1b, Rf1f, Rf2b and Rf3c having HI values less than 0.35 have acquired monadnocks geological stage i.e. have attained stable stage and are least susceptible to erosion. Fig. 4 showed the hypsometric curve of Gagas watershed, indicating monadnock stage. A map showing the sub-watersheds under different geological stages has shown in Fig. 5.

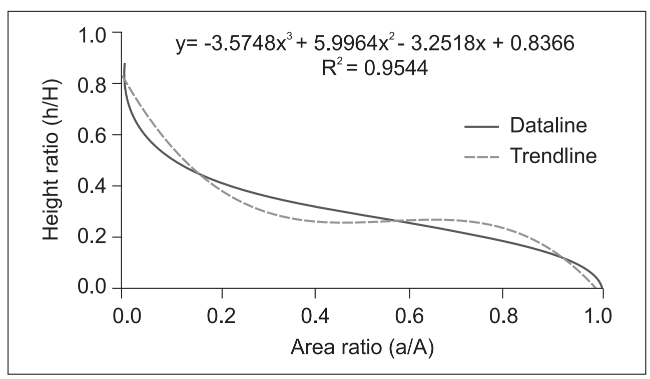


Fig. 4. Hypsometric curve of Gagas watershed

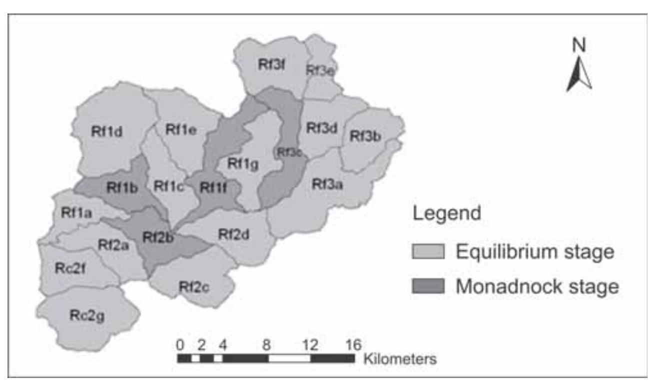


Fig. 5. A map showing the sub-watersheds under different geological stages

As per the procedure mentioned R-factor (EI) was determined and it was observed that, sub-watershed Rf2d had maximum weighted annual rainfall erosivity index value of 103.86 mton ha.hr^{-1} and minimum value of 75.70 mton ha.hr^{-1} for sub-watershed Rf1a. Also morphometric parameters were calculated for watershed and its all sub-watersheds. The high value of bifurcation ratio (>5) for Rf2d and Rf3b sub-watersheds may be due to large variation in stream frequencies between successive orders. The value of drainage density (D_d) of Gagas watershed was 3.211 and for sub-watersheds it varied from 2.689 to 3.848. The value of circulatory ratio (R_c) varied from 0.194 to 0.685 and that of elongation ratio (R_e) from 0.654 to 0.709 for all the 19 sub-watersheds.

The sub-watershed Rf3a with a compound parameter value of 4.67 received the highest priority rank (one) with the next in priority list is sub-watershed Rf1e having the compound parameter value of 5.22 (Table 1). Highest priority indicates the greater degree of erosion in the particular sub-watershed and it becomes potential candidate for applying soil conservative measure. In the present study, to categorize the sub-watersheds into very high, high, medium and low erosion intensity the values of compound parameter were considered as 0-4, 4-8, 8-11 and more than 11 respectively, keeping the results of hypsometric analysis in view. It was observed that, 4 sub-watersheds were under high erosion intensity, 8 sub-watersheds were under medium erosion intensity, 7 sub-watersheds were under low erosion intensity. These findings confirmed the findings of hypsometric analysis of Gagas watershed barring one sub-watershed (Rf1f). Lastly, prioritization map showing erosion level was prepared and shown in Fig. 6.

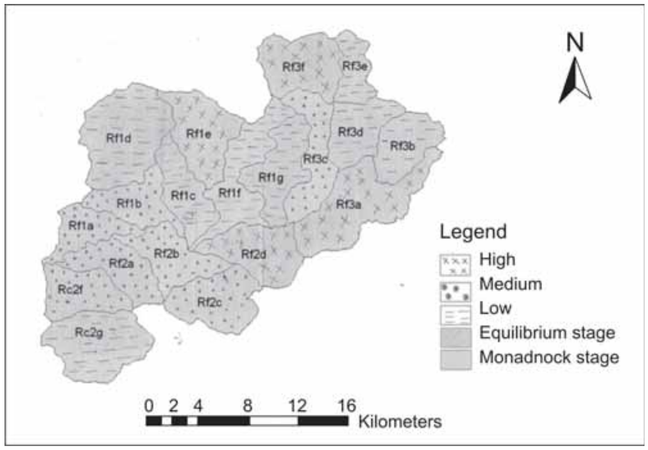


Fig. 6. Priority map showing erosion level of sub-watersheds

CONCLUSIONS

This present study demonstrates the usefulness of GIS for morphometric analysis and prioritization of the sub-watersheds of Gagas watershed. Results

Table 1. Priority ranking on the basis of morphological parameters and erosivity index of sub-watersheds

Sr. No.	Sub-watershed	Bifurcation Ratio (R_b)	Drainage Density (D_d)	Stream Frequency (F_u)	Texture Ratio (R_t)	Form Factor (F_f)	Circulatory Ratio (R_c)	Elongation Ratio (R_e)	Average slope	Erosivity Index	Compound parameter (C_p)	Final priority ranking
1.	Rc2f	15	14	17	14	13.5	14	13.5	7	18	14.00	18
2.	Rc2g	11	15	14	6	3	19	3	11	16	10.89	12
3.	Rf1a	4	11	12	18	18	3	18	4	19	11.89	15
4.	Rf1b	14	8	8	13	17	6	17	5	15	11.44	13
5.	Rf1c	3	17	11	12	4.5	9	13.5	15	5	10.00	9
6.	Rf1d	7	13	13	5	1	18	1	13	7	8.67	5
7.	Rf1e	10	1	1	1	6	11	5	10	2	5.22	2
8.	Rf1f	16	10	9	15	4.5	1	4	18	4	9.06	8
9.	Rf1g	18	9	7	9	10	7	9	17	6	10.22	10 or 11
10.	Rf2a	6	19	18	16	13.5	8	13.5	3	17	12.67	17
11.	Rf2b	19	18	19	19	12	5	11	12	14	14.33	19
12.	Rf2c	12	16	16	11	8.5	15	6.5	6	13	11.56	14
13.	Rf2d	1	7	10	8	8.5	12	8	16	1	7.94	4
14.	Rf3a	13	2	4	3	2	4	2	9	3	4.67	1
15.	Rf3b	2	3	3	4	16	17	16	8	10.5	8.83	6
16.	Rf3c	17	12	15	17	11	2	10	19	8	12.33	16
17.	Rf3d	8	5	6	7	15	13	13.5	14	10.5	10.22	10 or 11
18.	Rf3e	5	4	2	10	19	10	19	1	10.5	8.94	7
19.	Rf3f	9	6	5	2	7	16	6.5	2	10.5	7.11	3

of study indicates that out of 19 sub-watersheds 4, 8 and 7 number of sub-watersheds were under high, medium and low level of erosion intensity respectively, which confirmed the findings of hypsometric analysis barring the one sub-watershed (Rf1f). It was also found that the major part of the watershed was under equilibrium stage and needs implementation of both mechanical as well as vegetative soil and water conservation measures to arrest soil erosion and conserve the water for reuse. However, a small portion of the watershed covering 4 sub-watersheds were under monadnock geological stage and may need mainly vegetative barriers with minimum of mechanical measures to arrest the sediment loss and may require more water harvesting type structures at different location in the watershed to conserve the water for fruitful use.

REFERENCES

Bali, Y.P. and Karale, R.L. 1978. Soil survey interpretations for watershed development. *In: Soil Resource Data for Agricultural Development by Leslic, S. and D. Leslic* (edition), 73-84.

Biswas, S., Sudhakar, S. and Desai, V. R. 1999**.** Prioriization of subwatershed based on morphometric analysis of drainage basin: a Remote Sensing and GIS approach**.** *Journal of Indian Society of Remote Sensing,* 27(3):155-166.

Chow, V. T. 1964. Hand Book of Applied Hydrology, McGraw Hill Book Co., New York.

Dhruva Narayana, V.V. and Rambabu. 1983**.** Estimation of Soil Erosion in India. *Journal of Irrigation and Drainage Engineering.* 109 (4): 419-434.

Garg, S. K. 1983. *Geology – The science of the earth.* Khanna Publishers; 2-B, Nath Market, Nai Sarak , New Delhi.

Goel A. K. and Singh J. K**.** 2000. Probability analysis of rainfall of lower shivaliks in foothills of Himalaya. *Him. Jr. of Agri. Res.* 26 (1 & 2): 98-108.

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

Miller, V. C. 1953. A quantitative geomorphic study of drainage basin characteristics in the clinch mountain area, *Technical report-3*, Columbia. University department of Geology.

Pradhan, K. and Senapati, P. C. 2002. Hypsometric analysis of some selected watersheds for Hirakund catchment. *Indian Journal of Soil Conservation,* 30 (2): 183-185.

Rao, K. G., and Adinarayan, J. 1994. Qualitative assessment of soil erosion for watershed prioritization: a database approach, *Asian-Pacific Remote Sensing Journal*, 7(1): 147-154.

Schumn, S. A. 1956. Evolution of drainage systems and slopes in badlands at Perth Amboy, New Jersey. *Geol. Soc, Am. Bull.* 67: 597-646.

Singh Omvir. 2009. Hypsometric and erosion proneness: a case study in the lesser Himalayan watersheds. *Journal of Soil and Water Conservation*. 8(2): 53-59.

Strahler, A. N. 1964. Quantitative geomorphology of drainage and channel networks. *Handbook of Applied Hydrology*, Ed. by Ven Te Chow, Mc Graw Hill Book Company, New York. 4-39 - 4-76.

Sudhishri, S. and Patnaik, U. S. 2002. Rainfall erosivity assessment for Eastern Ghat High Land Zone of Orissa. *Journal of Soil and Water Conservation*, 1: 21-25.

Thakkar, A.K. and Dhiman S. D. 2007. Morphometric analysis and prioritization of mini-watersheds in Mohr watershed, Gujrat using Remote Sensing and G.I.S. techniques, *Journal of the Indian Society of Remote Sensing.* 35(4): 313-321.

Journal of Soil and Water Conservation **12**(1): 23-30, January-March 2013
ISSN: 022-457X

Assessment of runoff potential in the National Capital Region of Delhi

MANISHA E MANE[1], S CHANDRA[2], B R YADAV[3], D K SINGH[4], A SARANGI[5] and R N SAHOO[6]

Received: 12 September 2012; Accepted: 16 April 2012

ABSTRACT

Realistic quantification of water resources on regional basis is the preliminary step for its judicious utilization and sustainable agricultural production. Delhi, the capital city of India, has been undergoing rapid growth driven by strong economy resurgence. Government of India, with a view to insure plan, growth, and development of Delhi, created the National Capital Region (NCR) encircling the Delhi Metropolitan Area (DMA). The rapid urbanization of Delhi has resulted in sharp increase in the population, thereby increasing the demand for fresh water and food supply. In the present investigation, an attempt has been made to quantify the surface runoff potential in the National Capital Region of Delhi. This study uses the USDA-NRCS Curve Number (CN) method for estimation of runoff potential in the NCR. The digital database of soil, land use, and hydrologic soil groups were prepared in ArcGIS (ESRI) tool, which were required for the selection of curve numbers. The daily rainfall data (2000-2007) and monthly rainfall data (1976-2005) were collected for four and thirty three stations respectively. From the average annual rainfall data, isohyetal map and spatial variation map were generated for the study area. An empirical relationship was developed between monthly rainfall and monthly runoff estimated from daily and monthly rainfall values for the four stations for which daily rainfall data was available. A relationship was also developed between the monthly runoff from the monthly rainfall and monthly runoff from daily rainfall values. The relationships were found to be linear with R^2 values of 0.97 and 0.78. These relationships were used to estimate the monthly surface runoff for the other thirty three stations where only rainfall data was available. From average annual runoff of all the stations iso-runoff map and map of spatial variation of runoff were generated. The developed iso-hyetal maps could be useful for crop planning in the region and iso-runoff maps could be helpful to workers for deciding and designing water harvesting structures, crop intensification and for soil conservation.

Key words: surface runoff, curve number, GIS, Iso-hyetal map, National Capital Region

INTRODUCTION

The twentieth century has seen phenomenal growth in the use of water. The world population has tripled, but the use of water for human purpose has multiplied six fold. Per capita water availability is decreasing day by day. The world is fast heading towards 'a water shock', which may even dwarf the oil crisis. India supports about 16 % of the world population on 2.4 % of world's land and 4 % of world's water resource. Per capita water availability in most parts of India touching the water stress level of (1700m^3/ person / year). With a projected annual population growth of 1.8% it is a challenging task for the agricultural scientists in India to sustain the required level of grain production.

It is estimated that out of the 4×10^{-8} m^3 average annual precipitation that falls over India, the utilizable surface and groundwater resources are merely 0.69×10^{-8}m^3 and 0.432×10^{-8}m^3 respectively (Sharda and Juyal, 2006). In the coming decades, ever

[1]Corresponding Author, Ph.D. Scholar, Water Technology Centre, IARI, New Delhi. manishaiari@gmail.com
[2,3] Principal Scientist, Water Technology Centre, IARI, New Delhi
[4]Principal Scientist, Division of Agricultural Engineering, IARI, New Delhi
[5]Senior Scientist, Division of Agricultural Engineering, IARI, New Delhi
[6]Senior Scientist, Division of Agricultural Physics, IARI, New Delhi

increasing population, global warming, climate change, surface and ground water pollution will certainly decline the fresh water supply. Keeping all these factors in mind, the quantification and measurement of surface water resources is essential for sustainable resource utilization. For this purpose the estimation of surface runoff is essential. For the assessment of water yield potential, planning of water conservation measures, recharging the ground water zones and reducing the sedimentation and flooding hazards downstream the correct runoff estimation is a must. The availability of accurate information on runoff in India is however, scarce and therefore, there is an urgent need to generate information on runoff to promote watershed development and management programmes. Runoff from a watershed system is usually measured with the help of the gauging stations generally installed at the watershed outlets. This requires substantial investment of time and money and usually is not a practical option. In India, most of the agricultural watersheds are ungauged, having no past record for the study of rainfall-runoff processes (Sarangi *et al*., 2005). Therefore, understanding the rainfall-runoff relationship for estimation of runoff is of paramount importance. This knowledge can help to solve wide range of problems like irrigation scheduling, water harvesting, flood control, drought mitigation and design of various engineering structures.

Of the several methods proposed for runoff estimation from ungauged watershed, USDA's Natural Resources Conservation Services Curve Number method (NRCS-CN) along with its derivatives have been widely used by various workers because of its versatility for quick and reliable estimation of the surface runoff (Mishra, *et al*., 2003). The watershed hydrologic responses leading to generation of surface runoff are governed by the interaction of precipitation with the topographical, land use and soil physical properties of the land surface. It involves laborious work of collection of such data through ground survey so the use of Geographic Information System GIS is preferred to build the necessary feature classes and link these parameters to estimate the runoff using the CN method. Though, the Soil Conservation Service Curve Number (SCS-CN) method (SCS, 1956) was originally developed for use on small agricultural watershed it has since been extended and applied to rural, forest and urban watershed systems in many parts of the world, including India. In this method an index called the "Runoff Curve Number" represents the combined hydrologic effect of soil, land use and land treatments and the relationship between rainfall and runoff for these conditions is expressed through the Curve Number. A significant research on several issues related with the CN method's capabilities, limitations, uses, and possible advancements have been published in the recent past Ponce and Hawkins (1996), (Hjelmfelt 1991), (Hawkins 1993), (Bonta 1997), Sarangi and Bhattacharya (1999), Mishra and Singh (2003), (Bhuyan *et al*. 2003), (Mishra *et al*. 2008), Xiao Bo et al (2011) and El Hames (2012) suggested procedures for determining CN for a watershed using field data.

The potential runoff estimated from long term data for 33 stations distributed over the National Capital Region of Delhi has been utilized for preparing the Iso-Runoff map of the NCR. This map is intended to be a simple ready reckoner for the farmers and to the field agricultural development officers for designing rainwater harvesting structures and crop planning.

MATERIALS AND METHODS

Study area

National Capital Region of Delhi (NCRD) is an inter-state region consisting of the National Capital Territory of Delhi (NCTD), 7 Districts of Haryana, 5 Districts of Uttar Pradesh and Alwar District of Rajasthan with a total geographical area of 33,421 Km^2 (Table 1). The region is located between 27^{0}18' to 29^0 29' North latitude and 76^0 09' to 78^0 29' East longitude. The location and state wise composition of the NCRD is shown in figure 1.

Table 1. Statewise composition of National Capital Region of Delhi

Name	Area (km^2)	Geographical Area
NCTD	1483	Delhi State
NCRD	31,878	Haryana: 13,413 km^2 comprising of Faridabad, Mewat, Gurgaon, Rohtak, Sonepat, Faridabad, Rewari, Jhajjar & Panipat districts.
		Rajasthan: 7,829 km^2 comprising of Alwar district
		Uttar Pradesh: 10853 km^2 comprising Meerut, Gautam Budh Nagar, Ghaziabad, Bulandshahar and Baghpat districts.

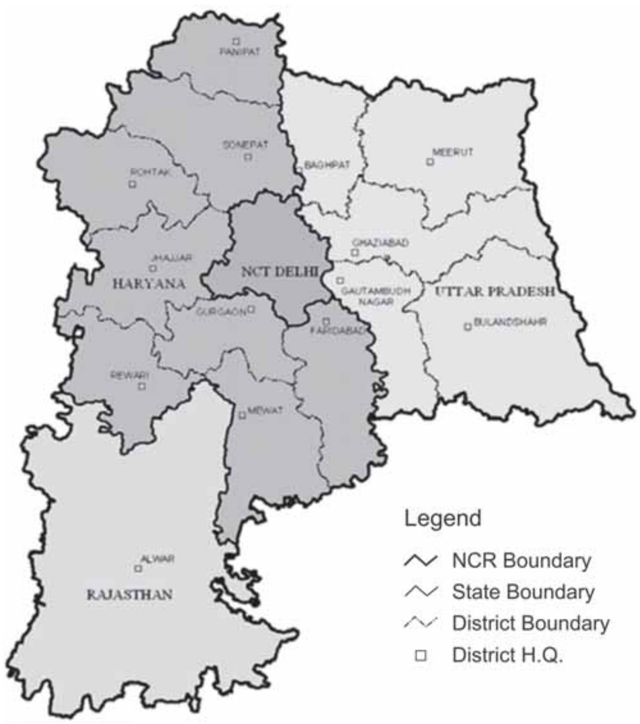


Fig. 1. Location map of the National Capital Region of Delhi

The average annual rainfall of Delhi is 611 mm and the annual average rainy days are about 27. Almost 90% of the total annual rainfall is concentrated in a three-month. Rainy season commence from July to September and often characterized by high intensity monsoonal rainstorms. Surely rainstorms produce heavy runoff and soil loss from agricultural lands. The region basically has alluvial soils ranging between hard clay-clayey, loam-sandy loam and sandy soils.

SCS-CN method

The SCS-CN method is based on the water balance equation and two fundamental hypotheses (SCS, 1956). The first hypothesis equates the ratio of the actual amount of direct surface runoff (Q) to the total rainfall (P) or maximum potential surface runoff with the ratio of the amount of actual infiltration (F) to the amount of the potential maximum retention (S). The second hypothesis relates the initial abstraction (I_a) to the potential maximum retention.

The retention parameter S is determined based on antecedent moisture condition (AMC) which is determined by the total rainfall in 5-day period preceding a storm and is related to a curve number CN. Curve number is dimensionless and its value varies from 0 to 100. The S can be obtained from CN by using the relationship.

$$S = \frac{25400}{CN} - 254 \tag{1}$$

Analysis of rainfall data

The monthly rainfall data for 30 years for thirty three different stations in the NCR of Delhi was collected from the India Meteorological Department, Pune. The rainfall data is generally collected at the district or taluka headquarters and thus it is often not possible to know the rainfall at any particular location falling in between the two rainfall data collection centers. Isohyets are the lines joining equal rainfall values. The isohyetal map eliminates this bottleneck and makes it possible to get a fairer estimation of rainfall for micro-level planning.

The average annual rainfall data of the thirty three stations was used to develop the isohyetal map of the NCRD and is presented in Fig. 2. So the area within two isohyets was considered as area with identical rainfall characteristics and this concept was used for calculating the weighted CN for that respective area. Using the CN values under different AMCs', the potential maximum retention S was estimated and was subsequently used in the formula of NRCS-CN method to estimate the daily and monthly surface runoff of the four stations.

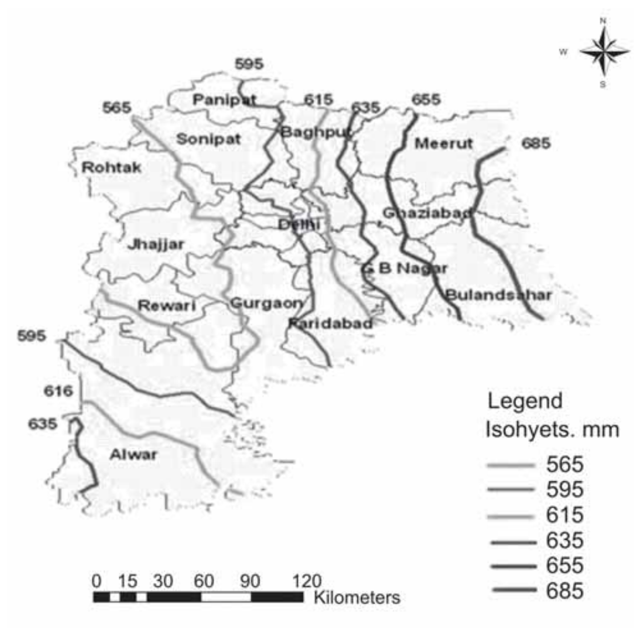


Fig. 2. Isohyetal map of NCR of Delhi

Soil information of NCRD

The soil data for the NCR were obtained from the National Bureau of Soil Survey & Land Use Planning (NBSS&LUP), Regional Centre, New Delhi. As the single soil map for NCR was not available so soil maps of different respective states were taken. Then the districts which are the part of NCR were traced on trace paper and these images were scanned and converted to same unit. After converting them to the same unit the images were merged together to get the single map representing different soil types of NCR region. The image was converted to GIS feature based digital format using ArcGIS tool. The attribute tables detailing the area under different soil groups were prepared. These different soil groups were again grouped into four hydrologic soil groups A, B, C and D according to infiltration rates, soil texture and depth of the soil. The percentage area of different soil groups of NCRD is given in figure 3.

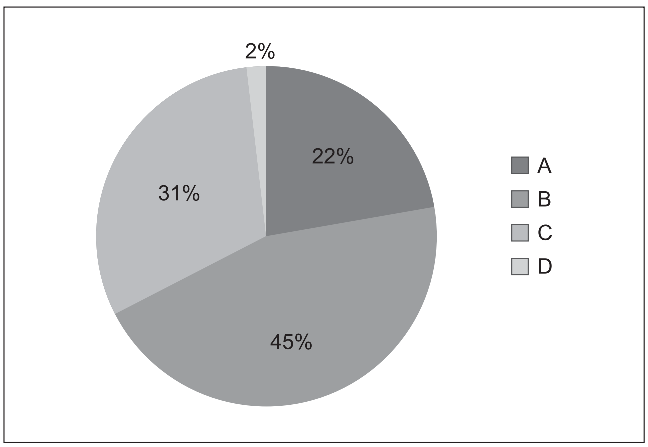


Fig. 3. Percentage area under different hydrologic soil group of NCRD used in CN method

Land use information of the NCRD

The land use map of the NCRD was developed using the remote sensing data. The remote sensing image of land use of IRS P6 satellite 26th Feb, 2005 was acquired from Division of Agricultural Physics, Indian Agricultural Research Institute, New Delhi. Geo-referencing of the image was done to bring it into real world co-ordinate system in ENVI software. The image was converted to GIS feature class based thematic digital format using the ArcGIS tool to be used as an input data for estimation of CN. The image was classified according to MODIS classification in four classes in terms of areas having cultivated land, forest land, waste / barren land and urbanized land Figure 4. The information on hydrologic soil group and the land use was used to assign the appropriate curve number and computation of surface runoff.

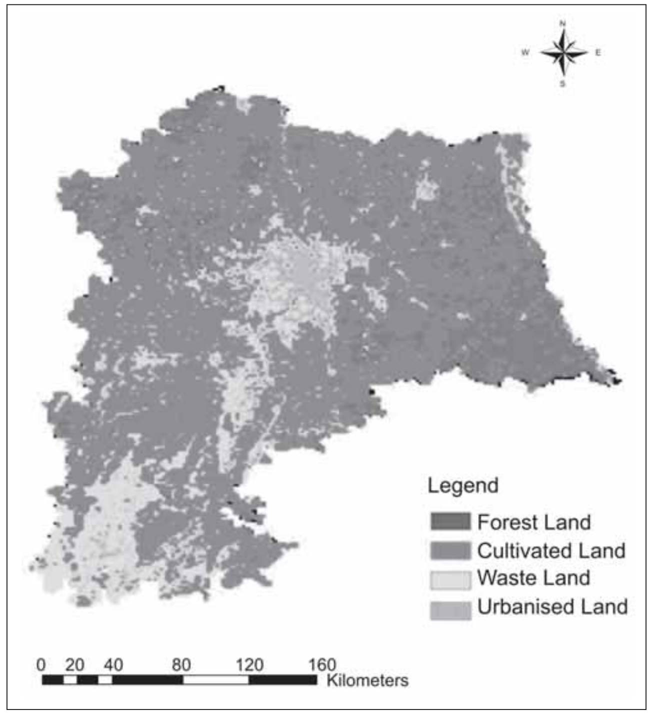


Fig. 4: Land use map of NCRD region for use in SCS-CN method for surface runoff estimation

The land use, soil type and hydrologic soil group maps in ArcGIS® format were generated and projected to polyconic projection system using ArcGIS projection utility (Sarangi et al. 2004). These digitized GIS feature classes of land uses, hydrologic soil group were used as the input data for estimation of the CN values.

RESULTS AND DISCUSSION

Development of relationship between monthly runoff estimated from daily and monthly rainfall

The purpose to derive the relationship between monthly and event based rainfall was basically to get relationship to estimate surface runoff from the region where the daily rainfall data is not easily available. To achieve this daily rainfall data of four stations namely, IARI, Palam, Rohtak, and Bulandshahar were used to predict the daily surface runoff using USDA-NRCS CN method. Due consideration was given to land use, soil type and hydrologic soil groups while selecting the curve number for these areas. The antecedent moisture conditions AMC I, II, III of each event was duly considered while using the curve number method. The monthly runoff was obtained by adding up the daily runoff. The monthly runoff was again estimated by taking the monthly rainfall values as one single event. The runoff estimated by these two methods was compared and a relationship between the monthly surface runoff estimated from daily rainfall and monthly rainfall values was developed for all the four stations using the monthly rainfall for AMC II condition.

Though the curve number method was developed for estimating runoff from individual storms Anonymous, 1985, but the exercise was done for the reason mentioned above. The relationship predicted from daily rainfall and monthly rainfall was developed using standard statistical significance estimator, Coefficient of Determination R^2. The criteria to use the empirical relationship was based on the R^2 values approaching one (Sarangi and Bhattacharya, 2005), (Sarangi et al., 2005). The relationship between daily and monthly runoff was estimated for the individual four stations and the R^2 was observed for each relationship.

Closer examination reveals that by enlarge except few cases the monthly surface runoff in monsoon season predicted from monthly rainfall values is 1.5 to 3.8 times larger than the monthly surface runoff predicted from daily rainfall values. This indicates that the possibility of deriving relationship between monthly surface runoff predicted from daily rainfall values and monthly surface runoff predicted from monthly rainfall values. A comparison of monthly surface runoff predicted from daily rainfall values and monthly surface runoff predicted from monthly rainfall values and the relationships between these two are shown in figures 5 and 6 for IARI, Palam, Rohtak and Bullandshahar districts respectively.

These figures reveal that runoff predicted from both the approaches was linearly related with rainfall with R^2 varying from 0.69 to 0.99 (Fig. 5: A, B, C and D). Also monthly surface runoff predicted from these two approaches was also linearly related in all the cases with R^2 values varying from 0.76 to 0.95 (Fig. 6: A, B, C and D). This implies that from the areas where only monthly rainfall data is available, it is possible to estimate the monthly surface runoff using these relationships.

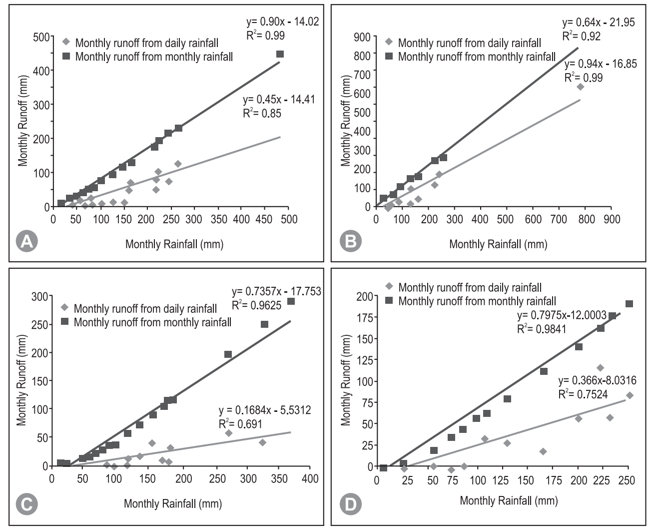


Fig. 5 (A, B, C and D): Comparison of monthly runoff estimated from daily and monthly rainfall for IARI, Palam, Rohtak and Bullandshahar

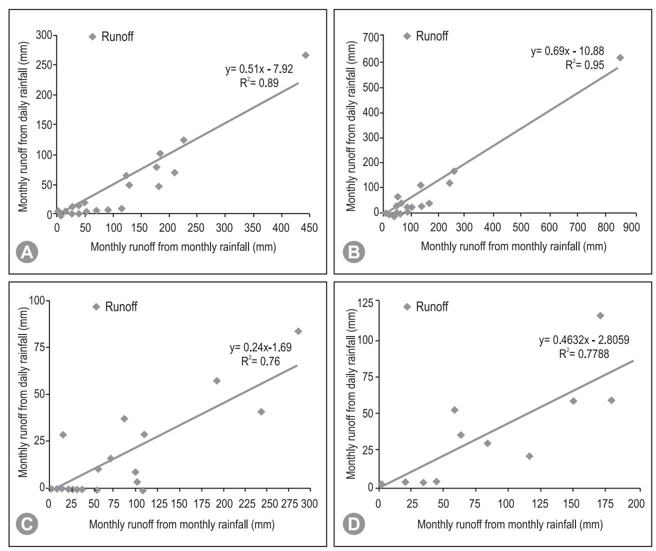


Fig. 6 (A, B, C and D): Relationship between monthly runoff estimated from daily and monthly Rainfall for IARI, Palam, Bullandshahar and Rohtak

The monthly surface runoff predicted using these approaches was pooled to derive the general relationship for prediction of monthly surface runoff in NCR. Since data is pooled from four stations of NCR, this also exhibits the similar kind of trend. The comparison was done between the monthly surface runoff estimated from daily rainfall data and monthly surface runoff estimated from monthly rainfall data using pooled data and the relationship is shown in figures 7 and 8.

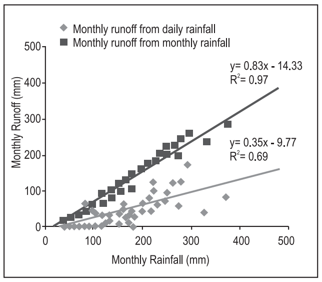


Fig.7. Comparison of monthly runoff estimated from daily and monthly rainfall for pooled data of four stations

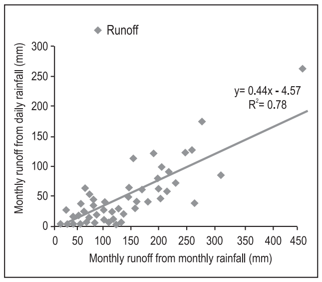


Fig. 8. Relationship between monthly runoff estimated from daily and monthly rainfall for pooled data of four stations

In this case also the monthly runoff and monthly rainfall are linearly related with R^2 value varying from 0.69 to 0.97. The relationship between monthly rainfall and monthly runoff predicted from daily rainfall values and monthly rainfall values (Fig.13) was described by linear equation as,

$$Y=0.83*X-14.33 \quad (2)$$

The relationship between monthly runoff predicted from daily rainfall and monthly runoff predicted from monthly rainfall (Fig.14) was also described by linear equation as,

$$Y=0.44*X-4.57 \quad (3)$$

A fairly good R^2 value 0.78 indicates that this equation can be used to predict the surface runoff from the National Capital Region of Delhi.

Estimation of surface runoff from different parts of NCR

Using the equations 2 and 3, the monthly surface runoff for the NCR was estimated. The developed relationship between monthly rainfall and monthly runoff for four stations as mentioned in above section was used to estimate the surface runoff for these 33 stations. But these relationship was seemingly over estimated the surface runoff. To get the surface runoff in acceptable limits the second relationship was used. The second relationship was developed between the monthly runoff i.e. sum of daily runoff values over a month and monthly runoff obtained from a single value of the total rainfall over a month. Likewise the surface runoff was estimated for the 33 stations using the two developed relationships. Using this information spatial distribution map of average annual runoff was prepared as shown in figure 9. The map shows that there is good runoff potential in the region which can be harvested to supplement the canal and ground water for productive agriculture. The lowest runoff ranging from 125-140 mm was observed in parts of Rewari and Alwar district. The highest runoff ranging from 190-210 mm was observed in parts of Bulandshahar, Ghaziabad and Meerut district. It shows that it is a very good runoff potential zone which can be used for water harvesting. Moderately low runoff ranging from 140 -165 mm was observed in parts of Gurgaon, Jhajjar,Rohtak and Rewari district. The moderately high runoff ranging from 165- 190 mm was observed in parts of G.B Nagar, Delhi, Baghput, Panipat and Sonipat district but still it can be harvest to augment the water supply in the National Capital Region. The annual surface runoff varies from 40.88 to 241.61 mm. The lowest surface runoff was observed in Bansur and highest surface runoff was observed in Narora.

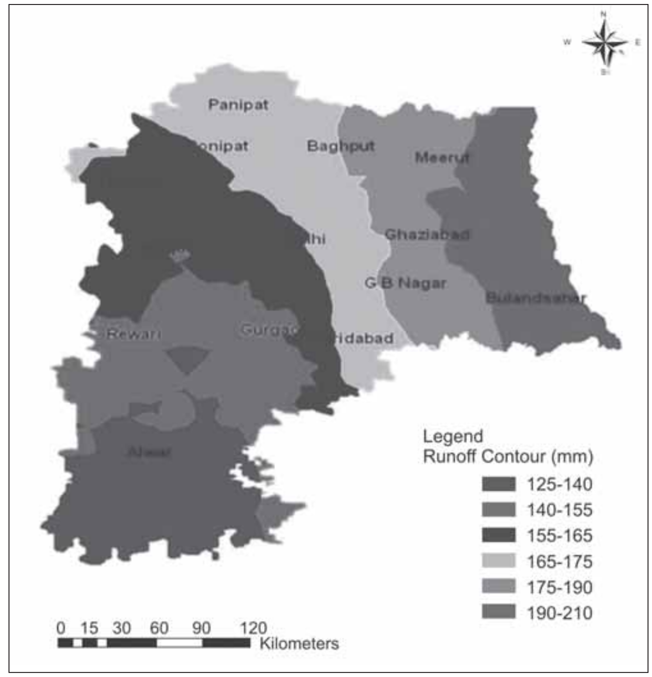


Fig. 9. Map showing spatial variation of 30 years average annual surface runoff of study area

For proper planning of water harvesting schemes, accurate estimation of surface runoff and its judicious utilization in conjunction with other sources of surface water and ground water resources is a key issue. The present study was undertaken to investigate the surface runoff from the national capital region. The basic purpose of study was to examine the possibility of augmenting the canal and ground water supplies in NCR through the rain water harvesting. The potential of rain water harvesting is depends on the surface runoff. Keeping this in view surface runoff generated through various parts of NCR was estimated using USDA-NRCS curve number method. Procedure used for estimation for surface runoff has been presented in chapter three. Results obtained from the analysis and pertinent discussions are represented in accordance in objective under following headings.

CONCLUSIONS

The study was undertaken to assess the surface runoff potential in the National Capital Region of Delhi for its optimal use in agriculture and other sectors. The study involves development of digital databases of soil, land use, and hydrologic soil groups of the NCRD for assigning appropriate curve number and estimation of daily and monthly surface runoff with USDA's SCS Curve Number method. Relationship between surface runoff estimated from daily rainfall and monthly rainfall data had also been developed with a view of estimate the runoff from large number of stations in the NCRD, where daily runoff data was not available. An Iso-runoff map of the NCRD has also been developed using runoff estimated on the basis of 30 years data for 33 locations and is hoped will provide a ready reconer.

The results of the study show that it is conveniently possible to simplify the procedure for estimation of surface runoff and a fair estimation of runoff can be made even for areas where daily rainfall data is not available. The map showing spatial distribution of runoff developed through this study show that there is good runoff potential in the region which can be harvested to supplement the canal and ground water for productive agriculture. Harvesting and utilization of surface runoff in rural areas of NCRD can be helpful in increasing the water availability in the cities of NCRD. The National Capital Region of Delhi is the fastest growing and the largest metropolitan city of the country and its balanced and harmonised growth is of utmost importance to the country. Strengthening of peri-urban agriculture activities in the national capital region through increased availability of water, which facilitates increased crop productivity, crop diversification and overall profitability, will indeed help to achieve the desired goal.

REFERENCES

Anonymous 1985. Soil water accounting using SCS hydrologic soil classification, National Institute of Hydrology, CS-15, Roorkee, India.

Bhuyan S J, Koelliker, J K and Barnes, P L, 2001. Modification of Curve Number Adjustment Technique for Prediction of Runoff, Presented in Soil Erosion Research for the 21st Century, Proc. Int. Symp. 3-5 January 2001, Honolulu, HI, USA. eds. J.C. Ascough II and D.C. (eds) Presented in soil erosion research for the 21st Century, Proc. Int. Symp., Honolulu, HI, USA, 3–5 January 2001, St. Joseph, MI: ASAE.701P0007, pp 287–290

Bhuyan S J, Mankin K R and Koelliker J K 2003. Watershed–Scale AMC Selection for Hydrologic Modelling. Trans ASAE 46(2):303–310

Bonta J V, 1997. Determination of watershed curve number using derived distributions, *Journal of Irrigation and Drainage Engineering, ASCE*, 1231,P- 28–36

El-Hames A S, 2012. An empirical method for peak discharge prediction in ungauged arid and semi-arid region catchments based on morphological parameters and SCS curve number. *Journal of Hydrology*. 94–100

Hawkins R H 1993, Asymptotic determination of runoff curve number from data, *Journal of Irrigation and Drainage Engineering, ASCE*, 1192: 334–345.

Hjelmfelt Jr., A T, 1991. Investigation of curve number procedure, *Journal of Hydraulic Engineering*, 1176: 725–737

Mishra S K and Singh V P, 2003. Soil Conservation Service Curve Number Methodology, volume 43, Kluwer Academic Publishers, Dordrecht, The Netherlands

Mishra S K, Singh V P, and Sansaleve J J, 2003. A modified SCS-CN Method: Characterization and Testing, *Water Resources Management*, 17:37-68

Mishra S K, Pandey R P, Jain M K, and Singh V P, 2008. A Rain Duration and Modified AMC-dependent SCS-CN Procedure for Long Duration Rainfall-runoff Events. *Water Resource Management*, 22:861–876

Ponce V M, and Hawkins R H, 1996. Runoff curve number: Has it reached maturity? *Journal of Hydrological Engineering, A.S.C.E.*, 11, 11–19

Sarangi A, and Bhattacharya A K, 1999. Small Watershed Runoff Generation Model, *Journal of Soil and Water Conservation*, 433&4: 176-188

Sarangi A, and Bhattacharya A K, 2005. Comparison of Artificial Neural Network and regression models for sediment loss prediction from Banha watershed in India. *Agricultural Water Management*, 78:195–208

Sarangi A , Madramootoo, C A, Enright P, Prasher, S O and Patel R M, 2005. Performance evaluation of ANN and geomorphology-based models for runoff and sediment yield prediction for a Canadian watershed, *Current Science*, 8912: 2022-2033

SCS 1956, 1964, 1969, 1971, 1972, 1985, 1993. Hydrology, National Engineering Handbook, supplement A, Section -4 Chapter 10, Soil Conservation Service, USDA, Washington, D.C.

SCS 1986. Urban hydrology for small watersheds, Technical release number 55, Soil Conservation Service, USDA, Washington D.C.

Sharda V N, and Juyal G P, 2006. Conservation Technologies for Sustaining Natural Resources, *Handbook of Agriculture*, Directorate of information and publication of agriculture, ICAR, New Delhi: 254-299

Xiao B, Wang Q, Fan J, Han, F and Dai Q, 2011. Application of the SCS-CN Model to runoff Estimation in a Small Watershed with High Spatial Heterogeneity. *Pedosphere* 21: 738–749.

Journal of Soil and Water Conservation **12**(1): 31-34, January-March 2013
ISSN: 022-457X

Soil information system for assessment and monitoring of crop insurance and economic compensation to small and marginal farming communities – a conceptual framework

S.N. DAS

Received: 30 August 2012; Accepted: 17 December 2012

ABSTRACT

Small and marginal farmers by virtue of their standing in the society often cannot avail the facilities/ opportunities of various governmental programmes/schemes due to ignorance and even cannot raise their voice of concern for justice. About 41% of the total farming communitity (54.4%) belongs to small and marginal farming categories whose land holding size varies from 0.4 to 1.42 ha. It is often found that the lands possessed by them are marginal lands and poor in fertility which are unfit for agriculture practices. Due to higher cost of various inputs such as seeds, fertilizer, pesticides, etc., they fall prey of the lenders resulting bankruptcy. The tragic climax of such situation is being witnessed in some parts of the country as farmers are committing suicides out of poverty.

An honest and transparent edeavour on the part of the government could be use of scientific data with modern tool such as remote sensing and geographic information system (GIS) for the benefit of the economically deprived section of the society. The paper deals with a conceptual framework for developing soil information system for assessing crop loan, crop insurance and economic compensation for the benefit of small and marginal farmers.

Digital soil data base at cadastral scale could be created under GIS environment through acquisition of detailed soil data base. Soil information system could be developed using digital soil data base with integration of digital data sets such as spatial distribution of small and marginal farmers and spatial distribution of land parceling of individual farmer with plot number to create new data set such as land use potential of small and marginal farmers that may serve as a decision support tool for sanctioning crop loan or any economic compensation to any distressed farmer. The data base on land use could be updated using real time remote sensing data on certain time scale to detect changes in land use pattern to evaluate the impact of loan amount sanctioned to the different farming communities. The overall biomass changes could be deduced using normalized difference vegetation index (NDVI) techniques employing temporal remote sensing data. Such data set could be integrated with the soil information system to verify any claim on crop loss for economic compensation. It will support the decision makers for monitoring of all the activities related to soil productivity, land use/ land cover, crop loan, crop insurance and economic compensation.

Key words: soil information system, small and marginal farmer, land holding, land use, NDVI

INTRODUCTION

The cost of cultivation of major crops has increased many folds over the years due to escalation of prices of various inputs and cost of labor resulting bankruptcy among the farming communities. The impact of increasing cost of cultivation badly hit the marginal and small farmers and there are reports that farmers are committing suicides out of poverty. It is reported that the agrarian distress has reached climax at the fag end of the 20th century manifesting the crisis of tragedy concerning number of farmers committing suicides in some parts of the country (Anon 2012).

Considering these facts it is essential to device a scientific mechanism to deal various activities such as crop loan, crop insurance and economic

Amity University, Noida (UP)

compensation in the event of natural calamities to the farmers based on the land use potential of the concerned land holder.

India is an agrarian country where65% of the total population practices agriculture out of which nearly 41% is categorized as marginal and small farmer based on land holding. The average sizes of land holding of marginal and small farmer are 0.4 ha and 1.42 ha respectively. Dependency on inputs in terms of chemical fertilizer (75%), FYM (35%) and pesticides (32%) are relatively higher than medium (67%, 26.3% and 32.7%) and large (51.6%, 17.7% and 28.5%) famers for agricultural operations (Anon 2012).

The Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India provides insurance coverage and financial support to the farmers in the event of prevented sowing and failure of any of the notified crop as a result of natural calamities, pests & diseases under National Agriculture Insurance Scheme. The objective of the scheme is to encourage the farming community to adopt progressive farming practices, high value inputs, and better technology in agriculture (Anon 2012).

Food crops, oilseed, commercial annual and horticulture crops are covered under NAIS and loans are sanctioned based on i) the past yield data on Crop Cutting Experiments (CCEs) for adequate number of years, and ii) requisite number of CCEs are conducted for estimating the yield during the proposed season. Considering the average land holding of marginal (0.4 ha) and small farmer (1.42 ha), there is least possibility of conducting CCEs and thumb rule is applied to sanction loan to the farmers.

Out of the net sown area of 141 m ha of the country, only 51.62 m ha is under irrigated agriculture and the rest is under rainfed agriculture. The farmers of the rainfed area depends solely on the rainfall which is now showing extremities of climate change endangering the livelihood security of rural people especially the marginal and small farmers and the food security of the country as well. It is observed that marginal and small farmers practice agriculture under irrigated (50.5%), partly irrigated (28.9%) and un-irrigated (39.3%) condition.

Thus marginal and small farmers are highly dependent on inputs for agricultural production. It is observed that the indebtness of marginal farmers is extremely high (61%) where it is 18.9% for small farmers. The indebtness of medium (6.4%) and large (1.2%) farmers are comparatively very less. The rational distribution of crop loan could be made based on soil productive capacity of the respective land holding that may prevent the farmers taking huge loan which is beyond their repaying capacity.

Soil information system (SIS) using detailed soil data base under GIS (geographic information system) platform for the benefit of not only the farming communities but also for the loan sanctioning authority. The detailed soil and land use data base will be generated using higher resolution satellite data (IRS LISS IV or Google). The identification of marginal and small farmers will be carried out using remote sensing data in consultation with cadastral map and field survey. The land suitability classification in respect of various crops would be carried out for different soils of a village or district based on soil morphological, physical, chemical and biological parameters. The soil information system (SIS) ultimately will act as a decision support system for the policy maker or planner for sanctioning crop loan or any economic compensation. Brief methodology is outlined to execute the project. The detailed digital spatial data base created by Soil and Land Use Survey of India, Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India (Anon 2012) may be utilized for development of SIS to fulfill the objectives of scheme such as NAIS. The conceptual framework for development of soil information system for assessing and monitoring of crop insurance, crop loan and economic compensation to small and marginal farmers is outlined below.

Soil information generated out of soil survey are documented in the form of report and maps which are provided to the user departments for formulation of working plan either at district or village level. The spatial and non-spatial soil information governs the soil resource data base.

Scientific land use planning, diagnosis of soil for optimal utilization, maintenance of soil health, suitability of land for various crops, fertility management and dissemination of soil information to the farming community etc. could be dealt with the soil resource data base (Johnson, 1998; Sanchez et al, 1982 and Olson, 1981) which must have the following datasets for the benefit of users.

1. Statistics with spatial distribution of various types of soils at detailed level

2. Morphological, physical and chemical properties of soils
3. Soil classification
4. Land Use / Land Cover
5. Interpretative groupings of soil data for various applications in the field of agriculture, forestry, horticulture, soil and water resource development and non-agricultural applications
6. Land Capability map

Considering the objective of the paper additional datasets such as cadastral map with spatial distribution of land parceling with plot number and list of small and marginal farmers with plot number would be required. The data set on land use could be further updated using real time satellite remote sensing data to derive changes in land use / land cover over certain periodicity and overall change in biomass status using NDVI techniques (Sabins et al 1977). The data sets could also be integrated with SIS under GIS platform to make it more robust for wider applications in land based developmental programmes.

The digital database for all these layers could be generated using Arc GIS software following standard procedures (Anon, 1993). The area of each soil mapping unit may be deduced out of digital soil database. The digital map showing the spatial distribution of small and marginal farmers with extent could be integrated with land capability map derived from digital soil map to generate a thematic map displaying the spatial distribution of land use potential of each small and marginal farmer with extent. Some digital datasets of Rd9f subwatershed of Rupnarayan catchment spread over Medinipur and Bankura districts, West Bengal (Source SLUSI) has been taken to demonstrate the potential of the soil information system (Fig. 1-4).

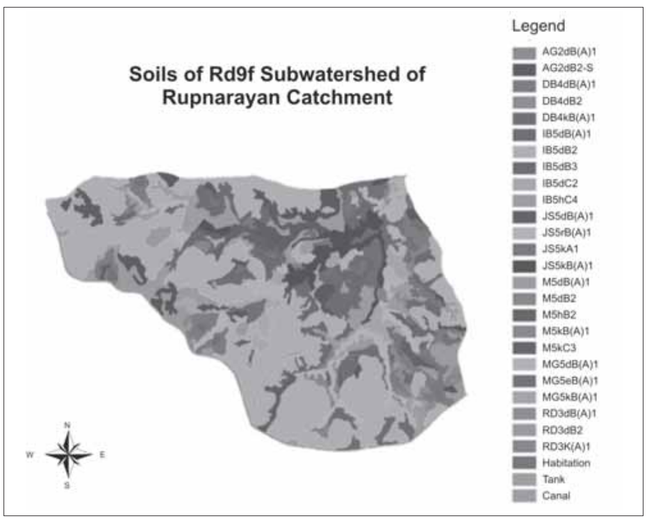


Fig. 1. Detailed soil map

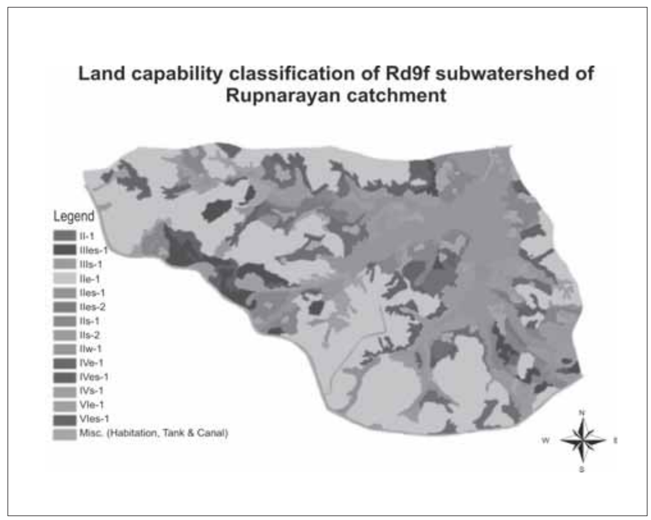


Fig. 2. Land capability map

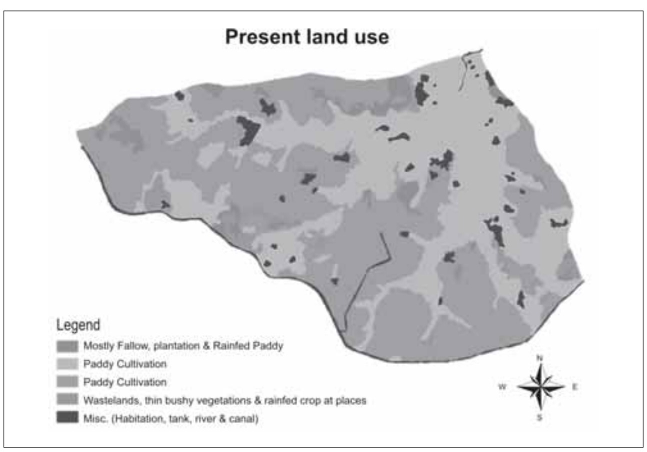


Fig. 3. Present land use map

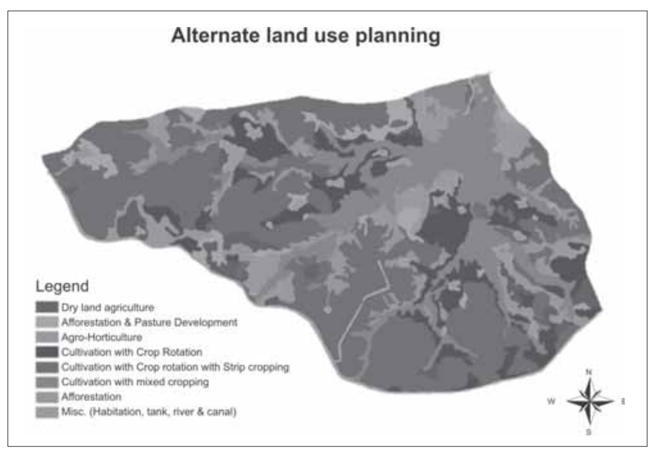


Fig. 4. Alternate land use map

Various thematic derived from the digital soil data base of the subwatershed dominated by marginal farmers could be integrated with the cadastral boundary and the digital map containing spatial distribution of the small and marginal farmers to generate new set of data. The land use potential map of each category of farming communities generated out of the various digital data sets could be used for sanctioning crop loan as well as compensation to the individual in the event of floods and droughts based on loan criteria. The alternate land use map could be generated out of land capability map to provide guidance to the farming communities to sustain livelihood as present land use practices is unsuitable as per soil productive capacity.

SIS will be an integrated system comprising a basic module covering the data sets on soil at cadastral scale, land use/ land cover, spatial extent with plot number of each small and marginal farmer to formulate criteria for sanctioning loan or insurance amount. The other module will update the land use/ land cover and overall change in biomass using real time remote sensing data to verify any claim on crop failure due to natural calamities for compensation purposes.

The conceptual framework for development of soil information system for assessing and monitoring the crop insurance and economic compensation to the small and marginal farmer is illustrated through the flow diagram (Fig.5) below for better understanding.

The scientific data base could be utilized efficiently for planning, implementation; monitoring and impact evaluation of various centrally sponsored schemes of GOI that may fulfill the objectives of one of the initiatives of Planning Commission on Development of Digital Spatial Data Base for GIS based Planning under G2G domain taken in 2004.

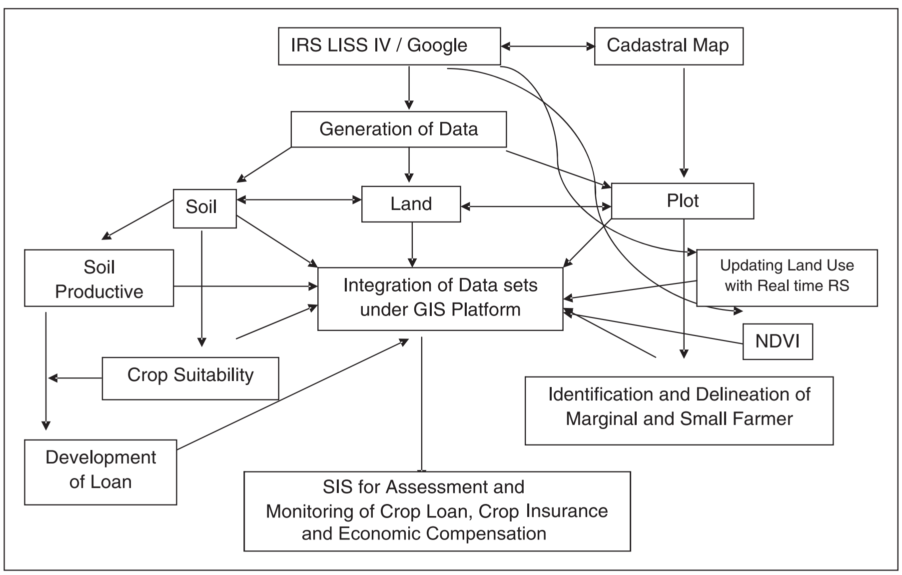


Fig. 5. SIS for assessment and monitoring of crop loan and economic compensation to small and marginal farmer

REFERENCES

Anon 1993. Global and National Soils and Terrain Digital Databases (SOTER), World Soil Resources Reports No.74, FAO, Rome.

Anon 2012. Land Holding Statistics of India, Department of Agriculture and Cooperation, Ministry of Agriculture, http://www.dac.nic.in

Anon 2012. NATIONAL AGRICULTURAL INSURANCE SCHEME (NAIS), http://www.dac.nic.in

Anon 2012. Report on Detailed Soil Survey of Rd9f Subwatershed of Rupnarayan Catchment, PS. Goaltore and Sarenga; Medinipore and Bankura District, West Bengal (Report No. 1195) published by Soil and Land Use Survey of India, New Delhi. http://slusi.dacnet.nic.in

Deshpande, R. S 2010. An Evaluation Study of Prime Minister's Rehabilitation Package for Farmers in Suicide-Prone Districts, http://www.dac.nic.in

Jhonson Paul 1998. Evaluation of Natural Resource's Management Programme. Proceedings of the 8th International Conference on Watershed Management held at New Delhi during Dec.7-9, 1998.

Olson, G.W. 1981. Soil and the Environment: A Guide to Soil Surveys and their Applications, Chapman and Hall, USA.

Sanchez, P.A., Couto, W and Boul, S.W 1982. The fertility capability soil classification system: interpretation, applicability and modification. Geoderma 27 (4): 283-309.

Sabins, Jr., F Floyd 1977. Remote Sensing - Principles and Interpretation, published by W.H. Freeman and Co., NY.

Journal of Soil and Water Conservation **12**(1): 35-43, January-March 2013
ISSN: 022-457X

Rainfall trend analysis: A case study of Pune district in western Maharashtra region

JYOTI P PATIL[1], A. SARANGI[2], D. K. SINGH[3], D. CHAKRABORTY[4], M. S. RAO[5] and S. DAHIYA[6]

Received: 30 November 2012; Accepted: 5 January 2013

ABSTRACT

Climate change studies indicate that monsoon rainfall pattern is changing in India during the latter half of the twentieth century, thus increasing the risk of drought and flood damage to the country's wet-season (*kharif*) crops. Pune district, Maharashtra forms a part of the tropical monsoon, shows seasonal variation in rainfall occurrences due to changing climate in the recent years. An attempt was made in this study to understand the trend of rainfall in Pune District using 47 years (1958-2004)data acquired from thirteen observatories pertaining to annual, seasonal (*kharif)* and monthly rainfall depths during *kharif* season. Non-parametric Mann-Kendall (MK) test and modified Mann-Kendall (MMK) trend test with the Sen's slope estimator have been used for detecting the trends. The trend analysis showed the pattern of rainfall distribution over the Pune district spatially as well as temporary during the period of analysis. Seasonal (*Kharif*) rainfall was observed to be decreasing and June month's rainfall showed increasing trend while July month's rainfall showed decreasing trend at 99%, 95% and 90% level of significance, respectively. The decreasing trend of rainfall was observed during July month for the rainfall gauging stations under high rainfall zone (*Welhe-99%, Mulshi-95%* and *Maval-95%*) and medium rainfall zone (*Bhor-99%, Ambegaon-99%, Junnar-95%, Khed-99%, Pune-99%* and *Purandhar-99%)* of Pune district. Sen's slope estimates also indicated increasing and decreasing trend of slope in accordance with other Mann-Kendall parameters. This study will assist in deciding the sowing date of crops and also water conservation measures for sustaining agricultural production as an adaptation measure to changing climate of the region.

Key words: trend analysis, Mann-Kendall, modified Mann-Kendall, Sen's slope, rainfall, Pune

INTRODUCTION

Water and agriculture sectors are likely to be most sensitive to climate change-induced impacts in Asia. Agricultural productivity in Asia is likely to suffer severe losses because of high temperature, severe drought, flood conditions and soil degradation. Inter-seasonal, inter-annual and spatial variability in rainfall trend is observed during the past few decades all across Asia (IPCC, 2007). India will reach a state of water stress before 2025 when the availability falls below 1000 m^3 per capita (CWC, 2001). The projected decrease in the winter precipitation over the Indian subcontinent would reduce the total seasonal precipitation during December, January and February implying lesser storage and greater water stress during the lean monsoon period. Intense rain occurring over fewer days, which implies increased frequency of floods during the monsoon, will also result in loss of the rainwater as direct runoff, resulting in reduced groundwater recharging potential. The global climate change had profound effects on various environmental variables including rainfall in many regions around the world. Changes in rainfall characteristics directly impact hydrology, water resources management, agricultural practices and ecosystems (Hsu, 2004). The changing pattern of rainfall deserves urgent and systematic attention, as it will affect the availability of food supply and

[1]Corresponding Author, Ph.D. Scholar, Division of Agricultural Engineering, IARI, New Delhi; E-mail: jyotipp2003@gmail.com
[2&3]Senior Scientist, Water Technology Centre, IARI, New Delhi
[4]Senior Scientist, Division of Agricultural Physics, IARI, New Delhi
[5]Senior Scientist, Division of Agricultural Statistics, IASRI, New Delhi
[6]Senior Scientist, Computer Applications, IASRI, New Delhi

the occurrence of water related disasters triggered by extreme events. It is the major driving force of the land phase of the hydrologic system, and changes in its pattern could have direct impacts on water resources (Dore, 2005). Therefore, it is imperative to investigate the climate change impact onspatial and temporal rainfall characteristics to facilitate better water management practices and strategy. One of the commonly used tools for detecting changes in climatic and hydrologic time series is trend analysis. Detecting the trend and periodicity of observed data is a meaningful method in the study of climatic and hydrological changes. However, it is necessary to possess a time series of adequate length and the mathematical tools that enable us to optimize the results.

It was investigated from rainfall trend that the frequency of occurrence of more intense rainfall events in many parts of Asia has increased, causing severe floods, landslides and debris and mud flows, while the number of rainy days and total annual amount of precipitation has decreased (IPCC, 2007). Some of the non-parametric statistical methods such as Mann-Whitney-Pettit (MWP) and Mann-Kendall rank correlation (MK) methods are widely used to test the existence of trends in annual rainfall, annual 1-day maximum rainfall, seasonal rainfalls, annual no-rain days, and annual maximum of consecutive no-rainfall days. The rank-based non-parametric Mann-Kendall (MK) statistical test (Mann, 1945; Kendall, 1975) has been commonly used to assess the significance of trends in hydro-meteorological time series such as water quality, stream flow, temperature and precipitation. The main reason for using non-parametric statistical tests compared with parametric statistical tests is that non-parametric tests are more suitable for non-normally distributed data and censored data, which are frequently encountered in hydro-meteorological time series (Yue *et al.* 2002). Many previous studies have used the MK test for detecting trends in hydrological and hydro-meteorological time series, including Hall *et al.* (2006), Kampata *et al.* (2008), Libiseller and Grimvall (2002), Cheng *et al.* (2004) .

Hamed and Rao (1998) modified the Mann-Kendall trend test by studying the effect of auto correlation on the variance of the test statistic which is often ignored in the original Mann-Kendall test. A theoretical relationship was derived to calculate the variance of the Mann-Kendall test statistic for auto correlated data. Based on the modified value of the variance of the Mann Kendall trend test statistic, a modified non-parametric trend test which is suitable for auto correlated data was proposed. The modified test was applied to annual average rainfall time series of Indiana with a length of 98 years (1895-1992) and to the stream flow data of Ohio (OH01) with a length of 90 years (1903-1992). The performance of the modified test was compared with the original Mann-Kendall trend test. The original test failed to identify the significant trends in two time series data at 5% significance level. It was apparent that the existence of either positive or negative autocorrelation in time series will interfere with proper identification of significant trends. The proposed trend test offers a simple, easy to calculate modification to account for autocorrelation in the data and the modification does not affect the power of the test while offering more accurate significance levels.

South-west summer monsoon rainfall in India is the majorsource of water for most of the regions. In the absence of irrigation facilities in several areas, farmers in India mostly follow rainfed farming. Annual variations in monsoon rainfall give rise to large uncertainties in the availability of water for agriculture. Uncertainties in suchwater availability are again enhanced due to variations in the intensity and duration of different categories of rainfall events during the monsoon season. In the past, many studies have been conducted on the inter-decadal, inter-annual, and intra-seasonal variations in the monsoon rainfall (Dash *et al.*, 2011). The rainfall over the India has a decreasing trend, which began around the second half ofthe 1960s (Kothyari and Singh, 1996). Using Non-parametric methods of trend analysis Kothyari *et al.* (1997) confirmed that in the Ganga Basin, total monsoon rainfalland the number of rainy days during the monsoon season would decline with rise in the annual maximum temperature. Many researchers (Thapliyal and Kulshrestha, 1991; Kripalani *et al.*, 2003; Sahai *et al.*, 2003) have observed variability in the Indian rainfall at different temporal and spatial scales. Pattanaik (2005) found that the variability in the large-scale atmospheric circulation is the main cause of the inter-decadal variability of stormactivity over the Indian region. Kumar *et al.* (1992) studied spatial and sub-seasonal patterns in Indian summer monsoon rainfall. They observed the excess or deficiency of the monsoon rainfall more frequently realized in the latter half of the season. Monsoon rainfall tends to be more concentrated in August, over the west coast and central India. Ramanathan *et al.*(2005) found that the average rainfall depth for the months June to September during 1961– 98 was about 5% below the mean for the previous 30-year period. In India, the frequency of days with low or moderate rainfall decreased significantly during 1951–2004, while the frequency of long rainy spells decreased and the frequency of shortrainy spells, dry spells, and prolonged dry spells all increased (Dash *et al.* 2009).

IPCC (2007) considered variation in rainfall occurrence and distribution as a result of climate change and suggested to analyse such variations regionally to manage resources, develop preparedness plans and adaptations for the changing climatic conditions. In the present analysis the variation in monthly, seasonal and annual rainfall over Pune district, Maharashtra was studied using non-parametric Mann-Kendall (MK) test and modified Mann-Kendall (MMK) trend test along with the Sen's slope estimator using long term rainfall record of 1958 to 2004.

MATERIALS AND METHODS

Study area

Pune district is situated in the western part of the Maharashtra state of India (Fig.1). It covers an area of nearly 15642 km^2 having 5.1% of total geographical area in Maharashtra State. The exact geographical location lies between 17°54'N to 19°24'N latitude and 73°29'E to 75°10'E longitude. For administrative convenience, it is divided into 14 *tehsils* (Fig.1) namely Pune City, *Haveli*, *Khed*, *Ambegaon*, *Junnar*, *Shirur*, *Daund*, *Indapur*, *Baramati*, *Purandha*r, *Bhor*, *Velhe*, *Muls*i and *Maval (Vadgaon)* (CGWB, 2009). The district encompasses seven major rivers, namely *Kukdi, Ghod, Bhima, Bhama, Indrayani, Mula-mutha Kanha and Neera.* The landscape of Pune district is distributed triangularly in western Maharashtra at the foothills of the Sahyadri mountains / Western ghats and is divided into three parts: "Ghatmatha", "Maval" and "Desh".

Pune district forms a part of the tropical monsoon land and therefore shows a significant seasonal variation in temperature as well as rainfall conditions. The climate of the western region of Pune district is cool, whereas the eastern part is hot and dry. Owing to the geographical conditions within the district, the rainfall is unevenly distributed. The Western part of the district adjacent to the West Ghats is hilly area having forest cover, due to which the rainfall intensity is more in this area as compared to the eastern parts. Most of this rainfall is due to the South-west monsoon winds during the summer and about 87% of rain occurs during the monsoon months. The monsoon arrives in the month of June, with the maximum intensity of rainfall during the month of July followed by August. The average annual rainfall of Pune district is 115 cm. *Tehsils* falling in the highest rainfall intensity zone are *Welhe, Mulshi* and *Maval (Vadgaon)*. Tehsils falling in the moderate rainfall intensity zone are *Bhor, Ambegaon, Junnar, Khed, haveli, Pune city* and *Purandhar*. Tehsils with lowest rainfall intensity, the dry and semi-arid zone are *Shirur, Daund, Indapur* and *Baramati* (MPCB, 2006).

Fig. 1. Administrative map of Pune district

For this study, daily rainfall depth (mm) from 1958 to 2004 (*i.e.* 47 years) was acquired from 13 meteorological stations of Pune district and maximum and minimum temperature data (from 1969 to 2008) recorded at Pune meteorological station was also acquired. The normal rainfall depths (*i.e.* from 1958 to 2004) of the thirteen meteorological stations are given in Table 1.

Table 1. Normal rainfall of 13 meteorological stations of Pune District

Sr. No.	Station	Normal Rainfall (mm)
1.	Ambegaon	812
2.	Baramati	521
3.	Bhor	1104
4.	Daund	494
5.	Indapur	556
6.	Junnar	685
7.	Khed	674
8.	Maval	1253
9.	Mulshi	1670
10.	Pune	752
11.	Purandhar	625
12.	Shirur	490
13.	Welhe	2499

Figure 2 shows the isohyets of the rainfall distribution in the district. It gives the synoptic view of uneven rainfall condition in the district. There are three distinct zones of rainfall conditions such as high rainfall zone which lies in Western ghats, medium rainfall zone and the scarcity zone.

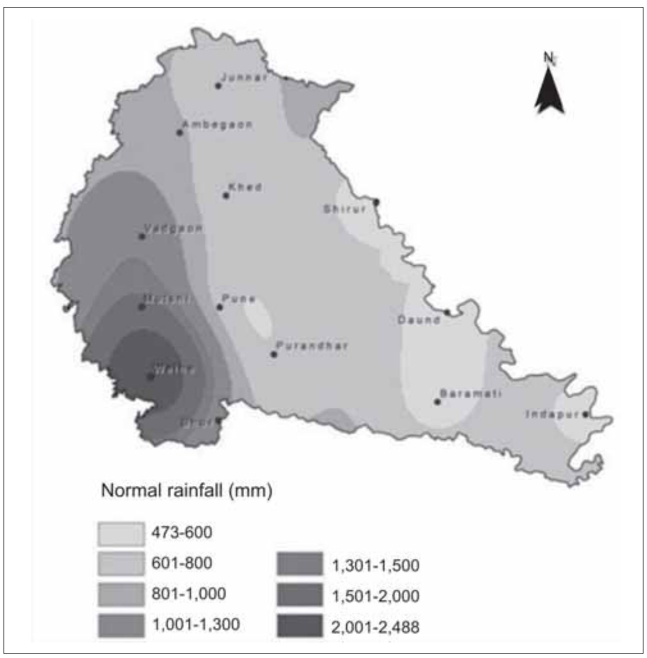


Fig. 2. Isohyets of normal rainfall in Pune district

Trend analysis

In this study, the trend analysis of annual, seasonal (*Kharif*) and monthly rainfall of *Kharif* season was estimated using Mann-Kendall and Modified Mann-Kendall tests besides the Sen's Slope estimator for determination of trend and slope magnitude of the long term rainfall data.

Mann Kendall test

The Mann-Kendall test is a non-parametric statistical procedure that is well suited for analyzing trends in data over time (Gilbert, 1987). The Mann-Kendall test can be viewed as a non-parametric test for zero slope of the first-order regression of time-ordered data versus time. The Mann-Kendall test does not require any assumptions as to the statistical distribution of the data (e.g. normal, lognormal, etc.) and can be used with data sets which include irregular sampling intervals and missing data..

The rank correlation test (Kendall, 1955) for two sets of observations X = $x_1, x_2, \ldots, X_n$ and Y = $Y_1, Y_2, \ldots, Y_n$ is formulated as follows. The statistic S is calculated as in Eq. (1):

$$S = \sum_{i<j} a_{ij} b_{ij} \quad (1)$$

Where

$$a_{ij} = sgn(x_j - x_i) = \begin{cases} x_i < x_j \\ 0 \; x_i = x_j \\ -1 \; x_i > x_j \end{cases} \quad (2)$$

and b_{ij} is similarly defined for the observations in Y. Under the null hypothesis that X and Y are independent and randomly ordered, the statistic S tends to normality for large n, with mean and variance given by:

$$E(S) = 0 \quad (3)$$

$$var(S) = n(n-1)(2n+5)/18 \quad (4)$$

If the values in Y are replaced with the time order of the time series X, i.e. 1,2,...,n, the test can be used as a trend test (Mann, 1945). In this case, the statistic S reduces to that given in eq. (5) with the same mean and variance as in equations (3) and (4).

$$S = \sum_{i<j} a_{ij} = \sum_{i<j} sgn(xj - xi) \quad (5)$$

Kendall (1955) gives a proof of the asymptotic normality of the statistic S. The significance of trends can be tested by comparing the standardized test statistic $Z = S/[var(S)]^{0.5}$ with the standard normal variate at the desired significance level.

Modified Mann Kendall (MMK) test

The main assumption of the original Mann-Kendall test is that the data are independent and randomly ordered, *i.e.* there is no trend or serial correlation structure among the observations. However, in many real situations the observed data are autocorrelated. The existence of positive autocorrelation in the data increases the probability of detecting trends when actually none exist, and vice versa. Although this is a well-known fact, autocorrelation in the data is often ignored. Hamed and Rao (1998) have discussed the effect of autocorrelation on the variance of the Mann-Kendall trend test statistic. A theoretical relationship was derived to calculate the variance of the Mann-Kendall test statistic for autocorrelated data. Based on the modified value of the variance of the Mann Kendall trend test statistic, a modified non-parametric trend test which is suitable for autocorrelated data was proposed. The empirical formula for calculating the variance of S in the case of autocorrelated data is given by equation (6).

$$V(S) = var(S).\frac{n}{n_s^*} = \frac{n(n-1)(2n+5)}{18}.\frac{n}{n_s^*} \quad (6)$$

Where, $\frac{n}{n_s^*}$ represents a correction due to the autocorrelation in the data. The correction of autocorrelation is given by equation 7.

$$\frac{n}{n_s^*} = 1 + \frac{2}{n(n-1)(n-2)} X \sum_{i=1}^{n-1}(n-1)(n-i-1)(n-i-2)\rho_s(i) \quad (7)$$

Where n is the actual number of observations and ρ_S (i) is the autocorrelation function of the ranks of the observations. The advantage of the approximation in equation (7) is that by using the ranks of the observations, the variance of S can be evaluated by equations (6) and (7) without the need for either the normalized data or their auto correlation function.

Sen's Slope Estimator

If a linear trend is present in a time series, then the true slope (change per unit time) can be estimated by using a simple nonparametric procedure developed by Sen (1968). Mann-Kendall test is used to evaluate a significant increase or decrease in parameter under consideration. Kendall's correlation of coefficient, an effective and general measurement of correlation between two variables (Kendall 1938, Mann 1945), is extensively used for testing thetrend in hydrological data. However, it does not estimate a trend slope. Therefore, the non-parametric Sen's method, which uses a linear model (Gilbert, 1987), is used to estimate the value and confidence interval for the slope of an existing trend. This approach involves computing slopes for all the pairs of time points and then using the median of these slopes as an estimate of the overall slope. Sen's method proceeds by calculating the slope of the line using all data pairs, as shown in the following equation:

$$Q_i = \frac{x_j - x_k}{j-k} \quad (8)$$

Where, $j > k$. If there are n values x_j in the time series, we get as many as $N = (n+1)/2)$ slope estimate Q_i. Sen's estimator of slope is simply given by the median of these N values of Q_i's.

$$Q = Q_{[(N+1)/2)]} \text{ if } N \text{ is odd} \quad (9)$$

$$Q = Q_{[N/2]} + Q_{[(N+2)/2]}/2 \text{ if } N \text{ is even.} \quad (10)$$

Sen's estimator is computed as Q_{med}=Q(N+1)/2 if N appears odd, and it is considered as $Q_{med}=[Q_{N/2}+Q_{(N+2)/2}]/2$ if N appears even. At the end, Q_{med} is computed by a two sided test at 100 (1-á) % confidence interval and then a true slope can be obtained by the non-parametric test.

Positive value of Q indicates an upward or increasing trend and a negative value of Q indicates a downward or decreasing trend in the time series.

RESULTS AND DISCUSSION

Trend analysis using Mann-Kendall (MK) test

The results of annual, seasonal (*kharif*) and monthly (June to September) rainfall (from 1958 to 2004) trend analysis using Mann-Kendall test are shown in Fig. 3. It was observed from the Fig.3 that there was variation in the rainfall depth for these periods at probability levels of 90%, 95% and 99%

The annual rainfall of nine out of thirteen meteorological stations showed decreasing trend in the rainfall depth over the period (Fig. 3(a)). *Welhe*, which is the highest rainfall station of the district showed the decreasing trend at 99% level of significance. Annual rainfall at *Khed* meteorological station also showed decreasing trend at 95% level of significance. The four meteorological stations *viz. Ambegaon, Pune, Daund* and *Baramati* showed non-significant increasing trend in the annual rainfall and other meteorological stations showed non-significant decreasing trend.

During *Kharif* season, decreasing trends were observed at *Welhe* and *Khed* with level of significance at 99% and 95%, respectively. Whereas, rainfall depths at *Daund* and *Baramati* meteorological stations exhibited non-significant increasing trends. The rainfall depths at other nine meteorological stations of district were observed to be decreasing with lower level of significance (Fig. 3(b)).

In order to examine further, whether the contribution of each month rainfall in the *Kharif* season shows any significant trend, trend analysis of monthwise rainfall depths from June to September, was carried out. It was interesting to observe that rainfall in June month exhibited overall increasing trends in the Pune district (Fig. 3(c)). During June, *Ambegaon*, *Pune* and *Bhor* at 99% level of significance and *Junnar*, *Khed* and *Mulshi* at 95% level of significance showed increasing trends in rainfall. *Daund* and *Purandhar* showed increasing trends rainfall at 90% level of significance and *Welhe, Maval, Shirur, Baramati* and *Indapur* showed non-significant increasing trends during June month.

On the contrary to June month trend results, rainfall analysis of July month exhibited significant decreasing trends (Fig. 3(d)). The part of the district which comes under high and medium rainfall zone showed significant decreasing trend of July rainfall. The meteorological stations like *Bhor* (99%), *Welhe* (99%), *Purandhar* (99%), *Pune* (99%), *Khed* (99%), *Junnar* (95%), *Ambegaon* (95%), *Maval* (95%) and *Mulshi* (95%) exhibit decreasing trend whereas *Shirur* and *Daund* exhibit non-significant decreasing trend for July month. The increasing trends were observed at *Indapur* at 90% level of significance and non-significant at *Baramati* meteorological stations.

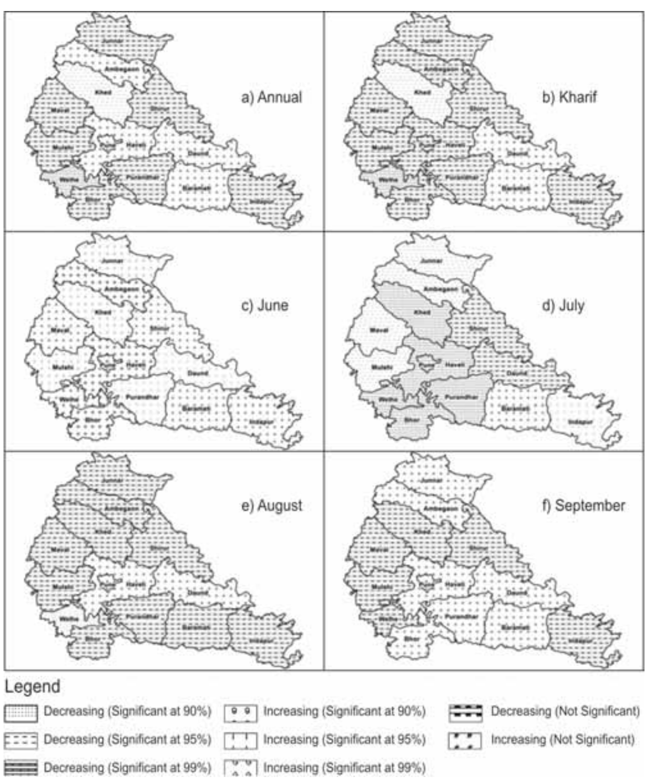


Fig. 3. Rainfall trend analysis of Pune district using Mann-Kendall test

The non-significant decreasing trend was observed at ten out of 13 meteorological stations in the August month, *Welhe* also showed decreasing trend at 90% level of significance and *Pune* and *Daund* showed non-significant increasing trend (Fig. 3(e)). The analysis for September month showed non-significant increasing and decreasing trends over the district's rainfall (Fig. 3(f)). All the high rainfall stations viz. *Welhe, Maval* and *Mulshi* showed non-significant decreasing trends for September month.

Trend analysis using Modified Mann-Kendall (MMK) test

The modified Mann-Kendall test, which provides trend of auto-correlated data was used for trend analysis of annual, seasonal (*Kharif*) and monthly (June to September) rainfall (from 1958 to 2004) of thirteen meteorological stations of Pune district. Comparison between the trend analysis results using Mann-Kendall (MK) test and modified Mann-Kendall test are shown in Table 2. The trends observed in annual rainfall using MK test and MMK test were same except at *Mulshi*, where the trend was observed to be decreasing at 95% level of significance by MMK which was observed non-significant by MK test. Also, for the Seasonal (*Kharif*) trend analysis, results of both tests were same except at *Mulshi*, MMK test, which showed significant decreasing trend at 90% level of significance which was non-significant by MK test. Analysis of rainfall data of June month showed different results only for *Bhor* and *Mulshi* meteorological stations. The *Bhor* and *Mulshi* showed different significant increasing trend with MMK as 95% and 99% level of significance, respectively which were 99% and 95% by MK test. However, for July month, both MMK and MK tests showed same trend results. For the month of August, *Welhe* showed significant decreasing trend by MK (90%) which was estimated to be not significant by MMK test. The trend results of MMK and MK tests

Period	Annual		Seasonal (*Kharif*)		June		July		August		Sept.	
Station	MK	MMK	MK	MMK	MK	MMK	MK	MMK	MK	MMK	MK	MMK
Baramati												
Bhor					**	*	**	**				
Daund					+	+						
Ambegaon					**	**	*	*				*
Indapur							+	+				
Junnar					*	*	*	*				
Khed	*	*	*	*	*	*	**	**				
Mulshi		*		+	*	**	*	*				
Pune					**	**	**	**				
Purandhar					+	+	**	**				
Shirur												
Maval							*	*				
Welhe	**	**	**	**			**	**	+			**

MK: Mann Kendall Trend Test
MMK: Modified Mann-Kendall Trend Test

** Significant at 99 %   * Significant at 95 %   + Significant at 90 %   ☐ Not Significant

were same for all other meteorological stations. For the rainfall data analysis of September month, MK test did not showed any significant trend but MMK test showed significant increasing trend at *Ambegaon* (95%) and decreasing trend at *Welhe* (99%).

The trend analysis was also carried out for maximum, minimum and average temperature data (from 1969 to 2008) recorded at Pune meteorological station. Fig. 4 shows the variation in the maximum temperature (30.85^0-32.54^0), minimum temperature (16.97^0-18.64^0) and average temperature (24.11^0-25.43^0) over the period of analysis. There were no significant trends for the maximum, minimum and average temperature data (from 1969 to 2008) recorded at Pune meteorological station. It can be concluded that the change in temperature of Pune meteorological station cannot be corroborated as an effect of climate change of the region.

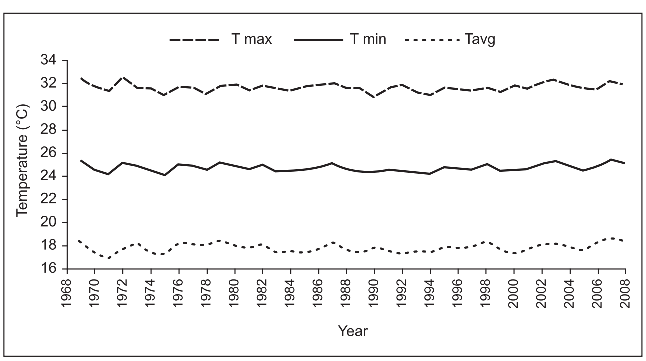


Fig. 4. Variation in maximum, minimum an average temperature data of Pune station from 1969 to 2008

Sen's slope estimator

Sen's slope estimator indicates the magnitude of trend for annual, seasonal (*kharif*) and monthly rainfall depths at 13 meteorological stations during 1958 to 2004 are shown in Table 3. The positive value of slope indicates an increasing trend and a negative value of slope shows decreasing trend in the rainfall depths over the period. For July, overall negative trend was observed with exception *Baramati* and *Indapur*. These Sen's slope estimates are useful for detecting the magnitude of the trend observed by MK test. At *Welhe*, high magnitude of negative trend was observed for annual, seasonal (*kharif*) and July month rainfall depths.

Table 3. Estimated Sen's slope from 1958 to 2004

	Sen's slope estimate					
Station	Annual	Seasonal (*Kharif*)	June	July	Aug.	Sept.
Baramati	0.57	2.20	0.81	0.36	-0.28	0.57
Bhor	-1.77	-1.18	3.09	-4.43	-0.40	0.31
Daund	1.32	0.66	1.21	-0.18	0.16	0.43
Ambegaon	0.26	-0.22	2.89	-2.81	-0.84	1.23
Indapur	-0.17	-0.13	0.64	0.78	-0.04	-0.69
Junnar	-0.78	0.42	1.66	-3.20	-0.45	0.59
Khed	-4.25	-3.01	1.40	-3.70	-0.54	-0.01
Mulshi	-5.63	-5.43	3.17	-7.33	-1.85	-1.20
Pune	0.16	-1.27	2.29	-2.64	0.26	0.04
Purandhar	-1.97	-1.00	1.05	-2.46	-0.89	1.04
Shirur	-1.37	-0.87	0.38	-0.35	-0.11	-0.38
Maval	-3.83	-2.48	2.03	-5.27	-0.33	-0.61
Welhe	-17.72	-16.52	2.85	-11.25	-5.00	-2.06

CONCLUSIONS

This study brings out a general trend for different meteorological stations of Pune district which fall under three different rainfall zones *viz*. high, medium and scarcity rainfall zones. The Mann-Kendall test and Modified Mann-Kendall test with the Sen's slope estimator were used for assessing the trend and its magnitude for annual, seasonal (*kharif*) and monthly rainfall depths.

Overall, the results showed a clear shift in the spatial and temporal rainfall pattern over the Pune district during the period of analysis. Seasonal (*Kharif*) rainfall was observed to be decreasing, June month's rainfall showed increasing trend while July month's rainfall showed decreasing trend at 99%, 95% and 90% level of significance, respectively. The decreasing trend was observed during July month for the stations which was under high rainfall zone (*Welhe-99%*, *Mulshi-95%* and *Maval-95%*) and medium rainfall zone (*Bhor-99%, Ambegaon-99%, Junnar-95%, Khed-99%*, *Pune-99%* and *Purandhar-99%)* of the district. Scarcity zone of the district *viz.Shirur*, *Daund*, *Baramati* and *Indapur* showed non-significant trends. Sen's Slope estimates generally indicated increasing and decreasing magnitude of slope in correspondence with the trend test. The temperature data analysed using 39 years record of Pune meteorological station did not exhibited any significant trend. Nonetheless, this study will assist in deciding the sowing date of crops and need of water conservation measures for different regions of Pune district, Maharashtra as an adaptation measure to changing climatic scenarios.

ACKNOWLEDGEMENTS

First author wishes to acknowledge the Post Graduate School, Indian Agricultural Research Institute (IARI), New Delhi, India for providing the fellowship and facilities for undertaking this research under the Ph.D programme.

REFERENCES

CGWB 2009. Ground Water Information of Pune District, Maharashtra. Central Region Nagpur, CGWB, Ministry of Water Resources: 1-2.

Cheng, K. Hsu, H., Tsai, M., Chang, K and Lee, R 2004. Test and analysis of trend existence in rainfall data." Proceedings 2nd Asia Pacific Association of Hydrology and Water Resources Conference, July 5-8, 2004, Singapore, 1-5.

Central Water Commission, 2001: Water and related statistics. Report of the Ministry of Water Resources, New Delhi.

Dash, S.K., Kulkarni M.A., Mohanty, U.C., Prasad K 2009. Changes in the characteristics of rain events in India. J Geophys Res 114:D10109.

Dash, S.K., Nair, A. A., Kulkarni, M.A. and Mohanty, U.C. 2011. Characteristic changes in the long and short spellsof different rain intensities in India. Theor Appl Climatol 105:563–570.

Dore MHI 2005. Climate change and changes in global precipitation patterns: what do we know? Environ. Int. 31: 1167–1181.

Gilbert, R. O. 1987. Statistical methods for environmental pollution monitoring. Van Nostrand Reinhold Co., New York, 320 pp.

Hall, A. W., Whitfield, P. H. and Cannon, A. J. 2006. Recent Variations in Temperature, Precipitation, and Streamflow in the Rio Grande and Pecos River Basins of New Mexico and Colorado. Reviews in Fisheries Science, 14:51-78.

Hamed, K. H. and Rao, A. R. 1998. A modified Mann-Kendall trend test for autocorrelated data. Journal of Hydrology 204: 182 -196.

Hsu, H. W. 2004. "Test and Analysis for Change Existence in Rainfall Data", Masterthesis, Department of Bioenvironmental Systems Engineering, National TaiwanUniversity.

IPCC 2007. Climate change impacts, adaptation and vulnerability. Working Group II contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report. Summary for policymakers, 23.

Kampata, J. M. Parida, B. P. and Moalafhi, D. B. 2008. Trend analysis of rainfall in the headstreams of the Zambezi River Basin in Zambia. Physics and Chemistry of the Earth. 33:621–625.

Kendall, M. G. 1975. Rank Correlation Methods . Charles Griffin: London.

Kothyari, U.C. and Singh, V.P. 1996. Rainfall and temperature trends in India. Hydrological Proceeding 10:357 –372.

Kothyari, U.C., Singh, V.P., Aravamuthan, V. 1997. An investigation of changes in rainfall and temperature regimes of the Ganga Basin in India. Water Resour Manag 11(1):17 –34.

Kripalani, R.H., Kulkarni, A., Sabade, S.S., Khandekar, M.L. 2003. Indian monsoon variability in a global warming scenario. Nat Hazards 29:189 –206.

Kumar, K.R., Pant, G. B., Parthasarathy, B. and Sontakke, N.A. 1992. Spatial and sub seasonal patterns of the long-term trends of Indian summer monsoon rainfall. Int J Climatol 12(3):257 –268.

Libiseller, C. and Grimvall, A. 2002. Performance of partial Mann-Kendall tests for trend detection in the presence of covariates. Environmetrics, 13:71-84.

Mann, H. B. 1945. Nonparametric tests against trend. Econometrica 13 :245 – 259.

MPCB 2006. District Environmental Atlas of Pune District. Maharashtra Pollution Control Board, Central Pollution Control Board, pp. 1-10.

Pattanaik, D.R. 2005. Variability of oceanic and atmospheric conditions during active and inactive periods of storm over the Indian Region. Int J Climatol 25:1523 –1530.

Ramanathan, V., Chung, C., Kim, D., Bettge, T., Buja, L., Kiehl, J.T., Washington, W.M., Fu Q, Sikka, D.R. and Wild, M. 2005. Atmospheric brown clouds: impacts on South Asian climate and hydrological cycle. Proc Natl Acad Sci USA 102:5326–5333.

Sahai, A.K., Pattanaik, D.R., Satyan, V., Grimm, Alice, M. 2003. Teleconnections in recent time and prediction of Indian summer monsoon rainfall. Met Atmos Phys 84:217 – 227.

Sen, P.K. 1968. Estimates of the regression co-efficient based on Kendall's tau. Journal of the American Statistical Association, 63:1379–1389.

Thapliyal, V., Kulshrestha, S.M. 1991. Climate changes and trends over India.Mausam 42:333–338.

Yue S., Pilon, P. and Cavadias G. 2002. Power of the Mann-Kendall and spearman's rho test for detecting monotonic trends in hydrological series. Journal of Hydrology, 259: 254-271.

Journal of Soil and Water Conservation **12**(1): 44-47, January-March 2013
ISSN: 022-457X

Assessment of underground water quality in Kathurah Block of Sonipat district in Haryana

PARDEEP[1], RAMESH SHARMA[2], SANJAY KUMAR[1], S.K. SHARMA[1] and B. RATH[2]

Received: 10 October 2012; Accepted: 13 January 2013

ABSTRACT

The present study is based on 149 water samples collected from different villages of Kathurah block of Sonipat district. Based on electrical conductivity (EC), sodium adsorption ration (SAR) and residual sodium carbonate (RSC) of waters, 28.2, 14.8, 7.4, 19.5, 1.3 and 28.9 per cent samples were found in good, marginally saline, saline, high SAR-saline, marginally alkali and highly alkali categories, respectively. EC, RSC and SAR ranged from 0.48 to12.13 dS/m, nil to 14.40 me/L and 0.22 to 31.14 (m mol/L)$^{1/2}$, respectively. Among cations, sodium was dominant ion which ranged from 0.54 to 83.70 me/L followed by magnesium (0.25 to 34.15 me/L) and calcium (0.25 to 39.40 me/L), whereas, among anions, $C1^-$ was dominant ion (1.00 to 75.00 me/L) followed by SO_4^{-2} (1.01 to 55.16 me/L), HCO_3^- (1.10 to 20.40 me/L) and CO_3^{-2} (0.20 to 8.00 me/L). The groundwaters of Kathurah block are Na-Mg-Ca type, dominated by chloride and the brackish waters are generally alkali in nature.

Key words: EC, groundwater, RSC, SAR, salinity, sodicity

INTRODUCTION

Ground water is one of the most valuable replenishable natural resource of the earth with multiple uses and a major source of fresh water on earth. In India, major share of water resource is used in agriculture (89 %) but according to an estimate the growing demand of water from municipalities, industries and energy generation will claim about 22 per cent (24.3 m ha-m/year) of the total resource by 2025 AD, thereby, reduce the good quality water supply for agriculture (Minhas and Tyagi, 1998). In most of the arid and semi-arid region of the country and south-eastern parts of Haryana, the farmer use poor quality groundwater due to limited availability of canals as well as good quality groundwater for sustainable crop production. The quality of the groundwater plays a key role in judging its suitability for crop production. Indiscriminate use of brackish water deteriorates the productivity of the soil through salinity, sodicity and toxicity effects and sometimes the land eventually go out of cultivation. Therefore, a prior appraisal of groundwater quality is important to assess pressures on groundwater resources and for judicious use of this scarce resource.

In the Haryana state, on an average 37 per cent of the ground water is of good quality, 8 per cent marginal and 55 per cent are of poor quality. Amongst poor quality water, 11, 18 and 26 per cent are saline, sodic and saline-sodic in nature (Manchanda 1976). Continuous use of poor quality water without drainage and soil management may adversely affect the soil health and agricultural production. Attempts also have been made in the past to establish water quality zones of Haryana state (Manchanda 1976), but a major change in water quality has occurred over the years due over exploitation and a shift in the cropping pattern (Phogat *et al*. 2008). Pressures on groundwater resources in semi-arid regions due to irrigation can be released through the judicious use of this scarce resource by knowing the groundwater quality of that area. Therefore, it is necessary to continuously monitor the quality of underground water for assessing the possible adverse effect on soil health. Keeping in view these facts, quality appraisal of groundwater used in irrigation for Kathurah block of Sonipat district was done for sound irrigation planning of the area.

[1]Department of Soil Science, CCSHAU, Hisar, Haryana, 125004
[2]Deptt. of Agricultural & Cooperation, Ministry of Agriculture, Govt. of India, Krishi Bhawan , New Delhi-110001

Groundwater resources in Sonipat district are currently under serious pressure. During the year 1972, only 25 per cent of the available groundwater was being used but it exceeded beyond the natural recharge with the increasing demand. During 2004, out of seven blocks in the district, three blocks were under the safe category and four blocks were under the overexploited category, which is just alarming. According to Central Ground Water Board, total replenishable groundwater resources in the district is 44958 ha-m and net groundwater draft is 51110 ha-m which indicates that 114 per cent of the available groundwater is being used (Anonymous, 2008). Irrigation through groundwater is being done in large parts of the district. Maximum number of minor irrigation units have been installed in Sonipat and Ganaur blocks and the lowest in Kathurah block. A large number of pump sets have been installed at shallow depth in range of 5 -10 m in Mundlana, Kathurah, Gohana, Kharkhoda blocks. Deep tubewells are installed in Sonipat, Ganaur and Rai blocks. Command area of canals and tube wells in the district is 83351 and 73048 ha, respectively.

MATERIALS AND METHODS

Survey and characterization of underground irrigation waters of Kathurah block of Sonipat district, Haryana was undertaken during 2006-07. It lies between 29º03′15″ to 29º14′40″ N latitude and 76º28′30″ to 76º41′15″ E longitude (Fig.1). Area of Kathurah block is 205.7 sq.km., comprising 9.5 per cent of the total district area. Geologically, Sonipat district is a part of the Indo-Gangatic plain of Peluvial age which has been laid down by tributaries of the Indus river system and other nonexistent rivers. Water table is shallow in areas having canal system and water quality is poor in these areas. The problem of water logging and salinisation exist there. However, in Yamuna belt the water table is deep because of over exploitation of underground water. One hundred forty nine water samples were collected from Kathurah block through random sampling of the running tubewells of the block from all sides of each village. The samples were analyzed for pH, electrical conductivity (EC), CO_3^{-2}, HCO_3^{-}, Cl^{-}, Ca^{+2}, Mg^{+2} and Na^{+} by following the procedures outlined in USDA Handbook No. 60 (Richards 1954). Water samples were categorized on the basis of criteria (Table 1) adopted by All India Coordinated Research Project on Management of Salt Affected Soil and Use of Saline Water through the values of EC, residual sodium carbonate (RSC) and sodium adsorption ratio (SAR) of the samples (Gupta *et al.* 1994). SAR and RSC were calculated as described by the following equations.

$$RSC\ (me\ /\ L) = (CO_3 + HCO_3) - (Ca + Mg) \quad \text{... (i)}$$

$$SAR\ (m\ mol\ /\ L)^{1/2} = \frac{Na}{\left\{\frac{Ca + Mg}{2}\right\}^{1/2}} \quad \text{... (ii)}$$

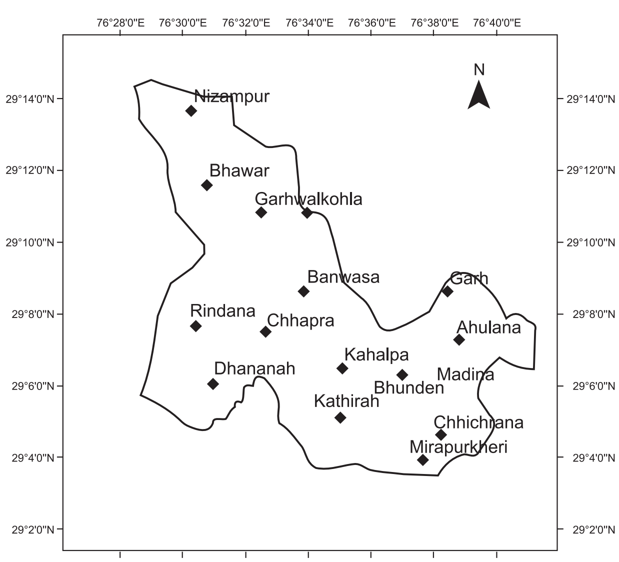


Fig.1. Location map of Kathurah block of Sonipat district

Table 1: Criteria for water quality classification

Quality	EC (dS / m)	SAR (m mol / L)$^{1/2}$	RSC (me / L)
Good	<2	<10	<2.5
Marginally saline	2-4	<10	<2.5
Saline	>4	<10	<2.5
High SAR - saline	>4	>10	<2.5
Marginally alkali	<2	<10	2.5-4.0
Alkali	<2	<10	>4.0
Highly alkali	Variable	>10	>4.0

RESULTS AND DISCUSSION

In Kathurah block, electrical conductivity (EC) ranged from 0.48 to 12.13 dS / m with a mean of 3.12 dS / m (Table 2). The lowest EC of 0.48 dS / m in water samples was observed in village Rindana and its highest value (12.13 dS / m) was recorded in village Garhwal (Fig.1). The pH ranged from 7.50 to 9.55 with an average of 8.18 and the highest pH of 9.55 in

Table 2: Range and mean of different water quality parameters in Kathurah block of Sonipat district

Sr. No.	Quality parameter	Range	Mean
1.	pH	7.50-9.55	8.18
2.	EC (dS/m)	0.48-12.13	3.12
3.	RSC (me/L)	nil -14.40	1.77
4.	SAR (m mol/L)½	0.22-31.14	8.68
5.	Ca^{+2} (me/L)	0.25-39.40	3.85
6.	Mg^{+2} (me/L)	0.25-34.15	7.09
7.	Na^{+} (me/L)	0.54-83.70	19.56
8.	K^{+} (me/L)	0.11-1.87	0.39
9.	$C1^{-}$ (me/L)	1.00-75.00	13.17
10.	SO_4^{-2} (me/L)	1.01-55.16	11.13
11.	HCO_3^{-} (me/L)	1.10-20.40	5.17
12.	CO_3^{-2} (me/L)	0.20-8.00	1.38

water samples was observed in village Bhawar. The SAR ranged from 0.22 to 31.14 (m mol/L)½ with a mean value of 8.68 (m mol/L)½. The lowest SAR value was observed in village Kathurah and its highest value was recorded in village Banwasa. The RSC varied from nil to 14.40 me/L with an average value of 1.77 me/L. Maximum value of the RSC (14.40 me/L) was found in the village Dhananah. In case of cations, sodium was dominant ion which ranged from 0.54 to 83.70 me/L followed by magnesium (0.25 to 34.15 me/L), calcium (0.25 to 39.40 me/L) and potassium (0.11 to 1.87 me/L). Mean value for Na^{+}, Mg^{+2}, Ca^{+2} and K^{+2} were 19.56, 7.09, 3.85 and 0.39 me/L, respectively.

In case of anions, chloride was the dominant ion with maximum value of 75.00 me/L observed in village Kathurah and minimum value of 1.00 me/L recorded in villages Nizampur and Rindana. Highest value of sulphate (55.16 me/L) was recorded in village Chhapra. Bicarbonate content ranged between 1.10 to 20.40 me/L and its minimum value was found in Kathurah village. The carbonates varied from 0.20 to 8.00 me/L and its highest value was found in the water samples of village Banwasa. Mean value for CO_3^{-2}, HCO_3^{-}, SO_4^{-2} and Cl^{-} and were found to be 1.38, 5.17, 11.13 and 13.17, respectively. Shahid *et al.* (2008) also reported the similar results in Julana block of Jind district. It was further observed that cations and anions in groundwater followed the order $Na^{+} > Mg^{2+} > Ca^{2+} > K^{+}$ and $Cl^{-} > SO_4^{-2} > HCO_3^{-} > CO_3^{-2}$, respectively. In arid and semi-arid regions, various workers have reported the dominance of sodium and chloride ions in irrigation waters (Paliwal and Yadav 1976; Sharma 1998; Shahid *et al.* 2008).

The mean chemical composition and related quality parameters in different EC ranges for Kathurah block are given in Table 3. Maximum numbers of samples (62) were in the EC range of 1-2 dS/m. The study revealed that 76.5 per cent of the samples showed EC less than 4 dS/m, 16.1 per cent had EC 4 to 8 dS/m and only 7.5 per cent samples were above 8 dS/m. Number of samples upto EC of 2 dS/m was increased, with further increase in EC, the number of samples deceased and its number was reduced significantly after an EC of 4 dS/m. Only eleven samples were recorded with EC greater than 8 dS/m. Concentration of Na^{+}, Mg^{+2}, Ca^{+2} and K^{+} increased with increase in the EC of the water samples and the magnitude of increase in Na^{+} and Mg^{+2} concentration was much higher than the other two. Similarly, concentration of Cl^{-} and SO_4^{-2} anions increased with the increase in the EC of the water samples. However, the SO_4^{-2} content remained higher than the Cl^{-} in waters having EC upto 4.0 dS/m, whereas, waters having EC greater than 4.0 dS/m had more average Cl^{-} content than SO_4^{-2}. HCO_3^{-} was also found to be in appreciable quantities,

Table 3. Average chemical composition of groundwater samples of Kathurah block in different EC classes

EC class (dS/m)	No. of water samples	Na^{+}	Ca^{+}	Mg^{+2}	K^{+}	CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}
				....................................me/L...					
0-1	12	3.64	1.00	2.27	0.33	0.70	3.61	1.97	1.61
1-2	62	8.80	1.61	3.17	0.31	1.36	4.92	3.37	4.28
2-3	23	14.51	2.98	5.52	0.38	1.46	4.73	6.40	11.01
3-4	17	21.59	3.35	9.40	0.41	2.35	6.09	11.29	14.71
4-5	7	27.83	4.32	9.89	0.50	0.80	3.30	19.37	18.78
5-6	6	36.22	5.13	13.04	0.61	0.80	2.68	31.07	19.24
6-7	5	45.22	5.91	12.69	0.43	1.60	8.94	30.04	23.74
7-8	6	44.75	14.23	12.56	0.53	1.30	8.38	41.50	20.80
>8	11	65.22	14.64	23.59	0.64	1.22	6.87	60.82	34.59

whereas, CO_3^{-2} was in low quantities, but the concentration of these two anions did not show any relation with EC of irrigation water.

According to AICRP classification, the maximum samples were found in highly alkali (28.9 per cent) category followed by good quality (28.2 per cent) (Fig. 2). The per cent samples in high SAR saline, marginally saline, saline and marginally alkali were 19.5, 14.8, 7.4 and 1.3, respectively. No sample was found in alkali category. Minhas *et al.* (1998) also reported that 32.84% of running wells in India were rated to be of poor quality. Earlier studies conducted by Manchanda (1976) indicated that in Kathurah block, 18, 18 and 64 per cent of groundwater was under marginally good, sodic and saline-sodic categories, respectively. During last three decades, minor improvement in groundwater quality has been observed because only 44 per cent of the available groundwater is being used in the block and watertable elevated in the range of 2 to 5 m (Anonymous, 2008).

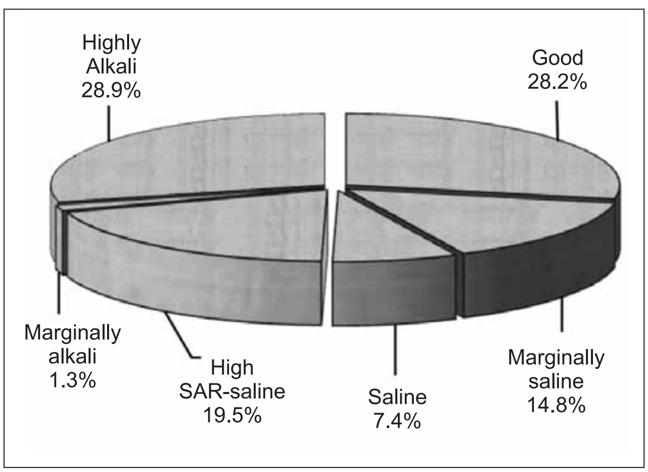


Fig. 2. Quality of groundwater (per cent) in Kathurah block of Sonipat district

CONCLUSIONS

It is concluded from this study that the groundwaters of Kathurah block are Na^{+}-Mg^{+2}-Ca^{+2} type, dominated by chloride and the brackish waters are generally alkali in nature. Good quality and marginally saline waters can be successfully used for crop production without any hazardous effect on soil and plant. The presence of sulphate, being important plant nutrient, is beneficial. The sulphate content of these waters in addition to supplying the sulphur nutrient to plant is beneficial in reducing the sodium hazard of waters having higher sodium content. Groundwater having EC more than 4 dS/m require special management practices depending upon the soil type, crop grown and climatic factors. Alkali water can be used successfully by using gypsum as an amendment tool (Anonymous, 2010). The waters rated as saline and high SAR saline is unfit for irrigation. Their indiscriminate use may cause secondary salinization and sodification of soil resulting in serious effect on crop growth. But in emergency these waters can be used with special management practices depending upon the rainfall, crop to be grown and soil type.

REFERENCES

Anonymous. 2008. CGWB ‘Groundwater report of Sonipat district’. Ministry of Water Resources, Government of India, North Western Region, Chandigarh.

Anonymous. 2010. AICRP on ‘Management of Salt Affected Soils and Use of Saline Water in Agriculture’, Annual report, CCSHAU, Hisar.

Gupta, R. K., Singh, N. T. and Sethi, M. 1994. Water quality for irrigation in India. Tech. Bull. 19, CSSRI, Karnal, India.

Manchanda, H. R. 1976. Quality of underground water of Haryana. Haryana Agricultural University, Hisar.

Minhas, P. S., Sharma, O. P. and Patil, S. G. 1998. Twenty five years of research on management of salt affected soils and use of saline water in agriculture. CSSRI Karnal India

Minhas, P. S. and Tyagi, N. K. 1998. Guidelines for irrigation with saline and alkali waters. Technical Bulletin no. 1/98, CSSRI, Karnal. pp.1.

Paliwal, K. V. and Yadav, B. R. 1976. Irrigation water quality and crop management in the union territory of Delhi. Research Bulletin 9 IARI, New Delhi. pp. 166.

Phogat, V., Sharma, S. K., Satyavan and Kumar, S. 2008. Assessment of groundwater quality for irrigation of Jind district for irrigation. Proceedings of 16th Nat. Symp. on Environ. (NSE-16), 16-18 Jul., 2008, Guru Jambheshwar Univ. Sci. and Tech., Hisar, India.

Richards, L. A. 1954. Diagnosis and improvement of saline and alkali soils. U.S.D.A. Hand Book No. 60 . Oxford & IBH Publishing Co., New Delhi.

Shahid, M., Singh, A. P., Bhandari, D. K. and Ahmad, I. 2008. Groundwater quality appraisal and categorization in Julana block of Jind district, Haryana. J. Indian Society of Soil Science. 56(1) 123-125.

Sharma, D. R. 1998. Assessment of the nature and extent of poor quality of underground water resources. National Seminar on Strategies for the Management of Poor Quality Water in Agriculture, held at CSSRI, Karnal. pp 4-5.

Journal of Soil and Water Conservation **12**(1): 48-54, January-March 2013
ISSN: 022-457X

Levenberg - Marquardt algorithm based ANN approach to rainfall - runoff modelling

JITENDRA SINHA[1], R K SAHU[2], AVINASH AGARWAL[3], A. R. SENTHIL KUMAR[3] and B L SINHA[1]

Received: 23 July 2012; Accepted: 30 January 2013

ABSTRACT

Runoff simulation constitutes the main requirement for planning, designing and operation of the water resources projects. Various rainfall-runoff models have been successfully applied in many problems and watersheds. One of the major lacunae with these models is that most of them are not quite flexible and require many parameters for accurate prediction of runoff. Such models perform well in calibration mode but not well in the verification phase. When limited records of the rainfall-runoff are available it becomes extremely difficult to calibrate and validate such models. In such a situation rainfall-runoff modelling is possible through the use of Artificial Neural Network (ANN) approach with reasonable accuracy. In the present study, back propagation ANN (BPANN) runoff models based on Levenburg – Marquardt algorithm have been developed to simulate streamflow for upper Kharun catchment in Chhattisgarh, India. In total three neural networks architecture has been developed for daily, weekly and monthly flow. Qualitative performance of the models have been evaluated by calculating statistical evaluation criteria viz. mean absolute deviation (MAD), root mean square error (RMSE), coefficient of correlation (CC), Nash - Sutcliffe coefficient efficiency (CE) and one hydrological evaluation criteria viz. volumetric error (EV). Multiple linear regression (MLR) models have also been developed under similar conditions of input to compare the performance of ANN models. The results showed that the ANN models outperformed the respective MLR models.

Key words: Levenburg – Marquardt algorithm, artificial neural networks; back propagation ANN, hidden layers; rainfall-runoff models; calibration; verification; performance criterion

INTRODUCTION

The period from 2005 to 2015 has been earmarked as the International Decade for Action, "Water for Life", by the United Nations General Assembly, emphasizing that water is critical for sustainable development, including environmental integrity and the eradication of poverty and hunger, and is indispensable for human health and well-being. The first step in water management is to quantify runoff produced in the area due to rainfall. Therefore, estimation or measurement of stream flow is essential for water supply, water harvesting, flood control, power generation, recreation, irrigation scheduling, drought mitigation, water quality, fish & wildlife propagation and design of various engineering structures. Several hydrological models ranging from empirical relationships to physically based models have been developed across the globe for runoff prediction. However, these models normally fail to represent the nonlinear dynamics inherent in the process of rainfall-runoff transformation. When limited records of the rainfall-runoff are available, it becomes extremely difficult to calibrate and validate the existing models. Complexity and non-linearity in-volved in rainfall-runoff transformation make it attractive to try the artificial neural network approach, which is inherently suited to problems that are mathematically difficult to describe. ANN has an excellent potential to represent complex hydrological

[1] Assistant Professor, Soil & Water Engineering, FAE, IGKV, Raipur
[2] Dean, Faculty of Agricultural Engineering, IGKV, Raipur,
[3] Scientist 'F' National Institute of Hydrology, Roorkee

processes in a simplified, logical, sequential and input-output manner. In the present study an attempt has been made to develop stream flow simulation models based on back propagation artificial neural network approach by considering a black box model with rainfall as input and runoff as output.

Study area

The State of Chhattisgarh has geographical area of about 135,100 km^2 and is drained by five river basins viz. Mahanadi, Godavari, Ganga, Brahmani and Narmada. These basins drain out 75858.45, 38694.02, 18406.65, 1394.55 and 743.88 $km^2$of catchment area respectively. The area selected for the study is the Upper Kharun Catchment and is situated inside the Shivnath basin of well known Mahanadi river basin. Kharun is one of the main tributary of Shivnath river. It is a non-perennial river, originating from village Petechua of Balod Tehsil in the south-east of Durg district and after flowing about 164 km joins Shivnath river near Somnath in the north. The total catchment area of Kharun river is 4118 km^2, lying upstream to the point where the river merges with Shivnath river and is situated between the geographical co-ordinates 20^0 33' 30" - 21^0 33' 38" N latitude and 81^0 17' 51" E - 81^0 55' 25" E longitude. However, the catchment upstream to the gauging and discharge measurement site of Central Water Commission on the river Kharun at "Pathardih", comprises an area of 2511 km^2. This area was taken up in this study for carrying out hydrological modelling and is hereafter being referred as Upper Kharun Catchment (UKC). The UKC is shown in Fig. 1 along with the Thiessen polygons, drawn to get average precipitation in the study area. The study area is located between 20^0 33' 30" N - 21^0 22' 05" N latitude and 81^0 17' 53" E - 81^0 45' 17" E longitude. Length of river Kharun up to gauging site Pathardih is 120 km. The gauging site "Pathardih" is located at 21^0 20' 28" N latitude and 81^0 35' 48" E longitude. The study area, UKC, generally has a dry tropical weather which is moderate except in summer when the peak temperatures usually reach is as high as 46^o C in May and January is the coldest month with daily minimum temperature drops to about 9^o C. The onset of monsoon is usually from 15th June and the monsoon season extends up to September. The long term rainfall data of UKC reveals that about 90% rainfall occurs in the five successive months from June to October. Frequency of moderate to severe drought in the UKC is around 6 to 7 years and the recurrence of drought on a lower scale is in every 3 to 4 years. The study area is underlain by diverse rock types of different geological ages from Pre-Cambrian to Recent and from Azoic to Quaternary. UKC drains from south to north and north-east. Maximum and minimum elevation in the UKC is 427 m and 271 m above the mean sea level respectively. Four major types of soil are found in the study area namely, Bhata (Entisols - Sandy loam), Matasi (Inceptisols - Sandy clay loam), Dorsa (Alfisols - Loam) and Kanhar (Vertisols - clay). Rice is the major crop grown in the UKC. The study area is a part of Chhattisgarh - popularly known as rice bowl of central India where large number of indigenous rice varieties is grown.

Data organization

Gauging of river Kharun at Pathardih site was started in September 1989 by the Central Water Commission, Ministry of Water Resources, Govt. of India, New Delhi. Locations of the daily rainfall measuring stations, installed at Raipur, Patan, Gurur, Dhamtari and Kurud are shown in Fig. 1 along with the thiessen polygon and CWC GD site Pathardih. The daily gauge – discharge data for the years from 1990 to 2009 (20 years) were obtained from the O/o Chief Engineer, Central Water Commission, Bhubaneshwar, Orissa. Rainfall data of the rain gauge stations in and around the study area were collected from Department of Agro-meteorology, IGKV, Raipur and State Data Centre, Department of Water Resources, Govt. of Chhattisgarh.

Weighted rainfall for the study area was then estimated by constructing the *Thiessen* polygons. The calculated weights of each raingauge station, starting from rainfall station one to five (Patan, Gurur, Dhamtari, Kurud and Raipur) were found to be 0.33, 0.18, 0.11, 0.15 and 0.23 respectively. It can be seen from the rainfall data that the monsoon rainfall occurs from June to October, and this period was considered as the active rainfall period (June 1st to October 31st) of the year. The active period data was then classified on the sub-basis of time units viz. daily, weekly and monthly to explore the applicability of ANN. Water availability from agricultural point of view is generally seen on standard meteorological week (SMW) basis. Therefore, weekly data of active period was

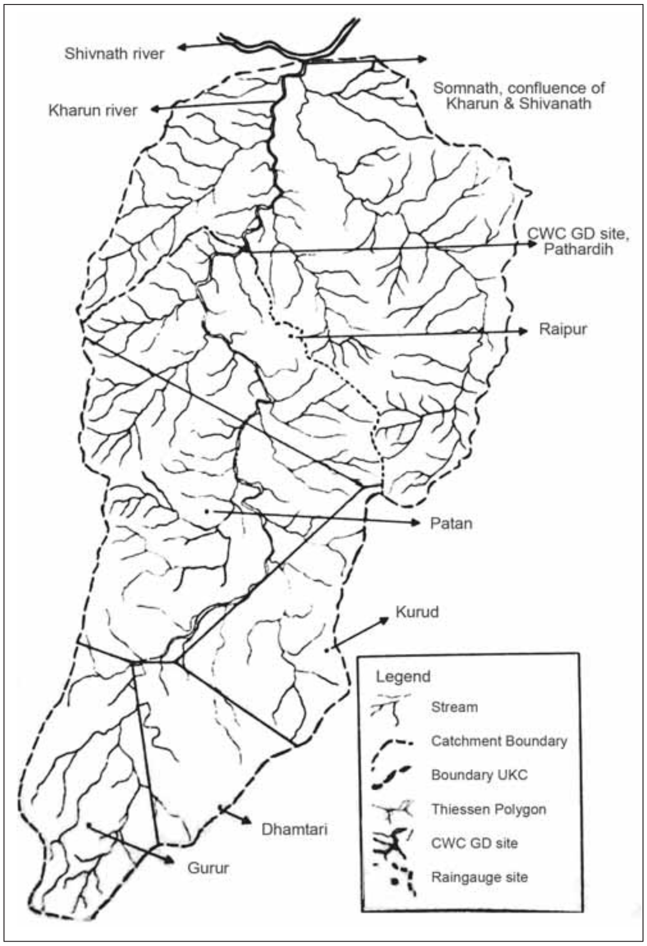


Fig. 1. Drainage network map of river Kharun showing UKC and thiessen polygon

considered from SMW 22 to SMW 44 (28th May to 4th Nov). The dataset had 3060 samples on daily basis, 460 samples on weekly basis and 100 samples on monthly basis.

Model formulation

For a discrete lumped hydrological system, the rainfall-runoff relationship as expressed by Hsu *et al.* (1995) was used for further analysis. The relation can be expressed as:

$$Q(t) = f[P(t), P(t\text{-}\Delta t),........P(t\text{-}n_x\,\Delta t), Q(t\text{-}\Delta t),........Q(t\text{-}n_y\,\Delta t)]$$

where, P represents rainfall, Q represents runoff at the outlet of the watershed, f is any kind of model structure (linear or nonlinear), ∇t is the data sampling interval, n_x and n_y are positive integer numbers reflecting the memory length of the watershed. Hence, in each of the dataset P_t, P_{t-1}, P_{t-2}...., Q_{t-1}, Q_{t-2} .....is also considered as inputs.

The set of variables was divided into two sets prior to the model building: the training or calibration set and verification set. The verification set was kept aside to evaluate the accuracy of the model derived from the training test. In the verification phase, the model output was compared with actual outputs using statistical measurements. It is worth noting that data division has significant impact on the results. In other words, the network may use low or high flow samples and give a yield of great precision for training set but fails to simulate outside the range of the training data (Tokar and Johnson, 1999). Training is most important in ANN modelling. Therefore, in this study 75% of the data (15 years, 1990 - 2004) was used for training while 25% of the data (5 years, 2005-2009) in each of the model was used for verification.

Development of multiple linear regression models

Regression analyses are among the oldest and computationally less demanding statistical techniques used in hydrology. The general equation of multiple linear regression models used in the study was:

$$y = a + b_1 x_1 + b_2 x_2 + \ldots\ldots + b_k x_k + e$$

where, y is dependent variable, $x_1, x_2, x_3, .., x_k$ are independent variables, a is constant, $b_1, b_2, .., b_k$ are the coefficients and 'e' is the residual or error. The objective requires the relationship between the variables 'y' and the variables $x_1, x_2, x_3, .., x_k$.

One of the most commonly used procedures for selecting the best regression equation is stepwise regression. In the present study input data is filed in MS excel and stepwise regression is performed using adds in function "Stepwise Regression", to decide the number of significant inputs. The detailed MLR analysis is performed using statistical category function 'linest'.

Development of back propagation ANN models

The architecture of an ANN is designed by weights between neurons, a transfer function that controls the generation of output in a neuron, and learning laws that define the relative importance of weights for input to a neuron (Caudill, 1987). BPANN is based on back propagation algorithm (Rumelhart and McClelland, 1986). It is used in layered feed-forward ANNs. The artificial neurons are arranged in layers, and send their signals "forward", and then the errors are propagated backwards. The network receives inputs by neurons in the input layer, and the output of the network is given by the neurons on an output layer. There may be one or more intermediate hidden layers. The back propagation algorithm uses supervised learning. The idea of the back propagation algorithm is to reduce the error (difference between actual and expected results), until the ANN learns the training data. The training begins with random weights, and the goal is to adjust them so that the error will be minimal.

An ANN network comprising of three layers viz., the input layer (i), the hidden layer (j) and the output layer (k) is shown in Fig. 2. x_i is input at the input node, a_{ij} is the weights before the hidden layer, S denotes sigmoid function, u_j summation at the hidden node, g^{hid} activation function for all nodes in the hidden layer, g^{out} activation function for all nodes in the output layer, b_{ij} is the weights after hidden layer, y_j output at hidden node, v_k summation at the output node, z_k output from the output node and f_k is target. Hence, error $= f_k - z_k$

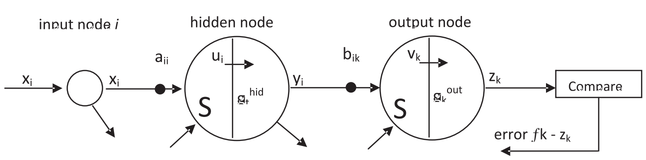


Fig. 2 Chain of nodes considered in the backpropagation algorithm

An optimal architecture is the one yielding the best performance in terms of error minimization while retaining a simple and compact structure. The selection of the number of hidden layers and the number of nodes within a layer is quite arbitrary. There are no fixed rules as to how many nodes should be included in a hidden layer. If there are less number of nodes in the hidden layer the network may have difficulty in generalization. On the other hand, the network may take a longer time to learn if there are too many nodes in the hidden layer and it may tend the network to memorize instead of learning and generalization (Vemuri, 1992). Most of the past research work suggest that one hidden layer is sufficient in explaining rainfall – runoff transformation. Hence, in this study, one hidden layer was adopted. For deciding the number of nodes in hidden layer, network growing technique (Gallant, 1986; Kwok and Yeung, 1995) was used. It started with one hidden nodes and the number of nodes were increased at an increment of one node. After each such trial the performance evaluation criteria were observed to see satisfactory results.

In the present study the BPANN was designed by using MATLAB codes. A programme was written, edited, debugged and run in MATLAB. The programme is flexible to accommodate different activation functions (tansig, logsig, purelin), performance functions (mse, sse and msereg), training algorithm (trainbr, trainlm etc.) and a preset number of iterations. In this study 'logsig' activation function was used. The training algorithm chosen was Levenberg-Marquardt (trainlm) and the performance function chosen is sum squared error (sse).

Qualitative evaluation of models

A number of statistical and hydrological criteria to evaluate the performance of hydrological models have been suggested by researchers (Chow, 1964; Abraham and Ledolter, 1983; Nash and Sutcliffe, 1970; Habaied, 1991 and Yu, 1994). The accuracy of model is generally linked with the objective function used for optimizing its parameters. The model evaluation criteria considered in this study are as follows:

Mean Absolute Deviation (MAD)

It is a measure of mean absolute deviation of the observed values from the estimated values. It has a unit and is not a normalized criterion. It is expressed as,

$$\text{MAD} = \frac{\sum_{j=1}^{n} \left| O_j - S_j \right|}{n}$$

where, O_j = Observed runoff (m^3/s), S_j = Simulated runoff (m^3/s), n = Total number of observations.

Root Mean Square Error (RMSE)

It is an alternative to the criterion of residual error (Yu, 1994) and is expressed as the measure of mean of the residual variance summed over the period, that is,

$$\text{RMSE} = \sqrt{\frac{\text{residual variance}}{\text{n}}} = \left(\frac{\sum_{j=1}^{n} (O_j - S_j)^2}{n} \right)^{1/2}$$

Correlation Coefficient (CC)

The correlation between the observed and simulated values is described by the correlation statistic, called the correlation coefficient. It is estimated by the equation:

$$CC = \frac{\sum_{j=1}^{n}\left\{\left(O_j - \bar{O}\right)\left(S_j - \bar{S}\right)\right\}}{\left\{\sum_{j=1}^{n}\left(O_j - \bar{O}\right)^2 \sum_{j=1}^{n}\left(S_j - \bar{S}\right)^2\right\}^{\frac{1}{2}}} x100$$

where, $\bar{O}$ and $\bar{S}$ are mean of observed and simulated runoff values.

Coefficient of Efficiency (CE)

Nash and Sutcliffe (1970) proposed the criterion on the basis of standardization of the residual variance with initial variance and named it as the coefficient of efficiency.

$$CE = \left\{1 - \frac{residual\ \text{var}iance}{initial\ \text{var}iance}\right\} x\ 100 = \left\{1 - \frac{\sum_{j=1}^{n}\left(O_j - S_j\right)^2}{\sum_{j=1}^{n}\left(O_j - \bar{O}\right)^2}\right\} x\ 100$$

Volumetric error

This is also called as absolute prediction error (Kachroo and Natale, 1992) and is estimated as follows:

$$EV = \left\{\frac{\sum_{j=1}^{n}\left(S_j - O_j\right)}{\sum_{j=1}^{n}\left(O_j\right)}\right\} x\ 100$$

Mathematicals models

The steps in identification of a nonlinear model of a system are selection of input-output data suitable for calibration and verification; selection of a model structure and estimation of its parameters; and validation of the identified models. Input variables are selected to describe the physical phenomena of the rainfall-runoff process. Record of 20 years of daily rainfall-runoff series of Upper Kharun Catchment at CWC GD site Pathardih, is selected to evaluate the performance of the neural network model. Increasing the number of training data in the training phase, with no change in neural network structure, will improve performance on the training and testing phase. The data consist of two sets: the first fifteen years of data (1990-2004) are used for model calibration (training) and the remaining five years of data (2005-2009) are used for model verification (testing).

Multiple linear regression models

These models were designed with Multiple Linear Regression (MLR) methodology using Daily (MLRD), weekly (MLRW) and monthly (MLRM) time bases. The models were represented by:

(MLRD) : $Q\text{-}_t = 1.93{*}P_t + 3.28{*}P_{t-1} - 0.51{*}P_{t-2} - 0.32{*}P_{t-3} - 0.60{*}P_{t-4} - 0.49{*}P_{t-5} + 0.78{*}Q_{t-1} - 0.19{*}Q_{t-2} + 0.13{*}Q_{t-3} + 0.04{*}Q_{t-4}$

(MLRW) : $Q\text{-}_t = 8.43{*}P_t + 0.32{*}Q_{t-1}$

(MLRM) : $Q\text{-}_t = 7.49{*}P_t + 3.70{*}P_{t-1}$

Back Propagation Artificial Neural Network (BPANN) models

The search for optimum number of hidden neurons was made through network growing technique. The number of hidden neurons with a particular number of iterations, resulting in the most acceptable performance evaluation criteria for both calibration and verification was accepted. When calibration of a particular model was finished, the structure and accompanying interconnections was saved as a MATLAB file. The model structures are shown in table 1.

Table 1. Structure of developed BPANN models

Model Name / Model structure	BPANND /	BPANNW /	BPANNM /
(NOL-NOIN-NOHN-NOON- NOI)	3-10-4-1-25	3-2-2-1-25	3-2-5-1-500

RESULTS AND DISCUSSION

All the models have been calibrated with 75% of patterns and verified with 25% of patterns. Performance of the developed models was adjudged by the goodness of fit between observed and simulated flows by estimating statistical and hydrological performance evaluation criteria, viz., MAD, RMSE, CC, CE and EV.

Multiple linear regression models were developed with optimization of error by the least square method, therefore, the developed models were found uniformly in calibration and verification period. As seen from Table 2 lumping of time units resulted in deterioration of the performance in both calibration and verification. Comparison of BPANN models for best generalization showed that a best fit network model could be obtained without going for higher number of iterations. A higher number of iterations over learned the training process and memorized the given patterns. As a result of which the model gave poor performance during verification period.

Comparison of the family of MLR and BPANN models on the basis of MAD, RMSE, CC, CE and EV showed that all the BPANN models outperformed the respective MLR models. The values of EV for all the BPANN models were negative. This clearly showed that ANN models underestimated the flow. However, the EV was very less for BP models in comparison to respective MLR models except the monthly model.

CONCLUSIONS

Application of ANN is appropriate for the nonlinear nature of the rainfall-runoff process. Results of the ANN models for rainfall-runoff modelling of the study area reflect that the performance of the ANN models is better than their respective MLR models. Hence, while assessing the water availability in active period (Kharif cropping), use of ANN models is certainly a much better choice than the MLR models.

Table 2. Comparative performance of the different models

Model Name	Performance evaluation criteria: Calibration period (1990 – 2004) MAD (cumec)	RMSE (cumec)	CC (%)	CE (%)	EV (%)	Verification period (2005 – 2009) MAD (cumec)	RMSE (cumec)	CC (%)	CE (%)	EV (%)
MLRD	33.46	73.08	89.91	80.56	9.82	34.04	86.63	87.72	76.84	6.18
BPANND	22.05	45.07	96.26	92.61	4.98	28.24	76.55	90.52	81.91	-0.10
MLRW	350.80	546.53	79.16	60.46	17.98	351.58	628.27	71.6	50.96	8.81
BPANNW	225.37	378.71	90.01	81.01	0.04	251.16	513.02	82.32	67.3	-4.86
MLRM	1313.34	1702.49	79.07	56.57	13.85	1180.42	1604.30	73.53	51.78	1.08
BPANNM	664.99	931.84	93.27	86.99	-0.57	953.24	1370.70	88.55	64.80	-24.85

ACKNOWLEDGEMENT

The authors wish to express their gratitude to the Chief Engineer (Mahanadi Project), Central Water Commission, Bhubaneshwar for providing the Gauge – Discharge data of the study site.

REFERNCES

Abraham, B. and Ledolter, J. 1983. Statistical Methods for Forecasting. John Wiley and Sons Inc., New York.

Agarwal, A., Mishra, S.K., Ram, S. and Singh, J.K. 2006. Simulation of Runoff and Sediment Yield Using Artificial Neural Networks. Biosystem Engineering, 32-48.

Caudill M. 1987. Neural Networks Primer, Part-I. AI Expert. Netherlands.

Chow, V.T. 1964. Hand Book of Applied Hydrology. McGraw Hill, New York.

Dawson, C.W. and Wilby, R. 1998. An artificial neural network approach to rainfall-runoff modelling. Hydrological Science Journal, 43: 47-66.

El-shafie,A. Mukhlisin, M. Najah, A. And Taha, M. 2011. Performance of artificial neural network and regression techniques for rainfall-runoff prediction. International Journal of the Physical Sciences 6: 1997-2003.

Gallant, S.I. 1986. Three constructive algorithms for network learning. *Proceedings of 8th Annual Conference of Cognition Science Society*, Michigan, 652-660.

Habaied, H.; Troch, P. A. and De Troch, F. P. 1991. A coupled rainfall-runoff and runoff routing model for adoptive real time forecasting. Water Resources Management, 5: 47-61.

Harun, S., Nor, A. and Kassim, M. 2002. Artificial Neural Network Model for Rainfall-Runoff Relationship. Journal of Technology University of Malaysia, 37: 1-12.

Hsu, K.L., Gupta, H.V. and Sorooshian, S. 1995. Artificial neural network modelling of the rainfall-runoff process, Water Resources Research, 31: 2517–2530.

Kachroo, R.K. and Natale, L. 1992. Non-linear modeling of the rainfall-runoff transromation. Journal of Hydrology, 135: 341-369.

Kwok, T. and Yeung, D. (1995). Constructive feed-forward neural networks for regression problems: a survey, Technical Report, Hong Kong .University of Science and Technology, Hong Kong.

McCulloch, W.S. and Pitts, W.H. 1943. A logical calculus of the ideas immanent in nervous activity. Bulletin of Mathematical Biophysics, 5: 115.

Nash, J.E. and Sutcliffe, J.V. 1970. River flow forecasting through conceptual models. Journal of Hydrological Science, 41: 399-417.

Rumelhart, D.E.. Hinton, G.E. and Williams, R.J. 1986. Learning internal representations by error propagation. Parallel Distributed Processing, Vol. I. MIT Press, Cambridge, Mass.: 318-362.

Sinha, J. 2011. Artificial Neural Network approach to rainfall-runoff modelling for upper Kharun catchment in Chhattisgarh. Ph.D. Thesis, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.).

Tokar, A.S. and Johnson, P.A. 1999. Rainfall-runoff modelling using artificial neural networks. Journal of Hydrologic Engineering, 4: 232-239.

Vemuri, V. .1992. Artificial Neural Networks : Concepts and Control Application. Los Alamitos, California. IEEE Computer Society Press. pp 509.

Yu, P. S., Liu, C. L. and Lee, T. Y. 1994. Application of a transfer function model to a storage runoff process. *Proceeding of Stochastic and Statistical Methods in Hydrology and Environmental Engineering*, Beijing. pp. 87-97.

Journal of Soil and Water Conservation **12**(1): 55-58, January-March 2013
ISSN: 022-457X

Study of soil water dynamics under bioline and inline drip laterals using groundwater and wastewater

DEEPAK SINGH[1], NEELAM PATEL[2], T.B.S. RAJPUT[3], LATA[4] and CINI VARGHESE[5]

Received: 19 October 2012; Accepted: 2 January 2013

ABSTRACT

The use of wastewater in agriculture is a centuries-old practice which is receiving renewed attention with the increasing scarcity of fresh water resources in many arid and semi-arid regions of the world. Driven by rapid urbanization and growing wastewater volumes, treated wastewater is widely used as a low-cost alternative to conventional irrigation water. A field experiment was conducted to investigate the soil water distribution in the root zone of Cauliflower under two types of drip lateral systems with groundwater as well as untreated wastewater application. Different type of drip lateral system resulted in different spatial distribution of soil water in the root zone. Initially soil water distribution was similar under both bioline as well as inline drip lateral systems but, with increasing time of operation the rate of soil wetting decreased. Soil water content at different soil depths varied from 17.93 to 31.07 cm^3/cm^3 under inline and 16.13 to 32.98 cm^3/cm^3 under bioline drip lateral systems at initial stage. Adequate water was available within the root zone of crop at all growth stages when the wastewater was dispersing through bioline but in case of inline drip lateral adequate water was not available upto the root zone of crop due to clogging by the wastewater.

Key words: bioline and inline laterals, wastewater, water regime

INTRODUCTION

The use of wastewater for irrigation purposes is being established as a future alternative in water scarce areas and in those areas where there is heavy competition for water. In this perspective, the irrigation system that has an edge over others in terms of the environment and public health is drip irrigation (Turral *et. al.,* 2010). Since efficient use of irrigation water is of major importance for sustainable agriculture development, different measures have been introduced to conserve water (Taylor *et. al.,* 1995). Drip irrigation is an efficient method of water application for vegetables and horticultural crops. This method is widely used because it allows efficient management of both water and fertilizer (Rajurkar *et. al.,* 2012). An appropriate filtration system combined with regular maintenance will help keep the system operational when using low-quality water (Ravina *et. al.,* 1992). Bioline tubing is a low volume drip line with integral and evenly spaced pressure compensating drippers at specified intervals with a flow rate of 2.3 L/hr. Bioline incorporates a Non-leakage mechanism, mechanical root intrusion barrier and silicon diaphragm. Bioline tubing is given identification through its purple.

One of the important aspects of planning and managing a drip irrigation system is the soil moisture movement pattern in the root zone soil (Pramanik et. al., 2012). The depth of the lateral below soil surface, emitter spacing and system pressure are very importance for delivering the required amount of water to the plant and for wetting the desired extent of plant root zone. Wetting pattern can be obtained by either direct measurement of soil wetting in the field, which is site-speciûc, (Dukes *et. al.,* 2005; Camp *et. al.,* 2003 and Puig *et. al.,* 2005). Despite its importance, global measurement and analysis of soil moisture and temperature remains an outstanding scientific problem with far-reaching significance to agriculture (Singh *et. al.,* 2006).

[1]Ph.D Scholar, WST (E mail: dpk905@gmail.com), [2]Senior Scientist, [3]Principal Scientist, Department of Agricultural Engineering, [4]Principal Scientist, Department of Microbiology, [5]Senior Scientist, Department of Agricultural Statistics, IASRI. Indian Agricultural Research Institute, New Delhi, 110012, India

A comprehensive field investigation was carried out in a sandy loam soil to study the soil water dynamics under bioline and inline drip lateral systems.

MATERIALS AND METHODS

The field experiment was conducted at the Precision Farming Development Centre, Water Technology Centre, Indian Agricultural Research Institute (IARI), Pusa, New Delhi, India, which is located at 28°8' N latitude and 77°12' E longitude and with an area of about 500 ha. Water table in the farm area is about 5-7 m. Field experimental area was having well-drained sandy loam soil comprising average 61.25 % sand, 17 % silt and 21.25 % clay as shown in Table 1. The bulk density of the soil was 1.57 g cm^{-3} and saturated hydraulic conductivity 1.11 cm h^{-1}, respectively.

Water requirement of cauliflower crop was estimated using the reference crop evaporation (ET_0) calculated on a daily basis using Panman-Monteith's semi-empirical formula. The crop coefficients of 0.7, 0.84, 1.05, and 0.95 at initial, development, curd formation and curd maturity stages, respectively were adopted during the crop season (Allen *et. al.*, 1998).

Table 1. Particle size distribution of soil

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Hydraulic Conductivity (cm h^{-1})	Bulk Density (g cm^{-3})
0-15	70	13	17	1.23	1.57
15-30	69	10	21	1.38	1.62
30-45	55	20	23	0.71	1.56
45-60	51	25	24	1.10	1.56
Average	61.25	17	21.25	1.11	1.57

A total of 8 access tubes of PVC were installed up to the depth of 100 cm in each treatments to measure the soil water content (volumetric). Measurements of soil water were taken on weekly basis before the irrigation. Wastewater was collected from the drain and stored for a period of 24 hours in a tank for primary treatment so that all suspended foreign particles get settled. The tank size was 3x2x3 m in length, width and depth respectively.

Bioline is a low volume dripper line designed for use with on-site wastewater drip dispersal systems. It has integral and evenly spaced pressure compensating drippers inside the tubing. Knowing the chemical and biological components of the source water helps in selecting the type of drip laterals to prevent drip lines clogging.

RESULTS AND DISCUSSION

Soil water distribution

Cauliflower is a shallow rooted crop and needs frequent irrigation during its growth stages. Frequency domain reflectometry readings were taken at initial, development, middle and maturity stages of the crop to find out the depth wise variation in soil water distribution. The volumetric moisture content at different soil depths and during different crop growth stages under bioline as well as inline systems are shown in Fig. 1-8.

Fig. 1 shows the water distribution at the initial stage below the emitter with the combination of different laterals (inline, bioline) dispersing groundwater. Soil water content in the various soil layers varied from 17.60 to 31.81 cm^3/cm^3 for inline and 18.29 To 31.20 cm^3/cm^3 for bioline, respectively. Similar trend were observed during other growth stages as shows in Fig 2-4, however the moisture content was found highest during initial stage of crop growth for both inline and bioline laterals. There was no significant difference in the soil moisture content between bioline and inline laterals.

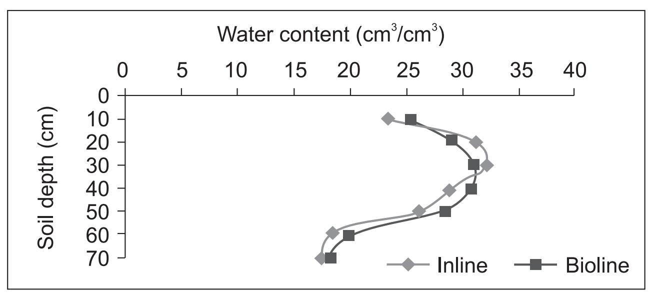


Fig 1. Spatial variation in water content at various depths at initial stage using groundwater

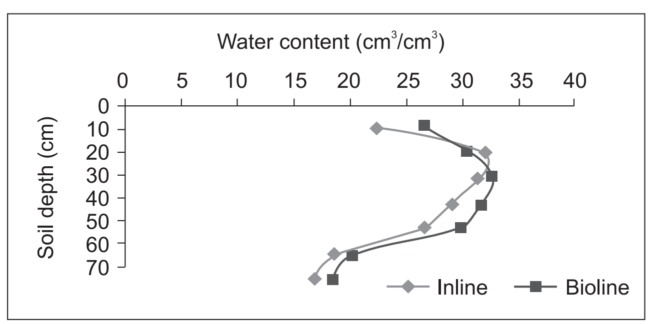


Fig 2. Spatial variation in water content at various depths at development stage using groundwater

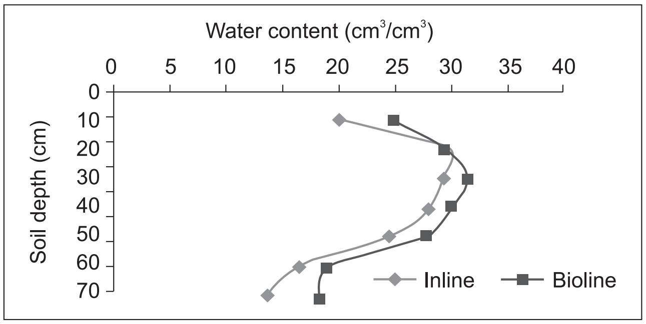


Fig. 3. Spatial variation in water content at various depths at maturity stage using groundwater

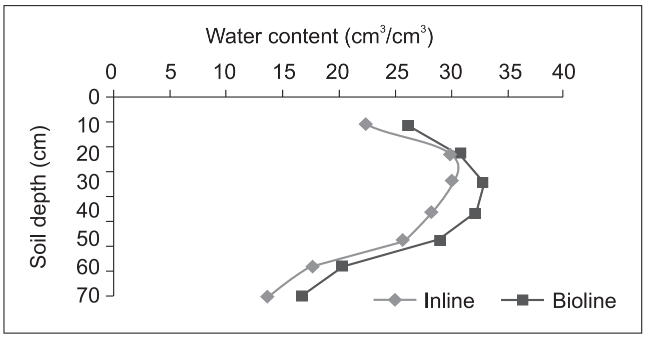


Fig. 4. Spatial variation in water content at various depths at maturity stage using groundwater

Fig 5 shows the water distribution at the initial stage below the emitter with the combination of different laterals (inline, bioline) dispersing wastewater. Soil water content at different soil depths varied from 17.93 to 31.07 cm^3/cm^3 for inline and 16.13 to 32.98 cm^3/cm^3 for bioline, respectively. Similar trend were observed during other growth stages for bioline lateral as shows in Fig 6-8, but the trend for inline lateral were different during other growth stages as shows in Fig 6-8, however the moisture content was found highest during initial

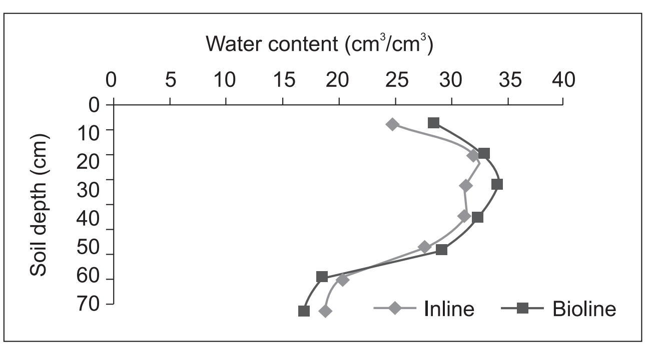


Fig. 5. Spatial variation in water content at various depths at initial stage using wastewater

stage of crop growth for both inline and bioline laterals. There was a significant difference in the soil moisture content between bioline and inline laterals except for initial stage.

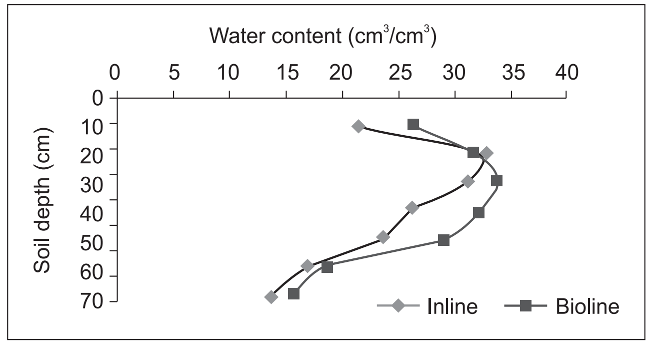


Fig. 6. Spatial variation in water content at various depths at development stage dispersing wastewater

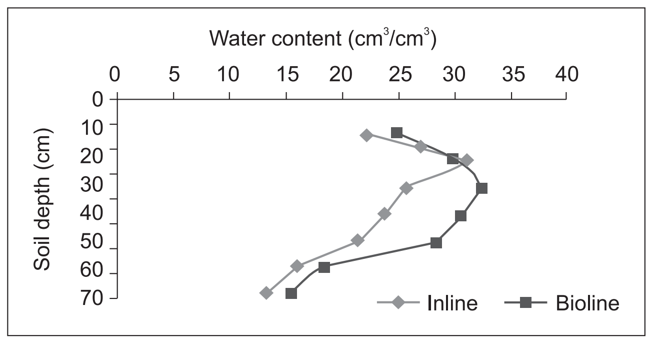


Fig. 7. Spatial variation in water content at various depths at maturity stage dispersing wastewater

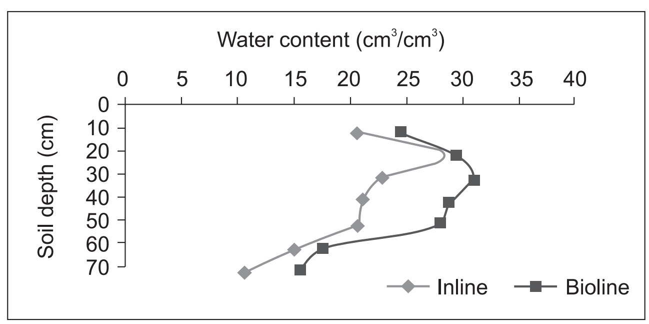


Fig. 8. Spatial variation in water content at various depths at harvesting stage dispersing wastewater

Wetting front

Results revealed that both the wetted soil width and depth increased with increasing the discharge rate of the emitter. The increase in wetted soil width was more than the wetted depth of soil. The maximum soil wetted width were 25 cm and 26.5 cm for both the inline and bioline drip laterals, respectively as shown in Fig 9. Both the drip laterals behaved as independent point sources until the 1.5 hours of operation, but later wetted zones started merging with each other resulting into a line source of water application. The similar trend was observed for the wetted soil depth also as is shown in Fig 10.

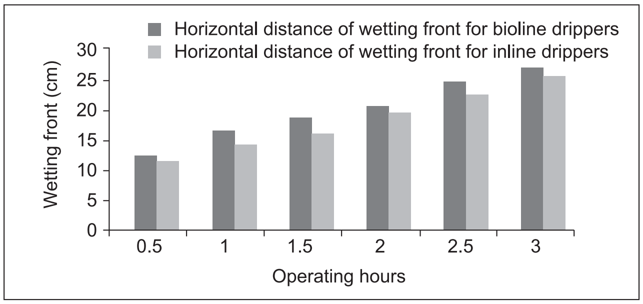


Fig. 9. Width of the wetted soil zone under different drip laterals

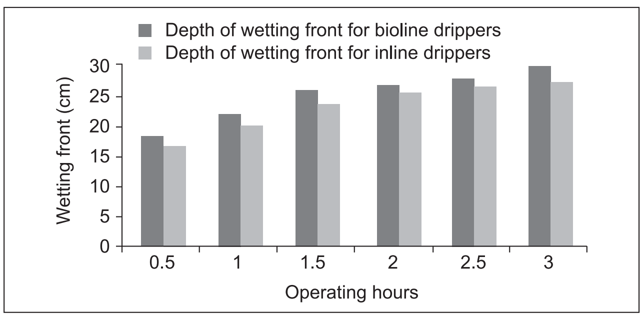


Fig.10. Depth of the wetted soil zone under different drip laterals

CONCLUSIONS

The moisture content was found highest during initial stage of crop growth for both inline and bioline laterals. There was a slight difference in the soil moisture content between bioline and inline laterals except for initial stage dispersing wastewater. Bioline drip lateral is simple and easily adoptable irrigation method and has great potential to prevent the clogging of emitter. Adequate water was available within the root zone of crop at all growth stages when the wastewater was dispersing through bioline but in case of inline drip lateral adequate water was not available upto the root zone of crop due to clogging by the wastewater.

REFERENCES

Allen R G, Pereira L S, Raes D and Smith M. 1998. Crop evapotranspiration guidelines for computing crop water requirements. *Irrigation and Drainage Paper* -56 (FAO), Rome, Italy, p. 300.

Camp C R and Lamm F R. 2003. Irrigation systems, subsurface drip. Marcel Dekker, New York, NY. *Encyclopedia of Water Science, 560-564.*

Dukes M D and Scholberg J M. 2005. Soil moisture controlled subsurface drip irrigation on sandy soils. *Applied Engineering Agriculture*, 21(1): 89-101.

Pramanik, S. and Biswas, R.K. 2012. Effect of drip fertigation on soil moisture distribution and irrigation water use efficiency of banana in West bengal. Journal of Soil and Water Conservation, 11 (3): 210-217.

Puig-Bargues J, Arbat G, Barragan J and Ramirez C F. 2005. Hydraulic performance of drip irrigation subunits using WWTP effluents. *Agricultural Water Management*, 77(1-3): 249-262.

Rajurkar, G., Patel, N., Rajput, T.B.S. and Varghese, C. 2012. Soil water and nitrate dynamics under drip irrigated cabbage. Journal of Soil and Water Conservation, 11 (3): 196-204.

Ravina L, Paz E, Sofer Z, Marcu A, Shisha A and Sagi G. 1992. Control of emitter clogging in drip irrigation with reclaimed wastewater. *Irrigation Science,* 13(3): 129--139.

Singh R, van J C and Feddes R A. 2006. Water productivity analysis of irrigated crops in Sirsa district, India. *Agricultural Water Management,* 82(3): 253-278.

Souza C F and Edson E. 2003. Multi-wire time domain reflectometry (TDR) probe with electrical impedance discontinuities for measuring water content distribution. *Agricultural Water Management*. 59: 205-216.

Taylor H D, Bastos X, Pearson H W and Mara D D. 1995. Drip irrigation with waste stabilization pond effects: solving the problem of emitter clogging. *Water Science and Technology,* 31(12): 417-424.

Turral H, Svendsen M and Faures J M. 2010. Investing in irrigation: Reviewing the past and looking to the future. *Agricultural Water Management,* 97(4): 551-560.

Journal of Soil and Water Conservation **12**(1): 59-65, January-March 2013
ISSN: 022-457X

Integrated use of organic manures and inorganic fertilizer on the productivity of wheat-soybean cropping system in the vertisols of central India

U.K. BEHERA[1], L.P. AMGAIN[2] and S.K. RAUTARAY[3]

Received: 29 August 2012; Accepted: 12 January 2013

ABSTRACT

Cultivation of durum wheat in winter season (November to April) following wet summer soybean is a potential cropping system in the Vertisols of central India. A field experiment was conducted during 1999-2002 under the fine-textured Vertisols at Indore, India to study the effects of night soil (NS), farmyard manure (FYM) and poultry manure (PM) in sole or their combined application with half of the recommended NPK on wheat, and their residual effect on soybean. Compared with recommended NPK, grain yield of durum wheat increased with half of recommended NPK + PM @ 5 t/ha while yields were similar under half of recommended NPK with FYM @ 10 t/ha or NS @ 5t/ha. Quality parameters of wheat viz. protein content and hectolitre weight improved, and yellow berry content reduced under the combined use of organic and inorganic fertilizers compared with the organics. Integrated use of half of recommended NPK and PM was at par with the recommended NPK regarding protein content, sedimentation value, β-carotene content, yellow berry content, and hectoliter weight. High levels of available P, K, Cu, Zn, and Mn were noted under PM. Thus, application of PM, FYM or NS and half of NPK to wheat improved productivity, grain quality, soil health and sustainability of wheat-soybean system.

Key words: wheat, soybean, organic manures, inorganic NPK, grain quality, soil health

INTRODUCTION

Wheat–soybean is the dominant cropping system in the Vertisols of central India with limited or scarce irrigation and fertilizer inputs. Presently, the system is practised on an area of 4.5 million ha but the productivity of wheat and soybean is only 1.7 and 0.9 t/ha, respectively (Anonymous, 2004). Cultivation of durum wheat is native to central India, while introduction of soybean during rainy season since mid-1980s has been a remarkable success, which has virtually brought about a revolutionary change in the economy of farmers of this region.

Until 1940s *durum* cultivation was predominant (90% of the wheat area) in central India. Thereafter, the area sown to *durum* wheat started declining because of limited yield potential and the susceptibility to rust, thus, *aestivum* wheat became dominant. Of late, the development of high yielding rust-resistant *durum* varieties lead to re-gaining popularity of its cultivation in the region. At present *durum* wheat is cultivated on an area of about 2 million ha in India, concentrating in this region. There is considerable scope to expand the area under *durum* wheat further due to increasing global demand, value addition potential, better price in the market and resistance to Karnal bunt compared with *aestivum* wheat (Nagarajan and Singh 1998; Pandey *et al.*, 2000). Ideal soil and climatic conditions prevailing in this region are responsible for production of quality *durum* wheat with good hectoliter value, high protein and less yellow berry content in grains (Pandey *et al.* 2000). Realizing the export potential and to meet the demand of growing pasta industries in the area as well as the typical local food (*Bati*, *Bafale*, *Rawa*, *Ladu*, *Churma*) requirement, there was a shift in focus for cultivation of *durum* wheat in the region towards later part of the 1990s. For this, breeding efforts were made to improve the

[1 &2]Division of Agronomy, Indian Agricultural Research Institute, Pusa, New Delhi -110012, India.
[3]DWM, Bhubaneswar

quality parameters to meet the above requirement. However, very little efforts were made to improve *durum* grain quality through agronomic management involving balanced nutrition through integrated nutrient management approach.

Vertisols of central India are largely deficient in N, P, S and Zn (Subba Rao *et al.* 1998). The farmers mostly grow soybean without fertilizer application and realize the carry-over effect of the legume on the following wheat. In some situations, the fertilizer application in soybean results in taller plants and excessive vegetative growth, leading to poor pod development and reduced yield (Behera 2005). Imbalanced and inadequate use of fertilizers in wheat results in poor yields, deterioration of soil fertility and emergence of multiple nutrient deficiencies (Rattan *et al.* 1999). Combined application of available organic sources along with inorganic fertilizers assures high crop and soil productivity on a sustainable basis in a cereal-legume cropping system (Subba Rao *et al.* 1998; Manna *et al.* 2003). It may also help in improving the quality of *durum* wheat, which is important from export point of view. Such information is lacking for the system as a whole in the Vertisols of semi-arid central India. A study was therefore initiated to improve the productivity, quality, profitability and soil health in soybean-wheat cropping system through balanced and integrated nutrient management practices.

MATERIALS AND METHODS

Experimental site

A field experiment was conducted at the research farm of Indian Agricultural Research Institute, Regional Station, Indore during 1999 to 2002 on a fixed site. The site is situated as $22^0 51'$ N latitude, $75^0 55'$ E longitude, 520 m above mean sea level, and has a semi-arid tropical climate with mean annual rainfall of 700 mm. The soil was very fine clay loam hyperthermic *Typic Haplustert* (Vertisol) with the following characteristics in 0-15 cm depth: pH 8.2 (1:2.5 soil: water suspension) (Jackson 1973), electrical conductivity 0.2 dS/m (Jackson 1973), cation exchange capacity 42 cmol /kg soil (leaching with 1N NH_4OAc and estimating NH_4^+ ions) (Jackson 1973), organic C 5.1 g/kg (Walklay and Black, 1934), $KMnO_4$-N 112.73 mg/kg (Subbiah and Asija 1956), Olsen's P 5.64 mg/kg (Olsen *et al.*, 1954) and NH_4OAc-K 182.73 mg/ kg soil (Jackson, 1973).

Treatments and crop culture

Eleven treatments combinations consisted of 3 different organic sources *viz.* farmyard manure (FYM), poultry manure (PM) and night soil (NS); two levels of NPK fertilizer *viz.* 0.5 and 1.0 of recommendation, besides one control (no NPK, no organic manure) were laid out in a randomized block design with 4 replications in a fixed plot size of 20 m^2. The treatments were applied to wheat during winter (November to April) and soybean was raised during rainy season (June to October) under residual soil fertility. Wheat could not be taken during 2000-01 due to drought conditions and non-availability of ground water for irrigation. In the final year (2001-02), wheat was grown solely on residual soil fertility accumulated over the years.

Organic manures were applied on oven-dry weight basis (i.e. 5 t/ha for PM, 10 t/ha for FYM, and 5.0 and 10 t/ha for NS) before sowing of wheat. The nutrient content of poultry manure was almost double as compared with night soil and FYM (Table 1).

Recommended fertilizer dose for wheat was 120 kg N, 26.2 kg P and 33.3 kg K/ha. Half N and full dose of P and K in the form of urea, single superphosphate and muriate of potash, respectively were applied at the time of sowing. Remaining N was top-dressed in the form of urea at crown root initiation stage of wheat along with first irrigation. High-yielding varieties of *durum* wheat 'Malavshakti' and soybean 'Pusa 16' were cultivated by following standard practices. Five irrigations each of 60 mm depth were applied to wheat by check basin

Table 1. Nutrient contents and addition through organics (mean of 1999-2001).

Organic manure	Organic carbon (g/kg)	Nutrient content (g/kg)			Nutrient added* (kg/ha)			C: N Ratio
		N	P	K	N	P	K	
Farm Yard manure (FYM)	182.3	7.02	2.0	5.6	35.0	10.0	28.0	26.1
Poultry manure (PM)	310.9	8.0	11.6	12.1	140.0	58.0	60.6	11.1
Night soil (NS)	172.8	7.2	3.0	6.1	36.0	15.0	30.5	24.1

*Application rate @5 t/ha of poultry manure, 10 t/ha for FYM and 5 t/ha for night soil method as per recommended schedule (Bharadwaj *et al*. 1975) and standard observations were recorded on yield and yield attributes.

Soil and plant analysis

Soil samples were collected from 0-15 cm depth at the start of the experiment in 1995 and at the end of 5th cropping cycle in 2001. These samples were analyzed for organic C by wet digestion using $K_2Cr_2O_7$ and concentrated H_2SO_4 (Walkley and Black, 1934) available (mineralizable) N by distilling with alkaline $KMnO_4$ and determining NH_3 trapped in boric acid as NH_4^+ (Subbiah and Asija 1956), available P by Olsen's method using 0.5 M $NaHCO_3$ (pH 8.5) extractant (Olsen *et al*., 1954) and exchangable K by extracting with 1N NH_4OAc (Jackson, 1958), available S by extracting with 0.15% $CaCl_2$ (Williams and Steinbergs, 1959) and DTPA extractable Zn, Mn and Cu (Lindsay and Norvell 1978).

Quality parameters of *durum* wheat *viz.* protein, yellow berry, hectoliter weight, sedimentation value and β-carotene content were estimated. Protein content was analyzed using INFRATEC 1255 Food and Feed analyzer, yellow berry content was recorded based on a sample of 500 grains, hectoliter weight was recorded using hectoliter meter, while sedimentation value and β-carotene were estimated using standard procedures suggested by Mishra and Gupta (1995). Soybean grains were analyzed for protein and oil content with the help of INFRATEC 1225 grain analyzer.

Data analysis

The data were analyzed individually for each year as well as pooled for all the years of experimentation as per the standard analysis of variance (ANOVA) technique using MSTAT-C software. Pooled analysis was done 2 years from 1999-2000 to 2001-2002 in case of wheat and 2000 to 2002 in case of soybean. The treatment comparisons were made using t-test at $P<0.05$ level of significance.

RESULTS AND DISCUSSION

Growth and yield of wheat

There was significant influence of various nutrient treatments on grain yield of wheat, dry matter and yield attributes (Table 2). Grain yield of wheat increased due to increase the level of inorganic NPK. The performance of sole application of both levels of night soil (NS) and FYM on grain yield was inferior to the recommended inorganic NPK. However, the reverse was true in case of poultry manure (PM). Wheat yield was further improved when 0.5 inorganic NPK was combined with PM. The response of 0.5 inorganic NPK + FYM or 0.5 inorganic NPK + NS was similar to recommended inorganic NPK fertilizer.

Growth and yield of soybean

Soybean did not show much response to residual effect of treatments in most years. Contrary to wheat, yield of soybean was higher under the residual

Table 2. Yield and yield attributes of *durum* wheat as influenced by different nutrient management practices

Treatment	Grain yield(t/ha)	Spikes/ m^2	Grains/ spike	1000-grain weight (g)	Harvest index	Dry-matter (g/m^2)
Control	2.67	243	29.85	28.45	0.485	540
0.5 RF : 60:30:15	4.05	290	43.62	26.14	0.480	914
1.0 RF :120:60:30	5.18	290	45.27	29.45	0.512	1046
NS @ 5 t/ha	3.39	208	38.67	28.06	0.445	666
NS @ 10 t/ha	3.66	200	46.3	28.69	0.451	656
PM @ 5 t/ha	5.52	234	48.60	30.22	0.491	1067
FYM @ 10 t /ha	3.31	220	38.80	28.07	0.446	676
0.5 RF+ NS @ 5 t/ha	4.90	248	45.57	29.33	0.472	1029
0.5 RF +FYM @ 10 t/ha	4.81	228	47.20	30.20	0.461	1055
0.5 RF+ PM @ 5 t/ha	6.07	267	52.87	29.27	0.479	1280
1.0 RF both to wheat and soybean	5.69	282	49.43	29.38	0.472	1193
CD (P=0.05)	0.428	32.0	6.253	0.889	0.029	145.9

effects of night soil or FYM as compared to PM. Significantly higher seed yield of soybean was recorded under the residual effect of either sole NS or sole FYM, or the combined use of NS or FYM with 0.5 inorganic NPK as compared to the residual effect under recommended NPK or 0.5 inorganic NPK combined with PM. Yields of soybean were inferior when grown under the residual effect of recommended NPK or integrated treatment using 0.5 recommended NPK+PM as compared to the direct application of recommended NPK for both wheat and soybean. Stover yield followed the similar trend as grain yield. No definite trend was observed in case of 1000- grain weight and pods per plant under different nutrient treatments (Table 3).

Quality parameters

Among organic sources, PM either sole or in combination with 50% inorganic NPK maintained higher protein contents of wheat compared with the NS or FYM. The lowest protein in wheat seed was recorded with night soil. In general, yellow berry content under organic treatments was higher than under inorganic NPK. Similar results are reported (Behera *et al*., 2007a). When organics was combined with inorganic NPK, the yellow berry content was drastically reduced as compared to organics alone. This was particularly evident with night soil and poultry manure (Table 4). Also, integrated use of organics and inorganics recorded higher protein content, β-carotene content and hectoliter weight as

Table 3. Yield and yield attributes of soybean as influenced by the residual effect of different nutrient management practices.

Treatments	Grain yield(t/ha)	Stover yield (t/ha)	Dry weight (g/ plant)	Grain weight (g)/10 plant	1000-grain weight (g)	Pods/ plant	Plant height(cm)
Control	1.254	1.624	16.48	58.75	84.9	37.68	35.99
0.5 RF : 60:30:15	1.282	1.720	18.70	61.75	79.5	38.62	44.06
1.0 RF :120:60:30	1.202	1.708	16.52	54.0	80.4	36.87	42.40
NS @ 5 t/ha	1.388	2.082	21.80	73.75	82.1	42.40	43.96
NS @ 10 t/ha	1.348	2.155	21.98	72.0	83.7	43.12	45.90
PM @ 5 t/ha	1.273	1.868	23.35	68.5	81.0	45.99	46.81
FYM @ 10 t /ha	1.398	2.094	22.0	74.2	82.4	42.60	45.0
0.5 RF+ NS @ 5 t/ha	1.415	2.122	22.45	71.0	80.3	42.46	44.68
0.5 RF +FYM @ 10 t/ha	1.379	1.999	24.02	80.5	81.2	42.34	45.31
0.5 RF+ PM @ 5 t/ha	1.073	2.036	26.82	89.75	79.7	41.40	49.24
1.0 RF both to wheat and soybean	1.409	2.182	22.90	79.5	80.4	38.21	51.49
CD (P=0.05)	0.182	0.220	4.44	9.34	7.30	3.215	4.33

Table 4. Grain quality parameters of *durum* wheat as influenced by different nutrient management practices.

Treatment	Protein(%)	Yellow Berry Content (%)	Sedimentation Value (ml)	β-carotene content(ppm)	Hectoliter weight(g)
Control	9.4	56.95	35.5	5.23	865
0.5 RF : 60:30:15	10.8	12.55	33.8	5.05	875
1.0 RF :120:60:30	11.7	12.25	33.8	5.02	870
NS @ 5 t/ha	9.2	52.75	33.5	4.95	853
NS @ 10 t/ha	9.2	48.65	33.0	4.78	868
PM @ 5 t/ha	10.6	42.85	30.3	4.85	864
FYM @ 10 t /ha	9.4	54.00	33.8	4.75	855
0.5 RF+ NS @ 5 t/ha	10.4	24.90	33.5	5.04	873
0.5 RF +FYM @ 10 t/ha	10.2	50.25	31.0	4.89	860
0.5 RF+ PM @ 5 t/ha	11.3	16.55	31.3	5.12	874
1.0 RF both to wheat and soybean	11.7	7.65	33.5	5.16	868
CD (P=0.05)	0.340	13.8	2.952	0.180	9.75

compared to the sole application of the organics. Highest sedimentation value was recorded under no fertilizer control followed by inorganic fertilizer treatments. Integrated use of 0.5 recommended NPK and PM 5 t/ha was at par with the recommended NPK alone regarding protein content, sedimentation value, β-carotene content, yellow berry content, and hectoliter weight.

Soil fertility status

Night soil either as sole or in the integrated form maintained the highest level of soil organic carbon. However, available P and K were highest in the poultry manure plots. Night soil maintained moderately higher level of available P and K. Micronutrients such as Cu, Zn, and Mn were also higher in poultry manure plots and these were at par with 100% recommended dose of inorganic NPK (Table 5). The lowest organic carbon, available P and K and micronutrients were recorded in control plot.

Effect of INM on yield attributes, yield and quality parameters of wheat and soybean

Highest grain and biomass yield of wheat was recorded under 50% recommended NPK with PM followed by 100% recommended NPK to both wheat and soybean. This was due to lowest C:N ratio of this organic source (11:1) and hence, ready release of nutrients. High residual fertility of P, K and Zn might be beneficial for high yield. Higher growth and yield attributes like dry weight, plant height and grain weight were also recorded with an integrated use of PM and inorganic NPK (Ghosh *et al.* 2003) as compared to inorganic alone. The benefits from recommended NPK to both wheat and soybean might be associated with the split application of N fertilizer coinciding critical growth stages of crops when full dose of nutrients was provided as inorganic fertilizers. In case of integrated nutrient treatments, organic matter in combination with the readily plant available inorganic fertilizer provided ideal condition for fast mineralization of nutrients as compared to the organic source alone (Henriksen and Breland, 1999). Further, increased soil micro-aggregates and enhanced water holding capacity of soil is expected from the organic component of the integrated treatments. Also, the root respiration, dehydrogenase and other microbial activities are reported to be higher in integrated nutrient treatments. Similar results with integrated use of inorganic and organics was reported by Ghosh *et al.* (2003); Singh *et al.* (2003); Rautaray *et al.* (2005), Behera *et al.* (2007a) and Behera *et al.* (2007b).

Higher seed and stover yield of soybean under the residual effects of integrated use of inorganic and organics was attributed to improvement in soil fertility status over sole application of inorganic fertilizer and control. This was due to the higher residual fertility under integrated nutrient treatments. In addition, the application of organic manures in combination with the inorganic fertilizers might have helped to increase the nodulation and hence activated the N fixation activities in soybean due to favourable soil condition leading to enhanced microbial activity. Several authors have reported that the nodulation activities will be higher with the addition of microbial fertilizers, P_2O_5 and micronutrients especially Mo, B and Co (Agbenin *et al.* (1990), Ouertatani *et al.*, (2011). The present study reveals residual effects of 50% recommended NPK

Table 5. Soil fertility parameters under different nutrient management practices.

Treatment	Organic C (%)	Olsen's P (kg/ha)	NH_4OAc-K (kg/ha)	DTPA extractable Cu (ppm)	DTPA extractable Zn (ppm)	DTPA extractable Mn (ppm)
Control	0.482	4.50	168.2	1.27	1.35	2.61
0.5 RF : 60:30:15	0.515	5.325	158.1	1.37	2.31	3.64
1.0 RF :120:60:30	0.535	5.475	178.2	1.43	2.45	5.18
NS @ 5 t/ha	0.508	12.287	175.6	1.35	1.96	3.32
NS @ 10 t/ha	0.624	10.15	193.2	1.34	1.83	3.67
PM @ 5 t/ha	0.533	15.10	203.5	1.52	2.97	4.78
FYM @ 10 t /ha	0.510	8.29	170	1.40	1.98	3.62
0.5 RF+ NS @ 5 t/ha	0.590	12.90	184.1	1.41	1.53	4.12
0.5 RF +FYM @ 10 t/ha	0.549	11.06	182.4	1.34	1.98	3.69
0.5 RF+ PM @ 5 t/ha	0.549	31.80	197.2	1.36	2.13	3.54
1.0 RF both to wheat and soybean	0.551	15.42	176.2	1.31	1.47	3.73
CD (P=0.05)	0.104	16.67	23.90	0.149	1.16	1.274

fertilizers along with farm yard manure, poultry manure or the night soil was important for improving the productivity of soybean as compared to the residual effect of 100% recommended NPK. Among the organic sources, lower yield of soybean under the residual effects of poultry manure based treatments might be due to the low available nitrogen in soil under this treatment as compared to high C:N ratio organic sources like FYM or night soil (Rautaray) 2003.

Effect of INM on soil fertility in wheat-soybean system

There was an improvement in organic C, $KMnO_4$-N, Olsen's P and DTPA extractable micronutrients compared with the initial status under the residual effect of combined use of NPK and organics, especially FYM and Poultry manure. This was due to the addition of organic matter, which contains major and micronutrients, besides organic C. Also, organic matters have solublizing effect on native nutrients (Manna *et al*. 2003). The highest root biomass produced under integrated treatments might be beneficial to improve soil fertility status. Organic manuring with poultry manure and FYM might be beneficial in retaining a major portion of the added P in plant available form by suppressing P sorption (Iyamuremye and Dick, 1996) and improving soil P fertility status (Reddy *et al.* 1999). Application of organics help to improve soil biological properties (Manna *et al.* 2003) due to the presence of easily water soluble carbon as source of energy for soil organisms (Manna and Ganguly, 1997).

Application of organic sources alone resulted in decreased yield in wheat. Providing the nutrient requirement through inorganic source alone to wheat crop, resulted in low yield of soybean and decreased soil health. Organic sources like poultry manure, FYM or night soil with 50% recommended dose of NPK to wheat was essential for improving productivity, grain quality, soil health and sustainability of wheat-soybean system. This practice will save in use of chemical fertilizer in agriculture.

REFERENCES

Agbenin, J.O., Lombin, G. and Owonubi, J.J. 1990. Effect of boron and nitrogen fertilization on cowpea nodulation, mineral nutrition and grain yield. *Nutrient Cycling in Agroecosystems* 22(2): 71-78.

Anonymous. 2004. Agricultural Statistics. Directorate of Agriculture, Madhya Pradesh, Bhopal, India.

Behera, U. K. 2005. Influence of varying levels of soil fertility on performance of *kharif* soybean (*Glycine max*) under wheat-soybean cropping system in the Vertisols of central India. *Annals of Agricultural Research* 26 (2): 263-266

Behera, U.K. and Sharma, A.R. 2004. Effect of tillage and crop establishment practices on performance of soybean. Annual Report. pp. 45. Indian Agric. Res. Inst., New Delhi.

Behera, U.K., Pradhan, S. and Sharma, A.R. 2007b. Effect of integrated nutrient management practices on productivity and quality of *durum* wheat in the Vertisols of central India. *Indian Journal of Agricultural Sciences* 77 (10): 35-38.

Behera, U.K, Sharma, A.R. and Pandey, H.N. 2007a. Sustaining productivity of wheat-soybean cropping system through integrated nutrient management practices on the Vertisols of central India. *Plant and Soil* 297:185-199

Bharadwaj, R.B.L., Wright, B.C., Gill, S.S., Jain, N.K., Sharma, K.C. and Krantz, B.A. 1975. The Agronomy of Dwarf Wheats, 94 p. Indian Council of Agricultural Research, New Delhi, India

Ghosh, P.K., Bandyopadhyay, K.K., Tripathi, A.K., Hati, K.M., Mandal, K.G. and Mishra, A.K. 2003. Effect of integrated nutrient management of farmyard manure, phospho-compost, poultry manure and inorganic fertilizers for rainfed sorghum in Vertisols of central India. *Indian Journal of Agronomy* 48 (1): 48-52.

Henriksen, T.M. and Breland, T.A. 1999. Nitrogen availability effects on carbon mineralization, fungal and bacterial growth, and enzyme activities during decomposition of wheat straw in soil. *Soil Biology and Biochemistry* 31(8): 1121-1134

Iyamuremye, F. and Dick, D. S. 1996. Organic amendments and phosphorus sorption by soil. *Advances in Agronomy* 56:139-185

Jacson, M.L. 1973. Soil Chemical Analysis. New Delhi, India: Prentice Hall of India. pp. 498.

Lindsay, W.L. and Norvell, W.A. 1978. Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of America Journal* 42: 421- 428.

Manna, M. C., and Ganuly, T. K. 1997. Soil biological activity and yield of crops influenced by compost and inorganic fertilizers under a cereal-legume system in a Typic Haplustert. Journal of Soil, Biology and Ecology 17 (2):88-94

Manna, M.C., Ghosh, P.K. and Ganguly, T.K. 2003. Comparative performance of four sources of enriched phospho-compost and inorganic fertilizer application on yield, uptake of nutrients and biological activity of soil under soybean-wheat rotation. *Food, Agriculture and Environment* 1(2): 203-208.

Mishra, B.K. and Gupta, R.K. 1995. Protocols for evaluation of wheat quality. Technical bulletin No. 3. 98 p. Directorate of wheat Research, Karnal, India.

Nagarajan, S. and Singh, Ghanasyam. 1998. Sustaining wheat (*Triticum aestivum*) revolution- restospect and prospect. *Indian Journal of Agricultural Sciences* 68: 396-404.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. US Department of Agriculture, Washington, DC. Circ. 939.

Ouertatani, S., Regaya, K, Ryan, J. and Gharbi, A. 2011. Soil liming and mineral fertilization for root nodulation and growth of faba beans in an acid soil in Tunisia. *Journal of Plant Nutrition* 34 (6): 850-860.

Pandey, H.N., Thakur, R.S., Bhawsar, R.C., Ruwali, K.N., Mishra, A.N., Verma, P.K., Behera, U.K. and Singh, R.B. 2000. Role of durum wheat cultivation in Indian wheat economy. *Indian Farming* 50(8): 14-16.

Rattan, R.K., Saharan, N. and Datta, S.P. 1999. Micronutrient depletion in Indian soils. *Fertilizer News* 44(2): 35-50.

Rautaray, S.K. and Swain, D.K. 2003. Direct and residual effect of fertilization sources and time of application on equivalent yield of rice-potato cropping sequence and soil properties. *Indian Journal of Hill Farming* 16 (1&2): 56-60.

Rautaray, S.K. 2005. Nutrient dynamics, dehydrogenase activity, and response of the rice plant to fertilization sources in an acid lateritic soil. *Acta Agriculturae Scandinavica .Plant soil sciences* 55 (3): 162-169.

Reddy, D D., Subba Rao, A., Reddy Sammi, K, and Takkar, P N. 1999. Yield sustainability and phosphorus utilization in soybean-wheat system on Vertisols in response ot integrated use of manure and fertilizer phosphorus. *Field Crops Res* 62: 181-190.

Subba, Rao, A., Singh, Muneswar, Reddy, D.D., Saha, J.K., Manna, M.C. and Singh, M.V. 1998. Integrated plant nutrient supply system to improve and sustain the productivity of soybean-wheat cropping system on Typic Haplusterts. Bulletin of Indian Institute of Soil Science No. 2, pp. 78-91.

Singh, A.B., Ghosh, P.K. and Ajay. 2003. Effect of integrated nutrient management practices on improvement in grain quality of soybean (*Glycine max*), sorghum (S*orghum bicolor*) and wheat (*Triticumn aestivum*) in multiple cropping systems in vertisol. *Indian Journal of Agricultural Sciences* 73(2): 65-8.

Singh, R.P., Das, S.K., Rao, U.M.B. and Reddy, M.N. 1990. Towards sustainable dryland agricultural practices. Bulletin, Central Research Institute for Dryland Agriculture, Hyderabad, pp. 5-9.

Subbiah, B.V. and Asija, G. L. 1956. A rapid procedure for determination of available nitrogen in soils. *Current Science* 25: 259-260.

Walkley, A. and Black, C. A. 1934. An examination of the Degtjareff method for determination of organic matter and a proposed modification of the chromic acid titration method. *Soil Science* 37: 29-38.

Williams, C.M. and Steinbergs, A. 1959. Soil sulphur fractions as chemical indices of available sulphure in some Australian soils. *Australian Journal of Agricultural Research* 10: 340-352.

Journal of Soil and Water Conservation **12**(1): 66-69, January-March 2013
ISSN: 022-457X

Status of micronutrient in rice based cropping cone of Madhya Pradesh

SOM RAJ[1], BRIJESH YADAV[2] and G.D. SHARMA[3]

Received: 15 July 2012; Accepted: 13 January 2013

ABSTRACT

Four hundred soil samples representing rice based cropping zone from Balaghat and Mandla districts of Madhya Pradesh using GPS were collected during 2009-10. Results showed that the available zinc(Zn), copper (Cu), iron (Fe)and manganese (Mn) varied from 0.06 to 3.24, 0.09 to 11.2 , 7.5 to 94.9 and 4.0 to 45.6 mg kg^{-}mg kg^{-1} respectively in Mandla and from ^{1}0.06 to 6.08, 0.75 to 22. 67, 4.0 to 62.5 and 5.1 to 64.9 in Balaghat districts. None of the soil sample was classified as deficient in available Cu, Mn and Fe content in both the districts whereas, Zn deficiency in soils was observed in 46.5 % in case of Balaghat and 31.0 % samples in Mandla districts. Correlation studies showed that the available iron and manganese were significantly and negatively correlated with pH (r=-0.407**and =-0.338**), in mixed red and black soils of Balaghat district. Negative and significant relationship was observed between Fe and Mn content with $CaCO_3$ content of the soil. The value of correlation coefficient between organic carbon and available micronutrients (Zn, Cu and Mn) in mixed red and black soils of Balaghat district were found to be positive and statistically significant, Zn (r=0.3538**), Cu (r=0.4045**), Mn (r=0.2372**).

Key words: DTPA - extractable micronutrients cations, soil properties, GPS, rice based cropping zone

INTRODUCTION

The word micronutrient represents some essential plant nutrients that are required in very small quantities for the growth, development and reproduction of plant as primary nutrients. Green revolution has significantly increased the food crop production in India, accomplished through growing of high yielding varieties & use of high analysis NPK fertilizers. Indiscriminate use of high analysis chemical fertilizers results in the deficiency of micronutrients in soils (Singh 2007). Variability in micronutrient contents of the soils is a mirror of the diversity in parent materials from which these have originated (Rattan *et al.* 2008).

Global-positioning system is the tool of such frontier technology which, would help in generation of agricultural management system and formulating plans for sustainable agricultural development. The geo- referenced sampling sites can be revisited with the help of GPS, which helps in monitoring the changes in the status of micronutrients over a period of time, which otherwise is not possible by traditional methods of sampling. The fertilizer recommendation for a crop in particular region may sharply differ from that in a different region for the same crop. Therefore, evaluation of critical limits of available micronutrients in soil for some important crops of Balaghat and Mandla districts of Madhya Pradesh is being needed and knowledge about status of micronutrients in soils of these districts will be helpful for preparing balanced fertilizer schedule and understanding the inherent capability of soil to supply micronutrients to the crops. Such information in rice based cropping zone soils of Madhya Pradesh is very meager.

[1] Department of Soil Science and Agricultural Chemistry, JNKVV, Jabalpur (M.P) 482004
[2]Division of Agricultural Physics, IARI, New Delhi-110012
[3]Corresponding author: Division of Agricultural Physics, IARI, New Delhi-110012; brijeshyadav571983@gmail.com

MATERIALS AND METHODS

The study area is spread between latitudes – 22^0 02' 16''.884 N to 23^0 08' 14''.676 N and longitude- 80^0 07' 45''.522 E to 80^0 58' 34''.200 E in Mandla district and latitudes – 21^0 34' 56''.776N to 22^0 11' 00''.396 N and longitudes- 79^0 47' 31''.254E to 80^0 32' 34''.224E in Balaghat district of Madhya Pradesh. Surface (0-15 cm) soil samples were collected from 200 sites in each district and locations of sampling sites were decided using global positioning system (GPS). Soil samples were analyzed for DTPA extractable micronutrients viz., Zn, Cu, Fe and Mn using atomic absorption spectrophotometer and also other soil properties analyzed viz., pH, EC, $CaCO_3$ and organic carbon. Soil pH in 1:2 soil suspension, was determined using pH meter. Electrical conductivity was determined in 1:2 soils: water supernatant solution with the help of conductivity-bridge, organic carbon was determined by Walkley and Black's rapid titration method and calcium carbonate content was carried out by the rapid titration method as described by Jackson (1965). The nutrient index (NI) values for available nutrients present in the soils were calculated utilizing the formula and given suggested by Parker *et al.* (1951) as below and classified this index as low (<1.67), medium (1.67 to 2.33) and high (>2.33).

$$NI= [(Nl \times 1) + (Nm \times 2) + (Nh \times 3)] / Nt,$$

Where, N1, Nm and Nh are the number of soil samples falling in low, medium and high categories for nutrient status. Nt is the total number of soil samples.

RESULTS AND DISCUSSION

Results of present study on soil properties and micronutrient are presented in (Table 1) and related that the soil pH varied from 4.4 to 7.9 with mean value of 6.0 in Balaghat district and from 4.8 to 7.8 with mean value of 6.50 in Mandla district. Thus, the soil samples of Balaghat district were found to be slightly acidic than Mandla district. Electrical conductivity ranged from 0.11 to 0.66 with mean value of 0.17 dS m^{-1}, and 0.13 to 0.50 with mean value of 0.20 dS m^{-1} in Balaghat and Mandla districts, respectively. Soils of both districts were found to be low in soluble salts. Organic carbon content in soils was found to vary from 2.62 to 15.10 g kg^{-1} with mean value of 6.8 g ka^{-1} in Balaghat and 2.7 to 15.5 g kg^{-1} with mean value of 6.7 g kg^{-1} in Mandla district. Calcium carbonate ($CaCO_3$) content varied from 5.0 to 47.5 g kg^{-1} with mean value of 21.0 g kg^{-1} and from 2.5 to 53.5 with mean value 19.5 g kg^{-1}, in Balaghat and Mandla districts, respectively. It indicates that the soil of rice based cropping zone of Balaghat and Mandla districts were medium in organic carbon content and non calcareous in respect of $CaCO_3$ content.

The available Zn content varied from 0.06 to 3.24 mg kg^{-1} with mean value of 0.69 mg kg^{-1} in Balaghat district and from 0.06 to 6.08 mg kg^{-1} with mean value of 1.23 mg kg^{-1} in Mandla district. Considering 0.6 mg kg^{-1} Zn as critical limit (Lindsay and Norvell, 1978), 46.5 % of the soils in mixed red and black soils of Balaghat district and 31% in Skeletal soil of

Table 1. Distribution of physio-chemical properties and available micronutrients in soils of Balaghat and Mandla districts

District and thesils	pH	EC (dS m^{-1})	$CaCO_3$ (g kg^{-1})	O.C. (g kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})	Fe (mg kg^{-1})
District Balaghat								
Lalbarra	4.4-7.2	0.11-0.44	5.0-45.5	3.40-15.10	0.48-2.35	0.76-7.49	7.9-41.15	17.0-69.0
Waraseoni	4.7-7.9	0.13-0.66	5.0-40.5	2.70-10.30	0.06-2.04	0.09-4.37	4.0-41.7	7.5-68.3
Kirnapur	4.8-6.2	0.12-0.66	5.0-45.5	3.40-13.7	0.23-1.87	1.77-11.20	3.9-40.9	8.2-63.6
Lanji	4.8-6.8	0.12-0.29	10.0-37.0	3.30-10.30	0.18-1.14	1.09-4.16	12.2-40.6	8.5-66.9
Baihar	4.7-6.5	0.11-0.46	10.5-42.5	3.60-9.50	0.23-3.24	0.68-10.50	5.5-45.5	17.1-65.0
Balaghat	5.2-6.8	0.12-0.23	7.5-47.5	2.62-10.40	0.16-1.08	2.02-9.60	6.6-43.4	15.0-94.9
Khairlanji	5.3-7.0	0.11-0.20	7.5-45.0	3.40-11.10	0.15-1.29	1.64-5.02	7.6-41.2	5.8-67.6
Katangi	5.3-7.0	0.13-0.23	7.5-45.5	4.00-8.90	0.08-1.75	1.42-3.79	12.5-42.7	16.5-65.0
District Mandla								
Niwas	5.4-7.3	0.13-0.45	2.5-35.6	3.9-15.5	0.25-3.48	2.12-19.64	5.1-60.0	11.5-62.5
Mandla	4.9-7.6	0.14-0.34	5.0-52.5	3.4-11.8	0.06-3.43	0.75-22.67	5.1-64.9	6.3-56.5
Bichhiya	5.2-7.8	0.14-0.37	5.0-53.5	2.7-13.3	0.50-6.08	2.68-16.35	7.3-61.8	9.8-56.5
Nainpur	4.8-7.7	0.20-0.50	5.0-52.2	3.0-13.3	0.25-2.43	2.32-18.45	7.6-61.7	4.0-56.2

Mandla district were found to be deficient in available Zinc. Available Cu, Fe and Mn in the soil samples varied from 0.09 to 11. 20, 5.8 to 94.9 and 4.0 to 45.5 mg kg^{-1} with mean values of 3.54, 50.1 and 29.20 mg kg^{-1} in Balaghat and from 0.74 to 22.67, 4.0 to 62.5 and 5.1 to 64.9 mg kg^{-1} with mean values of 8.60, 41.8 and 52.40 mg kg^{-1} in Mandla districts, respectively. Considering 0.2 mg kg^{-1} for Cu and 4.5 mg kg^{-1} for Fe and 1.0 mg kg^{-1} for Mn as critical limits suggested by (Lindsay and Norvell 1978). None of the samples were low in Cu, Fe and Mn . Very little information is available aswith regards to the micronutrients status, particularly in mixed red and black soils of Balaghat and Skeletal soils of Mandla districts of Madhya Pradesh. (Similar work has been reported by Dhane and Shukla (1995), Sharma *et al*. (2003), Dwivedi *et al*. (2005) and Mehra *et al*. (2005) in different soil types). It was observed from the data presented in (Table 2) that in Balaghat district 46.5, 7.5 and 46.0 percent samples were found in low, medium and high category, respectively. As regards copper content in soil, 0.5, 0.5 & 99.0 percent samples were found to be in low, medium and high category, respectively. In respect of iron content 2.0 and 98.0 percent samples were found to be in low and high category. As regards the manganese content in soil, 0.5 and 99.5 percent samples fall in low and high category. Considering soil nutrient index (Table 2) soils of Balaghat district were found of high status in respect of Cu, Fe and Mn while of low fertility status in case of Zn. The values worked out from nutrient index for Zn, Cu, Fe and Mn, were 1.61, 2.99 2.98 and 3.00 respectively. Against the nutrient index value <1.67 for low, 1.67 to 2.33 for medium and > 2.33 for high status. In Mandla district 31.0, 25.0 and 44.0 percent samples were found to fall in low, medium and high category, respectively in respect of Zn content whereas 100.0 percent samples were found to be high in copper and manganese content. As regards the iron content 1.5 and 98.5 percent samples were found as medium and high category, respectively. Considering soil nutrient index, soils of Mandla district were found of high fertility status for Cu, Fe, and Mn while of medium fertility status with respect to Zn. The values worked out from nutrient index for Zn, Cu, Fe and Mn, were 2.13, 3.00, 3.00, 3.00 respectively, against the nutrient index value <1.67 for low, 1.67 to 2.33 for medium and > 2.33 for high status.

Rice grain was content nutrients like, zinc, copper, iron and manganese ranged from 10.0 to 16.6, 2.0 to 3.9, 30.3 to 88.2, 23.6 to 75.6 mg kg^{-1} with mean value 12.9, 2.7, 49.8, 41.2 mg kg^{-1} respectively and rice straw was content zinc, copper, iron and manganese ranged from 18.1 to 28.4, 3.1 to 7.3, 67.1 to 194.4, 88.9 to 218.0 mg kg^{-1} with mean value were 23.9 4.7,124.8,155.6, mg kg^{-1} respectively, in Balaghat district and in respect of Mandla district, rice grain was content zinc, copper, iron and manganese ranged from 9.28 to 16.6, 2.3 to 5.5, 39.6 to 118.9, 22.4 to 91.4 mg kg^{-1} with mean value 13.4, 3.4,72.1, 52.6 mg kg^{-1} respectively, and rice straw was content ranged from 18.4 to 27.8 , 3.0 to 8.1 , 65.8 to 208.3, 67.9 to 252.2 mg kg^{-1} with mean value 23.0, 5.0, 143.8, 157.1 mg kg^{-} in, respectively. The value of correlation coefficient between the soil manganese and rice straw was found to be statistically significant in skeletal soils of Mandla district (Table 3). Similar relationships have also been reported by Rathore *et al.* (1995) and Kumar *et al.* (2012).

CONCLUSIONS

The data reported in this paper show on an average the soils of Balaghat district are slightly acidic whereas in Mandla district are found nearly neutral in soil reaction, safe in EC. Organic carbon are medium and calcareous to non calcareous in nature. Available Zn, Cu, and Mn content in soil of Balaghat district exhibited a significant and positive

Table 2. Categorization of soils in low, medium and high categories of nutrients

	District Balaghat					District Mandla				
Nutrients (mg kg^{-1})	Percent samples under various classes of nutrients			Nutrient index	Nutrient index class	Percent samples under various classes of nutrients			Nutrient index	Nutrient index class
	Low	Medium	High			Low	Medium	High		
Zinc	46.5	7.5	46.0	1.61	Low	31.0	25	44	2.13	Medium
Copper	0.5	0.5	99.0	2.99	High	-	-	100	3.00	High
Iron	2.0	-	98.0	2.98	High	-	1.5	98.5	3.00	High
Manganese	0.5	-	99.5	3.00	High	-	-	100	3.00	High

Table 3. Concentration of micronutrients in grain and straw of rice in Balaghat and Mandla districts

District & Tehsils	Zn(mg kg^{-1})		Cu (mg kg^{-1})		Fe(mg kg^{-1})		Mn(mg kg^{-1})	
	grain	straw	grain	straw	grain	straw	grain	straw
District Balaghat								
Lalbarra	10.3-16.3	18.1-28.4	2.4-3.6	3.1-6.1	33.1-80.2	87.0-194.4	23.7-74.6	95.2-218.0
Waraseoni	11.2-16.6	19.2-28.2	2.2-2.9	3.5-5.0	30.9-66.3	82.3-136.5	23.6-41.3	88.9-173.4
Kirnapur	10.0-15.8	19.8-26.8	2.0-3.6	3.6-5.9	36.1-77.5	75.8-163.0	25.1-52.2	91.7-192.0
Lanji	10.1-13.2	19.6-27.6	2.2-3.8	3.4-5.1	30.5-58.2	67.1-184.5	28.2-52.0	98.0-205.0
Baihar	10.6-14.6	23.3-27.8	2.3-3.9	3.5-7.1	36.9-88.2	97.4-180.6	25.6-74.8	98.2-215.1
Balaghat	12.3-14.9	21.3-27.2	2.1-3.0	3.3-7.3	30.3-43.6	89.6-170.8	24.6-72.7	161.8-215.3
Khairlanji	12.2-16.3	24.2-28.0	2.1-2.9	4.4-6.9	35.8-66.3	110.2-191.9	26.7-55.3	115.3-206.0
Katangi	11.9-14.3	23.7-26.8	2.9-3.0	5.3-6.0	35.7-48.2	77.0-112.8	38.5-75.6	89.3-198.2
District Mandla								
Niwas	11.0-15.7	19.0-27.8	2.8-5.5	3.1-8.1	44.8-118.9	90.6-206.1	37.8-68.9	75.0-150.1
Mandla	10.8-16.6	18.4-26.9	2.3-5.1	3.0-7.5	39.6-108.9	65.8-208.0	26.6-91.4	67.9-252.2
Bichhiya	9.28-14.6	13.4-26.9	2.5-5.1	3.0-6.5	39.9-111.9	67.8-202.0	23.6-84.4	68.9-241.2
Nainpur	10.8-16.4	19.2-26.5	2.3-5.0	3.0-7.3	45.8-98.7	81.2-208.3	22.4-75.5	101.5-250.2

correlation with organic carbon. Only available Cu content correlated significantly and positively with organic carbon in soils of Mandla district. These soils are deficient in available zinc and show high fertility status in respect to available Cu, Mn and Fe (Table 4). Thus, it can be concluded that the chemical properties like pH, EC, organic carbon and calcium carbonate content alone or in combination controls the avaibility of nutrients in the soils.

Table 4. Correlation coefficient (r) between available micronutrients and soil characteristics

Soil Charac-teristics	Correlation coefficient (r)			
District Balaghat				
	Zn	Cu	Fe	Mn
pH	0.0026	-0.0299	-0.4070**	-0.3380
EC	0.3538**	0.4054**	0.1816	0.2372*
O.C.	0.3538**	0.4045**	0.1816	0.2372*
$CaCO_3$	-0.0380	-0.0133	-0.3460**	-0.3120**
District Mandla				
pH	0.0026	-0.0889	- 0.0096	0.0598
EC	-0.0306	0.2565**	0.0043	-0.0039
O.C.	-0.0306	0.2565**	0.0043	-0.0039
$CaCO_3$	0.1314	-0.0491	-0.0395	0.0130

REFERENCES

Dhane S S and Shukla L M. 1995. Distribution of DTPA-extractable Zn , Cu, Fe and Mn in some soil series of Maharashtra and their relationship with some soil properties. *Journal of the Indian Society of Soil Science*, 43 (4): 597-600.

Dwivedi S K, Sharma V K and Vipin Bhardwas .2005.Status of available nutrients in soils of cold arid region of Ladakh. *Journal of the Indian Society of Soil Science*, 53 (3): 421-423.

Jackson M. L. 1965. Soil chemical analysis *Prentice Hall Inc.* Englewood Cliffs, *New Jersey*.

Kumar Anil, Singh, Manibhushan , Meena M K and Upadhyaya, Ashutosh. 2012. Effect of sulphur and zinc on rice performance and nutrient dynamics in plants and soil of Indo Gangetic Plains, *Journal of Agricultural Science* 4, 11.

Lindsay W L and Norvell WA. 1978. Development of DTPA soil test for Zinc, Iron, Manganese and Copper. *Soil Science Society* of America *Journal*, 42: 421-428.

Mehra R K, Manoj Kumar, Sharma, Jat J R and Dadheech R C.2005. Critical limits of Zinc and Iron in soil and plants for Maize in Haplustalfs of sub-humid southern plain and Aravalli hills of Rajasthan. *Journal of the Indian Society of Soil Science* , 53 (2): 227-231.

Parkar F W, Nelson WL, Winter Eric and Miller I E. 1951. The broad interpretation of soil test informations. *Journal of Agronomy*, 43:105-112.

Rathore G S, Khamparia R S, Gupta G P, Dubey S B, Sharma B L and Tomar V S. 1995. Twenty five years of micronutrients research in soil and crops of Madhya Pradesh, 45.

Rattan R K , Datta, S P and Katyal, JC. 2008. Micronutrient management, research achievements and future challenges. *Indian Journal of Fertilizers,* 4 (12): 103 – 118.

Sharma R P , Megh Singh and Sharma J P. 2003. Correlation studies on micronutrient Vis- à- Vis soil properties in some soils of Nagaur in semi arid region of Rajasthan. *Journal of the Indian Society of Soil Science*, 54 (2): 401-405.

Singh M V. 2007. Problems of micro and secondary nutrients in acid soils of India and their management. *Bulletin of the Indian Society of Soil Science* 25, 27 – 58.

Journal of Soil and Water Conservation **12**(1): 70-79, January-March 2013
ISSN: 022-457X

Diagnosis and Recommendation Integrated System (DRIS): Concepts and applications on nutritional diagnosis of plants – A review

DEBARATI BHADURI [1] and SHARMISTHA PAL[2]

Received: 30 August 2012; Accepted: 13 January 2013

ABSTRACT

Plant analysis has been considered a very promising tool to assess nutritional requirements of plants for cost effective and environment friendly agriculture. The DRIS is based on the comparison of crop nutrient ratios with optimum values from a high yielding group (DRIS norms). The DRIS provides a means of simultaneous identifying imbalances, deficiencies and excesses in crop nutrients and ranking them in order of importance. The major advantage of this approach lies in its ability to minimize the effect of tissue age on diagnosis, thus enabling one to sample over a wider range of tissue age than permissible under the conventional critical value approach. This paper reviews the research on various critical aspects of the use of plant analysis and hence suitability of DRIS as a diagnostic tool for nutrition management of several agricultural and horticultural crops.

Key words: plant nutrient concentration, DRIS method, norms, indices

INTRODUCTION

Plant analysis has been considered a very practical approach for diagnosing nutritional disorders and formulating fertilizer recommendations (Kelling *et al.* 2000). Plant analysis, in conjunction with soil testing, becomes a highly useful tool not only in diagnosing the nutritional status but also an aid in management decisions for improving the crop nutrition. Plant analysis is the quantitative analysis of the total nutrient content in a plant tissue, based on the principle that the amount of a nutrient in diagnostic plant parts indicates the soil's ability to supply that nutrient and is directly related to the available nutrient status in the soil (Havlin *et al.* 2004, Rashid 2005).

Approaches to diagnose leaf nutrient status over last few decades include the Critical Value Approach (CVA) (Bates 1971), the Diagnosis and Recommendation Integrated System (DRIS) (Walworth and Sumner 1987), and Compositional Nutrient Diagnosis (CND) (Parent and Dafir 1992, Parent *et al*. 1994).

The Diagnosis and Recommendation Integrated System (DRIS) is a method to evaluate plant nutritional status that uses a comparison of the leaf tissue nutrient concentration ratios (norms) of nutrient pairs with norms from a high-yielding group (Soltanpour *et al.* 1995). DRIS is a perfect combination of soil test and plant analysis. It identifies all the nutritional factors that retard optimum crop production. Nutrient concentration changes with the physiological growth stage of plant and varies in different plant parts. Here the results of plant analysis are compared with critical nutrient concentration. The first step to implement DRIS or any other foliar diagnostic system is the establishment of standard values or norms (Walworth and Sumner 1987, Bailey *et al.* 1997). In order to establish the DRIS norms, it is obligatory to use a representative value of leaf nutrient concentrations and respective yields to obtain accurate estimates of means and variances of certain nutrient ratios that discriminate between high- and low-yielding groups. This is done using a survey

[1] Directorate of Groundnut Research, Junagadh-362001, Gujarat
[2] Central Soil and Water Conservation Research and Training Institute, Research Centre, Madhya Marg, Chandigarh 160 019, India
[3]Corresponding author, E-mail: sharmistha.ars@gmail.com, sharmistha_ssac@yahoo.co.in

approach in which yield and nutrient concentration data are collected from commercial crops and / or field experiments from a large number of locations (Bailey *et al.* 1997) to form a databank.

Pair of nutrient ratios is calculated from the data bank of nutrient concentrations and then, the mean, the variance and the coefficient of variation of each ratio are calculated. There are two forms of expression for a pair of nutrients, although in DRIS calculations only one form is used. The way to select the form of ratio for a pair of nutrients to be used in DRIS calculation is described by Walworth and Sumner (1987) and Hartz *et al.* (1998). After the establishment of the DRIS norms, the formula was first proposed by Beaufils (1973).

Assessment of plant nutrition

One of the main aims of plant mineral nutrition is increasing net incomes through efficient fertilization management. To attain this goal, determination of the yield-limiting impact of a given nutrient correctly is necessary at initial stage. The search for an effective method to determine plant nutritional status has been the target of many researchers in plant nutrition. Current methods include both soil and tissues analysis. The soil analysis method is based on the assumption that the chemical extractants simulate the root system acquisition of soil nutrients in a comparable manner. However, it does not take into account factors such as soil temperature and aeration, and even the higher or lower absorption rate due to the plants' own nutritional demands. Another soil analysis limitation is soil sampling, which is supposed to actually represent the soil portion explored by the roots (Reuther and Smith 1954).

Tissue analysis is considered as a more direct method of plant nutritional evaluation than soil analysis, but that method must necessarily involve a precise analysis of plant parts (Hallmark and Beverly 1991). Among the several tissues to be considered for nutritional diagnosis purposes, leaves constitute the main sampling material (Chapman and Brown 1950). The improvement in tissue analysis techniques enabled the comparison of results from different soil type fertilization experiments. In the same way, it allowed the evaluation of fruit crop plants' response to treatments in nutrient solution experiments (Reuther *et al.* 1958). Leaf analysis can be a very suitable tool for plant nutritional diagnosis, since adequate procedures are already available. But the dynamic nature of the leaf tissue composition, strongly influenced by leaf age, maturation stage, and the interactions involving nutrient absorption and translocation, the tissue diagnosis may be a practice of difficult understanding and utilization (Walworth and Sumner 1987) no doubt. But, several methods for nutritional diagnosis using leaf tissue analysis have been proposed and used from last few decades, including the critical value (CV), sufficiency range approach (SRA), and diagnosis and recommendation integrated system (DRIS). Considering that DRIS uses the nutritional balancing concept (encompassing relationship among nutrients), it is postulated that this method proved to be more precise than the others in the detection of nutritional deficiencies or / and excesses.

Conceptual background

The traditional methods for leaf chemical analyses interpretation presume the nutrient concentration comparison with reference values. Nutrient concentrations far below or above reference values are associated with decreasing vegetative growth, yield and quality. These methods intended to evaluate deficiency or excess values, without measuring the overall nutritional balance. Moreover, researches related to this subject indicate a great difficulty in establishing consistent critical values and relate them with high yields, due to the nutritional status varies with leaf tissue maturation. A new interpretation for leaf analysis was firstly developed and proposed by Beaufils (1957, 1971, 1973) for rubber trees (*Hevea brasiliensis*), named as diagnosis and recommendation integrated system (DRIS). The DRIS method uses nutrient ratios instead of absolute and / or individual nutrient concentrations for interpretation of tissue analysis. Soon after the initial proposed DRIS norms for leaf analysis interpretation were released, further ones were developed for other agricultural, forest and horticultural crops. In countries such as United States, Canada, and China, DRIS is being adopted as part of a representative diagnosis in selected areas (Lopes 1998, Hallmark and Beverly 1991, Walworth and Sumner 1987).

Beaufils (1973) calculated an index for each nutrient that range from negative to positive values. All nutrient indices always sum to zero (Elwali and Gascho 1984). Essentially, a nutrient index is a mean of the deviations from the optimum or norms values (Bailey *et al.* 1997). Negative DRIS index values indicate that the nutrient level is below optimum, consequently the more negative index, the more deficient the nutrient. Similarly, a positive DRIS index indicates that the nutrient level is above the optimum, and the more positive the index, the more excessive the nutrient is relative to normal, and DRIS index equal to zero indicates that the nutrient is at the optimum level (Baldock and Schulte 1996). The DRIS also computes an overall index, which is the sum of the absolute values of the nutrient indices (Baldock and Schulte 1996), called nutrient balance index (NBI) (Rathfon and Burger 1991). The smaller the absolute sum of all DRIS indices, the lesser the imbalance among nutrients (Snyder and Kretschmer 1987). Although Beaufils (1973) suggests that every parameter which shows a significant difference of variance ratio between the two groups under comparison (low- and high-yielding) should be used in DRIS, other researchers have adopted the ratio which maximized the variance ratio between the low- and high-yielding group (Snyder *et al.* 1989, Payne *et al.* 1990, Malavolta *et al.* 1997, Hartz *et al.* 1998). The aim of this procedure is to determine the norms with the greatest predictive precision (Caldwell *et al.* 1994). The discrimination between nutritionally healthy and unhealthy plants is maximized when the ratio of variances of low- vs. high-yielding groups is also maximized (Walworth *et al.* 1986).

DRIS uses the binary relationships among the nutrients making it different from the traditional methods of diagnosis (Costa 1999). The calculation of DRIS indices depends, initially, on the establishment of reference norms. Therefore, it is necessary to select a population of high productivity (reference population), from the premise that there is a significant relationship between the supply of nutrients and its concentrations in the plant, so that increases and decreases in the fluxes and concentrations of nutrients provide variation in the production.

The DRIS method: Theoretical basis

The DRIS is based on the comparison of crop nutrient ratios with optimum values from a high yielding group (DRIS norms). The DRIS provides a means of simultaneous identifying imbalances, deficiencies and excesses in crop nutrients and ranking them in order of importance. The major advantage of this approach lies in its ability to minimize the effect of tissue age on diagnosis, thus enabling one to sample over a wider range of tissue age than permissible under the conventional critical value approach.

The DRIS method expresses results of plant nutritional diagnosis through indices, which represent, in a continuous numeric scale, the effect of each nutrient in the nutritional balance of the plant. These indices are expressed by positive or negative values, which indicate that the referred nutrient is in an excess or deficiency, respectively. The closer to zero are the indices for all the nutrients, the closer will be the plant to the adequate nutritional balance (Beverly 1991, Walworth and Sumner, 1987). The working premises for DRIS are based on: (a) the ratios among nutrients are frequently better indicators of nutrient deficiencies than isolated concentrations values; (b) some nutrient ratios are more important or significant than others; (c) maximum yields are only reached when important nutrient ratios are near the ideal or optimum values, which are obtained from high yielding-selected populations; (d) as a consequence of the stated in (c), the variance of an important nutrient ratio is smaller in a high yielding (reference population) than in a low yielding population, and to the relations between variances of high and low yielding populations can be used in the selection of significant nutrient ratios; (e) the DRIS indices can be calculated individually, for each nutrient, using the average nutrient ratio deviation obtained from the comparison with the optimum value of a given nutrient ratio, hence, as pointed by Jones (1981), Walworth and Sumner (1987), the ideal value of the DRIS index for each nutrient should be zero. In general, the DRIS has some advantages over other diagnosis methods: presents continuous scale and easy interpretation; allows nutrient classification (from the most deficient up to the most excessive); can detect cases of yield limiting due to nutrient unbalance, even when none of the nutrients is below the critical level; and finally, allows to diagnose the total plant nutritional balance, through an unbalance index (Baldock and Schulte, 1996).

Establishment of DRIS norms

The first step for the implementation of any nutritional diagnosis method is the establishment of standards or norms, and the same applies for the DRIS method. The following survey type approach is first employed in accumulating the basic data based on which DRIS norms are determined: (a) decide the area for which DRIS norms are to be developed (e.g. region, district, state) (b) a large number of sites where crop is growing are selected at random in order to represent the whole production area (c) at each site, plant and soil samples are taken for all essential element analyses (d) other parameters likely to be related directly or indirectly to yields are also recorded (e) entire population of observation is divided into two subpopulation (high and low yielders) on the basis of vigour, quality and yields (f) each element in the plant is expressed in as many ways as possible (g) mean of each type of expression for each subpopulation is calculated (h) each form of expression which significantly discriminates between the high and low yielding subpopulation is retained as a useful diagnostic parameter (i) the mean values for each of these forms of expression (diagnostic parameters) of high yielding group constitutes the diagnostic norm. The chosen population or database for norms definition should be subdivided in two sub-populations or categories (Beaufils 1973, Meldal-Johnsen and Sumner 1980, Walworth and Sumner, 1987). These subpopulations are the following: a) Non-abnormal plants, or reference population, that are not influenced by adverse conditions and present yield significantly higher than an arbitrarily established level; b) Abnormal plants, or non-reference population, influenced by other factors, with lower yields than the established. DRIS norms are originated after the reference population definition, in other words, the relation between all the nutrients pairs and their respective standard deviations or coefficients of variation are obtained. The ratio between a pair of nutrients can be direct or inverse. The concentrations of nitrogen and phosphorus, for instance, can be related either as N / P or P / N ratio.

DRIS norms

- Decide the area for which DRIS is to be developed.
- Decide the no. of representative samples.
- Collect paired soil and plant samples randomly
- Collect other relevant information having impact on yield i.e. yield data, cultural practices, dose of fertilizers and pesticides etc.
- Analyze the plants and soils for 17 essential elements
- Express the contents of these elements in plants in as many ways as possible.
- Divide the entire population into high yielder and low yielder groups.
- Work out correlation between ratio and yield.
- Retain those ratios having significant relationships with yield.
- Mean value of retained ratios for high yielder group constitute the DRIS norms.

DRIS indices- diagnosis, calculations and interpretations

Generally three nutrients are selected and relate to one another to make a DRIS chart in simple case. The point of intersection of the three axes corresponds to the mean value for the high-yielding population for each form of expression: N / P = 10.04, N / K = 1.49, K / P = 6.74. It is the desired composition to increase the chances of obtaining high yield. Signs commonly used are (→): balanced nutrition zone, (↘) (↗): zone of slight to moderate imbalance nutrition, (↑) (↓): zone of marked imbalance.

The DRIS for plant nutritional diagnosis can basically be applied in two forms: DRIS graphs and DRIS indices. The DRIS graphs are applied in the norms for only three nutrients and their ratios (Walworth and Sumner 1987). Although the use of diagrams or graphs enable the diagnosis for three nutrients, DRIS still favors the mathematical ranking of the nutrient ratios or their products in nutritional indices, which can be easily interpreted. Initially, the DRIS reference or norms values should be determined, as already described, for all the nutrient ratios or products (for all nutrient pairs) to be used in the indices calculation.

After norms definition, sample analysis results are ready to be submitted to the DRIS indices calculation, which are composed of each nutrient individual index, calculated in two steps: first, the functions for each nutrient pair ratio, and second, the sum of functions involving each nutrient. Hypothetical A to N nutrient indices can, therefore, be calculated as follows (Walworth and Sumner 1987):

Index A = $[f(A/B) + f(A/C) + f(A/D) \ldots + f(A/N)] / Z$

Index B = $[-f(A/B) + f(B/C) + f(B/D) \ldots + f(B/N)] / Z$

Index N = $[-f(A/N) - f(B/N) + f(C/N) \ldots - f(M/N)] / Z$

Where,

When A / B is larger or equal to a / b,

$F(A/B) = (A/B - 1)\ 1000 / CV$

or, when A / B is smaller than a / b,

$F(A/B) = (1 - a/b)\ 1000/CV$

In these equations, A / B is the tissue nutrient ratio of the plant to be diagnosed; a / b is the optimum value or norm for that given ratio; CV is the coefficient of variation associated with the norm; and z is the number of functions in the nutrient index composition. Values for other functions, such as *f*(A / C) and *f*(A / D) are calculated in the same way, using appropriate norms and CV. In other words, one nutrient index is the average function of all the ratios containing a given nutrient. The components of this average value are pondered by the CV reciprocal of the high yielding populations (reference populations).

Thus, if the A / B and A / C ratios are both used to generate an index for the A nutrient, the contribution of each one to the calculation of this index will be function of the CV values (reference ratios) associated to them, what will reflect the relative influence of these two expressions in the crop yield. The value of each ratio function is added to the subtotal of one index and subtracted from another [that is, the value *f (A/B)* is added to A index and subtracted from B index]; before the final ponderation, all the indexes are balanced around zero (Walworth and Sumner 1987). Consequently, the sum of the nutritional indexes must be zero. When results are negative (lower than zero),that means deficiency, and the more negative the index, the higher the deficiency will be in relation to the other diagnosed nutrients. On the other hand, high index values (the more positive and distant from zero indexes) indicate excessive quantity of the considered nutrient relatively to the others.

DRIS norms available for various crop: 1. Alfalfa (*Medicago sativa* L.), 2. Corn (*Zea mays* L.), 3. Citrus (*Citrus sinensis* L.), 4. Oats (*Avena sativa* L.), 5. Peaches (*Prunas persica*), 6. Pineapples (*Ananas comosus* L.), 7. Poplars (*Populas* spp.), 8. Potato (*Solanum*

Table 1. Applications of DRIS in horticultural crops

Crop Pineapple	Important findings related to DRIS norms	References
(*Annanus comosus* (L.) Merr.	Optimum leaf nutrient (N, P, K, Ca, Mg, Fe, Zn, Mn, Cu) concentrations for a defined yield level; DRIS norms for soil fertility at the similar yield range was determined in Alfisol.	Sema *et al.* (2010)
Mango (*Mangifera indica* L.)	Standard norms of N, P, K, Ca, Mg, S, Fe, Zn, Mn, Cu, B established from nutrient survey; sufficiency ranges also derived.	Hundal *et al.* (2005)
	Norms developed for (var. Alphonso) a reference population of productivity range of 5.4-7.4 t $ha^{-1}$and the low yield was associated to low Mg concentrations.	Raghupathi and Bhargava (1999)
	S / N, P / Zn, K / Ca, and K / Mg had greater physiological rationale. K has a key role in N uptake and translocation. Yield was found low during many cropping seasons as a result of imbalances of Mg, S, Fe, Mn, Zn, and Cu.	Raghupathi et al. (2005)
Ber (*Zizyphus mauritiana*)	Nutrient (N, P, K, Ca, Mg, Fe, Zn, Mn, Cu) sufficiency ranges derived from DRIS norms for semi-arid and arid regions of Punjab	Singh *et al.* (2010)
Sweet Potato (*Ipomoea batatas*)	N, P, K, and S -DRIS norms established from leaf nutrient concentration and tuber yield	Ramakrishna *et al.* (2009)
Citrus (*Citrus reticulata*)	Leaf analysis and fruit yield across northeast India were analysed to determine leaf nutrient (N, P, K, Ca, Mg, Fe, Zn, Mn, Cu) optima and GIS-based maps nutrient constraints distribution maps developed through DRIS-based software	Srivastava *et al.* (2010)
Grapes *(Vitis vinifera)*	Identified the most limiting nutrients (K and N) for var. Thompson Seedless w here indices were evaluated in a low yielding vineyard	Chelvan et al. (1984)
	A new criteria was developed to classify the N nutritional status of two grapevine cultivars based on the DRIS indices calculated with soil and leaf analysis data	Bhargava and Raghupathi (1995)
Apple *(Malus domestica Borkh.)*	Indices by traditional calculations indicated K-excess, P-deficiency, and the adequate N concentrations. The norms estimated by quadratic regression analyses indicated K excess and relative N and P deficiency, suggesting the later method derived more extreme nutrient ratios than the traditional method.	Szucs *et al.* (1990)
	Annual yields could be used instead of cumulative yields for developing norms. The incorporation of the dry matter index in the nutritional balance equations (M-DRIS) was important to better define the limiting and non-limiting nutrients.	Parent and Granger (1989)

tuberosum) 9. Rubber (*Hevia brasiliensis*), 10. Soybean (*Glycine max* L.), 11.Sugarcane (*Saccharaum officinarum* L.), 12.Sunflower (*Helianthus annus* L.), 13. Tea (*Camelia sinensis* L.) and 14. Wheat (*Triticum aestivum* L.).

DRIS has been used successfully to interpret the results of foliar analyses for a wide range of crops such as rubber and sugarcane (Elwali and Gascho, 1984), apple (Singh *et al.* 2000), peach (Awasthi *et al.* 2000), mango (Raj and Rao 2006), sweet potato (Ramakrishna *et al.* 2009), cauliflower (Hundal *et al.* 2003), rice (Singh and Agrawal 2007), corn (Soltanpour *et al.* 1995) , tomatoes (Hartz *et al.* 1998), pineapple (Teixeira *et al.* 2009), cotton (Dagbenonbakin *et al.* 2010). The DRIS is sometimes less sensitive than the sufficiency range approach to differences caused by leaf position, tissues age, climate, soil conditions, and cultivar's effect because it uses nutrient ratios (Sanchez *et al.* 1991).

Interpretation of the DRIS nutritional indices

The value of each ratio function is added to the subtotal of one index and subtracted from another [that is, the value *f (A/B)* is added to A index and subtracted from B index]; before the final ponderation, all the indexes are balanced around zero (Walworth and Sumner 1987). Consequently, the sum of the nutritional indexes must be zero. When results are negative (lower than zero), that means deficiency, and the more negative the index, the higher the deficiency will be in relation to the other diagnosed nutrients. On the other hand, high index values (the more positive and distant from zero indexes) indicate excessive quantity of the considered nutrient relatively to the others. The following example may illustrate the DRIS method interpretation, and to make it simple, this example refers only to nitrogen (N), phosphorus (P) and potassium (K). Other nutrients may be incorporated to the calculations using the same procedure. For nutritional diagnosis in banana (Table 2) and maize (Table 3), the interpretation norms are presented from previous literature.

Table 2. DRIS norms and critical nutrient levels in the 3rd lamina of banana established from published sources (Angeles *et al.*, 1993)

Nutrient expression (%)	DRIS	Critical value range	Av. of published critical values
N	3.04	1.81-4.00	3.03
P	0.23	0.12-0.41	0.22
K	4.49	1.66-5.40	3.40

Use of DRIS norms

The actual application of nutrient ratios has not been realized until the use of Diagnosis and Recommendation Integrated System (DRIS) was proposed. Beaufils at the University of Natal, South Africa developed this approach for the interpretation of leaf or plant analysis (Beaufils 1973). It is a comprehensive system that identifies all the nutritional factors limiting crop production and, hence, increases the chances of obtaining high crop yields by improving fertililzer recommendations. Index values that measure how far particular nutrients in the leaf or plant are from the optimum are used in the calibration to classify yield factors in order of limiting importance (Tisdale *et al.* 2002). The

Table 3. Maize DRIS norms for nitrogen, phosphorus and potassium (Sumner, 1882; Walworth and Sumner, 1887)

Representation	Low yielding population			High yielding population			Variance ratio
	Means	CV(%)	Variance(S_A)	Means	CV(%)	Variance(S_B)	(S_A / S_B)
N (%dm)	2.86	20	0.326	3.06	18	0.303	1.075
P (%dm)	0.30	20	0.0036	0.32	22	0.0050	0.720
K (%dm)	2.32	27	0.392	2.12	23	0.238	1.647
N / P	9.88	18	3.158	10.04	14	1.996	1.582
N / K	1.39	28	0.150	1.49	21	0.101	1.485
K / P	6.94	29	4.000	6.74	22	2.222	1.800
P / K	0.13	26	0.011	0.15	24	0.0013	0.846
P / N	0.10	18	0.00032	0.10	16	0.00026	1.231
K / N	0.81	24	0.0380	0.72	22	0.0259	1.467
NP	0.85	33	0.0792	0.98	32	0.0961	0.824
NK	6.59	34	5.040	5.45	34	4.910	1.026
PK	0.71	37	0.0675	0.68	36	0.0611	1.105

DRIS techniques of interpretation determine the order on nutrient requirements in plants by measuring the deviation of leaf analysis values from the standard norms. It is based on the interrelationships among nutrients. Walworth and Sumner (1987) addressed the principles of this innovative technique. The DRIS approach to interpreting the results of plant analysis involves creating a database from the analysis of thousands of samples of a specific crop (Kelling *et al.* 2000). Angeles *et al.* (1993) determined the DRIS norms for banana by using the procedures of Beaufils (1973). They assembled 915 observations from 26 published and un-published sources. The DRIS norms were established from the high yielding population with a yield >70 t / ha. About 16% of the total observations fell within the high-yielding population. They calculated the means of N, P and K concentrations, their ratios, products, and their respective coefficients of variation from the high yielding population to serve as norms. They compared the DRIS norms with critical values obtained from published sources (Table 1). The critical values were compiled and averaged. Except for K and its ratios and products with other nutrients, DRIS norms were very similar to the average critical values. The DRIS norms were validated in two fertilizer experiments, and their efficacy in making diagnosis was compared with critical values. The validity of DRIS norms and their superiority over the critical value in making correct diagnosis were partly confirmed in a single fertilizer experiment but further testing in field factorial experiment is needed.

Advantages and disadvantages of DRIS

In general, the DRIS has some advantages over other diagnosis methods: presents continuous scale and easy interpretation; allows nutrient classification (from the most deficient up to the most excessive); can detect cases of yield limiting due to nutrient unbalance, even when none of the nutrients is below the critical level; and finally, allows to diagnose the total plant nutritional balance, through an unbalance index (Baldock and Schulte 1996). An additional advantage of DRIS, acknowledged by some authors but rebutted by others, is that, overall, it is less sensitive to tissue aging in comparison to others (Walworth and Sumner 1987). Tissue aging influence the nutrient concentration (nutrient content / dry matter); several examples are reported in the literature, including studies in alfalfa, potato, corn, peach, and many other agricultural and horticultural crop species. Although some exceptions may occur, concentrations of nitrogen, phosphorus, potassium and sulfur tend to decrease with tissue aging. On the other hand, calcium and magnesium concentrations tend to increase in older tissues (low mobility), in spite of the opposite being reported in the very early or later stages for some crops. The dynamic nature of the plant tissue mineral composition tends to restrict the use of leaf analysis for nutritional diagnosis. As already stated, the criteria of critical levels or sufficiency ranges generally depend on norms for diagnosis derived from a specific plant tissue part and age, and classifies the plants based solely in the leaf nutrient concentration (leaf nutrient content / leaf dry matter). Thus, the plant growth stage for leaf sampling is an essential factor for the application of both methods, and therefore, the diagnoses based on these criteria are usually applied in leaf samples obtained from a well-defined growth stage.

An important limitation of these methods is that, especially in some annual crops, the established standard sampling period many times occurs too late in the growing season, so that fertilizer application will not be effective to correct a nutritional problem, or may not match the sudden symptoms of a nutritional disorder, when the producer mostly need the information (Walworth and Sumner 1987). To overcome this problem, it would be necessary to get nutritional reference values for several maturation stages and, as a matter of fact, some of these standards have already been established for a few crops. Although simple in theory, this procedure is of difficult application. First, there is a need for precise definition, at the sampling time, of plant maturation stages (or growth period) in the field. Later, the sampler should communicate this information to the analyst or person taking care of the diagnosis, so that appropriate norms can be selected and used.

Expansion of DRIS— MDRIS, CND

The over exploitation of the soil over the past and the present years acts as a catalyst to promote the deterioration of soil health. The imbalanced fertilization of the crops aggravates deficiencies of other nutrients especially the micronutrients, which in turn act additively with other biotic and abiotic stresses to limit crop production in the long run. Therefore it is essential to develop better and apt management strategies for monitoring the nutrient status and dynamics in the crop and soil. Since 1973, the most popular DRIS (Diagnosis and Recommendation Integrated System) of Beaufils and MDRIS (Modified - Diagnosis and Recommendation Integrated System) approaches were used as the tools to monitor the nutrient imbalances in the crop. Apart from the bivariate analysis tools (DRIS and M-DRIS), recently, the multivariate analysis tool like Compositional Nutritional Diagnosis (CND) were also found effective for monitoring the nutrient imbalances in the crops.

The major limitation over the years for using these nutrient diagnostic models was due to its robust computational steps involved. Now-a-days, the modern advancement of the informatics support (both software and hardware) transforms these tasks as simple as possible. In order to facilitate and assist the researchers pertaining to plant and soil nutrient diagnosis, a computer program for DRIS and MDRIS were developed completely and only for part of the CND analysis using FOXPRO. In the case of CND the computer program steps are stopped after the calculation of CND nutrient indices and before proceeding to the PCA (Principal Component Analysis) concepts.

CONCLUSIONS

Optimal nutrition of crop plants is an issue of concern for both farming community and the agricultural scientists that focus identification of mineral deficiency (or excessiveness) and its in-time management to nourish a healthy crop throughout the whole cropping season. From review of scientific literature it is evident that DRIS is an authoritative tool for the nutritional diagnosis in several crops. Most of the developed research works turns clear that DRIS is as effective as the conventional methods of nutritional diagnosis (critical values and sufficiency range) with the additional advantage of establishing a nutrient deficiency or excess ranking, according to its importance, and a strong relation among them, quantifying the plant nutrient balance. Further study is needed to answer the controversies regarding calculation procedures, method of validation and criteria for the reference sub-population definition. Except for a few studies, most of the developed research works turns clear that DRIS is as effective as the conventional methods of nutritional diagnosis (critical values and sufficiency range) with the additional advantage of establishing a nutrient deficiency or excess ranking, according to its importance, and a strong relation among them, hence quantifying the plant nutrient balance. There are arguments regarding calculation procedures for the norms and DRIS indices. DRIS norms should be developed for specific conditions, in which all other factors to be correlated with yield or quality (or any other variable) be known and isolated: cultivar, climate, soil and crop management, productivity etc. for attaining the specific objectives. Even investigations are necessary on the identification and isolation of those factors that significantly but locally affect productivity, under several fruit crop management production systems.

There are so many merits and demerits discussed about DRIS. No doubt, there is a considerable space for expansion of DRIS to make this diagnostic technique popular among farmers and also to make norms for various crop plants yet to be worked, considering neglected growth factors. Expansion of the data base and further validation of norms of existing norms are also obligatory to enhance the use of DRIS. As DRIS imparts an integrated approach towards plant nutrition diagnosis and thus proved a significant tool for modern agricultural practices.

REFERENCES

Angeles D E, Sumner M E and Lahav E.1993. Preliminary DRIS norms for banana. *Journal of Plant Nutrition* 16: 1059–1070.

Awasthi R P, Sharma S K and Bhutani V P. 2000. Diagnosis And Recommendation Integrated System (DRIS) norms for peach (*Prunus persica* L.) CV. July Elberta in Himachal Pradesh. *Indian Journal of Horticulture* 57(4): 277-280.

Bailey J S, Beattie, J A M and Kilpatrick D J. 1997. The diagnosis and recommendation integrated system (DRIS) for diagnosing the nutrient status of grassland swards: I. Model establishment. *Plant and Soil* 197:127-135.

Baldock J O and Schulte E E. 1996. Plant analysis with standarized scores combines DRIS and sufficiency range approaches for corn. *Agronomy Journal* 88: 448-456.

Baldock, J O and Schulte, E E. 1996. Plant analysis with standarized scores combines DRIS and sufficiency range approaches for corn. *Agronomy Journal* 88: 448-456.

Bates T E. 1971. Factors affecting critical nutrient concentrations in plant and their evaluation: A review. *Soil Science* 112:116-130.

Beaufils E R. 1957. Research for rational exploitation of *Hevea* using aphysiological diagnosis based on the mineral analysis of various parts of the plants. *Fertilite* 3: 27-38.

Beaufils E R. 1971. Physiological diagnosis - a guide for improving maize production based on principles developed for rubber trees. *Fertilizer Society of South African Journal* 1: 1-30.

Beaufils E R. 1973. Diagnosis and recommendation integrated system (DRIS).*Soil Science Bulletin* 1:1-132.

Beaufils E R. 1973. Diagnosis and recommendation integrated system (DRIS). *Soil Science* University of Natal, South Africa.

Beverly R B. 1991. A practical guide to the diagnosis and recommendation integrated system (DRIS). Micro-Macro, Athens. p. 87.

Bhargava B S and Raghupathi H B. 1995. Current status and new norms of nitrogen nutrition for grapevine (*Vitis vinifera*). *Indian Journal of Agricultural Sciences* 65: 165-169.

Chapman H D and Brown S M. 1950. Analysis of orange leaves for diagnosing nutrient status with reference to potassium. *Hilgardia* 19: 501-540.

Chelvan R C, Shikhamany S D and Chadha K L. 1984. Evaluation of low yielding vines of Thompson seedless for nutrient indices by DRIS analysis. *The Indian Journal of Horticulture* 41:166-170.

Costa A N. 1999. Sistema integrado de diagnose e recomendação (DRIS). *Boletim Informativo da Sociedade Brasileira de Ciência do Solo* 24:13-15.

Dagbénonbakin G D, Agbangba C E, Glèlè Kakaï R and Goldbach H. 2010. Preliminary diagnosis of the nutrient status of cotton (*Gossypium hirsutum L*) in Benin (West Africa). *Bulletin de la Recherche Agricole du Bénin* 67: 32-44.

Elwali A M O and Gascho G J. 1984. Soil testing, foliar analysis and DRIS as guides for sugarcane fertilization. *Agronomy Journal* 76: 466-470.

Elwali A M O and Gascho G J. 1984. Soil testing, foliar analysis, and DRIS as guide for sugarcane fertilization. *Agronomy Journal* 76: 466-470.

Hallmark W B and Beverly R B. 1991. Review – An update in the use of the Diagnosis and Recommendation Integrated System. *Journal of Fertilizer Issues* 8: 74-88.

Hartz T K, Miyao E M and Valencia J G. 1998. DRIS Evaluation of the Nutritional Status of Processing Tomato. *Horticultural Science* 33: 830-832.

Hartz T K, Miyao E M and Valencia J G. 1999. DRIS evaluation of the nutritional status of processing tomato. *HortTechnology* 9(1): 131.

Havlin J L, Beaton J D, Tisdale S L and Nelson W L. 2004. Soil Fertility and Fertilizers. 6th ed. Pearson Education, Patparganj Delhi, India.

Hundal H S, Arora C L and Brar J S. 2003. The Diagnosis and Recommendation Integrated System for Monitoring Status of N, P, K and S of cauliflower. *Journal of the Indian Society of Soil Science* 51(1): 80-82.

Hundal H S, Singh D and Brar J S. 2005. Diagnosis and Recommendation Integrated System for monitoring nutrient status of mango trees in submoutainous area f Punjab, India. *Communications in Soil Science and Plant Analysis* 36:2085-2099.

Jones, W W. 1981. Proposed modifications of the diagnosis and recommendation integrated system (DRIS) for interpreting plant analyses. *Communications in Soil Science and Plant Analysis* 12: 785-794.

Kelling K A, Combs S M and Peters J B. 2000. Plant Analysis as a diagnostic tool. http://www.soils.wisc.edu/extension/publications/horizons/2000/Plant%20Analysis%20as%20Tool.pdf.

Lopes A S. 1998. Manual internacional de fertilidade do solo. 2.ed. Piracicaba: POTAFOS, p.177.

Malavolta E, Vitti G C and Oliveira S A. 1997. Avaliação do estado nutricional das plantas:princípios e aplicações. Piracicaba: Associação Brasileira para Pesquisa da Potassa e do Fosfato, p. 319.

Meldal-Johnsen, A and Sumner, M E. 1980. Foliar Diagnostic Norms for Potatoes. *Journal of Plant Nutrition* 2: 569–576.

Parent L E and Dafir M A. 1992. Theoretical concept of compositional nutrient diagnosis. *Journal of the American Society of Horticultural Science* 117:239-242.

Parent L E and Granger R L. 1989. Derivation of DRIS norms from a high density apple orchard established in the Quebec Appalachian Mountains cherry. *Journal of the American Society for Horticultural Science* 114: 915-919.

Parent L E, Cambouris A N, Muhawenimana A. 1994. Multivariate diagnosis of nutrient imbalance in potato crops. *Soil Science Society of America Journal* 58: 1432-1438.

Payne G G, Rechcigl J E and Stephenson R L. 1990. Development of diagnosis and recommendation integrated system norms for bahiagrass. *Agronomy Journal* 82: 930-934.

Raghupathi H B and Bhargava B S. 1998. Diagnosis of nutrient imbalance in pomegranate by diagnosis and recommendation integrated system and compositional nutrient diagnosis. *Communications in Soil Science and Plant Analysis* 29: 2881-2892.

Raghupathi H B and Bhargava B S. 1999. Preliminary nutrient norms for 'Alphonso' mango using diagnosis and recommendation integrated system. *Indian Journal of Agricultural Sciences* 69: 648-650.

Raghupathi H B, Reddy N Y T, Kurian Reju, M and Bhargava B S. 2005. Diagnosis of Nutrient Imbalance in Mango by DRIS and PCA Approaches. *Journal of Plant Nutrition* 27(7HYPERLINK "http://www.informaworld.com/smpp/title~ content=

g713648597~db=all"): 1131 – 1148.

Raj G B and Rao A P. 2006. Identification of Yield- Limiting Nutrients in Mango through DRIS Indices. *Communications in Soil Science and Plant Analysis* 37(11): 1761-1774.

Ramakrishna A, Bailey J S and Kirchhof G. 2009. A preliminary diagnosis and recommendation integrated system (DRIS) model for diagnosing the nutrient status of sweet potato (*Ipomoea batatas*). *Plant and Soil* 316: 107-116.

Rashid A. 2005. Soils: Basic concepts and principles. In: Soil Science. Memon K S and Rashid A. (eds.). National Book Foundation, Islamabad.

Rathfon R A and Burger J A. 1991. Diagnosis and Recommendation Integrated System (DRIS) nutrient norms for Fraser Fir Christmas trees. *Forest Science*, 37: 998-1010.

Reuther W and Smith P F. 1954. Leaf analysis of citrus. In: Fruit nutrition. Childers N F (ed.) New Brunswick, Rutgers University, pp. 257-294.

Reuther W, Embleton T W and Jones W W. 1958. Mineral nutrition of tree crops. *Annual Review of Plant Physiology* 9: 175-205.

Sanchez C A, Sera G H and Burdine H W. 1991. DRIS Evaluation of the Nutritional Status of Crisphead Lettuce. *Hortscience* 26: 274-276.

Santos W R. 1997. dos. Avaliação do equilíbrio nutricional dos macronutrientes em citros com diferentes adubações. Piracicaba: USP / ESALQ, p.112.

Sema A, Maiti C S, Singh A K, Bendangsengla A. 2010. DRIS nutrient norms for pineapple on alfisol of India. *Journal of Plant Nutrition* 33:1384-1399.

Singh N P, Awasthi R P and Sud A. 2000. Diagnosis And Recommendation Integrated System (DRIS) norms for apple (Malus × Domestica Borkh. L. CV. Starking Delicious) in Himachal Pradesh. *Indian Journal of Horticulture* 57(3): 196-204.

Singh V K and Agrawal H P. 2007. Development of DRIS norms for Evaluating Nitrogen, Phosphorus, Potassium and Sulphur Requirements of Rice Crop. *Journal of the Indian Society of Soil Science* 55(3): 294-303.

Singh K, Hundal H S, Singh D and Boora R S. 2010. Monitoring nutrient status of Ber (*Zizyphus mauritana*) in semi-arid and arid regions of northwest India through diagnosis and recommendation integrated system approach. *Communications in Soil Science and Plant Analysis* 41: 2011-2021.

Snyder G H and Kretschmer A E. 1987. A DRIS analysis for bahiagrass pastures. *Soil Crop Science Society of Florida Proceedings* Gainesville 47:56-59.

Snyder G H, Sanchez C A and Alrichs J S. 1989. DRIS evaluation of the nutrient status of Bahia and St. Augustine turfgrasses. *Proceedings of the Florida State Horticultural Society* 102:133-137.

Soltanpour P N, Malakouti M J and Ronaghi A. 1995. Comparison of DRIS and nutrient sufficient range of corn. *Soil Science Society of America Journal* 59:133-139.

Soltanpour P N, Malakouti M J and Ronaghi A. 1995. Comparison of Diagnosis and Recommendation Integrated System and Nutrient Sufficient Range of Corn. *Soil Science Society of America Journal* 59: 133–139.

Srivastava A K, Singh S and Das S N. 2010. Nutrient optima-based productivity zonality delineation in citrus orchards of northeast India. 19th World Congress of Soil Science, Soil Solutions for a Changing World. 1 – 6 August 2010, Brisbane, Australia. Published on DVD. p. 136-138.

Sumner M E. 1982. The diagnosis and recommendation integrated system (DRIS). Soil / plant analysis workshop. Council of soil testing and plant analysis. Anaheim, CA, USA.

Szucs E, Kállay T and Szenci G. 1990. Determination of DRIS indices for apple (*Malus domestica* Borkh). *Acta Horticulturae* 274: 443-453.

Teixeira L A J, Quaggio J A and Zambrosi F C B. 2009. Preliminary DRIS norms for 'Smooth Cayenne' pineapple and derivation of Critical Levels of Leaf Nutrient Concentrations. *Acta Horticulture* 822: 131-138.

Tisdale S L, Nelson W L, Beaton J D and Havlin J L. 2002. Soil Fertility and Fertilizers. 5th ed. Prentice Hall, New Delhi, India.

Walworth J L and Sumner M E. 1987. The Diagnosis and Recommendation Integrated System (DRIS). *Advances in Soil Science* 6: 149-188.

Walworth J L and Sumner M E. 1987. The diagnosis and recommendation intergrated system (DRIS). In: Advances in Soil Science, Stewart B A (ed.), Springer – Verlag, New York, pp. 149–88.

Walworth J L, Sumner M E, Isaac R A and Plank C O. 1986. Use of boundry lines in establishing diagnostic norms. *Soil Science Society of America Journal* 50: 123-128.

Journal of Soil and Water Conservation **12**(1): 80-84, January-March 2013
ISSN: 022-457X

Temporal change in land use of himalayan watershed using remote sensing and GIS

R.K. SRIVASTAVA[1], H.C. SHARMA[2], SURESH KUMAR[3] and AMBRISH TIWARI[4]

Received: 28 July 2012; Accepted: 26 December 2012

ABSTRACT

Digital image processing was carried out on Landsat 7 ETM^+ imagery of 22 December, 2003 to map the land use classes in Badri Gad watershed which is a part of North Western Himalayan watershed of Uttarakhand India and change in land use was compared with the land use of Survey of India Toposheet of 1960. Image elements, obtained by Unsupervised Classification Technique, were correlated with the ground truthing. Satellite data were classified into dense forest, mixed forest, chir pine forest, agriculture, agriculture fallow, agri-horticulture, clear barren and barren with vegetation. It was found that agricultural area, over a period of 43 years i.e. 1960 – 2003, had increased slightly but area under barren land had reduced by 60 percent, which had converted mainly into forest land.

Key words: watershed, temporal distribution, landuse, unsupervised classification and ground truthing

INTRODUCTION

Remote sensing and GIS have emerged as a powerful tool for planning and management of watershed programme, formulation of proper management programmes require reliable and up to date information about various factors such as size and shape of the watershed, topography, soil and their characteristics, land use/land cover, drainage parameters etc., which have direct influence on the behaviour of a watershed. Over the years, remote sensing has been used for land use/land cover mapping in different part of India(Gautam and Narayana, 1983 [3]; Sharma *et al.*, 1984 [11]; Jain, 1992 [4]; Rathore, 1996 [7]; Palaniyandi and Nagaratthinam, 1997 [9]; Jaiswal *et al.*, 1999 [5]; Minakshi *et al.*, 1999 [8]; Brahamabhatt *et al.*, 2000 [1]; Kumar *et al.*, 2004 [6]; Mahajan and Panwar, 2005 [7].

Himalayan region characterized by young fragile ecosystem, diminishing bio diversity, marginalized and resources poor inhabitants with inadequate infrastructural facilities. Most of the Indian hilly watersheds could not get much attention of the researchers due lack of quality data. Moreover collection of data in such locations is tedious and difficult. Nowadays, watershed management is becoming a blue print for agricultural development in most parts of the country. Watershed management implies the proper use of all land and water resources for optimum production with minimum hazard to natural resources. The success of planning for developmental activities depends on the quality and quantity of information available on both natural and socio-economic resources. Remote Sensing and GIS are used to get the reliable data base generation for devising the ways for optimal planning and management of watersheds. As existing land use information about the watershed is helpful for estimation of runoff and further development of the watershed. Hence, present study is conducted to asses existing landuse pattern within the watershed and change in landuse with respect to toposheet of 1960 of the watershed.

[1] Division of Agricultural Engineering, SKUAST-J, Chatha, Jammu
[2] College of Technology, GBPUAT, Pantnagar
[3] Indian Institute of Remote Sensing, Dehradun
[4] Central Soil and Water Conservation Research and Training Institute, Dehradun

MATERIALS AND METHODS

Study area

The study area is located in Narendra Nagar block of Tehri Garhwal district of Uttrakhand as shown in Figure 1. The outlet of the watershed is located near the Yamuna bridge on the Dehradun-Yamunotri National Highway route, which is about 55 km away from Dehradun. The watershed is located in between the longitudes of 78^{0} 00’ 21.02"E and 78^{0} 10’ 21.43" E, and latitudes of 30^{0} 32’ 23" and 30^{0} 38’ 19.63" N. The total area of the watershed is 11,668.20 ha (116.68 km^{2}) with a perimeter of 51.82 km. The elevation of the watershed varies from 760 to 3000 m above mean sea level (amsl). About 70% of the watershed area is having a land slope of 15-50%.

The climate of the study area is humid temperate with an average rainfall of 1234.76 mm (1985-2008) of which about 70 to 80% is received during June to September. The average temperature in this area varies from 3 to 30 ^{o}C. Forest is the dominating land cover which mainly lies above 1600 m amsl. However, a major part of the agricultural area is found at the elevations of about 1200 to 1600 m amsl.

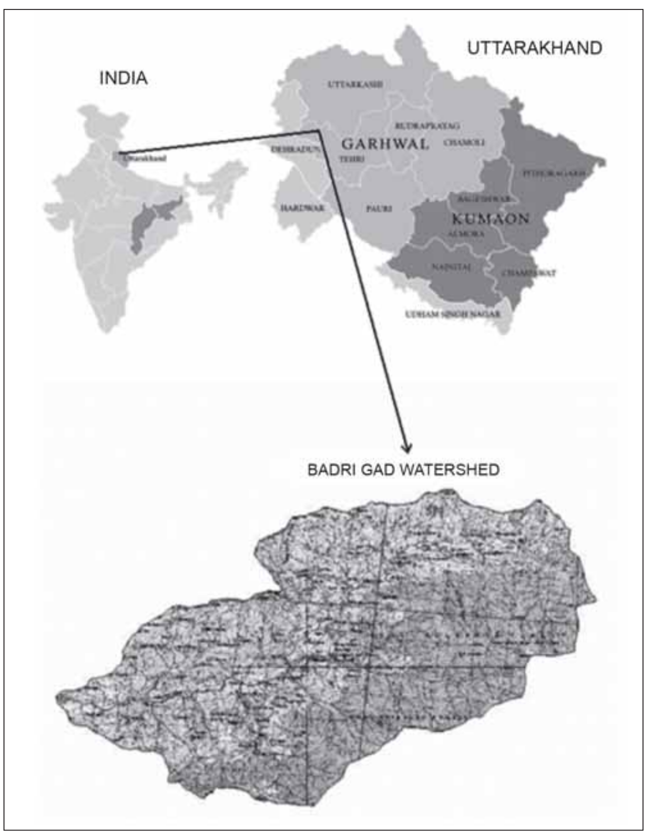


Fig. 1. Index map of Badri Gad watershed

The chemical properties of the soils in the study area are neutral to slightly acidic with high organic matter content.. At the mid and lower hills (1500-2200 and 800-1500 amsl) , sandy clay loam and clay loam soils are found, whereas sandy loam soils are found at higher elevation (2200-2900 amsl). The soils in general are shallow in depth.

Geo-referencing of toposheet

When an image is created, the information is stored in row and column geometry in raster format. This information is affected by geometric distortions due to sensor geometry, sensor and platform instabilities, earth rotation, earth curvature etc. There is no relationship between the row and column, and real world co-ordinates. In a process called geo-referencing each pixel is registered to real world co-ordinate system by cylindrical map projection. After geo-referencing each pixel in the image has its own co-ordinates, but its geometry is not corrected for geometric distortions and not adapted to a base map. To create a distortion free adapted image, the transformation that is defined during geo-referencing is executed. This process is called geo-coding, results in a new image in which the pixels are arranged in the geometry of the raster image or map. Survey of India topo maps have been used for geo-coding of raster digital imageries.

For this purpose, Toposheet (53 J/2) of Survey of India, of the scale 1: 50, 000, was used for the analysis of slope-area classification and watershed delineation. The study area was scanned (*tiff format*), translated to the *pix format* (PCIDSK format) using utility option of the software, and geo-referenced using Ortho Engine module of Geomatica (GIS and Image analysis software). This geo-referenced map was utilized to delineate the boundary of the watershed with GIS environment. The following local information was used as an input data in the geo-referencing of the toposheet.

- Projection UTM
- Earth Model Ellipsoid or Sphere
- Zone 44 (78^{o} E to 84^{o} E)
- Rows R (24^{o} N to 32^{o} N)
- Datum D076 Indian [India, Nepal]
- Resampling method Nearest

Base Map Preparation

Base maps were prepared using Survey of India (SOI) toposheet No. 53 J/2 of 1:50,000 scale. Base maps land use and watershed boundary were extracted from the topographic sheet using Focus module of GIS environment with UTM projection.

Image interpretation

Digital image processing is the collection of techniques for manipulation of digital images with the help of some specific software i.e. called image analyst. Remotely sensed digital image is typically composed of picture element (pixel) located at the intersection of each row and column, and in each band of imagery. With each pixel digital number (DN) or brightness value (BV) depicts the average radiance of relatively small area within a scene. It becomes necessary to process the voluminous data that are in digital form stored in a Magnetic Tape from it a visual image can be produced for further processing.

Aerial photographs as well as imagery obtained by remote sensing using aircraft or spacecraft as platforms have applicability in various fields. By studying the qualitative and quantitative aspects of images recorded by various sensor systems like aerial photographs (black and white, black and white infrared, colour and colour infrared), multiband photographs, satellite data (both pictorial and digital) including thermal and radar imagery, an interpreter well experienced in his field can derive lot of information. Image interpretation is nothing but act of examining image to identify objects and judge their significance.

Elements of image interpretations

Image interpretation is essential for the efficient and effective use of the data. While the above properties of aerial photographs/ imagery help an interpreter to detect objects due to their tonal variations, he must also take advantage of other important characteristics of the objects in order to recognize them. The following nine elements of image interpretation are regarded as being of general significance, irrespective of the precise nature of the imagery and the features it portrays.

Shape: Numerous components of the environment can be identified with reasonable certainty merely by their shape. This is true of both natural features and man-made objects.

Size: In many cases, the length, breadth, height, area and/ or volume of an object can be significant, whether these are surface features (e.g. different tree species) or atmospheric phenomena (e.g. cumulus versus cumulonimbus clouds). The approximate size of many objects can be judged by comparisons with familiar features (e.g. roads) in the same scene.

Tone: Different objects emit or reflect different wavelengths and intensities of radiant energy. Such differences may be recorded as variations of picture tone, colour or density. Which enable discrimination of many spatial variables, for example, on land different crop types or at sea water bodies of contrasting depths or temperatures. The terms 'light', 'medium' or 'dark' are used to describe variations in tone.

Shadow: Hidden profiles may be revealed in silhouette (e.g. the shapes of buildings or the forms of field boundaries). Shadows are especially useful in geomorphological studies where micro relief features may be easier to detect under conditions of low-angle solar illumination than when the sun is high in the sky.

Pattern: Repetitive patterns of both natural and cultural features are quite common, which is fortunate because much image interpretation is aimed at the mapping and analysis of relatively complex features than the more basic units of which they may be composed. Such features include agricultural complexes (e.g. farms and orchards) and terrain features (e.g. alluvial river valleys and coastal plains).

Texture: It is an important image characteristic closely associated with tone to be differentiated on the basis of microtonal patterns. Common image textures include smooth, rippled, mottled, lineated and irregular. Unfortunately, texture analysis tends to be rather subjective, since different interpreters may use the same terms in slightly different ways. Texture is rarely the only criterion of identification or correlation employed in interpretation. More often it is invoked as the basis for a subdivision of categories already established using more fundamental criteria. For example, two rock units may have the same tone but different textures.

Site: At an advanced stage in image interpretation, the location of an object with respect to terrain features of other objects may be helpful in refining the identification and classification of certain picture contents. For example, some tree species are found more commonly in one topographic situation than in others, while in industrial areas the association of several clustered, identifiable structures may help us determine the precise nature of the local enterprise.

Data acquisition

Toposheet (53 J / 2) of Survey of India (SOI), of the scale 1: 50, 000 was used for the analysis of land use classification and watershed delineation. The study area was scanned (*tiff format*), translated to the *pix format* (PCIDSK format) using utility option of the software, and geo-referenced using Ortho Engine module of Geomatica (GIS and Image analysis software). This geo-referenced map was utilized to delineate the boundary of the watershed with GIS environment. The Landsat 7 ETM^+ satellite data (22 December, 2003)of the study area were analyzed, for characterization of various land forms by preparing False Colour Composite (FCC) was reprojected to UTM projection using reprojection option of the software. Then, the area of interest was masked with watershed boundary using clipping / subsetting facilities of the software.

Different land uses / land covers were obtained with GIS environment by unsupervised classification technique, available in image processing module of the Geomatica v 10.0 software, using satellite data for the year 2003. During field visit, the image elements, obtained by Unsupervised Classification Technique, were correlated with the ground truthing.

RESULTS AND DISCUSSIONS

The study area delineated from the S.O.I. toposheet was redelineated for different landuse which were already classified in of Survey of India toposheet (53J / 2) and same are shown in Figure 2. Areal extent of different land use classes is shown in

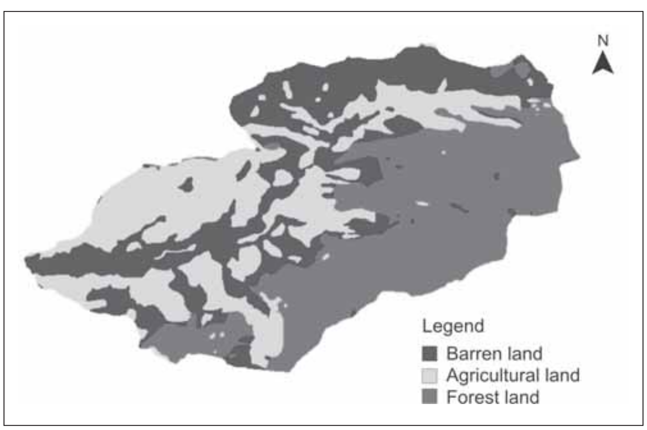


Fig. 2. Land use map on the basis of toposheet for the year 1960

Table 1. It was found that the highest percentage of area of the watershed was occupied by forest (39.18 %) followed by agriculture (30.58 %) and barren land (30.23 %).

Table 1. Areal extent under different land uses on the basis of toposheet for the year 1960.

Sl. No.	Land use	Area (ha)	Percent of total area
1.	Agricultural land	3568.54	30.58
2.	Forest land	4572.23	39.18
3.	Barren land	3527.45	30.23
	Total	11668.22	100.00

Satellite data were classified into three major class *viz*., forest, agriculture and barren. Further forest was classified in three sub class *viz*., dense forest, mixed forest, chir pine forest similarly agriculture in two groups *viz*., agriculture fallow, agri-horticulture, clear barren and barren with vegetation (Figure 3). Areal extent of various land use classes shown in table 2. Forest area was mainly observed at higher altitude (more than 1900 m), whereas major agriculture and barren land was found at less than 1900 m elevation. Dense forest area was dominated by *deodar, oak, and sal* whereas mixed forest area was dominated by *buranse, cyprus, bangh, aunger, panger, moru* and *khoru*. Major agricultural crops being grown were *manduwa, sawan*, paddy, wheat, barely, *rajmas*, black gram, green gram and maize and in valley's where irrigation was available, some vegetables and spice crops like tomato, potato, capsicum, cauliflower, peas, *arabi*, turmeric, ginger, onion and garlic were also grown. It is evident from table 2 that out of the total area under study, 28.92 per cent area was under dense forest, followed by agriculture fallow land (15.54 %), mixed forest (15.32 %), agriculture (12.85 %), chirpine forest (8.20 %) agri-horticulture (7.87 %), barren with vegetation (7.58 %) and clear barren (3.74 %). After clubbing all the subclasses in to three main classes, forest stand to occupy maximum area 52.43%, followed by agriculture (36.25%) and barren land(11.32%). Enhancement of area under different land use has been reported by other workers also Dewan *et al.* 2005 [2].

It was observed that agricultural area, over a period of 43 years i.e. 1960 – 2003 had increased slightly but area under barren land had reduced by 60 percent, which had replaced mainly by forest land

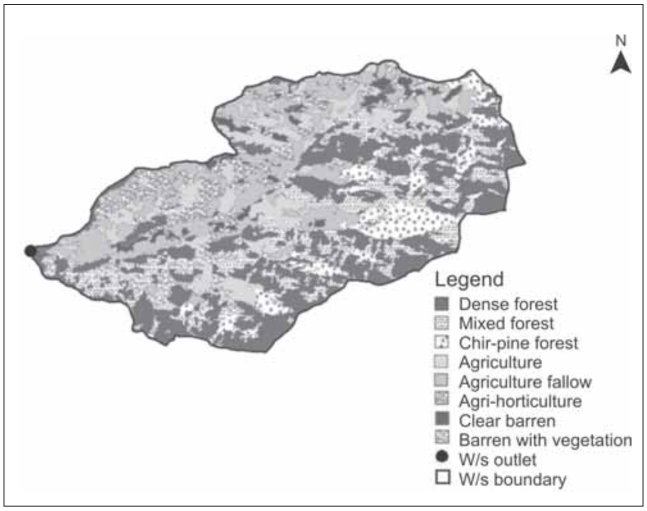


Fig. 3. Land use on the basis of satellite imagery for the year December, 2003.

Table 2 . Areal extent under different land use on the basis of imagery of Badri Gad watershed

	Land use Main class	Area (ha) Sub class	Percent of total area
Forest	Dense forest	3373.89	28.92
	Mixed forest	1787.30	15.32
	Chir pine forest	956.32	8.20
	Total Forest	6117.52	52.43
Agricultural Land	Agriculture	1499.21	12.85
	Agriculture fallow	1813.03	15.54
	Agri-horticulture	917.86	7.87
	Total Agricultural land	4230.10	36.25
Barren Land	Clear barren	436.37	3.74
	Barren with vegetation	884.22	7.58
	Total Barren Land	1320.59	11.32
	Total	11668.21	100.00

due to efforts made by the forest department of Uttarakhand and other agencies funded by central government and world bank.

REFERENCES

Brahabhatt, V.S., Dalwadi, G.B., Chhabra, S.B., Ray, S.S. and Dadhwal, V.K. 2000. Landuse / land cover change mapping in Mahi canal command area, Gujrat, using multi-temporal satellite data. *J. Indian Society of Remote Sensing*, **28** (4): 221-232

Dewan, M.L. and Jagdish Bhadur (Eds.) 2005. Uttaranchal: Vision and Action Programme. Concept Publishing Company, New Delhi.

Gautam, N.C. and Narayana, L.R.A. 1983. Landsat MSS data for landuse / landcover inventory and mapping: A case study of Andhra Pradesh. *J. Indian Society of Remote Sensing*, **11**(3): 15-28

Jain, S.K. 1992. Land use mapping of Tawi catchment using satellite data. Report No. CS-72, National Institute of Hydrology, Roorkee, 52p.

Jaiswal, R.K., Saxena, R. and Mukherjee, S. 1999. Application of remote sensing technology for land use / land cover change analysis. *J. Indian Soc. Remote Sensing*, **27**(2): 123-128

Kumar, Vijay, Rai, S. P. and Rathore, D. S., 2004. Land use mapping of Kandi belt of Jammu region. *Journal of the Indian Society of Remote Sensing*, **32** (4): 323-328.

Mahajan, S. and Panwar, P., 2005. Land use changes in Ashwani khad watershed using GIS techniques. *Journal of the Indian Society of Remote Sensing*, **33**(2): 227-232.

Minakshi, Chaurasia, R. and Sharma, P.K. 1999. Land use / land cover mapping and change detection using satellite data : A case study of Dehlon Block district Ludhiana, Punjab. *J. Indian Soc. Remote Sensing*, **27** (2): 115-121

Palaniyandi, M and Nagarathinam, V. 1997. Land use / land cover mapping and change detection using space born data. *J. Indian Soc. Remote Sensing*. **25**(1): 27-33

Rathore, D.S. 1996. Hydrological land use mapping of Narmada basin. Report No. CS (AR)-222, National Institute of Hydrology, Roorkee

Sharma, K.P., Jain, S.C. and Garg, P.K. 1984. Monitoring landuse and land cover changes using landsat images. *J. Indian Soc. Remote Sensing*, **12**(2): 115-121

Journal of Soil and Water Conservation, **12**(1): 85-92, January-March 2013
ISSN: 022-457x

Knowledge management for sustainable agricultural development

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

Received: 23 December 2012; Accepted: 20 January 2013

ABSTRACT

The farmers require information and knowledge on a variety of technical and market matters to manage their farms effectively. The information helps the farmers make correct decisions in the world of available choices. This includes the crop, the variety, various other inputs, and how much, when, and how to use them. Growing variation in the market and agro-climatic environment with globalization and climate change makes this more risky and crucial. Systems to provide good information and knowledge to the small farmers are thus, becoming increasingly important for their viability, well-being and productivity. Knowledge management is concerned with ways of exchanging knowledge among those who can develop it and those who can use it. The lack of exchange of knowledge amongst farmers, has often been regarded as the key issue in agricultural development. Hence, many agricultural extension and development programs have focused on propagating knowledge to farmers who, in turn, were expected to gain by applying this knowledge in their day-to-day farming practices. An organized effort to identify, create, accumulate, re-use, apply and distribute knowledge is collectively called as knowledge management.

Key words: community radio, knowledge management, agricultural information system, indigenous technology knowledge, e-learning, e-choupal, social networking

INTRODUCTION

Agriculture system in today's world stretches far beyond the farms and needs focus towards the food production and its distribution across the globle. The agricultural workforce includes not only farmers, but also other skilled professionals, including scientists, seed suppliers, food chemists, packaging engineers, food safety experts, risk assessors, grocery suppliers, and many others. This agricultural workforce must constantly respond to changes in the physical, economic, and social environment surrounding agriculture. The major challenges ahead in this fast developing world are closely related to food security and agriculture. With the need to develop competant professionals from agricultural sector and to face the challenges ahead, the under-graduate agricultural education needs a new focus.

In order to manage their farms successfully, small farmers require information and knowledge on a variety of technical and market matters. The information helps the farmers make correct decisions in the world of available choices. This includes the crop, the variety, various other inputs, and how much, when, and how to use them. With development, as the number of options expand and become more and more complex, this decision-making becomes increasingly difficult. Growing variation in the market and agro-climatic environment with globalization and climate change makes this more risky and crucial. Systems to provide good information and knowledge to the small farmers are thus, becoming increasingly important for their viability, well-being and productivity.

[1] Chief Production Officer,cpoicar@yahoo.com; [2] Information System Officer, Directorate of Knowledge Management in Agriculture, ICAR, KAB-I, New Delhi-110012
[3] President, Soil Conservation Society of India, New Delhi-110012

In any developing country, agriculture as the contributing factor of economic development is well recognized if it is realized with the help of science and technology. Hence, the scientific agricultural education becomes casual factor for the socio-economic prosperity of developing countries. Moreover agricultural education of the right nature is indispensible for the desired progress of the country. It provides teachers to teach the taughts, scientists to generate useful and better technologies, the extension workers to transfer generated technologies to the producers and utilizers.

The concept of "Agricultural Information System" was first introduced and explained by "Une Jens Nagel" of the Technical University of Berlin in 1980.An Agricultural Knowledge Information System is a system in which agricultural information is generated, transformed, transferred, consolidated, received, utilized, and feedback in such a manner that these process function synergically to underpin knowledge utilization by agricultural producers.

Development of farming community demands both knowledge and material technology which can be referred to as software and hardware. In most of the cases it is difficult for any extension organizations to meet both. However without facilitative strategy for different input simply providing of Knowledge bears no fruit. Knowledge input is likely to bring about attitudinal and cognitive changes. These developments will be meaningful only when immediate transformation of knowledge into action is ensured. Favourable attitudes created through knowledge input are put into action when the situation is favourable. Otherwise as the theory of mindlessness and mindfulness suggests, the individuals are likely to enter a stage of mindlessness, which ultimately results in non adoption. Palmerino et al (1984) define mindfulness as a state of conscious processing of environmental cues, and mindlessness as a state in which an individual processes cues in a reduced cognitive level and in a relatively automatic manner. The need for linking cognitive behaviour with the action behaviour has also been experienced by KVK staff , while establishing successful Self Help Groups. The moment members agree to form a group, it should not be delayed in facilitating them to link up with financial agencies to support them. Otherwise their enthusiasm is lost.

In the context of KVKs collection, validation and documentation of indigenous knowledge of the farmers are of immense importance as KVK also act as a technology developer through farmers' participation. KVKs are in advantageous position over research institutions to validate indigenous knowledge as scientific recommendations or to formal research system for the required integration.

Each KVK should have a Technology Park to showcase the technologies generated by different institutes, for different farming purposes. Likewise an Information Centre should also be established to provide some basic information on agriculture and allied enterprises. Sufficient reading materials in the form of farm literature (Leaflets, Bulletins, News letter etc) should be provided to the trainees to retain their knowledge gained for future reference. It is a good sign that recently KMAS(Kisan Mobile Advisory Services) have also been introduced in almost all the KVKs. Farmers, Agi-preneures can instantly avail different information from the KVK scientists to solve their problems. Similarly most of the KVKs are also having their own websites where all the relevant information about their activities and district database are depicted. But it is equally important to update the database of agril information so that one can have the latest information to make a judicious decision. Through e-linkage project some KVKs are already connected with satellite based communication with the ICAR Head Quarter. Periodically experts are delivering different need based topic of National, regional as well as global importance through these KVK hub. It has played a pivotal role in acquiring, sharing and disseminating knowledge on various important topics for different stakeholders. The KVKs should harness the potentialities of such mechanisms through wider publicity.

Knowledge Management (KM) is about facilitating the maximum sharing and leveraging of the knowledge and insights of people or organizations involved in Research and Development. In India, a country now famous for its dynamic computer software industry, many KM tools and services are available. A considerable number of vendors provide standard or customized solutions for both small and large organizations.

Technology mediated Knowledge Management in agriculture is relatively a new concept. The mammoth task of driving the knowledge sharing process in agriculture requires lot of capacity building exercises. The concept of KM in extension is emerging as a viable factor of production in the developing countries. Training on Knowledge Management strategies, exposure to knowledge management initiatives in agriculture worldwide, acquiring the first hand information and managerial skills holds key to KM strategies in agriculture.

On the other hand, need for improved agricultural extension throughout the developing world has never been greater. Agricultural and rural development and hence, rural extension continue to be in transition in the developing world. These transitions are happening because of the forces that are driving the world agriculture today. The vulnerability of farming in the developing world is quite evident due to forces like climate change, changes in natural resources quality (including desertification over large tracts), lack of coping strategies at micro and macro levels of decision making, coupled with globalization, emerging market forces like commodity markets, sustainability constraints etc. The challenges can only be met from information intensive efforts in the extension systems (Meera, Shaik N.et.al, 2010).

Agricultural extension in India has undergone sea changes over the last few decades, in terms of activities, organizational types and available manpower. In the past, extension emphasized to bring out broad-based community and rural development. The country has made various experimentations to enhance its technology outreach to the farmers by initiating a number of projects and programmes in agriculture sector.

The Council has established 44 Agricultural Technology Information Centres (ATIC) in 16 ICAR Institutes and 28 State Agricultural Universities to work as 'Single Window' support system for linking the various units of research institution with intermediary users and farmers in decision making and problem solving exercise though supply of technology inputs, products, information and advisory under Innovations in Technology Dissemination (ITD) component of National Agricultural Technology Project (NATP), which was funded by World Bank.

ICAR is also trying various frameworks for technology generation and transfer for agriculture and allied sectors. Essentially for first time ICAR has given a serious thought about knowledge as a viable factor of production.

E-learning in Extension

Application of E-Learning strategies in Agriculture is seen as a potential driving force in bringing about knowledge based on sustainable agricultural development. Efforts have been made to introduce initiatives on pilot basis without taking into consideration, the existing capabilities of the extension systems of the country. Any strategy aiming at providing learning opportunities to extension workers should be based on critical analysis of e-learning opportunities and e-readiness among the existing system. There is a need to synthesise various initiatives related to KM/ICT enabled extension efforts and to generalise the concepts of KM/KM to develop a strong approach within the existing extension systems of the country. The ultimate choice of the KM/ICT Enabled agricultural extension approach depends on (1) the KM/ICT policy environment, (2) the capacity of potential KM/ICT service providers, (3) the type of stakeholders KM/ICT approaches wish to target, and (4) the nature of the local communities, including their ability to cooperate and various e-readiness parameters.

Knowledge management is concerned with ways of exchanging knowledge among those who can develop it and those who can use it. The lack of exchange of knowledge amongst farmers, has often been regarded as the key issue in agricultural development. Hence, many agricultural extension and development programs have focused on propagating knowledge to farmers who, in turn, were expected to gain by applying this knowledge in their day-to-day farming practices. An organized effort to identify, create, accumulate, re-use, apply and distribute knowledge is collectively called as knowledge management.

Knowledge can be understood as both information and skills that are acquired through individual experience and trial & error, within an organization or a learning community, or from outsiders adapting it to local contexts. Knowledge that rural and farming communities are typically interested includes, cultural management practices, emerging technologies, diagnostic information about plant and animal disease, soil related problems, market information on inputs and sales (prices, seller, buyers, retailers); market demand, land records and government policies.

It is important to know the information needs before venturing into any KM initiative. Some of the information needs of the farmers are:

- Marketing information
- Land records
- Farm mechanization
- Fertilizers and agrochemicals
- Better practices elsewhere
- Productivity enhancing tools and techniques
- Rural development programs & subsidies
- Weather forecasting
- Post harvest technologies - including packaging and storing
- General agriculture news
- Information on crop protection / insurance, pest control
- Farm business and management
- Input material prices as well as procurement prices
- Soil testing and sampling
- Water resource and management

By pooling in the resources from various sources referred in this article, wealth of knowledge can be created and made accessible thru the Kissan Vikas Centres. A central repository of this knowledge with interactions, opinions, suggestions and experience by individual farmers and academicians, like in a blog, will make it a robust knowledge management system.

Knowledge always does not mean that it has to come from outside. It could very well be internal. An excellent approach followed in one region in tackling a particular problem can be knowledge to rest of the country. When this sharing of ideas happens, it is not only deployed for the benefit of all, but also it results in cross-pollination leading to even better and improved ideas. This cycle is an important by-product which, sometimes proves to be more useful than anything else.

Knowledge management: key for the growth of agriculture

Knowledge has to be accorded the prime input status in the growth of agriculture. The knowledge base includes not only the advancements and new technologies, but also the current practices and the results. It should aim to capture learning from the past - both successes and failures.

- Knowledge repositories should capture both explicit and tacit knowledge. It should also capture best practices and the specialized region-specific nuances that yield good results all over the country. The State Agricultural Institutes, various KVCs and other extension service centres should be tasked with this.
- Crop wise, Region-wise, Practice-wise knowledge has to be archived and categorized based on the above and the search and retrieval tool has to be developed based on the user need. This search and retrieval tool should also undergo revisions and be perfected based on the usage.
- Various methods, including field trips, guest speakers, group discussions, workshops, on-farm demonstrations, audio-visual materials, printed matter, and interactive communications should be part of knowledge sharing and developed archives.
- Regional Centres should be encouraged for more adaptive and application oriented research and the rewards to such results should be made very attractive and encouraging.
- Suitable IPR mechanisms should help the contributor and at the same time friendly to those who utilize the same. The social motive of the whole knowledge management has to be appreciated and structured for an active collaborative participation of all stakeholders including private and government agencies, academic and research bodies and farming communities.
- Rewards and recognition should be instituted for those who contribute knowledge and also those who use it effectively. This will have virtuous effect.
- Continuous training to use ICT tools should be started.

Private participation in agriculture

Private participation in agriculture will infuse more capital, better knowledge from across the world, and deploy the relevant technologies. Till date, the major initiatives on knowledge management and education have only come from Government, like establishment of Universities, Institutes of Agricultural Research, etc. But, we are certainly seeing more from private sector participation in this area.

Many companies have developed new models to reach to the farmers. From a knowledge management perspective, some of the prominent and successful info-sharing models are:

- J Farm of Tractors and Farm Equipment Limited (TAFE)
- e-choupal of ITC
- Tata Kisan Kendra
- Mahindra Krishi Vihar
- Hariyali Kisan Bazaars
- India agriline

Agriculture Knowledge Management through agropedia

In the present era, several services / platform are running around the country and across the globe in the space of agriculture. However, none of these existing services makes use of the semantic technology to neither catalogue nor retrieve the data. agropedia being an ICT (Information and Communication Technologies) initiative for Indian agriculture, has state-of-art enabled platform to aid both certified knowledge holders (scientists, researchers, teachers, students, extension workers) as well as Tacit knowledge holders (progressive farmers, businessman) to contribute, share and search agricultural content. agropedia is a read / write web, where the users of agropedia can not only read its content but also can add new information, edit the existing wiki page, comment on any existing page and also can rate the content.

Agropedia had been developed by NAIP-KM team of Indian Institute of Technology Kanpur (IITK)in consultation with a consortium of partners like International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and University of Agricultural Sciences (UAS), Dharwad for 'Redesigning the farmer extension agricultural research / education continuum in India with ICT mediated Knowledge Management under the aegis of the World Bank funded National Agricultural Innovation Programme (NAIP)of the Indian Council of Agricultural Research (ICAR).

Agropedia is visioned to develop an agricultural repository and to build a Digital Ecosystem in agricultural domain for proper knowledge circulation, which will help prepare a bridge between Explicit knowledge holders (like agricultural reserachers, scientist, experts) and Tacit knowledge holders (like farmers and other field workers). agropedia also aims to deploy extension services for agricultural development.

Social networking

agropedia aspires to cover all web2.0 features and also some of web3.0 as the platform is semantically enabled. Social networking has already acquired a critical level of importance in almost every sphere of web, and of course agriculture is also not left apart from the emerging trend of social media.

Meanwhile, it was also sense that for better use of scarce resources, effective use of communication systems to provide the right information at the right time while not losing track of episodic knowledge, embedded in the system from many years, is essential. Traditional or innovative practices followed in the field of agriculture comprise the emergent knowledge section of agropedia. The Interaction Space of agropedia is to motivate and enable a healthy exchange of ideas and that is how agropedia contributes to Social Networking.

The primary objective of social networking in agropedia is to capture tacit knowledge, and to provide a mechanism to link agricultural professionals within India and globally. To aid such facility agropedia has mainly four different sub containers called agrowiki, agroblog, Forum and agrochat.

agrowiki: This is the wiki section of agropedia, where a user can not only create a wiki page but can also create revisions for any existing wiki page too. Only a registered user is allowed to do that.

agroblog: Blogging is all about having a dairy like content that is any registered user can share their experiences or opinions under this section.

Forum: This is a crop based Question Answer forum of agropedia.

agrochat: This is a chat interface where all online users can share their opinions and in the same time can also ask their questions to the other online expert.

agropedia, thus, is trying to create a kind of a "facebook" for agriculture so that experts from different regions of the country are easily able to communicate with each other. Moreover, it is hoped that if agriculture can be viewed as a "cool" profession, equivalent to working in a call centre, for example, it would attract bright and eager young minds to study and practice agriculture.

In efforts to reduce the weakness of the extension and advisory system in India, innovative models have emerged, adopting decentralized, participatory, privatized and demand-driven processes. These processes may better address the needs of farmers, particularly in rainfed areas. Such initiatives include the public-sector extension institutional platform, the Agriculture Technology Management Agency (ATMA) model, the private-sector approach of the Indian Tobacco Company, e-Choupal, and the public-private program of Agriclinics. But what are the impacts of these approaches on remote and rainfed farmers? To measure agricultural extension impact is a difficult task, because of self-selection bias (more progressive farmers will seek out extension services or extension workers will work with progressive farmers) and secondary inter-farmer communication flow bias (Birkhaeuser 1991). Additionally agricultural extension impact varies from year to year. The variables and indicators chosen to monitor and measure extension impact also differs; from measurement of farmers awareness and knowledge of technology and farm practices, to adoption of technology and practices, or measures of farmer productivity and efficiency (Evenson, 1997).

The Agriculture Technology Management Agency (ATMA)

The Agriculture Technology Management Agency (ATMA) has been defined as a semi-autonomous decentralized participatory and market-driven extension model. ATMA represents a shift away from transferring technologies to diversifying output, through a district level platform that integrates extension programs across line departments, and links research and extension. The pilot test was initiated in 1998 under the National Agricultural Technology Project (NATP) with the support of the World Bank in 28 districts in 7 states of India, which was expanded in 2005 to 252 districts, and then to all districts in the 11th five year plan (Reddy and Swanson, 2006).

A major need for extension lies in the areas of appropriate storage, post-harvest handling and marketing of crops, but these aspects are not common in most public extension systems upon which ATMA capacity relies. The previous and current performance indicators do not examine these aspects. The impact indicators used to measure performance largely relate to input, that is, the number of trainings and number of participants, which does not hold staff accountable for the quality of their extension work.

e-Choupals

e-Choupal is an initiative of the Indian Tobacco Company (ITC), launched in 2000 and represents a private and commercial initiative in agricultural extension. According to the ITC website, the e-Choupal initiative covers 10 states, 40 000 villages, consists of 6 500 kiosks and serves 4 million farmers (ITC, 2010). An e-Choupal is a kiosk in a village equipped with computers with internet access. To manage the e-Choupal, ITC identifies and trains a local farmer (Sanchalak), who bears the operative costs. e-Choupal provides to farmers an alternative marketing channel, information on local district weather, agricultural best practices, feedback on quality of crops and input sales with accompanying field specific testing such as soil tests (Annamalai and Rao, 2003; Bowonder et al., 2007). However the main purpose for which the kiosks were started was to procure crops, including soy in Madhya Pradesh, wheat in Uttar Pradesh, coffee in Karnataka and seafood in Andhra Pradesh (Upton and Fuller, 2004), thus reducing the procurement costs of ITC (Annamalai and Rao, 2003). Farmers, who can access information on prices, can chose to sell directly to ITC through the e-Choupal. The initiative requires significant initial investment, which is large due to infrastructure challenges, such as poor power supply and limited bandwidth (Annamalai and Rao 2003). However Kumar (2004) reports that the project has a potential payback period for all capital investment and running costs of 3.9 years.

e-Choupal has opened a market channel, which appears more efficient than the mandi system and improved agricultural markets. Despite the noted benefits of e-Choupals, the social impacts are not well described. Caste, political alignments and farm size influenced access to e-Choupals in Madhya Pradesh, where e-Choupals have been established in larger and more prosperous villages (Kumar, 2004). There were also significant differences in education, income, social category and landholding size between users and non-users. Educated farmers were more likely to better informed decisions on agricultural practices. The e-Choupal initiative highlights the impact price information given by village internet kiosks can have on farmer decisions and ultimately profits, which is currently not provided in the public sector extension system. This would require further empirical studies, which could also examine the social impacts.

Agriclinics and Agribusiness centres scheme

The Agriclinic and Agribusiness centre scheme is a national program, which aims to provide extension services and farm inputs to farmers through agricultural graduates at the village level. The program is open to agricultural graduates nation-wide and has been implemented since 2002 (Karjagi et al 2002). The centres can provide a wide range of service depending on the interest of the graduate and can include but are not limited to soil, water quality and input testing laboratory, plant protection services, vermin composting units, horticulture, veterinary clinic and agroservice centres for farm machinery and primary processing. To set up the clinic the agricultural graduate can access a 25% subsidy, although States have adopted the approach to add their own additional subsidies for its implementation.

Indigenous Technology Knowledge (ITK)

In the emerging global knowledge economy, a country's ability to build and mobilize knowledge capital is equally essential for sustainable development as the availability of physical and financial capital. (World Bank, 1997) The basic component of any country's knowledge system is its indigenous knowledge. It encompasses the skills, experiences and insights of people, applied to maintain or improve their livelihood. Significant contributions to global knowledge have originated from indigenous people. Such knowledge is developed and adapted continuously to gradually changing environments and passed down from generation to generation and closely interwoven with people's cultural values. Indigenous knowledge is also the social capital of the poor, their main asset to invest in the struggle for survival, to produce food, to provide for shelter or to achieve control of their own lives.

Agriculture has not only been the means of livelihood for the rural mass but it has rather, also been a way of life since time immemorial. Right from the origin of mankind, life has nurtured and grown in close association with plants and animals. In fact, growing of various crop plants has led stability to nomadic hunting primitive society which subsequently developed into civilized societies.

CONCLUSIONS

The importance of knowledge management in agriculture is well established. It may be the best mean not only to develop Agricultural Extension, but also to expand agriculture research and education system. With the advancement of IT sector Knowledge Management Process has also been changed.

In the changing scenarios and shifting paradigms, the National Agricultural Research Systems (NARS) of the world are harnessing the power of ICTs and Indian Council of Agricultural Research (ICAR) promotes the initiatives of harnessing the ICTs by developing national level, multi-dimensional, multi stakeholder and hierarchical knowledge management portals for agriculture as a whole. While KM Portals will serve as the backbone for knowledge repositories, there here is a need to transform the way agricultural knowledge sharing is looked at in the recent past and to promote professionalism and pluralism in extension by developing potential 'Knowledge Consortia' of key players such as public, private, non-government and farmers organizations at national as well as global level.

Effective strategies to harness ICT enabled KM approaches to preserve, produce, and improve access to the agricultural knowledge using multiple delivery mechanism (both online and offline) will help bringing about a sustainable agricultural development in India. The impact of Agriclinics and e-Choupals have had positive outcome, their coverage is limited with small numbers in the case of Agriclinics, or specific crop focus like e-Choupal. Therefore in terms of reaching rainfed farmers, ATMA has the greatest scope due to the national coverage of the Department of Agriculture. However current implementation issues of ATMA are limiting this model, which could be greatly aided by effective monitoring and evaluation.

REFERENCES

Ali, J., S. Kumar. 2011 information and communication technologies (ICTs) and farmers decision-making across the agricultural supply chain. International Journal of Information Management. 31: 149-159.

Ananthraman, M, Ramanathan, S and Sivakumar, P.S 2002 Capacity Development for KVK-Internal and External Dimensions in Krishi Vigyan Kendra-The Capacity Builder of Farmers, edited book by Samanta, R.K. and Chandre Gowda, M.J pp 106-107.

Annamalai K., Rao S. 2003 What works: ITC's e-Choupal and Profitable Rural Transformation. Web-based information and procurement tools for Indian farmers., The Digital Dividend 'What Works' Case Study Series, World Resources Institute.

Arun Kumar S, Sailaja B. , Jyothi SSP and Viraktamath BC, 2010 Critical Analysis of E-learning opportunities and E-readiness in the Public Extension System: Empirical evidence from Tamil Nadu. Journal of Global Communication, Sydney. 3(2): 11-18.

Birkhaeuser D., Evenson R.E., Feder G. 1991 The Economic Impact of Agricultural Extension: A Review. Economic Development and Cultural Change 39:607-650.

Chattopadhyay, B.N and Das, P 2004 Information and Communication Technology for Sustainable Development in Communication Support for Sustainable Development, edited book by De, D and Jirli, B pp 72-73.

Dangi N., Singh H. 2010 eChoupal: Hope or Hype. American Journal of Economics and Business Administration 2:179-184.

Department of Agriculture and Cooperation. 2010 Guidelines for modified 'Support to State Extension Programmes for extension Reforms' Scheme, 2010, in: GOI, Ministry of Agriculture (Ed.), New Delhi.

Directorate of Economics and Statistics 2009 Agricultural Statistics at a glance 2009, Department of Agriculture and Cooperation, Ministry of Agriculture, , New Delhi.

Kumar R. 2004 eChoupal: A Study on the Financial Sustainability of Village Internet Centers in Rural Madhya Pradesh. Information Technologies and International Development 2:45-73.

Parshad, R 2006 Knowledge Management in KVK in Proceedings of Second National Conference on KVKs pp 156-162

Shaik N. Meera 2008 Transforming Extension through ICTs: Issues and Strategies for Developing World. Journal of Global Communication, Global Communication Research Association, Sydney. 1 (1): 68-75.

❑

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.

24th National Conference
on
Sustainable Farming Systems and Bioindustrial Watershed Management for Food Security and Enhancing Income of the Farming Community

16-17 April 2013

Sponsored by
State Department of Agriculture
&
State Department of Land Development & Water Resources
Govt. of Uttar Pradesh, Lucknow

Co-Sponsored by
Indian Council of Agricultural Research
New Delhi

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

ADDRESSES FOR CORRESPONDENCE

Shri D.M. Singh
Director (Agriculture)
State Agricultural Department
Govt. of Uttar Pradesh, Krishi Bhawan, Lucknow
Conference Convenor and Chairman
Organizing Committee
Tel: 0522-2205868, 09235629301; *Fax:* 0522-2206582
E-mail: dahq@sify.com

Dr. Suraj Bhan
President
Soil Conservation Society of India
National Societies Block G-4A
National Agricultural Science Centre Complex
(NASC), DPS Marg (Pusa), New Delhi – 110 012
Telefax: 011-25848244, (M) 09868808980
E-mail : soilcsi@gmail.com, bhan_suraj1945@yahoo.com
Website: www.soilcsi.com

INTERNATIONAL CONFERENCE ON
NATURAL RESOURCE MANAGEMENT FOR FOOD SECURITY & RURAL LIVELIHOOD (NRMFRC)

From 17-20 February 2015
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 G-4/A, National Agricultural Science Centre Complex (NASC), Dev Prakash Shastri Marg, Pusa, New Delhi - 110 012
E-mail: soilsci@gmail.com, bhan_suraj1945@yahoo.com; Website: http//www.soilcsi.com

Laser typeset by Dot & Design, D-35, 1st Floor, Ranjeet Nagar Comm. Complex, New Delhi 110 008 (dotdesign2011@gmail.com) and printed at M/s Chandu Press, D-97, Shakarpur, Delhi-110 092