e-Journal **Earth Science India**, Vol.2 (III), July, 2009, pp. 211 - 223
http://www.earthscienceindia.info/ ; ISSN: 0974 - 8350

Study of hydrological soil properties of salt affected areas around Gohana, Sonipat district, Haryana

V.K. Choubey, Omkar Singh and S.L. Srivastava
National Institute of Hydrology, Roorkee-247 667
Email: vkc@nih.ernet.in; omkar@nih.ernet.in

Abstract

Monitoring of hydrological data is pre-requisite for systematic and scientific designing of sub-surface drainage system for control water logging and salinity. In the present study, field experiments were conducted to determine various soil hydrological and physico-chemical properties (soil texture, color, permeability, infiltration, soil moisture characteristics, dry density, total dissolved solids, SAR, etc.) under saline soils around Gohana tehsil. The majority of the area is represented by silt loam texture with varying soil color having dominance of yellowish brown in top layer. The in-situ permeability was measured using Guelph Permeameter in the field and its values were found to vary from 0.01 to 0.69 m/d for silt loam. The SAR of the soil generally varied from 0.5 to 54. The infiltration data of area was fitted with Kostiakov's type cumulative infiltration function ($Y=a_*t^b$) and its coefficient of determination (r^2) varied from 0.956 to 0.998. The present data would be useful in planning of on farm land and water management strategies ultimately for enhancing the productivity of the land.

Introduction

Salt affected soils are extensive in the plains of Haryana state. The three distinct kinds of soils met with are alkali, saline and saline-alkali. Rainfall, surface topography, surface configuration (relief, aspect, micro-relief and microclimate) have influenced mineral weathering, ionic mobility and macro-chromatographic separation leading to formation of these soils in three distinct zones. Central Soil Salinity Research Institute has carried out extensive research work to upkeep of the sustainability of irrigated agriculture in India as threatened by waterlogging, soil salinity and alkalinity (Datta *et al.,* 2000; HOPP, 2004; Gupta, 2007).

Development of waterlogging is an inevitable consequence of introduction of irrigation without providing for adequate drainage. If the underground water quality is poor, soil salinity develops soon thereafter. As such, waterlogging and soil salinity have emerged as major problems in the irrigation commands affecting the agricultural productivity and sometime becomes too severe such that it becomes imperative to take the land out from crop production. In India, it is estimated that about 6.0 m ha land is affected from various nature and orders of waterlogging and about 8.5 m ha land is affected from different degrees of soil salinity (Anonymous, 2002).

The estimation of hydrological soil properties are essential for irrigation and drainage planning, rainfall runoff modeling and for ground water studies (Singh, 1991; Soni, 1991; Mishra, 1991). Soil moisture is a key variable required for hydrological and eco-hydrological modeling (Eagleson, 1982; Rodriguez-Iturbe *et al.,* 2006; Porporato *et al.,* 2001; Sofo *et al.,* 2008). Moreover, vegetation water stress is intimately related to relative soil moisture and the length of time that the soil moisture is below a given threshold. The crossing properties of the soil moisture levels are controlled by the drying process and the infiltration inputs into the soil matrix and finally vary soil to soil according to the texture and permeability (Manfreda *et al.,* 2009).

In view of above, the present study was conducted around Gohana in Sonipat District of Haryana facing problems of rising water table, water logging and soil salinization. The soil hydrological parameters include: soil texture, soil color, permeability, infiltration, soil moisture, dry density, total dissolved solids, pH, EC, TDS, SAR and % Na.

Study area

The study area spread over 150 sq km around Gohana Tehsil in Sonipat district, Haryana (Fig.1). The Sonipat district has an area of 2200 sq.km. The study area falls between Latitude 29^0 3′ N to 29^0 15′ N and Longitude 76^0 30′E to 76^0 45′E. Sonipat is one of the smallest districts of Haryana and covers 5.11 % area of the state. The district is surrounded by Panipat district in the north, Jinx district in the west, Rothay district in the Southwest and Delhi in the South. Sonipat district is one of the densely populated districts of the state. The population density is 471 persons per sq.km against the state average of 372 persons per sq.km (CGWB, 2008).

The project area forms part of the vast alluvial plain which belongs to Pleistocene epoch and Quaternary period. Surface and subsurface drainage conditions differ widely within the study area. The northern portion which is elevated than the rest of the area has better surface drainage than the southern and south eastern parts. Ground water consequently exists at shallow depths in the southern and south eastern parts in relation to the northern half. Continuous trampling of village track in the west by men, animals, farm machinery and other modes of transport results in loss of clay by wind. A part of this clay-depleted material is carried and deposited by wind and water in other parts of the area.

The region, therefore, has an Acidic Moisture Regime. In sonic soils due to highly deteriorated physical condition and extremely poor water transmission characteristics the moisture control section remains moist for a longer period following initial wetting during monsoon period. These soils are, therefore, put under Rustic while localized depressions and lowly placed old channels under Aqua moisture regime.

Climate of Gohana is semi-arid with mean annual rainfall about 550 mm. In the climate more than 80 per cent of annual rainfall is between July and September. Lying in the subtropical belt, the maximum temperature exceeds 40^0 C in May while the minimum temperatures of 3^0 to 4^0C are recorded in December or January. Evaporative demands (about 1100 mm) exceed mean rainfall and conditions of net saturation deficit prevail throughout the year.

Methodology

Field experiments were conducted to determine various soil hydrologic properties around Gohana tehsil in Haryana. Soil samples were collected in the field for determination of soil texture, soil moisture, colour, and chemical properties. Soil textural analysis was performed in two stages (*i.e.* Mechanical analysis for Coarse and Wet analysis for fine earth materials). The mechanical analysis of soil was performed using sieves as per I.S. 460-1962 (4.75 mm to 75 microns Seives). The wet analysis was performed for fine soil particles passing through 75 µm sieve using Master Sizer, which works on the "Mie Theory" model of light scattering (Malvern Instruments Ltd., 1993).

e-Journal **Earth Science India**, Vol.2 (III), July, 2009, pp. 211 - 223
http://www.earthscienceindia.info/ ; ISSN: 0974 - 8350

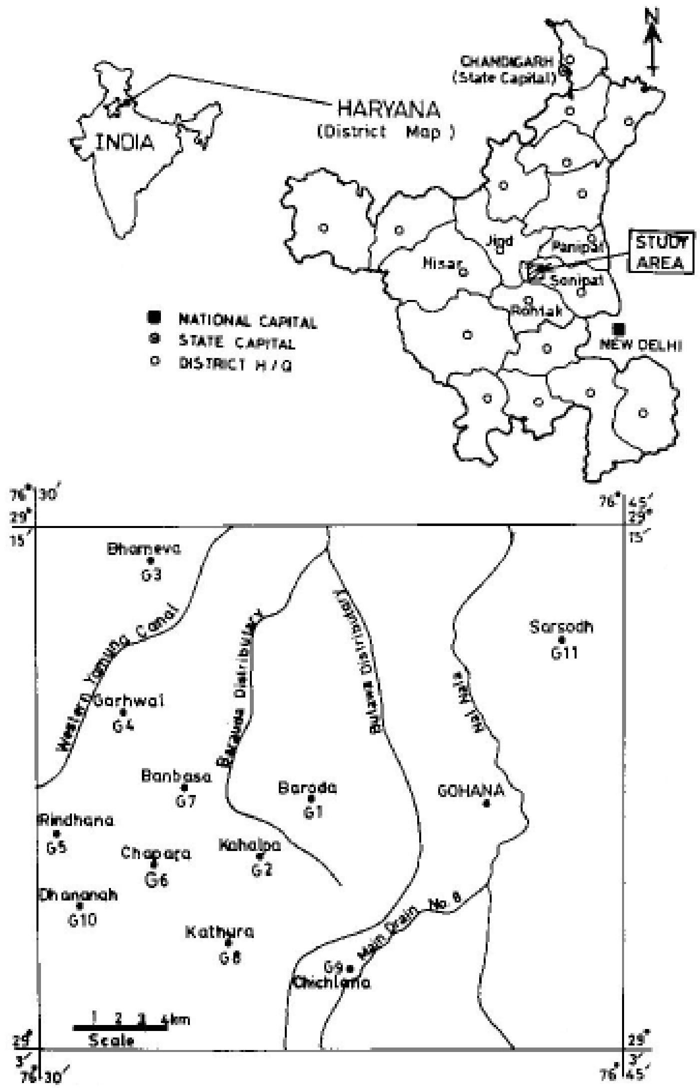


Fig.1: Study area showing field investigation sites around Gohana, Sonipat district, Haryana

Soil moisture was measured using gravimetric method. The colour of the soil was determined on the basis of Munsell System of International Color Notation (Eijkelkamp, 1997) having three components: hue (a specific colour), value (lightness and darkness), and chroma (colour intensity). Chemical analysis of soil samples was carried out in the laboratory as per standards procedures (Saxena, 1990). Sodium Adsorption Ratio (SAR) and sodium percentage (% Na) was calculated using the following formulae (USDA, 1954):

$$SAR = \frac{Na^{+}}{[(Ca^{++} + Mg^{++})/2]^{0.5}}$$

$$Na\% = \frac{Na^{+} + K^{+}}{Ca^{++} + Mg^{++} + Na^{+} + K^{+}} \times 100$$

In calculation of SAR and %Na, all ionic concentrations are expressed in milli equivalent per litre (meq/l).

The in-situ permeability was determined in the field using Guelph Permeameter (Soil Moisture Equipment Corporation, 1987). Guelph Permeameter method is considered to be the most useful amongst the field methods for unsaturated zone monitoring. Measurement of infiltration rates were carried out using double ring cylinder infiltrometers (size: 30 cm inner, 45 cm outer diameter and height 45 cm) made of mild steel sheet. The observed data of cumulative infiltration was fitted with Kostiakov (1932) soil infiltration model (Michael, 1990).

Results

Soil Texture and Colour:

The textural analysis of the soil samples collected from upper layer (0-40 cm) in the Gohana region was carried out in the laboratory. The results are given in Table 1a, which depict that sand varies from 16.62-69.43%, silt varies from 24.34-71.45% and clay varies 5.76-11.56%. The results indicated that silt loam is main textural group of soils in the study area.

The colour code and colour of the soils in the study area as determined from Munsell Classification are given in Table 1b, which indicates that color at the majority of the sites in the study area was Yellowish Brown (2.5 Y 5/3) in the upper soil layer.

Soil Moisture and Dry Density:

The gravimetric soil moisture (% db) and dry density (g/cc) analysis of soil samples collected for 0-40 cm and 40-60 cm depths during pre monsoon period in the Gohana area. These results are given in Table 2. The moisture content was found to vary from 8.07 to 21.59% db in upper layer (0-40 cm) and 7.93 to 24.32% db in lower layer (40-60 cm depth), respectively. In general, the moisture content was found to be increasing with the depth in the field usually showing profile variability of moisture content with depth.

The dry density varied from 1.50 to 1.80 g/cc upper layer (0-40 cm) and 1.38 to 1.77 g/cc in lower layer (40-60 cm depth), respectively, showing decreasing trend with depth in the study area.

Table-1a: Soil texture around Gohana in upper layer (0-40 cm)

S.No.	Site Name	Site Code	Gravel	Sand	Silt	Clay	Texture
1	Baroda	G1	0.01	33.23	55.2	11.56	Silt Loam
2	Kahalpa	G2	0.13	16.62	71.45	11.8	Silt Loam
3	Bhamewa	G3	0.08	26.44	64.4	9.08	Silt Loam
4	Garhwal	G4	0.21	31.56	61.28	6.95	Silt Loam
5	Rindhana	G5	3.74	35.82	52.72	7.72	Silt Loam
6	Chapara	G6	6.82	21.96	63.77	7.45	Silt Loam
7	Banbasa	G7	0.47	69.43	24.34	5.76	Sandy Loam
8	Kathura	G8	0	18.5	70.56	10.94	Silt Loam
9	Chicharana	G9	0.05	29.09	61.61	9.25	Silt Loam

Table-1b: Colour code and Soil colour at upper layer around Gohana

S.No.	Site Name	Site Code	Colour Code	Soil Colour
1	Baroda	G1	2.5 Y 5/3	Yellowish Brown
2	Kahalpa	G2	2.5 Y 5/3	Yellowish Brown
3	Bhamewa	G3	2.5 Y 4/3	Alive Brown
4	Garhwal	G4	2.5 Y 5/2	Dark Grayish Brown
5	Rindhana	G5	2.5 Y 5/3	Yellowish Brown
6	Chapara	G6	2.5 Y 5/3	Yellowish Brown
7	Banbasa	G7	2.5 Y 5/3	Yellowish Brown
8	Kathura	G8	2.5 Y 6/3	Dull Yellow
9	Chicharana	G9	2.5 Y 6/3	Dull Yellow

Table-2: Moisture Content (% db) and dry density (g/cc) in the study area

S.No.	Site Name	Soil moisture content, % db		Dry density (g/cc)	
		Depth (0-40cm)	Depth (40-60cm)	Depth (0-40cm)	Depth (40-60cm)
1	Baroda	17.98	19.31	1.67	1.69
2	Kahalpa	21.59	24.32	1.58	1.52
3	Bhamewa	17.81	18.28	1.72	1.68
4	Garhwal	18.06	14.57	-	-
5	Rindhana	11.34	16.32	1.75	1.77
6	Chapara	17.33	22.59	1.50	1.38
7	Banbasa	8.07	7.93	-	1.49
8	Kathura	20.18	22.67	1.60	1.62
9	Chicharana	21.53	20.73	1.80	1.71

Permeability:

Permeability is the measure of the ability of a soil to transmit water under a unit hydraulic gradient. For a particular soil, it represents its average water transmitting properties, which depends mainly on the number and the diameter of the pores present. In this study, in-situ permeability was determined in the field using Guelph Permeameter for depth 0-40 cm. The results (Table 3) show Permeability values were found to vary from 0.01 m/day to 0.69 m/day under silt loam. Permeability under sandy loam was found in the order of 8.23 m/day in the study area.

Table- 3: In-Situ Permeability (m/d) of soil in the study area

S.No.	Site Code	Site	Permeability, Kfs, m/d	Soil Texture
1	G1	Baroda	0.02	Silt loam
2	G2	Kahalpa	0.69	Silt loam
3	G3	Bhamewa	0.24	Silt loam
4	G4	Garhwal	0.09	Silt loam
5	G5	Rindhana	0.41	Silt loam
6	G6	Chapara	0.01	Silt loam
7	G7	Banbasa	8.23	Sandy laom
8	G8	Kathura	0.09	Silt loam

Soil Infiltration:

The infiltration tests were conducted under in the Gohana area using double ring cylinder infiltrometer. The results are given in Table 4, which show that initial infiltration rates vary 4.13 to 24.83 cm/hr and final infiltration from 0.56 to 1.9 cm/hr under silt loam texture. However, under sandy loam soil, the final and initial infiltration rates were found in the order of 7.16 and 47.75 cm/hr, respectively (Tables-4).

The observed infiltration data of the Gohana area was fitted using Kostiakov (1932) type function: $Y=a*t^b$; where "Y" is cumulative depth of infiltration (Y, cm), "t" is elapsed time (min), " a" & "b" are function coefficients of the Kostiakov Equation for cumulative depth of infiltration (cm). In addition, the observed data for rate of infiltration (y, cm/hr) was also fitted with other popular statistical functions for making comparison of the data fits. The results of both type of data fitting have shown a very good coefficients of determination (r^2) which, varied from 0.956 to 0.998 for Kostiakov type function for cumulative depth and 0.872 to 0.972 for observed data of infiltration rate (y, cm/h) using Power function ($y=ax^b$), respectively. However, it is pertinent to note that Kostiakov type function for cumulative depth of infiltration has shown slightly better performance over other statistical function as evident from their respective coefficient of determination values. The sample diagram of the infiltration rate curves under silt loam and sandy loam soils are given in Figs. 2 & 3, respectively.

Table- 4: Infiltration coefficients in the study area

Site	Soil Type	Initial Infiltration rate (Ia) cm/hr	Final infiltration rate (Ic) cm/h	Function Type	Function coefficients and coefficient of determination		
					A	b	r^2
Baroda	Silt Loam	8.59	0.56	Kostiakov	0.769	0.345	0.959
				Power	136.5	-1.18	0.972
Kahalpa	Silt Loam	11.46	1.78	Kostiakov	0.517	0.486	0.997
				Power	32.23	-0.67	0.957
Bhamewa	Silt Loam	11.46	1.9	Kostiakov	0.495	0.506	0.994
				Power	31.32	-0.64	0.933
Garhwal	Silt Loam	4.13	0.95	Kostiakov	0.118	0.634	0.997
				Power	9.26	-0.53	0.872
Rindhana	Silt Loam	7.64	0.859	Kostiakov	0.407	0.461	0.988
				Power	27.09	-0.75	0.901
Chapara	Silt Loam	6.04	0.954	Kostiakov	0.25	0.506	0.996
				Power	16.96	-0.65	0.903
Banbasa	Sandy Loam	47.75	7.16	Kostiakov	1.491	0.473	0.993
				Power	75	-0.67	0.916
Kathura	Silt Loam	24.83	0.764	Kostiakov	0.963	0.361	0.956
				Power	41.59	-0.48	0.958
Chichlana	Silt Loam	5.73	0.89	Kostiakov	0.191	0.537	0.998
				Power	15.74	-0.69	0.958

Physio-chemical Properties of Soils:

Some physico-chemical properties (pH, EC, TDS and SAR) of soils of Gohana area are given in Table 5. The results indicate alkaline nature of soil having pH variation from 8.12 to 9.01. Total dissolved solids (TDS) in the soil extract was found to vary from 700 mg/l to 11000.00 mg/l. Sodium adsorption ratio (SAR) varied from 0.47to 54. The mean values of pH (8.5), EC (6859 micro mhos/cm at 25^0c) and soluble sodium percentage, % Na (68), show that soils under the study area fall under saline-alkali group and soil particle remain flocculated.

Table-5: Soil Properties in Gohana Region

Site	pH	EC µS	TDS ppm	SAR Value	% Na
G1	8.45	2450	2000	7.16	65
G2	8.83	720	800	21.2	89
G3	-	-	-	16.7	79
G4	8.37	4610	4600	54	95
G5	8.2	2750	700	2.28	49
G6	8.78	14100	11000	38.9	93
G7	8.2	9020	7900	2.44	52
G8	8.12	2960	3900	0.47	13
G9	8.84	1010	1400	7.02	74
Mean	8.5	6859	3856	16.69	68

Conclusion

Various hydrological field investigations have been carried out in Gohana tehsil in Sonipat District of Haryana. The results of textural analysis indicated that silt loam is a major textural group in the study area. The soil pH varied from 8.12 to 9.01 which show an alkaline reaction of the soil of the study area. Total dissolved solids (TDS) in the soil extract were found to vary from 700 mg/l to 11000.00 mg/l showing higher concentration of salts in the root zone causing low food, fodder and fibre production. Sodium adsorption ratio (SAR) varied from 0.47to 54. The colour code and colour of the soils in the study area as determined from Munsell Classification indicated Yellowish Brown (2.5 Y 5/3) color at majority of sites. The dry density varied from 1.50 to 1.80 g/cc upper layer (0-40 cm) and 1.38 to 1.77 g/cc in lower layer (40-60 cm depth), respectively, showing decreasing trend with depth in the study area.

The in-situ Permeability was determined using Guelph Permeameter and its values were found to vary from 0.01 m/day to 0.69 m/day under silt loam. Infiltration and Permeability under sandy loam were found higher than silt loam. Kostiakov (1932) type cumulative infiltration function has shown a good correlation coefficients (r^2) varying from 0.956 to 0.998.

The obtained results indicate that the study site around Gohana affected by water logging and salinity. It is observed that the study area possess a low permeability (0.01 m/day to 0.69 m/day) as well as low basic infiltration rates (0.56 to 1.9 cm/hr), respectively, which indicate poor percolation of excess water through sub-surface due to presence of hard pan and ultimately causing waterlogging and salinity in the area. The above information on permeability, infiltration, texture, soil moisture, etc. along with other data invariably needed for adequate, efficient and longevity of the sub surface drainage system. Further intensive investigations are suggested to make a comprehensive assessment of waterlogging and salinity affected area from drainage design network point of view in the Sonipat district.

It is, therefore, evident that the data of infiltration, permeability, soil texture, soil moisture, etc. is pre-requisite for systematic and scientific designing of sub-surface drainage system for control water logging and salinity in the root zone. The results indicate that these problematic soils require special attention to maintain appropriate soil-water-plant relationship by providing adequate drainage system which may finally enhance crop yields in terms of food, fodder and fibre.

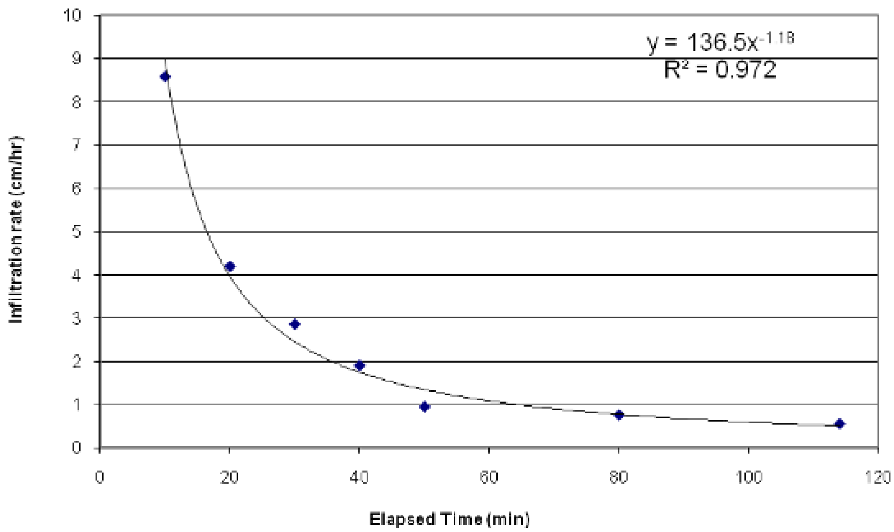


Fig. 2: Infiltration rate at Baroda under Silt Loam Soil (July,04)

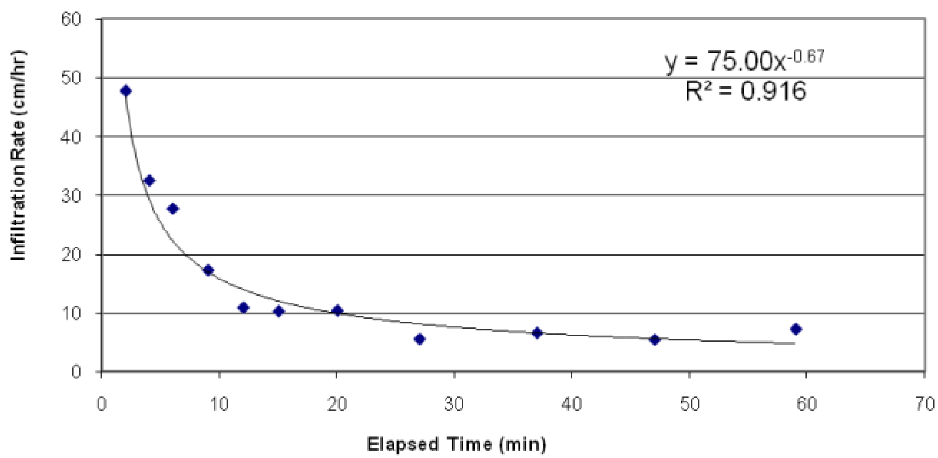


Fig. 3: Infiltration rate at Banbasa under Sandy Loam Soil (July,04)

References

Anonymous, (2002) Research on the control of water logging and salinization in irrigated agricultural lands, CSSRI, Karnal.

CGWB, (2008) Ground water information booklet of Sonipat district, Haryana, Central Ground Water Board, Government of India, North western region, Chandigarh.

Datta, K.K., C. de Jong and Singh, O. P. (2000) Reclaiming salt-affected land through drainage in Haryana, India: a financial analysis. Agricultural Water Management, v. 46, Issue 1, pp. 55-71.

Eijkelkamp, (1997) Soil Color Book, Cat. 08.11, The Netherlands.

Eagleson, P.S. (1982) Ecological optimally in water limited natural soil-vegetation systems, theory and hypothesis. Water Resour. Res., v.18, pp. 325-340.

Gupta, S. K. (2007) Experiences of subsurface drainage for reclamation of waterlogged saline lands in irrigation commands. *In: Ambast, S.K., Gupta, S.K. and Singh, Gurbachan eds.),* Agricultural Land Drainage: Reclamation of Waterlogged Saline Lands, Central Soil Salinity Research Institute, Karnal, India, 231 p.

HOPP, (2004) Report on Benefits of Subsurface Drainage in Gohana. HOPP, Department of Agriculture, Haryana.

Soil Moisture Equipment Corporation (1987) Guelph Permeameter-Model 2800KI: Operating and Instruction Manual, Santa Barbara, CA, 28 p.

Kostiakov,A.N.(1932) On the dynamics of the coefficients of water percolation in soils and on necessity for studying it from a dynamic point of view for purpose of amelioration. Trans. of the 6th Commission, Int. Soc. Soil Sci., Russian, pp.17-21.

Malvern Instruments Ltd., (1993) MaterSizer E: Instrument Manual, No. MAN 0060 Issue 2.1, Spring Lane South, Malvern, Worcs, WR14 1AT.

Manfreda, S., Kelly, K. Caylor and Todd, M. Scanlon (2009) Infiltration processes and soil moisture dynamics. Proc. Int. Conf. on Water, Environment, Energy and Society (WEES, 12-16 January 2009, New Delhi) organized by NIH Roorkee, M/s Allied Publishers Pvt. Ltd. New Delhi.

Michael, A. M. (1990). Irrigation: Theory & Practice. Vikas Publishing House Pvt Ltd.

Mishra, G.C. (1991) Design of sub-surface drainage using Hooghought equation. Proc. of UNESCO sponsored regional course on "Water Logging and Drainage", July 9-19, National Institute of Hydrology, Roorkee, India.

Porporato, A., Laio, F., Ridolfi, L. and Rodriguez-Iturbe, I. (2001). Plants in water controlled ecosystems: active role in hydrological processes and response to water stress.III, vegetation and water stress, Adv. Water Resour., v.24, pp.725-744.

Rodriguez-Iturbe, I., Isham, V., Cox, D.R., Manfreda, S. and Porporato, A. (2006) Space time modeling of soil moisture: stochastic rainfall forcing with heterogeneous vegetation, Water Resour. Res., v. 42, W06D05.

Saxena, M.M. (1990) Environmental Analysis: Water, Soil and Air. Argo Botanical Publishers, Bikaner.

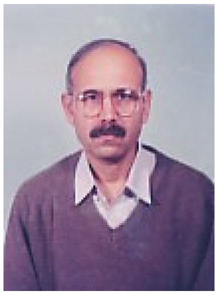
Singh, R.D. (1991) Hydrological parameters in drainage studies. Proc. of UNESCO sponsored regional course on "Water Logging and Drainage", July 9-19, National Institute of Hydrology, Roorkee, India.

Soni, B. (1991) Estimation of hydrological soil parameters. Proc. of UNESCO sponsored regional course on "Water Logging and Drainage", July 9-19, National Institute of Hydrology, Roorkee, India.

Sofo, A., Manfreda, S., Dichio, B., Fiorentino, M. and Xiloyannis, C. (2008) The olive tree: a paradigm for drought tolerance in mediterranean climates. Hydrol. Earth Syst. Sci., v.12, pp. 293-301.

USDA, (1954) Diagnosis and Improvement of Saline and Alkali Soils, Handbook No. 60, U.S., GPO, Washington, D.C., USA.

About the Authors

	**Dr. V.K. Choubey** is Scientist-F and Head, Environmental Hydrology Division, National Institute of Hydrology, Roorkee. He did M.Sc in Applied Geology from Jabalpur University, D.I.I.T in Remote Sensing from I.I.T, Bombay and Ph. D. in Remote Sensing Applications in Water Quality from Jawahar Lal Nehru University, New Delhi. He also holds the charge of Co-ordinator, Hard Rock Regional Centre, Belgaum. He has research & development experience of more than 28 years in different areas of Hydrology and Water Resources. He has published more than 75 research papers in the reputed International & National Journals. He was awarded National Hydrology Award in 1993 in recognition of his significant contributions in the area of Operational Hydrology.
	**Mr. Omkar Singh,** Scientist-E1, National Institute of Hydrology, Roorkee did his B. Tech. in Agricultural Engineering from College of Technology, G.B. Pant University of Agriculture and Technology, Pantnagar, and M.Tech., Soil & Water Conservation Engineering from Indian Institute of Technology, Kharagpur. He has research experience of more than 16 years in the area of Environmental Hydrology dealing with soil/water quality and hydro-meteorological aspects of the lakes and catchments. He has published more than 50 research papers in various journals and Edited books.
	**Mr. S.L. Srivastava** is a scientific staff under Soil & water testing laboratory, National Institute of Hydrology, Roorkee in 1987. He has been associated with field and laboratory investigation of SHE model project by the Danish Hydraulic Institute, Denmark. He also visited Denmark (Danish Land Development Service) for advance training on soil sampling and soil physical analysis in March 1991. He has published 12 research papers in various National journals, International /National seminars, workshop etc.