Annals of Arid Zone 41(2): 119-126, 2002

Soil-site Characteristics and Productivity Assessment of Nara-Dada-Manjhi Watershed in Semi-arid Hilly Tract of Punjab

K.R. Sharma, H.S. Jassal and A. Sondhi
Department of Soils, Punjab Agricultural University, Ludhiana 141 004, India

Abstract: The soil-site characteristics of Nara-Dada-Manjhi watershed, situated on the southern slopes of the Shiwalik hills in Hoshiarpur district of Punjab, were studied to work out the land productivity rating. Based on inherent soil characteristics and external land features, the Storie Index Rating factors A, B, C and X were evaluated. The results reveal that the soils of Nara-Dada-Manjhi watershed belong to four land productivity grades. The soils of lower piedmont plains generally belong to grade 2 and are suitable for most crops with good yield potential, whereas soils from upper piedmont plains qualify for grade 3 and may be used for selected crops. The soils developed on *choe* beds and hills qualify for grades 5 and 6, respectively. The soils on *choe* beds have limited use, except for pasture, whereas soils on hills are not suitable for agriculture.

Key words: Soil-landscape relationship, physico-chemical characteristics, Storie Index Rating.

Watershed development aims at management of all its natural resources to ensure their judicious utilization and proper protection. The formulation of proper development plan of a watershed needs characterization of land and water resources of the area (Murty, 1995). Since the ultimate goal of watershed development is achieved through greening of the area, soil is considered as one of the basic valuable resources. Watershed, being a distinct hydrological entity, has profound influence on its physical character (Linsley *et al.*, 1975) and thus influences the soil pattern within and among different catchments. During recent years, a definite conceptual change in soil research has been observed from broad soil-physiographic approach to narrower soil-watershed approach. Realizing its importance, various development programs in India have underlined the need for land and water resources study on watershed and micro-watershed basis.

Watershed management in arid and semi-arid regions requires special attention because of erratic and torrential rainfall pattern in these areas, thereby making the ecosystem highly fragile. In India, an appreciable area (29 m ha) is under arid climate, spreading over parts of Rajasthan, Punjab and Haryana states. Major watershed areas in Punjab (9.5% of the total) lie in the hilly tract of Shiwaliks in the north, and are subject to serious water erosion (Kukal *et al.*, 1991). Management of resources in the area needs special attention. Keeping in mind the comprehensive integrated approach of land resources management, soil characteristics and soil productivity aspects have been analyzed in the present study, so that optimum productivity of the watershed could be ascertained.

Materials and Methods

A detailed reconnaissance soil and land use survey of the Nara-Dada-Manjhi watershed, situated on the southern slopes of Shiwalik hills in Hoshiarpur district of Punjab, was carried out using cadestral maps at 1:20000 scale. The watershed lies between 31°31′03″ and 31°37′08″N latitudes and between 75°56′28″ and 76°4′31″E longitudes, covering a total area of 5310 ha. The area falls under semi-arid (sub-moist) climate (Sehgal *et al.*, 1987). The annual rainfall varies from 870 to 1060 mm, a major part of which is received as high intensity rains during the monsoon period from July to September.

The watershed forms a part of the Shiwalik hills, comprising of sandstones, clays/ siltstones and conglomerates (Wadia, 1976). The foot-hill belt was colluvial and alluvial deposits of variable texture. The terrain exhibits steep to very steep slopes in the north-eastern part and level to gently sloping plains in the south-eastern part. The area is drained by a fifth order stream/rivulet, which is fed by other lower order streams or *choes*.

Since the soil patterns were known to be closely related to the relief features (Hall, 1983), the watershed area was divided into broad and narrower physiographic units. Several auger bores and test pits were examined before finally selecting seven representative profiles, one each from different physiographic units (Fig. 1), for detailed field and laboratory studies. The various field/morphological characteristics of the profiles were described following the procedures outlined by Soil Survey Staff (1993). Soil samples were collected from the profiles horizon wise and analyzed for various physico-chemical characteristics (Soil Conservation Service, 1972). Although several approaches for land productivity assessment are available (Klingebiel and Montgomery, 1961; Riquier *et al*., 1970; FAO, 1976), in the present investigation the Storie Index Rating of land productivity (Storie, 1978) was used because of its simple and quantitative structure.

Results and Discussion

Physiography and soils

The watershed area was divided into three broad physiographic units, viz., Shiwalik hills, piedmont plains and rivulet beds, which were further subdivided into smaller units based on detailed morphological features. The soils showed varied characteristics, depending mainly on their topographic positions.

Shiwalik hills (H): This unit represents the low altitude (<775 m), elongated northwest-southwest running hills in the northern part of Punjab. These hills mainly comprise moderately indulated sandstones and clays/siltstones, with some occasional exposures of conglomerate. The general slope of the hills ranges from 25 to 50%. The unit is subdivided into upper (H1) and lower (H2) units.

The soils on upper parts of the Shiwalik hills (H1) are characterized by limited profile development, having A-C sequence of horizons. These soils have developed on sandstone and thus are coarse textured (coarser than loamy fine sand). The soils occurring on this unit (H1) are dominantly Typic Ustipsamments, and are often associated with Lithic Ustipasamments. The soils from lower parts of the Shiwalik hills (H2) have developed on calcareous siltstones and show, like the unit H1, an immature profile with no diagnostic horizon,

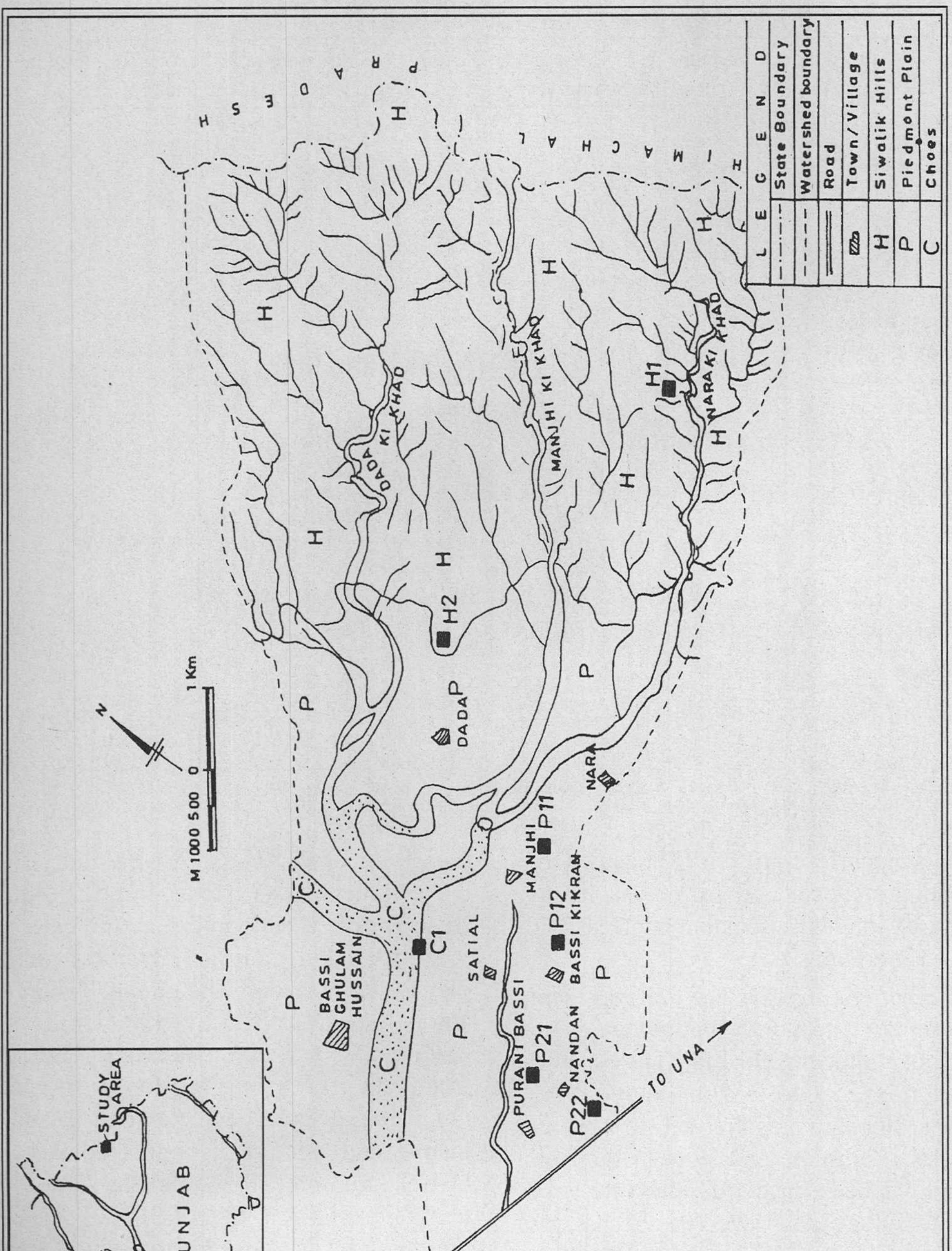

Fig. 1. Location and physiography of Nara-Dada-Manjhi watershed.

Table 1. Important morphological characteristics of the soils

Soil scape unit	Profile development	Depth (cm)	Color (moist)	Texture	Structure	Efferv-escence	Boundary
Hills							
H1	A-C*	0-150	10YR 6/1	S-LS	Sg-m	Nil-e	a, s-w
			10YR 7/2				
H2	A-C	0-185	10YR 5/4	SIL-SL	1, f, sbk	e-es	a-g, s-w
			10YR 6/4		2, m, sbk		
Piedmont plains							
P11	A-BW-C	0-192	10YR 4/3	SIL-SL	1, f, sbk	Nil-es	c-g, s
			10YR 5/4		2, m,sbk		
P12	A-C	0-200	10YR 5/3	S-LS	Sg-m	Nil	g-a, s
			10YR 6/3				
P21	A-Bw-C	0-155	10YR 3/3	SICL-SL	1, f, sbk	Nil	c-g, s
			10YR 4/3		2, m, sbk		
P22	A-Bw-C	0-153	10YR 4/3	SIL-L	2, m, sbk	Nil-e	g-a, s-w
			10YR 5/4				
***Choe* beds**							
C1	A-C	0-180	2.5Y 5/2	L-S	Sg-m	e-es	c-a, s-w
			2.5Y 6/3				

* Symbols as suggested in Soil Survey Staff (1993).

except an ochric epipedon. The unit (H2) is dominantly occupied by coarse loamy, Typic Ustorthents, associated at places with Lithic Ustorthents.

Piedmont plains (P): The unit represents the undulating to gently undulating plains at the foot of the Shiwalik hills. The elevation varies from 355 to 365 m above MSL, whereas slope ranges from 1 to 6%. On the basis of altitude and slope parameters, the unit has been further divided into upper (P1, 3-6% slope) and lower (P2, 1-3% slope) piedmonts. Further subdivision of the units (P1 and P2) is based upon height, slope, landscape position and soil texture into P11 (higher altitude P1), P12 (lower altitude P1), P21 (very gently sloping P2) and P22 (nearly level P2) units. All the units from the piedmont plains, except unit P12, exhibit weak profile development as indicated by presence of a cambic (Bw) subsurface diagnostic horizon. The major difference among these soils, however, is in their surface and subsurface texture. The soils from unit P12 being developed on recent fan material, are coarse textured (sand to loamy sand) and are distinguished as Typic Ustipsamments. The relatively medium textured soils from units P11, P21 and P22 are classified as coarse loamy Typic Ustepts, fine loamy Fluventic Ustepts and fine silty Typic Ustepts, respectively.

Choe beds (C): This unit consists of small seasonal streams draining the hills

Table 2. Important soil site characteristics

Soil-scape unit	Soil depth	Surface texture	Drainage	Slope (%)	Erosion	pH (1:2)	EC (dS m^{-1})	CEC (cmol (p^+) kg^{-1})	Clay (%)
Shiwalik hills									
H1	Shallow	LS-SIL	Excessive	30-45	Very severe	8.1 8.7	0.09 0.14	2.6 3.1	1.8 4.0
H2	Shallow moder-ately deep	GLS-G SL	Excessive	16-30	Severe	8.3 8.5	0.17 0.25	8.0 12.6	15.4 25.5
Piedmont plains									
P11	Deep	LS-SL	Well	3-6	Moderate	7.9 8.3	0.18 0.23	5.6 11.1	10.5 23.4
P12	Deep very deep	S-LS	Excessive	3-6	Moderate	6.3 6.9	0.04 0.10	3.0 6.7	5.3 10.4
P21	Deep	SL-SIL	Moderate	1-3	Slight	7.2 7.4	0.12 0.20	8.6 15.2	15.5 31.0
P22	Deep	L-SIL	Moderate well	1-3	Slight	7.9 8.1	0.16 0.21	4.2 10.3	8.6 20.0
***Choe* beds**									
Cl	Deep very deep	S-SL	Moderate	1-3	Slight	7.3 7.9	0.08 0.16	2.6 7.9	2.8 16.3

and piedmont plains. The rivulets have V-shaped valleys in the upper hilly tract and broad flat valleys in the lower piedmont plains. The soils are coarse textured, containing appreciable amount of rock fragment in the upper reaches, and are free of these in lower reaches. The soils occurring on this unit (C1) do not show any horizon differentiation associated with pedogenic processes. The soils are classified as coarse loamy, Typic Ustifluvents and Typic Ustipsamments.

Soil characteristics

The use of land for a particular crop is limited by various inherent soil characteristics and external land features (Sehgal, 1986). Some important soil and site characteristics are presented in Tables 1 and 2. The soils are discussed on physiographic basis because their characteristics are largely influenced by topographic position of pedons (Biswas *et al*., 1966). The soils developed on Shiwalik hills are shallow to moderately deep, having partly weathered sandstone or siltstones bedrocks, lying at 50 to 120 cm depth. The soil depth appears to be related to slope and degree of erosion (Gawande and Biswas, 1977) in this landscape position. On the piedmont plains and rivulet beds, the soils are moderately deep to very deep with no lithic contact within 150 cm of the solum. The soil matrix color does not indicate any sign of impeded drainage, except in soils on rivulet beds (hue 2.5 Y to 10 YR). The soils on hills and piedmont plains are excessively to well drained (hue 10 YR) as their topographic position and underlying texture do not allow water to stand in the solum for longer period. The rivulet bed soils not only show yellower hue (2.5 Y 6/3), but also have mottles in subsurface horizons, indicating reducing condition during some period in a year.

The Nara-Dada-Manjhi watershed has considerable potential erosion hazard (Kukal *et al.*, 1991) because of conducive land slope, fragile bedrocks and torrential rainfall pattern. The slope is highest on the hills, which allow maximum runoff of water, resulting in severe water erosion on these physiographic units (H1 and H2). The different physiographic units in the piedmont plains represent aggradational land forms due to deposition of materials removed from up-slope (Sidhu *et al.*, 1995). The slope in the piedmont plains is reduced to 1 to 6%. Because of the constructional nature these units (P11, P12, P21 and P22) are unstable.

The pedochemical characteristics show that all the soils, except on unit P12 which is neutral, are slightly to moderately alkaline in reaction (Table 2). The hill soils (units H1 and H2) have relatively higher pH (mean pH = 8.3-8.4) compared to other soils (mean pH = 6.6-8.1), possibly due to the influence of calcareous parent rocks (Sudhakar Rao *et al.*, 1997). The very low content of salts (EC = <0.8 dS m^{-1}) suggests that the soils are normal for growth of plants (Richards, 1968). The electrical conductivity (EC) values of relatively coarse textured soils (units H1, P12 and C1) are low (mean EC = 0.05-0.12 dS m^{-1}) compared to that in finer texture soils (units H2, P11, P21 and P22), which have relatively higher EC values (mean EC = 0.15-0.21 dS m^{-1}). The soils show wide variation in cation exchange capacity (2.6 to 15.2 cmol (p^+) kg^{-1}) within and among different soils. This variation may be ascribed primarily to differences in clay content (Sidhu and Sharma, 1990) as the soils are generally low in organic matter.

Land productivity assessment

The four factors A,B,C, and X of Storie Index Rating (Storie, 1978), which evaluate profile development, surface texture, ground slope and miscellaneous properties, respectively, have been worked out for the soils under study. The results are presented in Table 3. The soils which have developed on hilly terrain (units H1 and H2) score relatively lower values (Table 3) for factor A, compared to other soils, because of being underlain by poorly to moderately consolidated sedimentary rocks at depths varying from 50 to 120 cm. Among the various land characteristics, texture of the surface-soil often forms important criteria for land evaluation (Dent and Young, 1987). The land productivity assessment system of Storie (1978) has also given due weightage to texture, as measured through factor B. The system ascribes higher percentage of score to factor B for medium textured surface soils and lower percentage for heavy and coarse textured surface soils. The units H2 and C1 score minimum (60%) for factor B on account of relatively coarser texture and presence of rock fragment in the surface layers whereas unit P22 scores maximum (100%) because of loam to silt loam surface texture. The highest land is in the north-east with a general slope from north-east to south-west. The height initially

Table 3. Productivity grading of the soils based on Storie Index Rating factors

Soilscape unit	Factor				Storie Index Rating	Productivity grade
	A	B	C	X (d, e)*		
Soils of Shiwalik hills						
H1	70	70	40	25 (100, 25)	5	6
H2	75	60	70	30 (100, 30)	9	6
Soils of piedmont plains						
P11	85	85	95	66 (95, 70)	45	3
P12	95	70	95	80 (100, 80)	50	3
P21	85	95	100	72 (85, 85)	58	3
P22	85	100	100	72 (85, 85)	61	2
Soils of *choe* beds						
C1	80	60	95	32 (80,40)	15	5

*Letters d and e stand for drainage and erosion factors used to evaluate X.

decreases very rapidly in the hilly tract and then gradually to almost a level to gently sloping plains in the lower reaches. The slope factor C varies from 40% (Unit H1) to almost 100% (Units P21 and P22) in the different soils.

The evaluation of land for productivity assessment is largely based on soil and site attributes, which influence the crop growth (McRae and Burnham, 1981). Keeping this principle in mind, the miscellaneous factor X was estimated considering the drainage and erosion aspects, which might possibly have some limiting effect on crop production of the area. Alkalinity/acidity factor could not be taken into consideration. Soil pH varies within the normal range of 6.3 to 8.7, causing no adverse effect on plant growth. Shome and Raychaudhuri (1960) included a factor of climate in an attempt to make use of the system under Indian conditions. However, in the present investigation this factor was not taken into consideration because of limited climatic variation within the watershed area. All the soils, except the soils of unit Cl, are fairly well to well drained. The drainage score varies from 80% (unit C1) to 100% (units H1 and H2). The whole area is susceptible to water erosion. Gully erosion is mainly confined to the hilly tract in the north-eastern part whereas sheet erosion with occasional shallow gullies prevails on level to gently undulating piedmont plains (Kukal and Sur, 1992). The erosion factor scores minimum for unit H1 (25%) and highest for units P21 and P22 (85%).

Land productivity rating

The results of land productivity assessment reveals (Table 3) that the watershed can be divided into four land productivity grades viz., grade 2 (good), grade 3 (fair), grade 5 (very poor) and grade 6 (non-agricultural). The soils distinguished as grade 2 (unit P22) may be used for most crops with good yield potential. The soils rated as grade 3 (units P11, P12 and P21) have narrower range of suitability and can be used for only some selected crops. The soils of grade 5 (unit C1), because of the adverse conditions such as roughness, coarse texture and erosion, have very limited use, except pasture. The soil of grade 6 (units H1 and H2) are not suitable for agriculture because of shallow soil depth, steep broken land and associated problems.

References

Biswas, T.D., Narayana, M.R. and Vasudeva Rao, A.E. 1966. Characteristics of catenary soils on granite-gneiss parent rock in the Kurnool district of Andhra Pradesh. *Journal of the Indian Society of Soil Science* 14: 183-195.

Dent, D. and Young, A. 1987. *Soil Survey and Land Evaluation.* George Allen and Unwin, London, 278 p.

FAO 1976. *A Framework for Land Evaluation. FAO* Soils Bulletin 32: Rome.

Gawande, S.P. and Biswas, T.D. 1977. Characterization and classification of black soils developed on basalt in relation to micro-relief. *Journal of the Indian Society of Soil Science* 25: 233-238.

Hall, G.F. 1983. Pedology and geomorphology. In *Pedogenesis and Soil Taxonomy, I. Concepts and Interaction* (Eds. L.P. Wilding, N.E. Smeck and G.F. Hall), pp. 117-140. Elsevier Science Publishers, Amsterdam.

Klingbiel, A.A. and Montgomery, P.H. 1961. *Land-capability Classification.* USDA Handbook No. 210.

Kukal, S.S. and Sur, H.S. 1992. Soil erosion hazards in the foot hills of lower Shiwaliks. *Journal of the Indian Society of Soil Science* 40: 162-167.

Kukal, S.S., Sur, H.S. and Gill, S.S. 1991. Factors responsible for soil erosion hazard in submontane Punjab, India. *Soil Use and Management* 7: 38-44.

Linsley, R.K., Kohler, M.A. and Paulhus, J.L.H. 1975. *Hydrology for Engineers*. McGraw-Hill, Tokyo, 482 p.

McRae, S.G. and Burnham, C.P. 1981. *Land Evaluation.* Clarendon Press, Oxford, 239 p.

Murty, J.V.S. 1995. *Watershed Management in India.* Wiley Eastern Ltd., New Delhi, 198 p.

Riquier, J., Bramao, D.L. and Cornet, J.P. 1970. *A New System of Soil Appraisal in Terms of Actual and Potential Productivity.* AGL/TESR/70/6. FAO, Rome, 35 p.

Richards, L.A. 1968. *Diagnosis and Improvement of Saline and Alkali Soils.* USDA Handbook No. 60. Oxford and IBH, New Delhi, 160 p.

Sehgal, J.L. 1986. *Introductory Pedology.* Kalyani Publishers, New Delhi, 287 p.

Sehgal, J.L., Vernemmen, C. and Tavernier, R. 1987. *Agroclimatic Environments and Moisture Regime in North-west India.* National Bureau of Soil Survey and Land Use Planning Bulletin 17. Nagpur, 117 p.

Shome, K.B. and Raychaudhuri, S.P. 1960. Rating of soils of India. *Proceeding of the National Institute of Sciences of India* 26A: 260-289.

Sidhu, P.S. and Sharma, B.D. 1990. Characteristics and classification of arid zone soils of Punjab. *Arid Soil Research and Rehabilitation* 4: 223-232.

Sidhu, P.S., Sharma, B.D. and Mukhopadhyay, S.S. 1995. Soil-landscape relationships in the lower Himalayas. Abstracts, 60^{th} Annual Convention of Indian Society of Soil Science, Ludhiana, p. 173.

Soil Conservation Service 1972. *Soil Survey Laboratory Methods and Procedures for Collecting Soil Samples.* US Govt. Printing Office, Washington, 63 p.

Soil Survey Staff 1993. *Soil Survey Manual.* USDA Handbook No. 18. United States Department of Agriculture, Washington, 437 p.

Storie, R.E. 1978. *Storie Index Soil Rating.* Division of Agricultural Sciences, Special Publication No. 3203, California.

Sudhakar Rao, R.V., Mahapatra, S.K., Verma, T.P., Sidhu, G.S. and Rana, K.P.C. 1997. Characterization and classification of some soils of Shiwalik hills in Himachal Pradesh. *Agropedology* 7: 14-21.

Wadia, D.N. 1976. *Geology of India.* Tata McGraw Hill, New Delhi, 508 p.