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# Characterization and classification of Alfisols under lesser Himalayan temperate region

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Alfisols formed under forests have subsurface clay accumulation which are moderately leached and relatively high in native fertility, primarily found in temperate humid and subhumid regions of the world and occupy nearly 10.1% of the global ice-free land area supporting about 17% of the world's population (USDA, NRCS 2013) and considered to be one of the most productive soils (Rust 1983). These soils are physiographically categorized into high altitude (Kandi soils), mid- altitude (*Karewa*) and low altitude (valley basin). The mid altitude region belongs to Pleistocene and post-Pleistocene deposits of Lacustrine origin and presently under udic moisture regime with temperate climate, and precipitation is mostly in the form of snow. Alfisols in the valley are found in association with the Mollisols and Inceptisols (Shinde *et al.* 1984; Jalali *et al.*1989; Najar 2002). Lack of information on the properties and genesis of these mid-altitude (*Karewas*) soils has been an obstacle to assess the production potential and formulation of management recommendations. The objective of this study was to characterize and classify these soils, keeping in view the declining production and productivity of saffron and apple cultivated on these soils.

Geographically the valley lies on the northern flank of Pir Panjal range and southern flank of Greater Himalayan range, located at 33° 30' N to 34° 30' N and 74°10' E to 75° 03' E. The elevation of the valley is above 1500 m (msl). The *karewa* group, comprises of 450-500 m thick layers of sediments. The varied nature of these sediments alongwith some signatures in green sands of Pampore represent the Glacial Stage–IV (Pal *et al.* 1983). Two important sites, Pampore and Patten plateau lands from the recognized lacustrine belts of Kashmir valley having almost similar geology were selected from Pulwama and Baramulla districts of the valley. Ten pedons were selected - six from Pampore and four from Pattan plateau. The elevation of the sites under study varied from 1625 to 1700 m above msl. The topography of all the locations was flat except $P_5$, where terraced landform was found (Table 1). The slope of both the sites was nearly level. All the pedons were well drained. The morphology of the soils was described as in Soil Survey Staff (2003) and site characteristics were noted as per standard methods (Sehgal 1994).

**Table 1.** Physical and chemical characteristics of the soils

| Pedon No. & | Depth (cm) | pH (1:2.5) | EC ($dSm^{-1}$) | O.C. ($gm\ kg^{-1}$) | $CaCO_3$ (%) | CEC ($cmol_c\ kg^{-1}$) | Exchangeable cations ($cmol_c\ kg^{-1}$) | | | % Base saturation | Sand (%) | Silt (%) | Clay (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pedon 1: Fine-loamy, mixed, mesic Typic Hapludalf | | | | | | | | | | | | | |
| Ap | 0-20 | 6.70 | 0.05 | 7.80 | 0.00 | 11.35 | 6.50 | 1.92 | 0.78 | 81.07 | 33.7 | 48.0 | 17.8 |
| Bt1 | 20-55 | 7.20 | 0.12 | 5.07 | 0.00 | 16.50 | 9.53 | 2.50 | 0.70 | 77.13 | 26.1 | 44.1 | 29.2 |
| Bt2 | 55-85 | 7.40 | 0.21 | 3.90 | 0.00 | 17.16 | 9.78 | 2.75 | 0.78 | 77.56 | 23.7 | 43.3 | 32.2 |
| BCK | 85-120+ | 7.65 | 0.10 | 3.12 | 17.80 | 12.54 | 7.20 | 2.10 | 0.46 | 77.83 | 29.8 | 48.7 | 20.6 |
| Pedon 2: Fine-loamy, mixed, mesic Typic Hapludalf | | | | | | | | | | | | | |
| Ap | 0-20 | 6.50 | 0.10 | 9.75 | 0.00 | 15.31 | 8.73 | 2.50 | 0.70 | 77.87 | 32.3 | 49.1 | 17.8 |
| Bt1 | 20-52 | 7.20 | 0.04 | 5.85 | 0.00 | 16.24 | 9.20 | 2.60 | 0.78 | 77.49 | 27.5 | 44.9 | 27.5 |
| Bt2 | 52-88 | 7.39 | 0.07 | 1.95 | 0.00 | 17.29 | 9.86 | 2.77 | 0.70 | 77.03 | 24.2 | 43.0 | 32.5 |
| BCK | 88-120+ | 7.82 | 0.10 | 1.17 | 15.70 | 12.14 | 6.70 | 1.94 | 0.70 | 76.90 | 28.6 | 48.2 | 19.8 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pedon 3: Fine-loamy, mixed, mesic Typic Hapludalf | | | | | | | | | | | | | |
| Ap | 0-17 | 7.13 | 0.06 | 6.24 | 0.00 | 12.54 | 7.10 | 2.10 | 0.87 | 80.30 | 32.6 | 48.9 | 17.5 |
| Bw | 17-34 | 7.30 | 0.13 | 1.95 | 0.00 | 15.58 | 8.88 | 2.49 | 0.78 | 78.03 | 28.2 | 42.3 | 28.5 |
| Bt | 34-88 | 7.10 | 0.05 | 3.51 | 0.00 | 17.82 | 9.85 | 2.85 | 0.78 | 75.67 | 24.0 | 41.9 | 34.1 |
| Ck | 88-120+ | 7.80 | 0.09 | 1.95 | 16.50 | 12.28 | 7.00 | 1.96 | 0.70 | 78.69 | 28.3 | 48.0 | 22.4 |
| Pedon 4: Fine-loamy, mixed, mesic Typic Hapludalf | | | | | | | | | | | | | |
| Ap | 0-20 | 7.42 | 0.13 | 8.97 | 1.40 | 9.90 | 5.12 | 1.58 | 0.57 | 73.47 | 34.9 | 49.0 | 16.0 |
| BA | 20-40 | 7.70 | 0.10 | 6.63 | 1.20 | 13.33 | 7.30 | 2.23 | 0.70 | 76.70 | 35.0 | 48.7 | 15.6 |
| Bt1 | 40-70 | 7.28 | 0.08 | 2.73 | 2.40 | 15.18 | 8.12 | 2.43 | 0.70 | 74.08 | 27.2 | 45.1 | 27.2 |
| Bt2 | 70-100 | 7.90 | 0.10 | 2.24 | 5.70 | 16.63 | 8.98 | 2.66 | 0.61 | 73.65 | 23.9 | 42.8 | 32.8 |
| BCK | 100-120+ | 7.44 | 0.13 | 1.95 | 10.80 | 13.99 | 7.98 | 2.24 | 0.61 | 77.35 | 26.5 | 48.0 | 20.4 |
| Pedon 5: Fine-loamy, mixed, mesic Typic Hapludalf | | | | | | | | | | | | | |
| Ap | 0-20 | 6.89 | 0.80 | 12.87 | 0.00 | 14.92 | 8.23 | 2.39 | 0.96 | 77.59 | 31.2 | 44.7 | 22.5 |
| Bt1 | 20-55 | 7.43 | 0.04 | 8.97 | 0.00 | 15.31 | 8.33 | 2.45 | 1.04 | 77.22 | 27.8 | 39.0 | 32.0 |
| Bt2 | 55-90 | 7.64 | 0.10 | 7.80 | 1.40 | 17.03 | 9.35 | 2.72 | 0.78 | 75.51 | 22.3 | 40.1 | 36.9 |
| Bt3 | 90-120+ | 7.60 | 0.09 | 4.68 | 1.80 | 16.50 | 9.25 | 2.64 | 0.78 | 76.81 | 23.5 | 39.5 | 37.0 |
| Pedon 6: Fine-loamy, mixed, mesic Ruptic-Alfic-Eutrudepts | | | | | | | | | | | | | |
| Ap | 0-15 | 7.31 | 0.09 | 3.90 | 1.10 | 15.71 | 8.32 | 2.53 | 0.70 | 73.50 | 35.4 | 42.8 | 20.5 |
| Bw | 15-40 | 7.78 | 0.10 | 6.63 | 3.40 | 15.71 | 8.45 | 2.51 | 0.61 | 73.67 | 27.7 | 41.5 | 30.2 |
| BC1 | 40-90 | 7.84 | 0.10 | 2.80 | 5.60 | 12.80 | 6.85 | 2.10 | 0.70 | 75.34 | 28.4 | 49.0 | 22.6 |
| BC2 | 90-120+ | 7.60 | 0.11 | 2.30 | 6.20 | 11.62 | 6.23 | 1.86 | 0.29 | 72.13 | 28.0 | 51.7 | 20.1 |
| Pedon 7: Fine-loamy, mixed, mesic Typic Hapludalf | | | | | | | | | | | | | |
| Ap | 0-20 | 5.00 | 0.10 | 11.70 | 0.00 | 10.16 | 5.79 | 1.72 | 0.45 | 78.35 | 28.8 | 47.5 | 22.5 |
| Bt1 | 20-55 | 6.23 | 0.02 | 5.85 | 0.00 | 13.99 | 7.98 | 2.24 | 0.29 | 75.07 | 26.6 | 48.2 | 32.8 |
| Bt2 | 55-90 | 6.70 | 0.12 | 3.90 | 0.00 | 14.78 | 8.13 | 2.30 | 0.44 | 73.49 | 25.9 | 36.0 | 37.9 |
| Bt3 | 90-120+ | 6.34 | 0.05 | 3.90 | 0.00 | 15.84 | 8.68 | 2.53 | 0.44 | 73.54 | 26.6 | 37.0 | 36.4 |
| Pedon 8: Fine-loamy, mixed, mesic Typic Hapludalf | | | | | | | | | | | | | |
| Ap | 0-20 | 6.24 | 0.03 | 6.63 | 0.20 | 13.33 | 7.40 | 2.22 | 0.58 | 76.51 | 28.2 | 46.2 | 23.8 |
| Bt1 | 20-55 | 6.71 | 0.02 | 7.80 | 0.00 | 15.05 | 8.58 | 2.30 | 0.29 | 74.21 | 24.9 | 38.2 | 36.8 |
| Bt2 | 55-88 | 6.85 | 0.02 | 6.63 | 0.00 | 15.44 | 8.76 | 2.40 | 0.44 | 75.08 | 25.8 | 36.0 | 38.2 |
| Bt3 | 88-120+ | 6.67 | 0.06 | 5.85 | 0.00 | 15.71 | 8.65 | 2.51 | 0.87 | 76.61 | 24.3 | 36.5 | 39.1 |
| Pedon 9: Fine-loamy, mixed, mesic Typic Hapludalf | | | | | | | | | | | | | |
| Ap | 0-15 | 5.88 | 0.06 | 10.92 | 0.00 | 10.56 | 6.02 | 1.72 | 0.73 | 80.15 | 28.8 | 48.6 | 21.6 |
| Bt1 | 15-30 | 6.16 | 0.02 | 9.75 | 0.00 | 14.78 | 8.22 | 2.37 | 0.44 | 74.54 | 24.7 | 42.5 | 32.6 |
| Bt2 | 30-60 | 6.60 | 0.02 | 5.85 | 1.00 | 15.31 | 8.62 | 2.45 | 0.44 | 75.14 | 23.6 | 38.5 | 37.5 |
| Bt3 | 60-90 | 6.26 | 0.03 | 3.90 | 1.20 | 15.18 | 8.61 | 2.38 | 0.44 | 75.26 | 24.4 | 36.3 | 39.0 |
| Bt4 | 90-120+ | 6.76 | 0.03 | 3.90 | 1.80 | 16.37 | 8.99 | 2.62 | 0.44 | 73.58 | 24.5 | 36.8 | 39.6 |
| Pedon 10: Fine-loamy, mixed, mesic Typic Hapludalf | | | | | | | | | | | | | |
| Ap | 0-20 | 6.16 | 0.02 | 10.53 | 0.00 | 9.37 | 5.34 | 1.60 | 0.44 | 78.71 | 28.9 | 48.0 | 22.5 |
| Bt1 | 20-50 | 6.10 | 0.03 | 7.41 | 0.00 | 13.99 | 7.65 | 2.24 | 0.29 | 72.75 | 27.3 | 36.4 | 36.1 |
| Bt2 | 50-85 | 6.60 | 0.02 | 5.46 | 1.00 | 15.84 | 8.85 | 2.53 | 0.44 | 74.62 | 26.2 | 34.3 | 39.3 |
| Bt3 | 85-120+ | 7.87 | 0.03 | 5.46 | 1.20 | 14.52 | 8.28 | 2.32 | 0.44 | 76.00 | 23.6 | 36.6 | 39.1 |

Horizon-wise samples were collected and analyzed for pH and EC in 1:2.5 soil:water suspension (Peach 1965), organic carbon by wet digestion method (Walkley 1935), $CaCO_3$ by rapid titration method (Puri 1930). Particle-size distribution was determined by pipette method (Gee and Baudar 1986), CEC and exchangeable base by following standard procedure (SCS 1972).

The morphological characteristics of these sites show that most of the pedons had a hue of 10YR, value

ranged from 3 to 6 and chroma ranged from 2 to 4. All the soils being well drained, no aquic features were found. The Bt horizons of all the pedons had clay cutans (argillans), their orientation was thick and continuous in almost all the pedons except in $P_6$, where thin and broken orientation was observed. The thickness of a argillic horizons varied from 17 to 100 cm in Pampore plateau, whereas in Patten plateau the thickness was upto 120 cm depth. The horizon boundaries were clear except few abrupt changes in boundary was observed. Mottles and coarse fragments were absent throughout the depth except in pedon 6 where 10-30% coarse fragments were observed below 40 cm of depth. Violent effervescence was observed in the lower most horizons of the first six pedons, however, $P_4$ and $P_6$ showed effervescence through out the profile.

Clay content increased significantly (> 40%) in Bt horizon over the surface horizon, leading to distinct horizonation, in Pattan plateau it increased below 85 cm of depth (Table 1). The soil pH was neutral in Pampore plateau (pedons 1 to 6) whereas it was slightly acidic in Pattan plateau. Soil pH slightly increased with depth, the mean pH value of surface horizon was lower than the sub-surface horizons. The electrical conductivity was found to be low. The organic carbon content decreased with depth (Verma *et al.* 2012). Calcium carbonate in the pedons 1, 2, 3, 7, 8 and 10 was comparatively less than foot hill pedons 4, 5 and 6. The CEC was low and it varied with respect to clay content. Calcium dominated among the exchangeable cations and base saturation was more than 75 per cent (Sharma *et al.* 1994).

The random powder X-ray diffractograms of sand fractions of these soils gave strong and sharp reflections of quartz, plagioclase and orthoclase feldspars and mica with calcite in lower layer of $P_1$, whereas $P_6$, $P_8$ showed the dominance of plagioclase followed by quartz, orthoclase and calcite in all the horizons of $P_6$. The silt fractions of these soils also showed the dominance of quartz, plagioclase and orthoclase with calcite in lower horizons. Clay fractions showed the dominance of illite. Solvation with glycerol showed the presence of very small amounts of smectite. Vermiculite and chlorite was also observed. The nature of clay minerals was found almost similar with depth.

The formation of argillic horizon is the most conspicuous development in the table lands of Kashmir Himalayas. Thus, the soils have been classified to the Alfisol order (Soil Survey Staff 2006, 2010). Pedons 1 to 5 of Pampore karewa keys out as fine-loamy, mixed, mesic, Typic Hapludalfs, pedon 6 is classified to fine-loamy, mixed, mesic Ruptic-Alfic-Eutrudepts, and pedons 7 to 10 to fine-loamy, mixed, mesic Typic Hapludalfs. Below a depth of 1 m there is often formation of hard clay pans which indicated consequential a pedological significance.

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