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# Characterisation, Classification and Evaluation of Soil Resources in Sivagiri Micro-watershed of Chittoor District in Andhra Pradesh for Sustainable Land Use Planning

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**Abstract:** The morphological, physical and physico-chemical characteristics of soils in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh have been studied. The study revealed that the soils are deep to very deep, light yellowish brown to dark red, excessively to poorly drained, slightly acidic to moderately alkaline, low to medium in organic carbon and low to medium in cation exchange capacity with wide textural variations. Soils are low to medium in available nitrogen, phosphorus and potassium and high in sulphur whereas deficient in Fe, deficient to sufficient in available Zn and sufficient in available Cu and Mn. The soils on gently sloping topography exhibit the development of argillic horizon (Bt) while the soils on nearly level lands have cambic horizons (Bw). However, the Entisol pedons do not show presence of any diagnostic horizons. The soils have been classified as Aquic Ustorthents, Typic Ustipsamments, Typic Ustifluvents, Typic Haplustepts, Vertic Haplustepts, Typic Haplustalfs and Typic Rhodustalfs. On the basis of the major soil constraints, sustainable land use plan for the micro-watershed has also been suggested for their better management.
***(Key words:** Micro-watershed, soil classification, land use plan, cambic horizon, argillic horizon)*



Watershed is a "geo-hydrological" entity or piece of land that drains at a common outlet. This natural unit is evolved through the interaction of the rainwater and land mass and normally comprises of arable and non-arable lands along with drainage lines. Thus, the watershed area is delineated based on distribution and flow of rainwater, which facilitates scientific developments of natural resources like soil, water and vegetation. Characterisation and classification of soil resources in Palar-Manimuthar watershed of Tamil Nadu played a crucial role in optimal utilisation of natural resources on a sustained basis (Arunkumar *et al.* 2002). Sivagiri micro-watershed in Chittoor district of Andhra Pradesh was selected for this study as it has wide variety of soils. As the catchment area is an undulating terrain, it is quite likely that the land is subjected to different degrees of erosion resulting in varied depth of soils, making them fit for growing only a few set of crops. Keeping these factors in mind the study has been undertaken to characterize and classify the soils of Sivagiri micro-watershed and to suggest the land use plan to protect the natural resources for sustainable crop production.

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## Materials and Methods

The study area, comprising of 1220 ha, lies between 13°25' and 13°29' N latitude, and 79°32' and 79°36' E longitude. It represents semi-arid monsoon type climate. The annual precipitation is 1215 mm of which 89% is received during July to November. The mean annual soil temperature is 31.5 °C with mean summer and winter soil temperatures 32.1 °C and 27.3 °C, respectively. Hence, the area qualifies for 'iso-hyperthermic' temperature regime. The soil moisture control section is dry for more than 90 cumulative days or 45 consecutive days in four months following summer solstice. So it qualifies for ustic soil moisture regime. The natural vegetation includes grasses, *Prosopis juliflora*, *Parthenium* sp., *Tridax* sp., mango (*Mangifera indica*) and *neem* (*Azadirachta indica*) *etc.,* The soils were developed from granite-gneiss and quartzite parent materials.

Nine typical pedons representing nearly level to gently sloping (3 to 5% slope) topography were studied in detail and the morphological characteristics were presented in table 1. The detailed morphological description of these nine pedons was studied as per the procedure outlined in soil survey manual (Soil Survey Staff 1951). The soil samples representing each horizon of the pedons were collected and characterized for important physical, physico-chemical properties and available nutrient status using standard procedures. The soil samples collected from the control section (25 to 100 cm) of each pedon were analysed for clay minerals by sedimentation technique (Jackson 1979) and semi-quantitative estimation of clay minerals was made based on the peak intensities (Gjems 1967). The soils were classified according to Keys to Soil Taxonomy (Soil Survey Staff 1998). Considering limitations and potentials of the soils, land capability classification was evaluated upto sub-class level (Klingebiel and Montgomery 1966) and based on that a suitable land use plan has also been suggested.

## Results and Discussion

*Soil Morphology*

The pedons 1, 2, 5, 6 and 7 have developed on nearly level (0-1%) lands while the pedons 3, 4, 8 and 9 have originated from gently sloping (3-5%) topography. The soils are deep to very deep, poorly drained to excessively drained. The soils on gently sloping topography have yellowish brown (10 YR 5/6) to dark red (2.5 YR 3/6) colour and becomes light yellowish brown (10 YR 6/4) to very dark grayish brown (10 YR 3/2) in nearly level lands. The soil colour appears to be the function of chemical and mineralogical composition as well as textural make up of soils and conditioned by topographic position and moisture regime (Walia and Rao 1997). The soils of the micro-watershed show wide textural variations (Clay to sandy) caused by parent material, topography, *in situ* weathering and translocation of clay. Presence of very dark gray (10 YR 3/1) to very dark grayish brown (10 YR 3/2) mottles in pedons 1 and 5 reflects impeded drainage in the sub-soil. The structure of the soils is crumb, sub-angular blocky, angular blocky and single grain. The consistence of the soils is loose to very hard (dry), loose to very firm (moist) and non-sticky to very sticky and non-plastic to very plastic (wet) depending on the clay content. Pedons 4, 8 and 9 have argillic (Bt) sub-surface diagnostic horizons, whereas pedons 1, 6 and 7 exhibit cambic (Bw) sub-surface diagnostic horizons. However, pedons 2, 3 and 5 do not have any diagnostic horizons. Slight to violent effervescence with dilute HCl is observed in pedons 3, 4 and 7. Pedon 7 alone exhibits vertic properties such as 3 to 7 mm wide cracks extended up to 35 cm depth and weak indistinct slickensides in lower horizons.

*Soil Characteristics*

*Physical characteristics:* Physical characteristics of the soils are presented in table 2. Granulometric data indicated that the clay content varied from 2.50 to 58.30%. The increase in clay content in Bt horizons of pedons 4, 8 and 9 could be attributed to vertical migration or translocation of clay (Sarkar *et al.* 2002), whereas the enrichment of clay in Bw horizon of pedon 7 was primarily due to *in situ* weathering of parent material. An irregular decrease of clay content in pedons 1, 2, 3, 5 and 6 might be due to variability in weathering in different horizons. Silt content of all the pedons exhibited an irregular trend with depth. Coarse fraction (Sand) constitutes the bulk of mechanical fractions, which could be attributed to the dominance of alluvial sandy parent material.

The bulk density varied from 1.32 to 1.90 Mg $m^{-3}$ and increased with depth which might be due to more compaction of finer particles in deeper layers caused by over-head weight of the surface soils (Jewitt *et al.* 1979). Low bulk density values of surface soils could be attributed due to high organic matter content. Water holding capacity of different pedons ranged from 13.05 to 58.99%. These differences were due to the variation in the depth and clay, silt and organic carbon content. This observation is further supported by positive and significant correlation of water holding capacity with clay (r=0.82**) and silt (r=0.88**).

*Physico-chemical characteristics:* All the pedons studied were slightly acidic (5.83) to moderately alkaline (8.47) in reaction and appear to be related with parent materials, rainfall and topography. The KCl-pH values were lower than the water pH values, indicating the existence of net negative charge on colloidal particles. All the pedons showed very low electrical conductivity values ranging from 0.02 to 0.36 dS $m^{-1}$, suggesting very low amount of soluble salts.

Organic carbon content of the soils was low to medium (0.4 to 6.4 g $kg^{-1}$) (Table 3). The organic carbon content decreased with the depth of the pedons except in pedons 3 and 4. This could be attributed to the addition of plant residues and farmyard manure to surface horizons than in the lower horizons. The removal of surface soil containing high organic carbon due to erosion was found to be a

**Table 1.** Morphological characteristics of soils

| Pedon no. & horizon | Depth (m) | Colour | | Mottle colour | Tex-ture | Structure | | | Consistency | | | Efferve-scence | Boundary | | Cutans | | | Pores | | Roots | | Other features |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Dry | Moist | | | S | G | T | Dry | Moist | Wet | | D | T | Ty | Th | Q | S | Q | S | Q | |
| **Pedon 1. Fine-loamy, mixed, iso-hyperthermic, Typic Haplustepts** | | | | | | | | | | | | | | | | | | | | | | |
| Ap | 0.00-0.26 | 10 YR 5/1 | 10 YR 5/1 | - | l | f | 1 | cr | s | fr | ssps | - | c | s | | - | | f | c | f | c | - |
| A1 | 0.26-0.63 | 10 YR 5/3 | 10 YR 4/3 | - | l | m | 2 | sbk | sh | fi | sp | - | d | w | | - | | f | c | f | c | - |
| Bw1 | 0.63-0.92 | 10 YR 6/4 | 10 YR 6/2 | - | l | m | 2 | sbk | sh | fi | sp | - | d | w | | - | | f | c | f | c | - |
| Bw2 | 0.92-1.30 | 10 YR 5/4 | 10 YR 5/3 | 10 YR 3/2 | l | m | 2 | sbk | sh | fi | sp | - | d | s | | - | | f | c | f | f | - |
| Bw3 | 1.30-1.56 | 10 YR 5/6 | 10 YR 5/4 | - | l | f | 1 | sbk | l | l | sopo | - | d | w | | - | | m | c | - | - | - |
| C | 1.56-2.00+ | 10 YR 5/8 | 10 YR 5/8 | - | sl | c | 0 | sg | l | l | sopo | - | - | - | | - | | m | c | - | - | - |
| **Pedon 2. Sandy, siliceous, iso-hyperthermic, Typic Ustipsamments** | | | | | | | | | | | | | | | | | | | | | | |
| Ap | 0.00-0.19 | 10 YR 4/2 | 10 YR 4/1 | - | ls | f | 1 | cr | s | l | sopo | - | c | s | | - | | f | c | f | c | - |
| A1 | 0.19-0.42 | 10 YR 6/4 | 10 YR 6/4 | - | ls | f | 0 | sg | l | l | sopo | - | c | s | | - | | c | f | f | c | - |
| A2 | 0.42-0.70 | 10 YR 5/8 | 10 YR 5/6 | - | ls | f | 0 | sg | l | l | sopo | - | c | s | | - | | c | f | f | c | - |
| C1 | 0.70-1.02 | 10 YR 6/6 | 10 YR 6/6 | - | ls | f | 0 | sg | l | l | sopo | - | d | s | | - | | c | f | - | - | - |
| C2 | 1.02-1.40 | 10 YR 6/4 | 10 YR 6/4 | - | ls | f | 0 | sg | l | l | sopo | - | d | s | | - | | c | f | - | - | - |
| C3 | 1.40-2.00+ | 10 YR 6/4 | 10 YR 6/4 | - | ls | f | 0 | sg | l | l | sopo | - | - | - | | - | | c | f | - | - | - |
| **Pedon 3. Coarse-loamy, siliceous, iso-hyperthermic, Typic Ustifluvents** | | | | | | | | | | | | | | | | | | | | | | |
| Ap | 0.00-0.12 | 10 YR 6/3 | 10 YR 6/2 | - | ls | vf | 0 | sg | l | l | sopo | - | c | s | | - | | c | f | f | c | - |
| A1 | 0.12-0.54 | 7.5 YR 5/6 | 7.5 YR 5/4 | - | l | m | 2 | sbk | s | fr | ssps | - | c | s | | - | | m | c | c | c | - |
| A2 | 0.54-0.86 | 10 YR 5/6 | 10 YR 5/6 | - | sl | f | 1 | sbk | l | l | sopo | es | c | s | | - | | c | f | f | c | - |
| A3 | 0.86-0.94 | 10 YR 5/6 | 10 YR 5/6 | - | sl | c | 0 | sg | l | l | sopo | ev | c | s | | - | | c | f | - | - | - |
| Cr | 0.94+Parent rock mixed with soil | | | | | | | | | | | | | | | | | | | | | |
| **Pedon 4. Fine-loamy, mixed, iso-hyperthermic, Typic Rhodustalfs** | | | | | | | | | | | | | | | | | | | | | | |
| Ap | 0.00-0.14 | 5 YR 6/6 | 5 YR 6/6 | - | sl | f | 1 | cr | l | l | sopo | es | c | s | | - | | c | f | f | c | - |
| E | 0.14-0.41 | 2.5 YR 3/6 | 2.5 YR 3/6 | - | l | m | 2 | sbk | sh | fi | sp | es | c | s | | - | | m | c | m | c | - |
| Bt1 | 0.41-0.81 | 2.5 YR 4/6 | 2.5 YR 3/6 | - | cl | m | 2 | sbk | h | fi | sp | ev | c | s | t | th | c | m | c | m | c | - |
| Bt2 | 0.81-1.40 | 2.5 YR 4/6 | 2.5 YR 3/6 | - | cl | m | 2 | sbk | sh | fi | sp | ev | c | s | t | th | c | m | c | - | - | - |
| C | 1.40 +Weathered gneiss mixed with soil | | | | | | | | | | | | | | | | | | | | | |
| **Pedon 5. Coarse-loamy, siliceous, iso-hyperthermic, Aquic Ustorthents** | | | | | | | | | | | | | | | | | | | | | | |
| Ap | 0.00-0.25 | 10 YR 4/2 | 10 YR 4/2 | - | l | m | 2 | sbk | s | fr | sp | - | c | s | | - | | f | c | f | c | - |
| A1 | 0.25-0.42 | 10 YR 5/6 | 10 YR 5/6 | - | sl | f | 1 | sbk | l | l | sopo | - | c | s | | - | | f | c | f | c | - |
| A2 | 0.42-0.66 | 10 YR 4/6 | 10 YR 414 | 10 YR 3/2 | sl | m | 2 | sbk | s | fr | ssps | - | g | s | | - | | f | c | f | c | - |
| A3 | 0.66-0.95 | 10 YR 4/6 | 10 YR 414 | 10 YR 3/1 | sl | m | 2 | sbk | s | fr | ssps | - | c | s | | - | | f | c | f | f | - |
| A4 | 0.95-1.20 | 10 YR 5/8 | 10 YR 5/6 | - | sl | f | 0 | sg | l | l | sopo | - | g | s | | - | | c | f | - | - | - |
| C | 1.20-1.50+ | 10 YR 6/8 | 10 YR 6/8 | - | ls | f | 0 | sg | l | l | sopo | - | | | | - | | c | f | - | - | - |
| **Pedon 6. Fine-loamy, mixed, iso-hypethermic, Typic Haplustepts** | | | | | | | | | | | | | | | | | | | | | | |
| Ap | 0.00-0.18 | 10 YR 3/2 | 10 YR 3/1 | - | cl | m | 2 | sbk | s | fr | ssps | - | c | s | | - | | f | c | f | f | - |
| Bw1 | 0.18-0.48 | 10 YR 5/6 | 10 YR 5/6 | - | l | c | 3 | abk | sh | fi | vsps | - | d | s | | - | | f | m | f | f | - |
| Bw2 | 0.48-0.81 | 10 YR 4/6 | 10 YR 4/6 | - | l | c | 3 | abk | h | fi | vsps | - | g | s | | - | | f | m | f | f | - |
| Bw3 | 0.81-1.11 | 10 YR 6/6 | 10 YR 6/6 | - | scl | m | s | abk | sh | fi | ssps | - | g | s | | - | | m | f | f | f | - |

*Contd.*

**Table 1.** Morphological characteristics of soils — *Contd.*

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C1 | 1.11-1.35 | 10 YR 4/6 | 10 YR 4/6 | - | s | f | 0 | sg | l | l | sopo | - | g | w | | - | | c | | - | - | - |
| C2 | 1.35-1.54+ | 10 YR 4/4 | 10 YR 4/4 | - | sl | f | 0 | sg | l | l | sopo | - | g | s | | - | | c | f | - | - | - |
| **Pedon 7. Fine, smectitic, iso-hyperthermic, Vertic Haplustepts** | | | | | | | | | | | | | | | | | | | | | | |
| Ap | 0.00-0.15 | 10 YR 5/2 | 10 YR 5/1 | - | l | m | 2 | sbk | sh | fr | sp | ev | c | s | | - | | f | c | f | m | - |
| A1 | 0.15-0.35 | 10 YR 5/3 | 10 YR 5/2 | - | cl | m | 2 | sbk | h | fi | sp | ev | d | s | | - | | f | c | f | f | - |
| | | | | | | | | | | | | | | | | | | Poorly formed | | | | |
| Bw1 | 0.35-0.48 | 10 YR 4/2 | 10 YR 4/2 | - | c | c | 3 | abk | vh | fi | vsps | ev | d | s | | - | | vf | m | f | f | Slicken sides |
| | | | | | | | | | | | | | | | | | | Poorly formed | | | | |
| Bw2 | 0.48-0.72 | 10 YR 4/2 | 10 YR 4/2 | - | c | c | 3 | abk | vh | vfi | vsps | ev | d | s | | - | | vf | m | f | f | Slicken sides |
| Bw3 | 0.72-.1.02 | 10 YR 3/3 | 10 YR 3/2 | - | c | c | 3 | abk | vh | vfi | vsps | ev | d | s | | - | | vf | m | - | - | |
| Bw4 | 1.02-1.50+ | 10 YR 3/2 | 10 YR 3/2 | - | c | c | 3 | abk | vh | vfi | vsps | ev | d | s | | - | | vf | m | - | - | |
| **Pedon 8. Fine-loamy, mixed, iso-hyperthermic, Typic Rhodustalfs** | | | | | | | | | | | | | | | | | | | | | | |
| Ap | 0.00-0.16 | 5 YR 5/8 | 5 YR 5/8 | - | l | f | 1 | cr | s | fr | ssps | - | c | s | | - | | m | c | f | f | - |
| Bt1 | 0.16-0.42 | 2.54YR 4/4 | 2.5 YR 3/4 | - | cl | m | 2 | sbk | sh | fi | sp | - | g | s | t | tn | p | m | c | m | c | - |
| Bt2 | 0.42-0.68 | 2.5 YR 4/4 | 2.5YR 3/4 | - | cl | m | 2 | sbk | sh | fi | sp | - | g | s | t | tn | p | m | c | m | c | - |
| C | 0.68+Weathered gneiss mixed with soil | | | | | | | | | | | | | | | | | | | | | |
| **Pedon 9. Fine, kaolinitic, iso-hyperthermic, Typic Haplustalfs** | | | | | | | | | | | | | | | | | | | | | | |
| Ap | 0.00-0.18 | 5 YR 3/4 | 5 YR 3/3 | - | cl | m | 2 | sbk | sh | fi | sp | - | c | s | | - | | f | c | f | m | - |
| AB | 0.18-0.47 | 5 YR 4/4 | 5 YR 4/4 | - | c | c | 3 | abk | h | vfi | vsvp | - | g | s | | - | | f | c | vf | c | - |
| Bt1 | 0.47-0.73 | 5 YR 5/6 | 5 YR 5/6 | - | c | c | 3 | abk | h | vfi | vsvp | - | g | s | t | tk | c | f | c | f | f | - |
| Bt2 | 0.73-1.09 | 5 YR 5/8 | 5 YR 5/6 | - | cl | c | 2 | abk | h | vfi | vsvp | - | d | w | t | tk | c | f | m | - | - | - |
| Bt3 | 1.09-1.38 | 5 YR 5/8 | 5 YR 5/8 | - | scl | c | 2 | abk | h | vfi | vsvp | - | c | s | t | tk | c | c | f | - | - | - |
| Cr | 1.38+Parent rock mixed with soil | | | | | | | | | | | | | | | | | | | | | |

**Texture:** c - clay, cl - clay loam, l - loam, s - sandy, sl - sandy loam, scl - sandy clay loam, ls - loamy sand,

**Structure:** Size (S) - vf - very fine, f - fine, m - medium, c - coarse ; Grade (G) - O - structureless, 1 - weak, 2 - moderate, 3 - strong ; Type (T)-cr - crumb, sg - single grain, abk - angular blocky, sbk - sub-angular blocky.

**Consistency:**

**Dry:** s - soft, l - loose, sh - slightly hard, h - hard, vh - very hard,

**Moist:** l - loose, fr - friable, fi - firm, vfi - very firm

**Wet:** so - non-sticky, ss - slightly sticky, sticky - s, vs - very sticky ; po - non plastic ps - slightly plastic, p - plastic, vp - very plastic.

**Cutans** Ty - Type - t- Argillan, Th - Thickness tn - thin, thick - th Quantity (Q) p - patchy c - continuous

**Pores:** Size (S) f - fine, m - medium, c - coarse ; Q - Quantity f - few, c - common, m - many

**Roots:** Size (S) f - fine, m - medium, c - coarse ; Q -Quantity f - few, c - common, m - many

**Effervescence:** es - strong effervescence, ev - violent effervescence

**Boundary:** D - Distinctness, c - clear, g - gradual, d - diffuse

T - Topography ; s - smooth ; w - wavy

**Table 2.** Physical properties of the soils

| Pedon no. & horizon | Depth (m) | Sand (%) (0.05 - 2.0 mm) | Silt (%) (0.002-0.05 mm) | Clay (%) (<0.002 mm) | Bulk density (Mg $m^{-3}$) | Particle density (Mg $m^{-3}$) | Water holding capacity (%) |
|---|---|---|---|---|---|---|---|
| **Pedon 1. Fine-loamy, mixed, iso-hyperthermic, Typic Haplustepts** | | | | | | | |
| Ap | 0.00-0.26 | 40.02 | 36.93 | 23.05 | 1.44 | 2.44 | 44.32 |
| A1 | 0.26-0.63 | 42.00 | 31.90 | 25.56 | 1.53 | 2.55 | 41.61 |
| Bw1 | 0.63-0.92 | 43.50 | 36.50 | 20.00 | 1.61 | 2.48 | 41.08 |
| Bw2 | 0.92-1.30 | 38.02 | 38.88 | 23.10 | 1.69 | 2.52 | 48.76 |
| Bw3 | 1.30-1.56 | 45.95 | 39.05 | 15.00 | 1.72 | 2.51 | 35.51 |
| C | 1.56-2.00+ | 62.00 | 33.00 | 5.00 | 1.73 | 2.39 | 29.74 |
| **Pedon 2. Sandy, siliceous, iso-hyperthermic, Typic Ustipsamments** | | | | | | | |
| Ap | 0.00-0.19 | 76.00 | 19.00 | 5.00 | 1.49 | 2.62 | 21.89 |
| A1 | 0.19-0.42 | 77.39 | 15.00 | 7.61 | 1.52 | 2.43 | 20.42 |
| A2 | 0.42-0.70 | 74.75 | 21.21 | 4.04 | 1.58 | 2.47 | 21.50 |
| C1 | 0.70-1.02 | 80.56 | 16.94 | 2.50 | 1.66 | 2.4 | 19.38 |
| C2 | 1.02-1.40 | 82.02 | 15.48 | 2.50 | 1.68 | 2.53 | 14.63 |
| C3 | 1.40-2.00 | 84.55 | 12.95 | 2.50 | 1.73 | 2.49 | 13.53 |
| **Pedon 3. Coarse-loamy, siliceous, iso-hyperthermic, Typic Ustifluvents** | | | | | | | |
| Ap | 0.00-0.12 | 76.00 | 21.50 | 2.50 | 1.49 | 2.44 | 13.05 |
| A1 | 0.12-0.54 | 49.00 | 31.00 | 20.00 | 1.55 | 2.46 | 31.65 |
| A2 | 0.54-0.86 | 64.44 | 23.06 | 12.50 | 1.70 | 2.17 | 27.51 |
| A3 | 0.86-0.94 | 72.00 | 23.00 | 5.00 | 1.72 | 2.30 | 23.61 |
| Cr | 0.94+ | Parent rock mixed with soil | | | | | |
| **Pedon 4. Fine-loamy, mixed, iso-hyperthermic, Typic Rhodustalfs** | | | | | | | |
| Ap | 0.00-0.14 | 63.88 | 31.00 | 5.12 | 1.43 | 2.36 | 25.50 |
| E | 0.14-0.41 | 49.77 | 40.00 | 10.23 | 1.50 | 2.46 | 35.69 |
| Bt1 | 0.41-0.81 | 36.12 | 25.20 | 39.04 | 1.61 | 2.40 | 41.13 |
| Bt2 | 0.81-1.40 | 24.04 | 37.78 | 38.18 | 1.67 | 2.45 | 45.79 |
| C | 1.40+ | Weathered gneiss mixed with soil | | | | | |
| **Pedon 5. Coarse-loamy, siliceous, iso-hyperthermic, Aquic Ustorthents** | | | | | | | |
| Ap | 0.00-0.25 | 37.30 | 39.78 | 22.92 | 1.39 | 2.46 | 30.79 |
| A1 | 0.25-0.42 | 54.48 | 27.60 | 17.92 | 1.46 | 2.52 | 30.83 |
| A2 | 0.42-0.66 | 53.68 | 28.75 | 17.57 | 1.57 | 2.53 | 25.12 |
| A3 | 0.66-0.95 | 52.08 | 34.78 | 13.14 | 1.64 | 2.50 | 20.07 |
| A4 | 0.95-1.20 | 74.32 | 13.01 | 12.67 | 1.73 | 2.54 | 23.26 |
| C | 1.20-1.50 | 83.48 | 14.02 | 2.50 | 1.90 | 2.72 | 21.69 |
| **Pedon 6. Fine-loamy, mixed, iso-hyperthermic, Typic Haplustepts** | | | | | | | |
| Ap | 0.00-0.18 | 42.18 | 30.15 | 27.67 | 1.42 | 2.53 | 30.92 |
| Bw1 | 0.18-0.48 | 43.88 | 35.62 | 20.50 | 1.48 | 2.48 | 37.94 |
| Bw2 | 0.48-0.81 | 42.58 | 33.40 | 24.02 | 1.51 | 2.58 | 42.68 |
| Bw3 | 0.81-1.11 | 57.00 | 23.00 | 20.00 | 1.56 | 2.67 | 40.90 |
| C1 | 1.11-1.35 | 87.78 | 7.22 | 5.00 | 1.61 | 2.42 | 41.02 |
| C2 | 1.35-1.54 | 71.94 | 15.26 | 12.80 | 1.61 | 2.25 | 28.70 |
| **Pedon 7. Fine, smectitic, iso-hyperthermic, Vertic Haplustepts** | | | | | | | |
| Ap | 0.00-0.15 | 39.58 | 40.02 | 20.40 | 1.34 | 2.52 | 30.63 |
| A1 | 0.15-0.35 | 36.21 | 30.32 | 33.47 | 1.38 | 2.52 | 37.66 |
| Bw1 | 0.35-0.48 | 22.00 | 33.91 | 44.09 | 1.47 | 2.42 | 48.77 |
| Bw2 | 0.48-0.72 | 22.00 | 37.00 | 41.00 | 1.52 | 2.49 | 53.42 |
| Bw3 | 0.72-1.02 | 22.00 | 32.76 | 45.24 | 1.57 | 2.39 | 45.62 |
| Bw4 | 1.02-1.50 | 17.20 | 24.50 | 58.30 | 1.62 | 2.67 | 58.99 |
| **Pedon 8. Fine-loamy, mixed, iso-hyperthermic, Typic Rhodustalfs** | | | | | | | |
| Ap | 0.00-0.16 | 50.02 | 35.86 | 14.12 | 1.32 | 2.43 | 34.88 |
| Bt1 | 0.16-0.42 | 34.84 | 36.13 | 29.03 | 1.49 | 2.43 | 45.72 |
| Bt2 | 0.42-0.68 | 36.00 | 30.90 | 33.10 | 1.58 | 2.48 | 46.64 |
| C | 0.68+ | Weathered gneiss mixed with soil | | | | | |
| **Pedon 9. Fine, kaolinitic, iso-hyperthermic, Typic Haplustalfs** | | | | | | | |
| Ap | 0.00-0.18 | 37.00 | 24.94 | 38.06 | 1.48 | 2.42 | 44.64 |
| AB | 0.18-0.47 | 28.14 | 25.70 | 46.16 | 1.49 | 2.34 | 50.60 |
| Bt1 | 0.47-0.73 | 27.50 | 28.50 | 44.00 | 1.49 | 2.51 | 50.53 |
| Bt2 | 0.73-1.09 | 36.31 | 26.19 | 37.50 | 1.53 | 2.62 | 50.01 |
| Bt3 | 1.09-1.38 | 50.00 | 17.50 | 32.50 | 1.62 | 2.34 | 46.21 |
| Cr | 1.38+ | Parent rock mixed with soil | | | | | |

**Table 3.** Physico-chemical properties of the soils

| Pedon No. & Horizon | Depth (m) | pH (1:2.5) | | EC (dS $m^{-1}$) | Organic carbon (g $kg^{-1}$) | $CaCO_3$ (g $kg^{-1}$) | CEC [cmol ($p^+$) $kg^{-1}$] (1 *N* $NH_4$ OAc, pH 7.0) | Exchangeable bases [cmol($p^+$) $kg^{-1}$] (1 *N* $NH_4$OAc, pH 7.0) | | | | Base saturation (%) (1 *N* $NH_4$OAc pH 7.0) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2O$ | 1 *N* KCl | | | | | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ | |
| **Pedon 1. Fine-loamy, mixed, iso-hyperthermic, Typic Haplustepts** | | | | | | | | | | | | |
| Ap | 0.00-0.26 | 7.98 | 7.70 | 0.18 | 5.5 | 4.1 | 13.62 | 5.85 | 4.25 | 0.27 | 0.25 | 77.97 |
| A1 | 0.26-0.63 | 8.02 | 6.81 | 0.07 | 1.8 | 8.3 | 13.43 | 5.75 | 3.91 | 0.20 | 0.12 | 74.31 |
| Bw1 | 0.63-0.92 | 8.15 | 6.68 | 0.08 | 1.5 | 4.1 | 16.97 | 6.55 | 4.30 | 0.61 | 0.10 | 68.12 |
| Bw2 | 0.92-1.30 | 8.22 | 6.94 | 0.07 | 1.1 | 4.1 | 14.44 | 5.65 | 4.50 | 0.40 | 0.13 | 73.96 |
| Bw3 | 1.30-1.56 | 8.28 | 6.68 | 0.07 | 0.5 | 8.3 | 12.41 | 5.50 | 4.25 | 0.31 | 0.09 | 81.79 |
| C | 1.56-2.00+ | 8.30 | 7.12 | 0.05 | 0.4 | 8.3 | 4.72 | 2.50 | 0.90 | 0.18 | 0.04 | 76.69 |
| **Pedon 2. Sandy, siliceous, iso-hyperthermic, Typic Ustipsamments** | | | | | | | | | | | | |
| Ap | 0.00-0.19 | 7.73 | 7.05 | 0.12 | 3.7 | 12.5 | 7.66 | 4.80 | 1.35 | 0.29 | 0.10 | 85.38 |
| A1 | 0.19-0.42 | 8.32 | 7.57 | 0.09 | 1.9 | 12.5 | 4.00 | 1.60 | 1.30 | 0.38 | 0.13 | 85.25 |
| A2 | 0.42-0.70 | 8.15 | 7.36 | 0.11 | 1.2 | 4.2 | 5.13 | 2.55 | 0.95 | 0.22 | 0.08 | 74.07 |
| C1 | 0.70-1.02 | 8.04 | 7.02 | 0.09 | 1.0 | 16.6 | 3.64 | 1.80 | 0.90 | 0.13 | 0.09 | 80.22 |
| C2 | 1.02-1.40 | 8.04 | 7.02 | 0.09 | 0.8 | 16.6 | 5.53 | 2.55 | 1.25 | 0.13 | 0.09 | 72.69 |
| C3 | 1.40-2.00+ | 8.01 | 6.98 | 0.08 | 0.6 | 21.0 | 7.45 | 3.90 | 1.15 | 0.18 | 0.10 | 71.54 |
| **Pedon 3. Coarse - loamy, siliceous, iso-hyperthermic, Typic Ustifluvents** | | | | | | | | | | | | |
| Ap | 0.00-0.12 | 6.54 | 6.09 | 0.05 | 1.5 | 4.2 | 1.50 | 0.70 | 0.40 | 0.07 | 0.04 | 80.67 |
| A1 | 0.12-0.54 | 6.63 | 5.54 | 0.02 | 3.7 | 8.3 | 5.34 | 2.00 | 1.75 | 0.04 | 0.05 | 71.91 |
| A2 | 0.54-0.86 | 6.83 | 5.90 | 0.03 | 1.3 | 16.6 | 6.63 | 3.70 | 1.85 | 0.04 | 0.06 | 85.22 |
| A3 | 0.86-0.94 | 7.19 | 5.98 | 0.04 | 2.1 | 41.6 | 18.49 | 12.05 | 2.10 | 0.15 | 0.14 | 78.10 |
| Cr | 0.94+Parent rock mixed with soil | | | | | | | | | | | |
| **Pedon 4. Fine - loamy, mixed, iso-hyperthermic, Typic Rhodustalfs** | | | | | | | | | | | | |
| Ap | 0.00-0.14 | 6.37 | 5.86 | 0.05 | 2.5 | 16.6 | 3.19 | 1.60 | 0.40 | 0.20 | 0.25 | 76.80 |
| E | 0.14-0.41 | 5.83 | 4.77 | 0.03 | 3.6 | 29.1 | 12.02 | 2.70 | 0.85 | 0.04 | 0.20 | 31.53 |
| Bt1 | 0.41-0.81 | 6.08 | 5.12 | 0.08 | 4.1 | 37.4 | 26.15 | 6.90 | 2.35 | 0.04 | 0.17 | 36.18 |
| Bt2 | 0.81-1.40 | 7.96 | 7.23 | 0.30 | 2.1 | 108.1 | 45.14 | 16.90 | 2.95 | 0.11 | 0.40 | 45.10 |
| C | 1.40+Weathered gneiss mixed with soil | | | | | | | | | | | |
| **Pedon 5. Coarse - loamy, siliceous, iso-hyperthermic, Aquic Ustorthents** | | | | | | | | | | | | |
| Ap | 0.0-0.25 | 8.38 | 7.68 | 0.22 | 5.8 | 20.8 | 14.52 | 6.70 | 4.00 | 0.42 | 0.09 | 77.20 |
| A1 | 0.25-.42 | 8.00 | 7.22 | 0.19 | 1.7 | 25.0 | 8.48 | 4.30 | 2.60 | 0.20 | 0.09 | 84.79 |
| A2 | 0.42-0.66 | 7.94 | 6.85 | 0.16 | 1.8 | 25.0 | 15.20 | 6.50 | 4.00 | 0.26 | 0.10 | 71.45 |
| A3 | 0.66-0.95 | 8.06 | 6.60 | 0.13 | 1.4 | 20.8 | 18.84 | 8.85 | 4.10 | 0.46 | 0.12 | 71.82 |
| A4 | 0.95-1.20 | 7.91 | 6.62 | 0.11 | 1.6 | 49.9 | 14.76 | 5.65 | 4.20 | 0.46 | 0.07 | 70.33 |
| C | 1.20-1.50+ | 8.32 | 6.78 | 0.06 | 0.9 | 49.9 | 7.59 | 3.80 | 1.60 | 0.31 | 0.03 | 75.63 |
| **Pedon 6. Fine - loamy, mixed, iso-hyperthermic, Typic Haplustepts** | | | | | | | | | | | | |
| Ap | 0.00-0.18 | 7.99 | 7.38 | 0.26 | 6.4 | 54.1 | 22.45 | 12.70 | 5.40 | 0.44 | 0.20 | 83.47 |
| Bw1 | 0.18-0.48 | 7.92 | 6.78 | 0.12 | 1.4 | 12.5 | 9.13 | 5.75 | 2.40 | 0.22 | 0.10 | 92.77 |
| Bw2 | 0.48-0.81 | 7.73 | 6.45 | 0.14 | 1.4 | 41.6 | 19.13 | 10.80 | 5.50 | 0.31 | 0.14 | 87.56 |
| Bw3 | 0.81-1.11 | 8.11 | 6.45 | 0.08 | 0.8 | 49.9 | 18.56 | 8.55 | 5.55 | 0.53 | 0.17 | 79.74 |
| C1 | 1.11-1.35 | 8.36 | 6.90 | 0.07 | 0.6 | 33.3 | 6.29 | 2.80 | 1.85 | 0.20 | 0.07 | 78.22 |
| C2 | 1.35-1.54+ | 8.42 | 6.70 | 0.09 | 0.5 | 45.8 | 8.53 | 3.80 | 2.20 | 0.24 | 0.07 | 73.97 |
| **Pedon 7. Fine, smectitic, iso-hyperthermic, Vertic Haplustepts** | | | | | | | | | | | | |
| Ap | 0.00-0.15 | 8.33 | 7.73 | 0.27 | 6.3 | 16.6 | 15.86 | 8.40 | 3.90 | 0.40 | 0.25 | 81.65 |
| A1 | 0.15-0.35 | 8.10 | 7.08 | 0.20 | 3.5 | 12.4 | 20.75 | 7.90 | 6.45 | 1.28 | 0.20 | 76.29 |
| Bw1 | 0.35-0.48 | 7.76 | 6.65 | 0.28 | 2.7 | 25.0 | 18.37 | 7.10 | 4.30 | 0.66 | 0.17 | 66.58 |
| Bw2 | 0.48-0.72 | 7.82 | 6.77 | 0.36 | 2.5 | 41.6 | 17.56 | 6.40 | 4.50 | 0.99 | 0.14 | 68.51 |
| Bw3 | 0.72-1.02 | 8.04 | 6.76 | 0.31 | 2.4 | 41.6 | 13.28 | 6.60 | 4.05 | 0.79 | 0.13 | 87.12 |
| Bw4 | 1.02-1.50+ | 8.27 | 6.84 | 0.19 | 2.4 | 49.9 | 15.55 | 8.80 | 3.85 | 1.25 | 0.21 | 90.74 |
| **Pedon 8. Fine - loamy, mixed, iso-hyperthermic, Typic Rhodustalfs** | | | | | | | | | | | | |
| Ap | 0.00-0.16 | 6.97 | 5.98 | 0.07 | 3.4 | 12.5 | 6.88 | 1.75 | 1.15 | 0.13 | 0.10 | 45.49 |
| Bt1 | 0.16-0.42 | 6.46 | 5.20 | 0.04 | 1.7 | 33.3 | 18.77 | 5.75 | 1.70 | 0.29 | 0.14 | 41.98 |
| Bt2 | 0.42-0.68 | 6.52 | 4.70 | 0.08 | 1.4 | 41.6 | 15.72 | 4.15 | 3.35 | 0.37 | 0.16 | 51.08 |
| C | 0.68+Weathered gneiss mixed with soil | | | | | | | | | | | |
| **Pedon 9. Fine, kaolinitic, iso-hyperthermic, Typic Haplustalfs** | | | | | | | | | | | | |
| Ap | 0.00-0.18 | 7.68 | 6.75 | 0.14 | 4.7 | 54.1 | 11.92 | 4.15 | 3.55 | 0.35 | 0.22 | 69.38 |
| AB | 0.18-0.47 | 8.05 | 6.92 | 0.10 | 2.3 | 66.6 | 12.96 | 8.70 | 1.45 | 1.06 | 0.20 | 88.04 |
| Bt1 | 0.47-0.73 | 8.42 | 7.15 | 0.15 | 1.3 | 66.6 | 10.38 | 4.60 | 3.50 | 0.11 | 0.13 | 80.35 |
| Bt2 | 0.73-1.09 | 8.46 | 6.91 | 0.15 | 1.3 | 70.7 | 12.06 | 7.30 | 2.60 | 0.75 | 0.12 | 89.30 |
| Bt3 | 1.09-1.38 | 8.47 | 7.19 | 0.21 | 1.1 | 83.2 | 9.43 | 4.35 | 2.80 | 0.11 | 0.14 | 78.47 |
| Cr | 1.38+Parent rock mixed with soil | | | | | | | | | | | |

factor for the lower organic carbon content in the surface soils of the pedons 3 and 4. The CEC of the soils ranged from 1.50 to 45.14 cmol $(p^+)$ $kg^{-1}$ which corresponds to clay content in the respective horizons. Content of $CaCO_3$ was less which ranged from 4.1 to 108.1 g $kg^{-1}$. Exchangeable bases in all the pedons were in the order of $Ca^{2+} > Mg^{2+} > Na^+ > K^+$ except in pedon 4 which had a sequence of $Ca^{2+} > Mg^{2+} > K^+ > Na^+$ on the exchange complex. The base saturation varied from 31.53 to 92.77%.

*Nutrient Status and Soil Fertility*

*Macronutrients*: Soil fertility exhibits the status of different soils with regard to the amount and availability of nutrients essential for plant growth. The available nitrogen content of the soils varied from 59 to 502 kg $ha^{-1}$ (Table 4) throughout the depth. However, available nitrogen content was found to be maximum in surface horizon and decreased regularly with soil depth which might be due to decreasing trend of organic carbon with depth. These observations are in accordance with the findings of Prasuna Rani *et al.* (1992).

The available phosphorus content in the horizons of the pedons varied from 4.5 to 29.3 kg $ha^{-1}$. However, the highest available phosphorus was observed in the surface horizons. The available P decreased regularly with depth. The reason for higher P in surface horizons might possibly be the confinement of crop cultivation to the rhizosphere and supplementing of the depleted phosphorous through external sources *i.e.* fertilizers.

The content of available K in all the pedons varied from 22 to 212 kg $ha^{-1}$. The highest available K content was noticed in the surface horizons and showed more or less decreasing trend with depth. This could be attributed to more intense weathering, release of labile K from organic residues, application of K fertilizers and upward translocation of K from lower depths along with capillary rise of ground water. Similar results were reported by Hirekurabar *et al.* (2000).

The available sulphur content varied from 12.5 to 35.2 mg $kg^{-1}$ soil. Surface layers contained more available content than in the deeper layers which could be due to higher amount of organic matter in surface layers than in deeper layers.

*Micronutrients:* The DTPA extractable Zn ranged from 0.42 to 0.94 mg $kg^{-1}$ soil in surface and 0.10 to 0.96 mg $kg^{-1}$ soil in sub-surface horizons. Vertical distribution of zinc exhibited little variation with depth. Considering 0.60 mg $kg^{-1}$ as critical level (Lindsay and Norvell 1978), these soils are sufficient in surface horizons while deficient in sub-surface horizons. Similar views were also expressed by Sarkar *et al.* (2002).

All the pedons were found to be sufficient in available copper (0.28 to 1.68 mg $kg^{-1}$) as all the values were well above the critical limit of 0.20 mg $kg^{-1}$ soil as suggested by Lindsay and Norvell (1978). Similar results were also reported by Sarkar *et al.* (2000).

The DTPA extractable Fe content varied from 0.48 to 7.74 mg $kg^{-1}$ soil. According to critical limit of 4.5 mg $kg^{-1}$ of Lindsay and Norvell (1978) the soils were low in available iron except in Bt1 and Bt2 horizons of pedon 8. The higher concentration of DTPA-iron in Bt1 and Bt2 horizons might be due to the accumulation of iron brought down as a result of illuviation of clay from the upper horizons. The available iron showed a decreasing trend with depth. These findings are in agreement with the findings of Prasad and Sakal (1991). The available Mn content of these soils varied from 3.68 to 17.24 mg $kg^{-1}$ soil. It was high in the surface horizons and gradually decreased with depth, which might be due to higher biological activity and organic carbon in the surface horizons. These observations are in agreement with the findings of Murthy *et al.* (1997).

The micronutrient analysis of the Sivagiri micro-watershed revealed that the samples were deficient in available iron and well supplied with Cu and Mn. However, the available Zn was sufficient in surface horizons whereas it was deficient in sub-surface horizons.

*Soil Classification*

Based on morphology and soil properties, the soils were classified according to Keys to Soil Taxonomy (Soil Survey Staff 1998) into the order Entisols (Pedons 3 & 5) which do not have any diagnostic horizons, Inceptisols (Pedons 1, 6 & 7) with cambic (Bw) sub-surface diagnostic horizon and Alfisols (Pedons 4, 8 & 9) having argillic (Bt) sub-surface diagnostic horizon. Pedon 2 was placed under Psamments at sub-order level because of loamy sand or sandy texture. These are put as Ustipsamments at great group level due to the presence of ustic soil moisture regime. Further, the pedon 2 was classified as Typic Ustipsamments at sub-group level as it is characterized by the absence of lithic contact, saturation with water, frigid or mesic or thermic or hyperthermic or isomesic soil temperature regimes and lamellae and did not show a Munsell

**Table 4.** Available nutrient status of the soils

| Pedon no. & horizon | Depth (m) | Available macronutrients N | P | K | S | Available micronutrients Zn | Cu | Fe | Mn |
|---|---|---|---|---|---|---|---|---|---|
| | | (kg ha$^{-1}$) | | | (mg kg$^{-1}$) | (mg kg$^{-1}$) | | | |
| **Pedon 1. Fine -loamy, mixed, iso-hyperthermic, Typic Haplustepts** | | | | | | | | | |
| Ap | 0.00-0.26 | 502 | 15.9 | 212 | 32.8 | 0.74 | 1.18 | 2.38 | 8.02 |
| A1 | 0.26-0.63 | 218 | 12.8 | 100 | 23.7 | 0.62 | 1.18 | 2.14 | 7.26 |
| Bw1 | 0.63-0.92 | 170 | 12.6 | 89 | 23.2 | 0.56 | 1.08 | 1.68 | 6.38 |
| Bw2 | 0.92-1.30 | 151 | 10.9 | 112 | 21.8 | 0.46 | 1.14 | 1.52 | 5.64 |
| Bw3 | 1.30-1.56 | 85 | 9.8 | 78 | 20.4 | 0.28 | 0.96 | 1.10 | 4.10 |
| C | 1.56-2.00+ | 59 | 4.5 | 33 | 17.1 | 0.22 | 0.64 | 1.02 | 3.88 |
| **Pedon 2. Sandy, siliceous, iso-hyperthermic, Typic Ustipsamments** | | | | | | | | | |
| Ap | 0.00-0.19 | 273 | 14.3 | 89 | 34.2 | 0.58 | 0.92 | 2.54 | 6.08 |
| A1 | 0.19-0.42 | 121 | 11.4 | 112 | 24.1 | 0.36 | 0.82 | 2.26 | 5.16 |
| A2 | 0.42-0.70 | 107 | 25.4 | 67 | 24.0 | 0.32 | 0.66 | 1.64 | 4.72 |
| C1 | 0.70-1.02 | 73 | 24.7 | 67 | 23.3 | 0.34 | 0.64 | 0.92 | 4.24 |
| C2 | 1.02-1.40 | 70 | 10.8 | 78 | 20.0 | 0.28 | 0.74 | 0.48 | 3.68 |
| C3 | 1.40-2.00+ | 59 | 5.8 | 89 | 17.1 | 0.18 | 0.48 | 0.78 | 3.68 |
| **Pedon 3. Coarse- loamy, siliceous, iso-hyperthermic, Typic Ustifluvents** | | | | | | | | | |
| Ap | 0.00-0.12 | 121 | 16.8 | 33 | 23.1 | 0.62 | 1.44 | 0.80 | 7.44 |
| A1 | 0.12-0.54 | 266 | 29.3 | 44 | 23.7 | 0.54 | 1.26 | 1.74 | 7.40 |
| A2 | 0.54-0.86 | 255 | 12.6 | 56 | 21.8 | 0.58 | 0.98 | 1.28 | 4.96 |
| A3 | 0.86-0.94 | 195 | 12.4 | 123 | 12.5 | 0.24 | 0.70 | 1.04 | 4.32 |
| Cr | 0.94+Parent rock mixed with soil | | | | | | | | |
| **Pedon 4. Fine - loamy, mixed, iso-hyperthermic, Typic Rhodustalfs** | | | | | | | | | |
| Ap | 0.00-0.14 | 229 | 8.5 | 212 | 20.3 | 0.64 | 1.68 | 1.92 | 10.30 |
| E | 0.14-0.41 | 373 | 10.3 | 168 | 23.8 | 0.64 | 1.50 | 3.18 | 8.94 |
| Bt1 | 0.41-0.81 | 303 | 12.8 | 145 | 21.8 | 0.48 | 1.24 | 3.44 | 8.12 |
| Bt2 | 0.81-1.40 | 158 | 8.4 | 123 | 15.6 | 0.40 | 1.24 | 4.08 | 6.5 |
| C | 1.40+Weathered gneiss mixed with soil | | | | | | | | |
| **Pedon 5. Coarse- loamy, siliceous, iso-hyperthermic, Aquic Ustorthents** | | | | | | | | | |
| Ap | 0.0-0.25 | 373 | 24.0 | 78 | 34.2 | 0.94 | 0.82 | 2.58 | 12.04 |
| A1 | 0.25-.42 | 269 | 18.3 | 78 | 32.5 | 0.66 | 0.78 | 2.24 | 11.74 |
| A2 | 0.42-0.66 | 225 | 17.2 | 89 | 23.7 | 0.56 | 0.74 | 2.26 | 8.62 |
| A3 | 0.66-0.95 | 218 | 13.4 | 100 | 17.1 | 0.56 | 0.76 | 2.18 | 9.40 |
| A4 | 0.95-1.20 | 107 | 12.9 | 56 | 16.8 | 0.40 | 0.58 | 1.34 | 5.38 |
| C | 1.20-1.50+ | 77 | 12.8 | 22 | 16.5 | 0.34 | 0.48 | 1.08 | 4.40 |
| **Pedon 6. Fine - loamy, mixed, iso-hyperthermic, Typic Haplustepts** | | | | | | | | | |
| Ap | 0.00-0.18 | 399 | 25.3 | 168 | 35.2 | 0.88 | 0.68 | 4.32 | 10.82 |
| Bw1 | 0.18-0.48 | 229 | 13.8 | 89 | 30.0 | 0.86 | 0.62 | 2.90 | 8.78 |
| Bw2 | 0.48-0.81 | 166 | 8.1 | 123 | 21.2 | 0.78 | 0.52 | 2.74 | 8.48 |
| Bw3 | 0.81-1.11 | 158 | 7.8 | 145 | 17.5 | 0.72 | 0.44 | 1.56 | 7.68 |
| C1 | 1.11-1.35 | 99 | 7.1 | 56 | 16.8 | 0.52 | 0.34 | 1.88 | 6.04 |
| C2 | 1.35-1.54+ | 77 | 5.0 | 56 | 12.5 | 0.50 | 0.28 | 1.82 | 5.84 |
| **Pedon 7. Fine, smectitic, iso-hyperthermic, Vertic Haplustepts** | | | | | | | | | |
| Ap | 0.00-0.15 | 428 | 14.8 | 212 | 32.8 | 0.86 | 0.98 | 3.92 | 17.24 |
| A1 | 0.15-0.35 | 266 | 13.8 | 168 | 31.8 | 0.46 | 0.46 | 2.80 | 16.54 |
| Bw1 | 0.35-0.48 | 255 | 7.2 | 145 | 30.0 | 0.74 | 0.44 | 2.74 | 10.8 |
| Bw2 | 0.48-0.62 | 188 | 6.0 | 123 | 23.7 | 0.84 | 0.38 | 2.68 | 8.58 |
| Bw3 | 0.72-1.02 | 170 | 5.6 | 112 | 17.1 | 0.28 | 0.38 | 2.58 | 7.78 |
| Bw4 | 1.02-1.50+ | 144 | 5.0 | 190 | 16.5 | 0.22 | 0.44 | 2.50 | 7.18 |
| **Pedon 8 Fine- loamy, mixed, iso-hyperthermic, Typic Rhodustalfs** | | | | | | | | | |
| Ap | 0.00-0.16 | 288 | 13.7 | 89 | 29.6 | 0.42 | 0.76 | 4.42 | 10.04 |
| Bt1 | 0.16-0.42 | 170 | 28.0 | 123 | 24.0 | 0.10 | 0.40 | 7.74 | 4.54 |
| Bt2 | 0.42-0.68 | 85 | 10.6 | 134 | 13.1 | 0.10 | 0.66 | 5.84 | 4.54 |
| C | 0.68+Weathered gneiss mixed with soil | | | | | | | | |
| **Pedon 9. Fine, kaolinitic, iso-hyperthermic, Typic Haplustalfs** | | | | | | | | | |
| Ap | 0.00-0.18 | 425 | 16.8 | 190 | 32.5 | 0.90 | 0.54 | 4.34 | 8.76 |
| AB | 0.18-0.47 | 236 | 10.9 | 123 | 31.8 | 0.96 | 0.48 | 2.80 | 8.22 |
| Bt1 | 0.47-0.73 | 144 | 10.4 | 112 | 24.1 | 0.48 | 0.44 | 2.24 | 7.72 |
| Bt2 | 0.73-1.09 | 140 | 7.8 | 100 | 23.4 | 0.38 | 0.42 | 2.22 | 4.28 |
| Bt3 | 1.09-1.38 | 99 | 7.2 | 168 | 15.0 | 0.16 | 0.32 | 2.16 | 4.28 |
| Cr | 1.38+Parent rock mixed with soil | | | | | | | | |

colour notation of 2.5 YR hue and value (moist) of 3 or less. Pedon 3 was grouped under Fluvents at sub-order level due to irregular decrease in the organic carbon from 25 cm to lithic contact and Ustifluvents at great group level due to ustic soil moisture regime. As this pedon did not show any inter-gradation with any other taxa or any extra-gradation from the central concept, therefore, it is logically classified as Typic Ustifluvents at sub-group level. Pedon 5 had an irregular decrease in organic carbon with depth but have less than 2.0 g $kg^{-1}$ organic carbon at 1.25 m depth. Hence, it is classified as Orthents and Ustorthents at great group level due to ustic soil moisture regime. Further, it was placed under Aquic Ustorthents at sub-group level due to the aquic conditions indicated by the presence of mottles with chroma 2 or less.

Pedons 1, 6 and 7 were grouped under Ustepts at sub-order level due to ustic soil moisture regime and Haplustepts at great group level because these pedons did not have either duripan or calcic horizon and base saturation was more than 60%. Further, the pedons 1, 6 and 7 did not have vertic properties and lithic contact within 50 cm from the soil surface. Hence, these three pedons (Pedons 1, 6 and 7) were logically classified as Typic Haplustepts at sub-group level.

The pedons 4, 8 and 9 showed the presence of argillic (Bt) sub-surface diagnostic horizon as evidenced by the fact that the illuvial horizon contains

**Table 5.** Interpretation of soils of Sivagiri micro-watershed

| Pedon no. | Land capability class with limitations | Description | Major limitations | Suggested land use |
|---|---|---|---|---|
| 1 | IIs | Good cultivable land for sustainable agriculture | Did not have any major limitations except high permeability to water | Climatically adopted double cropping including legume in rotation with the addition of optimum dose of fertilizers and manures. Sugarcane can also be grown |
| 2 | IVs | Fairly good cultivable land for sustainable agriculture | Sandy texture, excessive drainage, low water holding capacity and poor nutrient holding capacity | Addition of tank silt (Pond mud) is recommended and very careful soil and water management practices could be followed |
| 3 | IIIes | Moderately good cultivable land for sustainable agriculture | Gentle slope with moderate erosion, moderate run off and high permeability | Suitable for mango, pulses, oilseeds and vegetables |
| 4 | IIIes | Moderately good cultivable land for sustainable agriculture | Gentle slope with moderate erosion, moderate run-off and high permeability | Suitable for mango, pulses, oilseeds and vegetables |
| 5 | IIs | Good cultivable land for sustainable agriculture | Slight erosion and high permeability | Climatically adopted double cropping including legume in rotation with the addition of optimum dose of fertilizers and manures. Sugarcane can also be grown |
| 6 | IIs | Good cultivable land for sustainable agriculture | Slight erosion and high permeability | Climatically adopted double cropping including legume in rotation with the addition of optimum dose of fertilizers and manures. Sugarcane can also be grown. |
| 7 | IIIw | Moderately good cultivable land for sustainable agriculture | Slight erosion poor drainage, poor soil aeration and severe soil tillage problems | Double cropping including legume in rotation with proper drainage facilities. |
| 8 | IIIes | Moderately good cultivable land for sustainable agriculture | Gentle slope with moderate erosion, moderate run-off and high permeability | Suitable for horticultural crops like mango, sapota, guava and pomegranate |
| 9 | IIIes | Moderately good cultivable land for sustainable agriculture | Gentle slope with moderate erosion and moderate run-off | Sugarcane, pulses and oil seeds can be grown. Horticultural crops like mango preferable |

1.2 times more clay than the eluvial horizon and also had base saturation more than 35% throughout the profile. However, these pedons were classified as Ustalfs at sub-order lever due to the presence of ustic soil moisture regime. The pedons (4 & 8) were classified as Rhodustalfs at great group level because the argillic horizon exhibited a hue of 2.5 YR and moist value of 3. These pedons (4 and 8) have not shown lithic contact within 50 cm from the surface and had dry period more than 120 cumulative days per year, hence these pedons were classified as Typic Rhodustalfs at sub-group level. However, Pedon 9 did not have duripan, plinthite, kandic, natric, or petrocalcic horizons and the argillic horizon did not exhibit a hue of 2.5 YR, hence pedon 9 was logically classified as Haplustalfs at great group level. Finally, the pedon 9 was classified into Typic Haplustalf at sub-group level due to the absence of lithic or paralithic contact, cracks, pumice like fragments, volcanic ash, lamellae and calcic horizon and also due to the presence of argillic horizon with >75 base saturation and iso-hyperthermic temperature regime.

### *Land Capability Classification*

The land capability classification is an interpretative grouping of different soil units into different classes based on their limitations and potentials and designed to emphasize the hazards in different kinds of soils. It serves as a guide to assess the suitability of the land for arable crops, grazing and forestry. The grouping of soils into capability classes and sub-classes is done mainly based on severity of limitations *viz.*, erosion risk (e), wetness (w), rooting zone, soils (s) and climatic limitations (c).

Based on these criteria, the soils of Sivagiri micro-watershed have been classified into three land capability sub-classes for better management of lands. The pedons 1, 5 and 6 of Sivagiri micro-watershed were placed in the land capability class IIs, whereas the pedons 3, 4, 8 and 9 were kept in IIIes. Pedon 7 alone was placed in IIIw and pedon 2 was placed in IVs. The detailed description of land capability classes with potentials, limitations and suggested land use is given in the table 5. By adopting suggested land use in the respective areas sustained crop production can be achieved as it helps in the conservation of soil and water besides the improvement of physical properties of soils.

## Conclusion

The study of morphological, physical and physico-chemical analysis of soil samples revealed that the soils of Sivagiri micro-watershed were slightly acidic to moderately alkaline in soil reaction, non-saline and low to medium in organic carbon content. Further CEC was also low to medium and exchange complex was dominated by $Ca^{2+}$. Regarding nutrient status, the soils were low to medium in available N, P and K and high in available S. Further, the soils were deficient in iron, deficient to sufficient in available zinc and sufficient in available copper and manganese. The soils of micro-watershed were classified upto sub-group level. Based on the soil properties land capability classes were fixed and suitable land use plan was also suggested for sustaining yields of the crops in the Sivagiri micro-watershed.

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# Characteristics, Classification and Management of Aridisols of Punjab

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**Abstract:** Morphological, physical and chemical characteristics of Aridisols occurring on two dominant landscape positions *viz*., inter-dunal areas and alluvial terraces in the south-west Punjab have been investigated. The soils developed on inter-dunal areas are coarse textured, calcareous, and show the development of a structural B horizon and are classified as Ustic Haplocambids. On the other hand, soils developed on alluvial terraces are relatively finer in texture, calcareous to non-calcareous and show the development of cambic and calcic horizons and are classified as Ustic Haplocambids and Typic Haplocalcids. All the soils have mixed mineralogy and hyperthermic temperature regimes. Topography, along with nature of parent material and time were found to be responsible for the pedogenic differences in the soils developed on different landforms within the comparable climatic conditions. Mineralogical, physical and chemical properties and land use limitations of these soils are discussed. Low and erratic rainfall is the major constraint for sustaining crop growth. Poor quality underground irrigation water further limits the selection of crops. Regular failure of cotton crop in these areas due to waterlogging and availability of good quality canal water, has led to large scale shift in cropping pattern from cotton-wheat to rice–wheat. Use of underground saline water for sustaining paddy growth is increasing surface salinity in these areas. ***(Key words:** Aridisols, soil characteristics, calcic horizon, cambic horizon, mixed mineralogy)*

Aridisols occur in the arid and semi-arid environment and occupy 36% of the earth's surface (Shantz 1956). Aridisols have one or more pedogenic horizons that might have formed in the present environment, or may be relict from a former fluvial period. A few Aridisols are in semi-arid region and are dry